



# 2<sup>nd</sup> International Conference on Industrial and Manufacturing System



# CIMS-2021

11<sup>TH</sup>- 13<sup>TH</sup> NOVEMBER, 2021



Conference Proceeding: ISBN: 978-93-91535-06-3

JOINTLY ORGANIZED BY

DEPARTMENT OF PRODUCTION AND INDUSTRIAL ENGINEERING  
PUNJAB ENGINEERING COLLEGE, CHANDIGARH

DEPARTMENT OF INDUSTRIAL AND PRODUCTION ENGINEERING  
DR. B.R. AMBEDKAR NATIONAL INSTITUTE OF TECHNOLOGY, JALANDHAR

IN ASSOCIATION WITH

TIET, PATIALA | IGDTUW, DELHI

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Punjab Engineering College (Deemed to be University) (PEC) having its roots in Lahore as Mugalpura Engineering College since 1921, moved to its present campus in 1953 as PEC affiliated to Panjab University. The institute became Deemed University in 2003 through a MHRD notification and rechristened as PEC University of Technology in 2009. For the last 100 years PEC is moving strong with a vision of becoming centre of excellence in technical education and research. The institute collaborates very closely with research organisations, industries, alumni and other academic institutions both India and abroad, and has signed MoUs to pursue joint research in niche areas. The students graduating from this institute are placed in highly reputed companies with handsome salary packages. With a history of about 100 years now, the institute has produced a number of alumni who have earned name and fame both for themselves and the institute.



Dr B R Ambedkar National Institute of Technology was established in the year 1987 as Regional Engineering College and was given the status of National Institute of Technology (Deemed University) by the Government of India on October 17, 2002 under the aegis of Ministry of Education (Shiksha Mantralaya), New Delhi. Now the Ministry of Education (Shiksha Mantralaya), Government of India has declared the Institute as "Institute of National Importance" under the act of Parliament-2007. A large number of reputed Industrial houses in the country visit the Institution and select the final year students as Engineers/ Management Trainees. As one of the National Institutes of Technology (NIT), the Institute has the responsibility of providing high quality education in Engineering, Technology and Sciences to produce competent technical and scientific manpower for the country. The Institute offers BTech, MTech, MSc, MBA and PhD programmes in the several disciplines of Engineering, Technology and Sciences.



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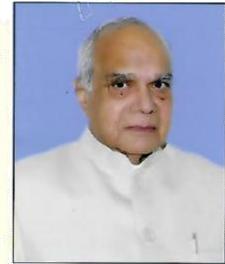
**Banwarilal Purohit**

*Governor of Punjab  
and  
Administrator  
Union Territory, Chandigarh*



*Raj Bhavan  
Chandigarh.*

*November 8, 2021*



**MESSAGE**

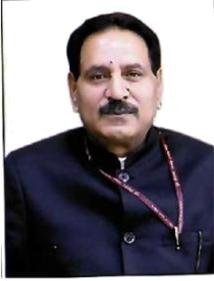
It gives me immense pleasure to note that the 2nd International Conference on Industrial and Manufacturing Systems, CIMS-2021 is being held at Punjab Engineering College (Deemed to be University) in collaboration with Dr. B. R. Ambedkar National Institute of Technology, Jalandhar from November 11<sup>th</sup>-13<sup>th</sup>, 2021.

This year marks a significant milestone for PEC as it celebrates 100 glorious years of its existence. For 100 years, PEC has contributed to the country with some brilliant minds for nation. Since its inception in 1921, it has pioneered engineering and technical education in the northern region of India. I am sure this conference will inspire more young minds to explore, innovate and find creative solutions to the impending challenges in Production and Industrial Engineering.

I congratulate PEC for organizing this event and hope that it contributes significantly to the advancement of technical education and engineering.

  
[Banwarilal Purohit]

**Dharam Pal, IAS**  
**Adviser to the Administrator**



**U.T. Secretariat, Deluxe Building,**  
**Sector 9-D, Chandigarh-160009**

D.O. No. PS/AA/2021/713....

Dated : 03/11/2021.....

## MESSAGE

I am pleased to learn that the second international conference - "Industrial and Manufacturing Systems" (CIMS-2021) is being held at Punjab Engineering College (Deemed to be University) in tandem with Dr. B. R. Ambedkar National Institute of Technology, Jalandhar from November 11th to 13th, 2021. The conference aims at providing interdisciplinary platform for academic scholars, engineers, and students to discuss research in the areas of Production and Industrial engineering. I am happy to note that the Conference will have international participants, including prominent industry experts, speakers, delegates, and researchers round the world.

The advancement of technical education is a crucial aspect of a healthy administrative system. India has the potential to become a superpower by focusing on the manufacturing sector, which can be achieved by the synergies of administration and technical education. The conference facilitates discourse on the latest research results, ideas, developments, and applications in the areas of industrial and manufacturing systems. Hence, it provides opportunities for the advancement of technical education, research, and development.

As an alumnus of Punjab Engineering College, I am pleased to inform you that this year marks the completion of 100 glorious years since the establishment of PEC. It is commendable that the institute in its centennial year heralds the progress of innovation, education, research, and development. I wish the conference a grand success, and hope the technical education lights the way forward towards innovative creation.

(DHARAM PAL)

**MESSAGE**



I am delighted to note that the top ranked engineering Institutes of India, namely Punjab Engineering College Chandigarh, Dr B. R. Ambedkar National Institute of Technology, Jalandhar have collaborated together for 2<sup>nd</sup> International Conference on Industrial and Manufacturing Systems (CIMS 2021) lead by the Production and Industrial Engineering Department, PEC Chandigarh on 11<sup>th</sup>-13<sup>th</sup> November, 2021.

Production and Industrial Engineering has always been the key driver of the growth engine for the prosperity of nations. With the same essence, the theme of the conference inculcates the government vision of "Make in India" addressing the new challenges in the Manufacturing sector and their innovative solutions. We are sure that rich deliberations in the Conference shall focus on areas where academia, industry and research institutions would work together for meeting the grand challenges facing the nation.

I congratulate the organizing committee of CIMS 2021 and am confident that it will have a takeaway for each one of us according to our choice for our quest for knowledge in future. We hope that CIMS 2021 shall prove to be very purposeful and enlightening for all the delegates.

  
(Rajinder Gupta)

Chairman, BOG, PEC and Chairman Board of Directors of Trident Group

**S.S.Gill, IAS**



**Message**

**Secretary**

**Chandigarh Administration**

**D.O. NO.....**

**DATED:.....**

It gives me immense pleasure to state that the 2<sup>nd</sup> International Conference on Industrial and Manufacturing Systems (CIMS-2021) will be co-hosted by Punjab Engineering College (Deemed to be University) and Dr. B. R. Ambedkar National Institute of Technology, Jalandhar, on 11<sup>th</sup>-13<sup>th</sup> November 2021.

The conference will be subsequent to the 100<sup>th</sup> foundation day of the Punjab Engineering College (Deemed to be University) since its inception in 1921.

I am sure that this conference will witness rich deliberations that will be breeding grounds for key industry solutions to multiple problems that our nation faces today in research and technology.

Production and Industrial Engineering have always played a significant role in the growth of nations. In that regard, I am confident that various research ideas and creative solutions will get a much-needed platform with this conference.

I am happy to state that with conferences like CIMS 2021, we have been able to inculcate research and innovation culture among students and delegates from very early on, and this will help significantly in the evolution of technical education.

I congratulate the organizing committee for their best efforts to conduct this international conference and wish them great success in future endeavors.

S. S. Gill, IAS  
Secretary Technical Education  
Chandigarh Administration



Office Address : Room no 312, 3<sup>rd</sup> Floor, U.T Secretariat, Sector 9-D, Chandigarh 160009  
Phone: +91 172 2747275, Email ; ss.gill29@gov.in

## Message

It is very heartening to know that the Department of Production and Industrial Engineering of the Institute is conducting the *2<sup>nd</sup> International Conference on Industrial and Manufacturing Systems (CIMS 2021)* in collaboration with Dr B R Ambedkar National Institute of Technology, Jalandhar and in association with Thapar University Patiala and Indira Gandhi Delhi Technical University for Women, Delhi. The organization of the Conference assumes great significance as it falls at a time when the Institute has completed 100 years of its glorious existence.



PEC has been the fertile ground for talent and innovations, where ideas have been nurturing and growing into applications for over 100 years now. As we know, Industry 4.0 is revolutionizing the way companies manufacture, improve and distribute their products. In the same spirit of technical excellence, the International Conference will address the challenges of the modern industry and provide innovative solutions.

I am sure that CIMS 2021 will bring together global talent, focusing on excellent opportunities for researchers, scientists and industrialists to share their thoughts and deliberate on the latest developments in the area of Engineering and Technology. The academically rich deliberations among the delegates during the conference will pave the way for meeting the grand challenges of the present and the future.

I come forward to express my best wishes to the organisers for the success of the Conference.

A handwritten signature in green ink, which appears to read 'Baldev Setia'.

**(Prof. Baldev Setia)**  
Director



**Manish Gupta**  
Chairman, CII Chandigarh UT



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Northern Region  
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### Message



It gives me immense pleasure to note that the Production and Industrial Engineering Department, Punjab Engineering College Chandigarh and Department of Industrial and Production Engineering, Dr B. R. Ambedkar National Institute of Technology, Jalandhar in association with Thapar Institute of Engineering and Technology, Patiala and Indira Gandhi Delhi Technological University for women, Delhi are organizing the 2nd International Conference on Industrial and Manufacturing Systems (CIMS2021) on 11th -13th November, 2021. The international conference will address the new challenges in the modern industries and their innovative solutions. I am sure that academically rich deliberations as would be in the conference shall focus on areas where academic, industry and research institutions would work together for meeting grand challenges.

The role of Production and Industrial Engineering is inevitable in building the nation. The sustainability and productivity can be enhanced by improving product quality with safe working environment using innovative techniques in the applied fields for the development of society at national and international level. As an Alumni of PEC, I can proudly say that this institute has been the breeding ground for talent and innovations for 100 years, where ideas germinate and grow into applications.

I am sure that CIMS 2021 will bring together the global talent on single platform where researchers, scientists and industrialists will share their thoughts and converse on the latest developments in the area of industrial and manufacturing systems. I wish grand success to the conference and congratulate the organizers for their excellent efforts in getting some of the best brains in this conference.

Manish Gupta  
Chairman, CII Chandigarh UT



### Message

On behalf of the organizing committee of 2<sup>nd</sup> International Conference on Industrial and Manufacturing Systems (CIMS-2021). I am extremely humbled and honoured to welcome all the eminent experts and distinguished participants from different parts of the globe to the CIMS-2021 jointly organized by Production and Industrial Engineering Department, Punjab Engineering College Chandigarh and Department of Industrial and Production Engineering, Dr B. R. Ambedkar National Institute of Technology, Jalandhar in association with Thapar Institute of Engineering and Technology and Indira Gandhi Delhi Technological University for Women, Delhi.

CIMS-2021 aims to pave a path to discuss cutting edge ideas in technology for creating a sustainable future for the upcoming generations. The prime motive of CIMS-2021 is to seek new windows for discovery and exploration in Production and Industrial Engineering which plays a major role in almost all fields of scientific growth and to provide an arena for showcasing these advancements and research endeavors being undertaken in all parts of the world.

We are privileged to host a congregation of world renowned scholars and experts as keynote speakers, who have gathered for this conference to grace us with their words of wisdom in their fields of expertise. We feel proud in saying that the first edition CIMS-2020 was a huge success and this edition we have maintained the similar standards and touched the new heights. We have received more than 350 technical papers out of which more than 280 were selected after a rigorous peer review.

We feel privileged to have Web of Sciences and Scopus indexed journals in the fields of production and industrial engineering from top publishers like Taylor & Francis, FME Transactions and Springer as our publication partners.

We hope that CIMS-2021 shall prove to be very purposeful and effectual for all the delegates.

We wish all the delegates and guests a wonderful experience and a baggage full of good memories and great ideas to carry back from the Conference.

(Prof R S Walia)

Chairman CIMS-2021

Prof & Head

Production and Industrial Engineering Department



**डा बी आर अम्बेडकर राष्ट्रीय प्रौद्योगिकी संस्थान, जालन्धर**  
**Dr B R Ambedkar National Institute of Technology, Jalandhar**  
जी टी रोड बाईपास, जालन्धर-144011, पंजाब, भारत  
G T Road Bye Pass, Jalandhar-144011, Punjab, India

Ref. No. ....

Dated .....

**MESSAGE**

It gives me immense pleasure to announce that 2<sup>nd</sup> *International Conference on Industrial and Manufacturing Systems* (CIMS-2021), is being jointly organised by Punjab Engineering College Chandigarh and Dr. B.R. Ambedkar National Institute of Technology, Jalandhar (Punjab), from 11<sup>th</sup>-13<sup>th</sup> November 2021 at PEC Chandigarh.



In the present era of global competition, technology is an ever-evolving field, constantly mixing in new iterations and innovations to create exciting new opportunities for today's manufacturers to reimagine their operations. The prime motive of CIMS 2021 is to seek new windows for discovery and exploration in Industrial and Manufacturing Engineering which plays a major role in almost all fields of scientific growth. The conference intends to provide arena for showcasing these advancements and research endeavours being undertaken in all parts of the world. I am sure that this conference will provide a vibrant platform for academicians, researchers and industry practitioners to unveil what needs to be changed in the Industrial and Manufacturing systems for a sustainable future.

We are privileged to host a congregation of the renowned researchers and experts in the conference, who will grace us with their experiences and wisdom in the respective field of expertise. We are extremely proud that the first version of the conference held in 2020 had overwhelming response with around 400 technical papers being presented in the event.

We hope that CIMS 2021 shall prove to be purposeful and informative for all the delegates participating in the event. We are looking forward to an excellent meeting with great scientists from different countries around the world sharing their new and exciting work in the field.

We sincerely hope that all the delegates and guests have a rich experience and networking alongwith great ideas from the conference.

Prof Anish Sachdeva  
Dean - Academic

## MESSAGE

I along with my colleagues organising secretaries *Dr. Ravi Pratap Singh, Dr. Dilbagh Panchal and Dr Narendra Kumar* and pleased to share that CIMS-2020 is now one-year younger as *2<sup>nd</sup> International Conference on Industrial and Manufacturing Systems (CIMS-2021)*, which is being organizing as a joint venture of Department of Industrial & Production Engineering, Dr. B.R. Ambedkar National Institute of Technology, Jalandhar, Punjab, India and Department of Production and Industrial Engineering, Punjab Engineering College, Chandigarh, India. CIMS-2021



is a platform to bring researchers and experts from academia and industry on a common platform for discussing the latest technologies and techniques being adopted in the field of Industrial and Manufacturing Engineering. It will help to provide opportunity for all branches of industry, to disseminate the information on most recent and relevant research, theories and practices in the area of Industrial & Manufacturing Engineering. CIMS-2021 highlights the Role of Industrial and Manufacturing Systems towards future growth. It got prodigious response to the call for papers from the academicians, researchers and students of the institutes of repute situated globally. The research articles so submitted by academicians, researchers and students, presents theoretical and application based outcomes, to meet the societal needs.

I would like to thanks the reviewers and the members of National/International advisory committee, faculty members of Industrial & Production Engineering Department of for their support. I am very thankful to all authors and sessions chairs for their active contribution in this conference. I would acknowledge the student volunteers for their assistance. I am extremely thankful to our associate partners TIET Patiala and IGDTU Delhi for extending their valuable support to this conference.

I am extremely thankful to Prof. L. K. Awasthi, Prof. Baldev Setia and Prof. R. K. Garg, for their constant support and encouragement in making this international conference a grand success. I am also pleased to Dr. S. K. Mishra, Registrar, NIT Jalandhar for providing us administrative support for smooth conduct of this joint venture.

A handwritten signature in blue ink that reads "M Tyagi". The signature is written in a cursive style.

**Dr. Mohit Tyagi,**  
Organising Secretary CIMS-2021



## Keynote Speakers



Dr. Kumar Krishen  
Adjunct Professor,  
University of Houston  
USA.

Dr. Krishen is Adjunct Professor, University of Houston. Dr. Kumar Krishen has supported space exploration from January 1965 and was with NASA in various capacities from February 1976 to September 2018. Dr. Krishen has served as Innovation Champion and ST/ Chief Technologist for NASA Johnson Space Center (JSC) and represented JSC as the Principal Technologist on the NASA Council on Science and Technology. Dr. Krishen authoring more than 170 technical papers/reports/proceedings, Dr. Krishen is a Fellow of the Society for Design and Process Science (SDPS), Fellow and Distinguished Speaker of the Institution of Electronics and Telecommunication Engineers (IETE), and an Assoc. Fellow of the American Institute of Aeronautics and Astronautics (AIAA). Dr. Krishen received the NASA Exceptional Service Medal in September 2018 recognizing his exceptional and sustained service to NASA and the United States in the realm of technological advancements in support of Human Spaceflight.

**Title for talk: New Technology Innovations with Potential for Space Exploration.**



Dr. Wolfgang Borutzky  
Bonn-Rhein-Sieg  
University  
Germany.

Wolfgang Borutzky is a retired Professor of Modelling and Simulation of Engineering Systems from Bonn-Rhein-Sieg University, Germany. Since 2008 he holds an honorary position as Associate Professor of Electrical Engineering and Information Technology at the University of Dubrovnik, Croatia. Dr. Borutzky has published extensively in the proceedings of many international conferences on Modelling and Simulation and conferences on Control and in refereed scientific journals. He is the author of three Springer books on Bond Graph related topics and the editor and co-author of two Springer compilation texts with contributions from experts in various fields from all over the world. He was a visiting professor at universities in the Netherlands, the U.S.A., France, and in Argentina and has served as an invited external examiner and as a member of Ph.D. defense committees in various countries.

**Title for talk: Bond graphs for modeling and simulation, control, fault diagnosis and failure prognosis of industrial engineering system.**



Dr. J Haider Senior  
Lecturer Manchestr  
Mertopolitan University  
UK.

Dr Julfikar Haider is currently working as a Senior Lecturer in Mechanical Engineering at the Department of Engineering, Manchester Metropolitan University, UK. Prior to this he worked as an assistant engineer in Rural Electrification Board, Bangladesh and Research Engineer at the School of Computing, Engineering & Information Sciences, Northumbria University, UK. He was awarded PhD from Dublin City University, Ireland in the area of surface engineering. Dr Haider's main research interests are in composite materials, surface engineering, metal cutting machining, advance welding, manufacturing systems for Industry 4.0 (e.g., lean manufacturing, Six sigma, mass customisation) and finite element modelling. To date he has supervised to completion four KTP associates (research associate). He was REF returnable in 2014 and preparing to contribute in REF2021 submission. He has published and presented over 80 technical papers in international journals and conferences and books in the above areas.

**Title for talk: Multipoint cutting tool products machined by multipoint cutting tools-industrial prospective.**





Dr. Pradeep Kumar  
Professor  
IIT Roorkee  
India.

Prof. Pradeep Kumar is Professor of Mechanical and Industrial Engineering, Indian Institute of Technology Roorkee, He was a Visiting Assistant Professor at West Virginia University, U.S.A., Wayne State University, U.S.A., AIT Bangkok, King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia, as Visiting Professor. He also did serve the Delhi Technological University as Vice Chancellor. In his 30 years of long carrier, he has supervised more than 40 Ph.D. theses. He has more than 600 research papers several patents under his name. His research interests include Advanced Manufacturing Processes; Microwave Joining of Metals, Metal Casting; Industrial Engineering; Supply Chain Management (SCM), Quality Engineering; Robust Design Methodologies, Reliability Engineering; and Production & Operations Management. Prof. Pradeep Kumar has received a number of prizes and honors. He was honored with an Outstanding Teacher Award at IIT Roorkee two times. He has received 4 best paper/case studies prizes for his papers published in Journals and conference proceedings. He has been honored as eminent mechanical engineer for his contribution in the field of mechanical engineering by The Institution of Engineers (India).

**Title for talk: Sustainable green supply chain management.**



Dr. Yigit Kazancoglu  
Professor  
Yasar Univeristy  
Turke.

Prof. Kazancoglu graduated from Izmir American College in 1998. Kazancoglu received his B.S. degree from Eastern Mediterranean University, Dept. of Industrial Engineering. He has graduated from Coventry University, England, MBA and Izmir University of Economics MBA programs, respectively in 2003 and 2004. Kazancoglu has received his PhD. at Ege University (Production&Operations Management). He was working in Izmir University of Economics, Dept. of Business Administration between 2002-2016 He was the director of Izmir University of Economics Continuing Education Center between 2009-2014 and member of the executive board in Center for Urban and Regional Development and Environment between 2008-2016. Between December 2016 - May 2019 he worked as Associate Professor Dr. in Yasar University, Logistics Management Department. In May 2019, he is assigned as Full Professor Dr. in the same department. He is the head of Logistics Management Department in Yasar University since 2017.

**Title for talk: The use of decision-making models for sustainability and circular economy.**



Mr. Tarun Kumar  
Senior Program  
Manager- Amazon  
Operations, USA.

Mr. Tarun Kumar is one of the best students of Punjab Engineering College, Chandigarh. After graduating form Production and Industrial department he pursued his masters form University of Michigan Ann Arbor USA. He is green belt in reactive problem solving. His area of expertise includes quality engineering, new product development, six sigma, lean manufacturing, interior and exterior design, supply chain, cost engineering and strategic sourcing. He got an opportunity to work in the field of industrial engineering with many multinational companies on various projects. Currently, He is working as senior program manager-amazon operations, North America

**Title for talk: Global work trend in industrial engineering.**



## CIMS-2021 Schedule

### Day I: November 11, 2021 (Thursday)

Activity	Time
Inaugural Ceremony at Senate Hall, PEC Chandigarh	10.00 AM – 11.00 AM
High Tea	11.00 AM – 12.00
<b>Plenary Talk – I</b> (Dr. Kumar Krishen, Chief Technologist, NASA, Johnson Space Center, USA, (Formerly), Adjunct Professor, University of Houston, USA)	12.00 Noon: 12.25 PM
<b>Plenary Talk – II</b> (Prof. Ing. Wolfgang Borutzky, University of Applied Sciences, Sankt Augustin, Germany)	12.35: 01.00 PM
<i>Lunch Break</i>	01.00: 02.00 PM
<b>Plenary Talk – III</b> (Dr. J Haider, Senior Lecturer, Manchester Metropolitan University, UK)	02.00: 02.25 PM
<b>Technical Session (TS) – I</b> (I-A, I-B, I-C, I-D, I-E)	02.45: 04.45 PM
<b>Cultural Programme</b> (Auditorium)	06:30: 07:00 PM

### Day II: November 12, 2021 (Friday)

Activity	Time
<b>Plenary Talk –IV</b> (Prof Yigit Kazancoglu, Yasar University Turkey)	10.00: 10.25 AM
<b>Technical Session – II</b> (II-A, II-B, II-C, II-D, II-E)	10.30: 12.30 PM
<b>Plenary Talk –V</b> (Prof. Pradeep Kumar, IIT Roorkee)	12.35: 01.00 PM
<i>Lunch Break</i>	01.00: 01.45 PM
<b>Technical Session – III</b> (III-A, III-B, III-C, III-D, III-E)	01.45: 03.30 PM
<b>Technical Session – IV</b> (IV-A, IV-B, IV-C, IV-D, IV-E)	03.45: 05.30 PM

### Day III: November 13, 2021 (Saturday)

Activity	Time
<b>Plenary Talk – VI</b> (Mr. Tarun Goyal, Amazon, USA)	10.00: 10.25 AM
<b>Technical Session – V</b> (V-A, V-B, V-C, V-D, V-E)	10.30: 12.30 PM
<i>Valedictory Session*</i>	12.30 PM Onwards
<b>Announcement of Best Paper Awardees Vote of Thanks</b>	



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# 2nd International Conference on Industrial and Manufacturing System CIMS-2021

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## Index

S.No	Paper-ID	Title	Authors	Page No
1	CIMS2021-045	Design and Analysis of Cooling System for Li-ion Batteries in Electric Vehicles	T Chinnadurai*, M Karthigaipandian, K Saravanakumar, J Dhanaselvam, B Banuselvasaraswathy	01-06
2	CIMS2021-048	"A Review study on fatigue life assessment of engineering components by using FEA"	Mr. Gaurav U. Mankar*, Dr. Rajesh M. Metkar	07-11

3	CIMS2021-066	Design and Analysis of High Pressure Hydraulic Accumulator	Jyoti Prakash Sahoo*, Ritesh Kumar Patel,Gaurab Kumar Ghosh	12-18
4	CIMS2021-069	Commercial Product Development of Kinetic Sculpture Table	Dipak Gopal Aher*, B.B. Ahuja , Maneetkumar R. Dhanvijay	19-25
5	CIMS2021-070	Forecasting of Soft drinks Production	Zoheib Tufail Khan*, Mohd Faiz Aslam	26-28
6	CIMS2021-073	Nanomaterials: Aerospace Solution	Vani Sadadiwala*, Vimlesh Singh, Air Cmde. Devender Sharma	29-43
7	CIMS2021-075	EEG Signal Classification for Neurological Disorder Detection	Malika Garg*, Jasbir Kaur, Neelam Rup Prakash, Bipan Kaushal	44-49
8	CIMS2021-080	Speech Recognition Approach for Under Resourced languages with reference to Sylheti	Gautam Chakraborty*	50-57
9	CIMS2021-106	Role of Circular Economy in Global Perspective	Shubhangi Chourasia*, Ankit Tyagi, Qasim Murtaza, R S Walia, GP Joshi, Prince Sharma	58-65
10	CIMS2021-113	A Review on Differentially Rotating Shells-Significant Geo dynamo Model	Bharti Sharma*, Dr. Neetu Srivastava	66-77
11	CIMS2021-125	Overview of DSTATCOM for Power Quality Improvement	Ehsanul Haque Peerzadah*, Rehana Perveen, Abdul Hamid Bhat	78-83
12	CIMS2021-151	Analysis of pH Value of Water for Treatment Plant of Kekri and Surajpura (Rajasthan)	Roop Singh Sinsinwar* and Munna Verma	84-89
13	CIMS2021-155	Feature Optimization Methods: A step towards improvement in	Shelly Garg* and Balkrishan Jindal	90-98
14	CIMS2021-159	MODELLING OF STEM DETACHMENT MACHINE FOR TOBACCO LEAF	Vardhan Eswar*, Mohammed Asif. M, Pesarlanka Damodara Nagasai, B.Singaravel, Yaragani Saidarao	99-103
15	CIMS2021-161	PNEUMONIA PREDICTION ON CXR IMAGE DATASET USING MACHINE LEARNING	Lekha Sree J *, Shana J	104-109
16	CIMS2021-163	Designing Parameter Optimization for Manufacturing of Masks	Shreemann Mishra*, Vamsikrishna A	110-113
17	CIMS2021-0170	Finite Element Simulation of Laser Beam Bending Process	Ruby Singh*, Param Singh, Roopak Varshney	114-119
18	CIMS2021-0171	Thermal Analysis in Friction Stir Welding	Ishan Sharma*, Param Singh, Roopak Varshney	120-126
19	CIMS2021-172	Experimental Investigation On Tensile Behavior Of Sugarcane Bagasse Filled With Rice Husk Epoxy Composite	Pitamber Chandra*, Praveen Kumar , Dilbag Singh Mondloe, Ajay Singh Paikra, Ashish Patle, Ram Krishna Dewangan	127-131

20	CIMS2021-0173	Wanderer: Mars rover prototype with a modified four-link suspension system	Dhruvi Shah, Gaurav Patel, Uchit Shriyan*, and Chetna Sharma	132-137
21	CIMS2021-0189	Process modelling of Electrical Discharge Machining by Artificial Neural Networks: A review	Piyush Pant*, Pushpendra S. Bharti	138-148
22	CIMS2021-190	A systematic review of TMJ (Temporomandibular joint) Prosthetic: Dysfunction Index, Design and Success Rate	Deepak Sharma*, Parveen Kalra, Shagun Sharma	149-159
23	CIMS2021-193	PHYSICAL RISK AND MUSCULOSKELETAL INJURIES ASSESSMENT AMONG WORKERS IN CLEANING OCCUPATION	Rajat Pratap Singh*, Prof. Parveen Kalra, Dr. Suman Kant	160-166
24	CIMS2021-208	A Systematic Review on Color Homography Estimation System	Geetanjali Babbar*, Rohit Bajaj, Yogesh Kumar	167-172
25	CIMS2021-214	A Review on Advancements and Characteristics of Cryogenic Propulsion Rocket Engine	Gokul Raj R*, J V Muruga Lal Jeyan	173-178
26	CIMS2021-221	Effect of Working Posture, Feed Force, and Drill Speed on Productivity and Perceived Discomfort	Umair Arif, Saman Ahmad	179-185
27	CIMS2021-228	Study on Fluoride Uptake by Modified Polyaniline with Doped Chloride	Sarungbam Pipileimaa*, Potsangbam Albino Kumarb	186-192
28	CIMS2021-230	STUDY OF BIOMASS TORREFACTION FUNDAMENTALS AND PROPERTIES	Jaswinder Singh*, Madhur Chauhan, Sumit Kumar, Prateek Srivastava	193-199
29	CIMS2021-234	DESIGN AND MODELLING OF PERFORATION MACHINE FOR SDC CHILLIES	Pesarlanka Damodara Nagasaia, Mohammed Asif.Ma*, Yaragani Saidaraoa, T.Niranjanb, Vardhan Eswera,	200-209
30	CIMS2021-247	A review of performance and emission characteristics of single cylinder diesel engine fuelled with different alcohols.	Somit Shivhare*, Aryan Kumar and Ashish Kumar Singh	210-214
31	CIMS2021-0277	A Comprehensive Study of Lean Manufacturing Approaches and Applications in Industries JIT, Lean and Agile Manufacturing	Nittin, Mahesh Chand	215-225
32	CIMS2021-0286	An Algorithm for Minimum Zone Sphericity Evaluation from Coordinate Data	G Rajamohan*	226-232
33	CIMS2021-0291	Current voltage relationships in electrochemical wastewater treatment	Vinod Kumar Meena, Himadri Roy Ghatak* (ORCID 0000-000-9-78)	233-237

34	CIMS2021-302	Dimensions for the optimized siting location of EVs charging station: The Indian scenario	Mohammed Sayeed Ejaz, *, Sharad Singh, Dr Akhilesh Barve	238-243
35	CIMS2021-315	All-Terrain Vehicle Rollcage Design and Analysis	Deepshikha*, Kritika, Yukta, Dr Tina Chaudhary	244-250
36	CIMS2021-319	Elemental analysis of Ayurvedic medicines using X-ray tube based portable energy dispersive XRF setup	Kailash*, Ashutosh Kapil, Devinder Mehta and Sanjeev Kumar,	251-254
37	CIMS2021-320	Hardware-in-loop simulation of Grid Connected PV system for optimizing maximum output power	Sanjiba Kumar Bisoyi*, Parveen Poon Terang, Aayush Srivastava,	255-261
38	CIMS2021-325	Artificial intelligence and Cyber security as key challenges of Industry 4.0	Rupen Trehan*, Rishabh Machhan, Perminderjit Singh, Kuldip Singh Sangwan	262-274
39	CIMS2021-328	Efficiency Enhancement of Iterative Filtering Algorithm by Simulative Analysis	Supriya*, Nikhil, Charu Madhu, Nidhi Garg	275-278
40	CIMS2021-331	Fabrication of nano-Al <sub>2</sub> O <sub>3</sub> dispersed W-Zr alloy by mechanical alloying and conventional sintering	Bappa Das*, Anshuman Patra	279-284
41	CIMS2021-334	Photovoltaic panel integration using phase-change material (PCM): Review	Kamesh Verma*, Om Prakash, A.S. Paikra, Piyush Tiwari	285-293







## Design and Analysis of Cooling System for Li-ion Batteries in Electric Vehicles

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### Abstract

To ensure that the battery pack works safely and shows good charging/discharging performance during its operation, it is necessary to adopt a proper Cooling system. This work intends to design an efficient liquid cooling system and to compare the performance of different cooling liquids. Heat transfer between a coolant and battery depends on the thermal conductivity of the coolant. The most commonly used coolants in a liquid cooling system are water and oil. In this research work, a 1 kW Li-ion battery is used and its performance is tested with and without a cooling system. It is observed that the battery temperature is reduced to 1°C with a cooling system. Likewise, liquid cooling shows better performance in comparison with water cooling. From the analysis, it is explicit that the room temperature also influences the battery performance considerably.

**Keywords-** Li-ion Battery, Thermal analysis, Cooling system, Liquid Cooling

### 1. INTRODUCTION

Traditional automobiles need a large amount of oil resources for their operation and they are the main sources of air pollution in major cities in India. To overcome the problems caused by these automobiles, electrical vehicles are widely promoted as an effective solution. In comparison with traditional automobiles, electric vehicles are much simpler in structure and have the advantages of zero tailpipe emission, quiet and high efficiency [1]. The development of electric vehicles in India is facing major challenges that include battery price, mileage, cycle life, charging time, safety and reliability [2]. Lithium-ion battery [LIB] has become the focus of electric vehicle research owing of its high voltage platform, high energy density, low self-discharge rate and long cycle life [3].

However, due to its own characteristics, the suitable operating temperature range of lithium-ion battery is relatively narrow, the best operating temperature is between 20–40 °C and the temperature either too high or too low affects the performance of battery, and would even cause safety problems [4]. In order to ensure that the battery pack can work safely and show good charging/discharging performance during operation, it is necessary to adopt a proper Cooling system to make the battery pack work effectively [5]. Various types of cooling systems available are air cooling, liquid cooling, phase change material cooling and heat pipe cooling systems, based on the the cooling medium [6].

The ability of heat transfer between coolant and battery depends on the thermal conductivity, viscosity, density and flow rate of the coolant [7]. The most commonly used coolants in the liquid cooling system are water and oil [8]. Compared to other cooling strategies, liquid cooling is an efficient cooling method because of the high thermal conductivity and high specific heat capacity of liquid. Meanwhile, the liquid cooling system has a more compact structure which makes it to occupy a less volume and it could be placed in a narrower space. These factors make liquid cooling preferable strategy with high practicability [9].

Li-ion batteries prove to be attractive option for electric vehicles, in comparison with other battery chemistries, due to high energy storage density and competitive cost. However, Li-ion batteries generate significant heat during high power discharge [10]. A Li-ion battery has a nominal cell voltage of 3.7 volts compared to 1.4 volts in Nickel Metal Hydrides and 2.1 volts in Lead Acid batteries, which translates to significant energy density. Also, Li-ion batteries have a much wider operating temperature range compared

to Nickel Metal Hydrides. Depending on the battery's chemistry, the surface temperature of a battery pack can rise up to 90°C after 10 minutes of battery operation in charging or discharging modes. However, the temperature of the Li-ion battery must be regulated within the optimum range, failure of which can adversely affect the electrochemical performance of Li-ion cell charge acceptance, power and energy capability, reliability, cycle life, safety and cost [11].

Most of the temperature effects are related to chemical reactions occurring in the batteries and also depend on the materials used in batteries. Regarding chemical reactions, the relationship between the rate of chemical reactions and reaction temperature follows Arrhenius equation, and temperature variation can lead to the change of electrochemical reaction rate in batteries. Besides chemical reactions, the ionic conductivities of electrodes and electrolytes are also affected by temperature. With these effects in concern, the LIBs used in EVs and HEVs can hardly meet the basic expectation of a 10-year life. The functions performed by the electric component in a BEV are: Power supply to electrically driven accessories, including air-conditioning. Stop & start. Power supply for traction purposes in electric mode only (EV), Brake energy regeneration and Plug-in charging HEVs. HEVs run on both an internal combustion engine and an electric motor that uses energy stored in a battery. Unlike most electric vehicles, however, HEV drivers charge their batteries via regenerative braking.

Thermal challenges exist in the applications of LIBs due to their temperature-dependent performance. The optimal operating temperature range of LIBs is generally limited to 15–35°C. Both low temperature and high temperature lying out of this scope will affect the performance and may cause irreversible change to the LIBs. At low temperatures, the degradation of performance is mainly caused by the reduction of ionic conductivity and the increase of charge-transfer resistance. Lithium plating is a specific effect that occurs on the surface of graphite and other carbon-based anodes, which leads to the loss of capacity at low temperatures. High temperature conditions accelerate the thermal aging and may shorten the lifetime of LIBs. Heat generation within the batteries is another considerable factor at high temperatures. With the stimulation of elevated temperature, the exothermic reactions are triggered and generate more heat, leading to the further increase of temperature. Such uncontrolled heat generation will result in thermal runaway [12]. The heat produced by the battery is reduced and controlled mainly by the cooling methods. These cooling methods are connected to the battery for reducing its warmth level. This Battery Thermal Management System (BTMS) is employed to maintain the thermal level of the battery. In the time of charging and discharging of the battery, the temperature of the battery changes and exceeds the fixed value. The standard transmission of battery temperature ranges from 25°C and 35°C. When the heat is transferred from battery, this warmth increases the temperature level of the battery and at this time the cooling system starts its functions. An experimental comparison is performed based on different coolants for an advanced battery thermal management system designed for emerging electric vehicles. The liquid coolant has indirect battery contact and is a method to get rid of the warmth generated from the battery during operation.

## 2. RESEARCH METHODS

### 2.1 Li-ion Battery

In this study, a 1 KW Li-ion (LiFePO<sub>4</sub>) battery pack is utilized for the analysis. The individual cell capacity is bound to be 3.2V/6Ah. Nominal voltage of the battery is 24 V and capacity of the battery is 48 Ah range. Battery lifetime is 3000 cycles and working temperature of the battery is > 45°C. Individual cells are arranged in the form of a passive cooling system. The battery arrangements are shown in “Fig. 1”. For converting the DC to AC, a 1.5 kW inverter is used. This AC load is connected with battery to analyze its discharge characteristics. This load is connected with five 210 W bulbs and an individual load is connected with switch. The load setup is shown in “Fig. 2”.

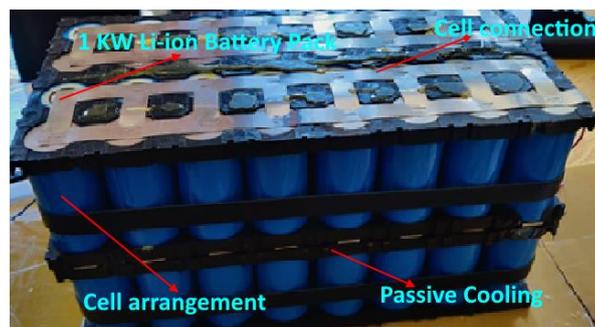


Fig. 1. 1 kW Li-ion battery pack

Fig. 2.

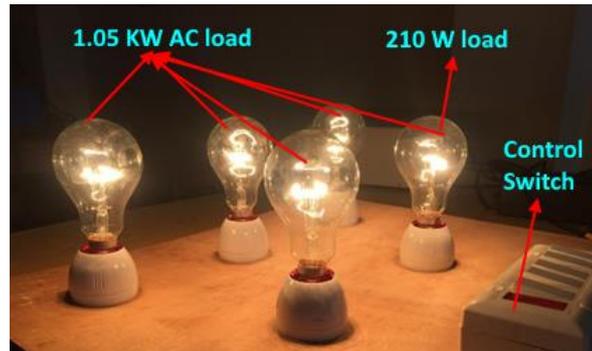


Fig. 3. 1.05 kW AC Load

## 2.2 Cooling System

Modern technology has successfully exploited the exceptional properties of copper and copper alloys employed in tube and pipe products. Copper tube is used widely as a means of conveyance of potable water in houses and buildings. Another important application of copper tube is in refrigeration and air-conditioning systems. Copper is mostly used for plumbing because of the following properties.

- Resistant to corrosion
- High level heat transfer
- Machinability and
- Consumption of less refrigerant designations.

The specifications of copper tube are: outer diameter of 8 mm and wall thickness is 25 gauge. Material is designed based on ASTM B280 copper tube. Working model of the system is shown in “Fig.3”. The system is receiving cooling liquid from tank through pump. The control valve is controlling the flow of liquid into the inlet section. The different cooling pipes are installed around the battery pack. For battery discharge AC load is used at 1kW range.

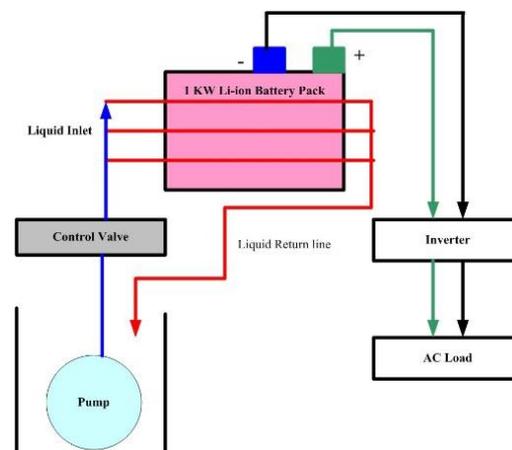


Fig.3. Working of cooling system

## 3. RESULT DISCUSSION

Liquid cooling is Carried out by natural minerals, water and oil coolant forms. Comparing liquid cooling to air cooling for thermal conductivity, air cooling is bound to have poor conductivity. Hence, an alternative solution is preferred in the form of liquid cooling that provides higher conductivity. Liquid cooling is basically divided into direct cooling and indirect cooling methods. Direct cooling is done by immersing the battery pack into the circulated dielectric coolant (for example, oil). Indirect cooling is done by passing the fluid through tubes or jacket and then around the pack or cold plate where the packs are placed over it.

By comparing the cooling efficiency of direct and indirect methods, direct cooling has higher heat transfer rate due to its tendency to absorb heat in the contact surface between pack and coolant. But due to the usage of high viscosity coolant like oil, they need more power in case of using high forced flow rate. And also,

indirect cooling uses water for cooling that does not have this high-power consumption problem, owing to its low-viscosity rate. In this analysis oil and water are used as coolants in indirect cooling method. Comparing the thermal performance of the air-cooling system and liquid cooling system, the results indicate that air cooling requires large power, and also proves that 2 to 3 times higher amount of energy is utilized in this method.

### 3.1 Battery charging analysis

Charging of battery is carried out first at room temperature and then with the cooling system. Battery voltage and temperature are continuously monitored both with cooling and without cooling environments. Experimental data are given in Table 1. Voltage variations with different timings are shown in Fig.4. Likewise, the temperature variations of battery at different timing are shown in Fig.5.

In the second stage, liquid coolant is used to cool the battery instead of air cooling. Thermal runaway occurs when the cell is hot that leads either to overcharging or short circuit. Li-ion cells are placed in the HPAC phase change material container for cooling the battery. Here multiple-channels are coupled to carry the coolant to the battery surroundings. Liquid mass flow rate and channel numbers both are expected to have an impact on cooling. When the number of channels was increased, mass flow rate is reduced and this increases the battery cooling. From Fig.4, voltage is analyzed with different cooling conditions such as without cooling, water-based cooling and oil-based cooling. Here the voltage variations are very minimal throughout the process. Slight variations are only recorded between these three cooling methods.

Table 1 Battery Charging of Li-Ion Battery With and Without Cooling

Time (min)	voltage without cooling (V)	voltage with water cooling (V)	voltage with oil cooling (V)	Et-Temperature °C	Temperature without cooling °C	Temperature with water cooling °C	Temperature with oil cooling °C
0	21	21.3	21.4	32.6	34.2	33.6	33.1
15	21.9	22.1	22.2	32.6	34.8	34	33.3
30	23.6	23.6	23.5	32.7	34.9	34.1	33.4
45	24.1	24	24	32.8	35.2	34.3	33.6
60	24.5	24.3	24.2	32.9	35.2	34.4	33.6
75	24.6	24.5	24.4	32.9	35.3	34.4	33.7
90	24.8	24.6	24.5	33	35.4	34.5	34
105	25	25	24.8	33.1	35.6	34.6	34
120	25.2	25.1	25	33.3	35.7	34.7	34.1
135	25.4	25.2	25	33.3	35.9	34.7	34.2
150	25.5	25.4	25.1	33.4	35.9	34.9	34.2
165	25.7	25.5	25.2	33.6	36	35.1	34.3
180	25.9	25.6	25.3	33.9	36.1	35.2	34.5
195	26	25.8	25.5	34	36.4	35.4	34.6
210	26.2	26.2	25.9	34.1	36.8	35.6	34.8
225	26.3	26.3	26	34	36.9	35.8	34.9
240	26.3	26.3	26.1	33.8	36.9	35.9	34.9
255	26.4	26.4	26.1	34	37	35.9	35.1
270	26.5	26.5	26.3	33.7	37.1	36	35.2
285	26.7	26.6	26.5	33.8	37.5	36.2	35.3

In Fig. 5, the temperature of battery is analyzed with different cooling methods. Environmental temperature is also considered in this analysis. It is deduced that the battery placed in standard room environment has high temperature variations, leading to fast charging. Likewise, the water-based cooling system removes higher heat from the battery, thus the cooling rate is also high. However, water-based cooling is not more efficient when compared with oil-cooling method. Oil-cooling method reduces the battery heat at 2°C from its initial heat value.

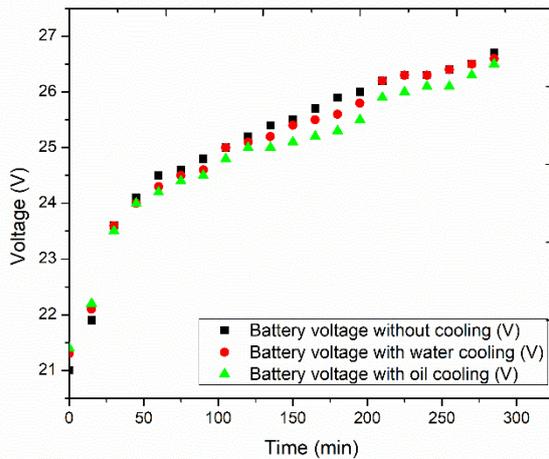


Fig.4. Voltage analysis with different timings

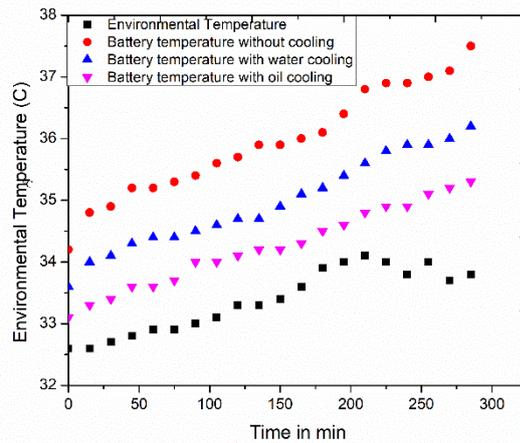


Fig.5. Temperature analysis with different timings

### 3.2 Battery discharge analysis

Heat generation in a battery is expressed in two ways, first is entropic heat generation due to electrochemical reactions happening inside the battery, second is ohmic heat generation due to current transfer process during charging and discharging. This heat generation will vary depending on the internal resistance of the battery. Ohmic heat generation will normally contribute to 54% in overall heat generation of battery. Both entropic and ohmic heat generation will vary with temperature variations of the battery.

A greater amount of heat is generated during discharge at the positive and negative terminals due to high current density. This temperature variations causes the changes in state of charge and life time of the battery. Table 2 shows the discharge characteristics of Li-ion battery with and without the influence of cooling system. Here, the analysis is done for different timings with its voltage and temperature variations. Fig. 6 explains the different cooling methods and its discharge voltage analysis. Based on the cooling effect, battery voltage drops tend to vary. At room temperature, the battery voltage is reduced, when compared with water and oil cooling methods. Likewise, the cooling liquid is also having influence on the battery voltage at the time of discharge. Fig.7 shows the temperature effects of different cooling methods. Here, the temperature variations of battery at different timings are measured. Oil cooling removes high heat from the battery, which increases the battery state of charge and also reduces the over discharging.

Table 2 Discharge Battery Performance Analysis

Time (min)	Battery voltage without cooling (V)	Battery voltage with water cooling (V)	Battery voltage with oil cooling (V)	Environmental Temperature	Battery Temperature without Cooling	Battery Temperature with water Cooling	Battery Temperature with oil Cooling	Time (min)
0	26.5	26.3	26.2	33.5	34.2	33.3	32.8	0
15	26.3	26.1	26	33.5	34.4	33.4	32.9	15
30	25.9	26	26	33.6	34.7	33.6	33	30
45	25.7	25.8	25.9	33.8	34.9	33.6	33.1	45
60	25.3	25.5	25.8	33.8	35.1	33.8	33.2	60
75	25.1	25.2	25.5	33.7	35.3	34.3	33.4	75
90	24.8	24.9	25.1	33.9	35.7	34.6	33.7	90
105	24.5	24.6	24.8	34.1	35.9	35	34	105
120	24.2	24.3	24.5	34	36.2	35.3	34.5	120
135	23.8	24	24.3	34.2	36.6	35.5	34.7	135

A greater amount of heat is generated during discharge at the positive and negative terminals due to high current density. This temperature variations causes the changes in state of charge and life time of the battery. Table 2 shows the discharge characteristics of Li-ion battery with and without the influence of cooling system. Here, the analysis is done for different timings with its voltage and temperature variations. Fig. 6 explains the different cooling methods and its discharge voltage analysis. Based on the cooling effect, battery voltage drops tend to vary. At room temperature, the battery voltage is reduced, when compared with water and oil cooling methods. Likewise, the cooling liquid is also having influence on the battery voltage at the time of discharge. Fig.7 shows the temperature effects of different cooling methods. Here, the temperature variations of battery at different timings are measured. Oil cooling removes high heat from the battery, which increases the battery state of charge and also reduces the over discharging.

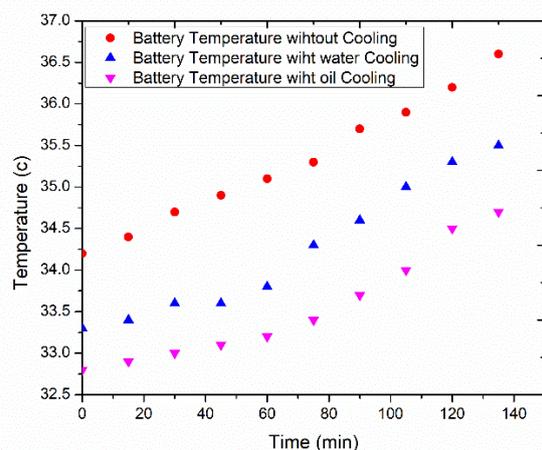
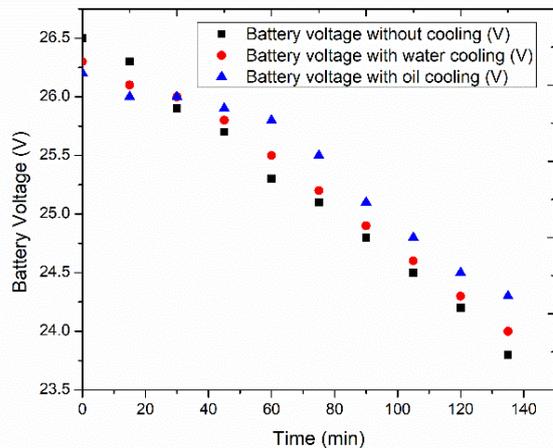


Fig.6. Battery voltage analysis with different timings during discharge Fig.7. Battery cooling effects on different timings of discharge

#### 4. Conclusion

In this paper, a cooling tube with multiple channel configuration is designed. A Li-Ion Battery is tested with cooling and without cooling systems to analyze the thermal influence. For cooling system, water and oil are used as coolants, and are pumped through copper tube. The coolant flow is fixed at a constant rate. The performance of copper tube with different cooling liquids are studied and the relevant conclusions are summarized as follows: (i) at normal environmental conditions, battery temperature varies alarmingly that will have a degrading impact on the battery cycle time and performance. (ii) compared with water and oil cooling as a cooling medium, oil carries higher amount of heat from battery compared with water. (iii) the inlet temperature of the coolant has little influence on heat removal from the battery. In fact, reducing the temperature of the coolant is an effective method to cool the batteries at a specific flow rate.

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## A Review study on fatigue life assessment of engineering components by using FEA

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### Abstract

The last few decades have seen an enormous rise in computing power and, with it, methods of numerical analysis which allow us to simulate complex systems. This has had a profound effect on engineering design: today, techniques to estimate the forces and stresses in components such multi-body analysis and FEA are available to designers even in relatively small engineering companies. This is bringing about a qualitative change in the way in which components are being designed, as we move away from simplified analytical calculations and empirical rules towards computer simulations. A good example is weather forecasting, where systems which are so complex that analytical solutions will never be possible can now be tackled using large computer models. These developments have naturally brought about corresponding changes in the way in which research is being conducted. This paper focused on evaluation method of fatigue life and FEA. Various evaluation methods are predicted by using FEA. Various analysis methods are predicted by using FEA and it shows the stress concentration and mean stress.

**Keywords-** FEA, fatigue life, fracture mechanics, impeller, compressor, welding and riveted joints.

### 1. INTRODUCTION

Fatigue is by far the most common cause of mechanical failure in engineering components; the prevention of fatigue failure is major preoccupation of designers in many industries, such as power generation and transport. When fatigue occurs in critical components the potential exists not only for economic loss but for loss of life. Fatigue cracks usually initiate at stress concentration features, and this is only to be expected because such features are almost inevitable in the design of engineering components. Even in those rare cases where the stress is constant throughout the part fatigue cracks will probably initiate from stress-concentrating defects such as inclusions or porosity. It follows then that the ability to predict the effect of stress concentrations on fatigue life and fatigue strength is crucial in engineering design; any improvements in prediction methods will inevitably pay major dividends in terms of more efficient design and reduced incidence of failure

However, failure under cyclic loading conditions is a more complex phenomenon than failure under static or monotonic loading. From the start, one can see that there are many more parameters to take into account. Fatigue is dependent on the entire history of cyclic loading experienced by the components. In general, this will be a complex, variable-amplitude loading involving cycles of both high and low magnitude; even in the simple case of constant-amplitude cycles, one must consider not only the stress amplitude but also the mean stress of the cycle and, in some circumstances, the frequency. The problem is further complicated by the fact that fatigue is a multi-stage process. We can divide the total fatigue life into a period is normally assumed to include a stage of short-crack growth. These different stages involve distinctly different mechanisms, controlled and affected in different ways by the loading history. Different stages may dominate in different circumstances.

Early work on fatigue, which goes back to the middle of the nineteenth century, defined the total life (i.e. the number of cycles to failure for an initially uncracked specimen) in terms of the stress range or strain range. With the advent of fracture mechanics the crack propagation stage began to be studied in greater detail. The

1960s and 1970s were decades of great advances in our understanding of the growth of long cracks, the realization that short cracks behaved differently, and the discovery of the important mechanism of crack closure. Since that time, improvements have been made at a slower pace; work has concentrated on refining our knowledge of existing mechanism and on developing numerical simulations which take advantage of modern computer technology.

## 2. LITERATURE REVIEW

FEA structural stress of Modalohr system for semi-trailer rail transportation weld root focus was studied by Practice Klein [1]. Modalohr roll-on-roll-off system can reach half the distance done by a French TGV and therefore it is high fatigue demanding freight. Even if fatigue becomes as demanding as it is on bogie, in the same way Modalohr design and weld design cannot be managed. To carry 4 meter high semi-trailer, fully 38t loaded in UIC kinematic with standard big wheel implemented in Y25 and T33 bogies is the main objectives of Modalohr. The longitudinal forces between Modalohr units increase when the train length is increasing. The longitudinal dynamics of the train is increased by necessary gaps involved between units. High longitudinal forces in the chassis frame are induced by semi-trailer natural attachment. It has to be considered as low cycle fatigue requirement because it can reach up to 50000 cycles over vehicle life. A strong railway design methodology is given with the help of Modalohr system. Including EN15085-3 specification, it takes into account CAD model to CAE idealization. Modalohr car body design is cost effective and also very fatigue demanding. Complete tool boxes for modalohr design allow both the time saving and also to design right welds at right location. The methodology leads to an optimized design in terms of mass which is critical for transportation system and also in term of process parameters.

Shujie Liu [2] observed the fatigue life assessment of centrifugal compressor impeller based on FEA. The centrifugal load and aerodynamic load have been considered, in the analysis of impeller life using FEA. Existing load, an alternating cycle load and dynamic load caused by centrifugal loads affects under working condition. 3D modeling, meshing, adding fluid field and uploading are the four steps involved in FEA. Zhang [2] carried out the experiment and a computer data acquisition system recorded experimental observations and data. For the experimental observations and data analysis of fatigue failure mechanism the fatigue life model for the FV520B was established. He concluded that, compared to the working conditions which is set for the simulation, real operational conditions of the FV520B impeller blade is long away more complex. The proposed simulation model is not universal. By considering the material properties, structure and working conditions a more accurate model to be proposed. Impeller blade may suffer by multiple competing failure modes thus it needs to include this modes. The error in data is due to noise and uncertainties in the fatigue lab experiment. The noise sources are variation in human factor, material samples, the data acquisition system, environmental conditions and equipment adjustment. To reduce the errors in the lab experiment results, a well designed experiment and data analysis procedure are highly recommended.

Due to metallurgical imperfections the repeating fluctuating stress causes fatigue cracks at the toe and throat of welding joints as welding joints are weak regions for the components of all earth moving machines. As some components of the machine are exposed to repeat stresses due to this the weld toe fatigue crack occurs also malfunction, fracture and may even cause danger to life. By taking this serious problem into consideration Vikrant Garud [3] studied the effect of post weld toe treatments on fatigue life of welded structures using FEA. For the improvement of fatigue life of components using FEA, he proposed the most common post weld toe grinding treatment methods. He concluded that the well suited parameters of welded structures are, for eight mm weld size, post weld toe grinding with hemispherical burr tool as post toe grinding with weld size of eight mm. Both the graphs are approximately parallel to each other this is observed from experimental validation result. On high capacity server the limitations on mesh size in ANSYS can be overcome as there is difference in the results. The results of this experimental analysis are approximately accurate and also can be differ by proportionality constant.

Jean Abry [4] tried to enhanced fatigue structural stress analysis of a heavy vehicle seam welded steel chassis frame. For assemblies relative to seam weld and bolt the LOHR industries have developed FEA models for vehicle structure analysis. The structural stress is not directly extracted from finite element solving but from element nodal forces and moments it is calculated. He concluded that, for welded structure

fatigue strength evaluation. LOHR industries have developed a shell element model. The fatigue limit was not correct that in this specific case, a detailed analysis of the model emphasized. Plate cut edge and weld termination toe are two attributes has to fit by the location of crack. With the appropriate stress components in tangential direction along with the plate edge, for fatigue assessment only plate cut edge indication had been use and has been corrected. Later fatigue results were predictive and also exceeding the fatigue limits. This includes at plate cut edge allows POSTAL, the LOHR industries fatigue assessment tool, are more robust in this improvement.

Hongfeng Ma [5] studied the fatigue redesign of failed sub frame using stress measuring, FEA and British standard 7608. The bridge inspection vehicle that can provide a work platform is a kind of special vehicle for the bridge maintenance. To improve the design the test is carried out and a practical method using finite element analysis to identify the cause of crack failure and propose an approach. For the bridge maintenance a work platform can be provided by a special kind of vehicle i.e. bridge inspection vehicle. In design stage to solve the problem of fatigue crack the only way is reduce stress concentration. In according to the FEA model results stress reduction in critical areas near to one third of the initial level stresses can be obtained. The stress distribution has been improved as the operation of system for fifteen months without crack initiation is allowed by the new design of sub frame. According S-N models on the fatigue life the stress distribution is reflected.

Jean sores Miranda [6] studied the effect of different loading pistons on stress distribution of CAD/CAM silica based ceramic and analyze the fatigue survival and CAD FEA modeling. He concluded that pistons are made of different materials led to differences in the bending strength, fatigue behavior and stress distribution on the tested CAD/CAM feldspar ceramic and epoxy resin piston was able to generate to more homogeneous stress distribution in the ceramic specimens, reaching more evenly and resulting failures in a shorter period, when compared with the tungsten and steel piston materials.

Vartharaj Neelakandan [7] conduct weight optimization of housing bracket for electrical starter motor using FEA and concluded that based on the analysis result of the initial level finite element analysis for the existing housing bracket, the housing bracket over design material and unwanted material additions was removed. With method of robust design weight and fatigue life optimization results were presented to meet the customer demand as well as to aligning to the vehicle operating conditions. For calculating the stress and fatigue life finite element analysis software used in the optimization of housing bracket and the weight was optimized to 20%. With increased cost margined the optimized new housing bracket was proposed for new starter projects to capture new business.

Wang Jinlong [8] studied the remanufacturing critical threshold and remanufacturability evaluation for FV520B-I blade based on fatigue life and FEA. He predicted the new fatigue life with fatigue crack for the model. To integrate the remanufacturability evaluation and fatigue life prediction, which is beneficial to improve the reliability of the remanufacturability evaluation results an effective way is provided by the proposal of the new remanufacturability evaluation method. The evaluation result is more comprehensive and reasonable, the safety of the remanufactured FV520B-I can be guaranteed. Some others parameters related to service capability into the remanufacturability evaluated by introducing the fatigue life.

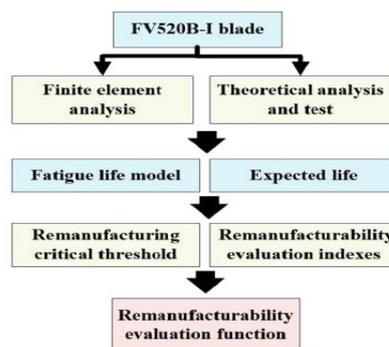


Fig. 1. Research line of the remanufacturability evaluation based on fatigue life 112 (2020).[8]

Wang Jinlong [9] studied the fatigue evaluation of FV520B-I shrouded impeller blade with fatigue crack based on FEA and fracture mechanics and he concluded that in actual operational process FEA for FV520B-I shrouded impeller with fatigue crack is performed to analyze the stress status. The common position for fatigue failure the significant stress concentration region is predicted at the top of the blade. With different fatigue crack size the element mean stress values of the crack tip are obtained.

Wang Jinlong [10] conduct the experiment by using USF-2000 fatigue test system is employed with an operating frequency of 20 kHz, which is close to the loading frequency of TC17 shaft in operational condition. He found that the surface fatigue failure is the common failure type for TC17 titanium alloy in HCF and VHCF regime. The primary cause of the fatigue failure of TC17 titanium alloy is the surface micro- scratch.

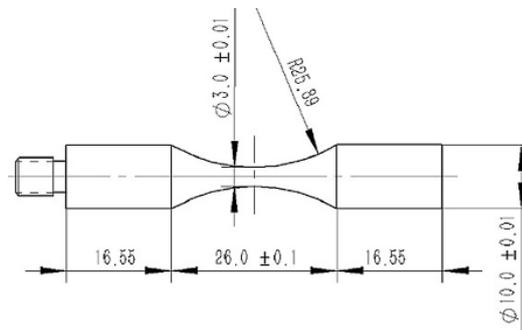


Fig. 2.The specimen 117 (2020) [10]

### 3. CONCLUSION

Finite Element Analysis or FEA is the simulation of a physical phenomenon using a numerical mathematic technique referred to as the Finite Element Method, or FEM. This process is at the core of mechanical engineering, as well as a variety of other disciplines. It also is one of the key principles used in the development of simulation software. Engineers can use these FEM to reduce the number of physical prototypes and run virtual experiments to optimize their designs. Complex mathematics is required in order to understand the physical phenomena that occur all around us. These include things like fluid dynamics, wave propagation, and thermal analysis. Analyzing most of these phenomena can be done using partial differential equations, but in complex situations where multiple highly variable equations are needed, Finite Element Analysis is the leading mathematical technique. Essentially, FEA algorithms are integrated into simulation software like Autodesk Inventor Nastran or ANSYS's suite of software. These programs are usually integrated into computer-aided design (CAD) software, making it much easier for engineers to go from design to running complex structural analysis.

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## Design and Analysis of High Pressure Hydraulic Accumulator

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### Abstract

A hydraulic accumulator works as a pressure storage reservoir, which stores incompressible fluid pressure form. It helps to reduce the installed power, absorb the pressure variation, and improve the efficiency of hydraulic systems. But, there are drawbacks of less energy storage capacity. To overcome this limitation, in this study a compound cylindrical model has been proposed to be used as the hydraulic accumulator instead of the commonly used single cylinder. Two models of a hydraulic accumulator, one of single-cylinder and another of compound-cylinder have been modelled in CATIA V5. Structural analysis has been performed on ANSYS workbench for both the single cylinder and compound cylinder hydraulic accumulator. Stress, strain, and deformation have been obtained analytically. These are also validated by theoretical calculations. A comparison has been made between the stress, strain, and deformation obtained in both the single and compound cylinder case, and finally, it is observed that the stress, strain, and deformation is less in the case of the compound cylinder hydraulic accumulator. It is because of the contact pressure due to the shrink fit between the cylinder, and the jacket of the compound cylinder, which resulted in the generation of residual stress at the contact surface, which helps in reducing the overall maximum stress, strain, and deformation.

**Keywords – Hydraulic accumulator, Compound cylinder, Single Cylinder, Pressure, Stress**

### 1. INTRODUCTION

A hydraulic accumulator is a type of pressure vessel. It is widely used to store incompressible fluid in the form of pressure. The pressure energy stored in the hydraulic accumulator is used during any sudden or large requirement. It is also used to improve the efficiency of hydraulic systems, absorb the pressure variation and reduce the power requirement. Hydraulic accumulators work in high pressure, so thick cylinder pressure vessels are used. But, still, the efficiency is not up to mark. In this project, we are giving a proposal of using the compound cylinder as a hydraulic accumulator. Compound cylinders have a wide range of applications in hydraulic presses, forging presses, power plants, gas storages, chemical and nuclear plants, military applications such as gun barrels, tanks, etc. So, here our objective is to use a compound cylinder as a hydraulic accumulator to increase its pressure accumulation capacity, thus increasing its efficiency.

### 2. LITERATURE REVIEW

Many kinds of research have already been done on the Hydraulic Accumulator. To name a few, Chetan Kumar and Shararth Kumar (2017) showed the design and analysis of a high-pressure hydraulic accumulator in their research. Van de Ven (2013) showed in his research that the use of a rolling diaphragm in a hydraulic accumulator can eliminate the pressure variation. But till now, there is not been any remarkable research to increase the efficiency of a hydraulic accumulator. Also, every research work on the hydraulic accumulator is done with a single-cylinder hydraulic accumulator. So the efficiency is not up to mark. So here in this paper, for the first time, we are going to use a compound cylinder pressure vessel as a hydraulic accumulator to increase its efficiency significantly.

### 3. METHODOLOGY

#### 3.1. Method of Analysis

1. At first, we design two hydraulic accumulators, one of a single-cylinder and another of a compound cylinder in CATIA V5, both having the same geometry and dimensions.
2. Then, stress analysis of both the single cylinder and compound cylinder hydraulic accumulator is done in ANSYS Mechanical workbench, and different generated stress values are obtained.

3. Then the analytical tangential stress value is compared with the theoretical tangential stress value to check the acceptability of the ANSYS analysis results.
4. Then, a comparison of different stresses and strain is done between both the hydraulic accumulators.

### 3.2. Mechanism of Compounding

In a compound cylinder, there are multiple layers, and there is a shrink-fit between the layers. Because of this shrink-fit, the contact pressure is generated at the contact of two layers, which resulted in compressive residual stress at the inner surface of the cylinder, which helps in reducing the total resultant stress generated in the cylinder because of the pressure of the liquid stored inside it.

### 3.3. Software Used

#### 3.3.1. CATIA V5

The design of both the single and compound cylinder hydraulic accumulator is done in CATIA V5. Then the files are saved as IGES files to import into ANSYS for analysis purposes.

#### 3.3.2. ANSYS

The stress and deformation analysis is done in Ansys mechanical workbench.

## 4. RESULTS

### 4.1. CAD Design

Here is a model of a piston-type single cylinder hydraulic accumulator. It has a single-layer cylinder, fluid connections, and a piston inside it.

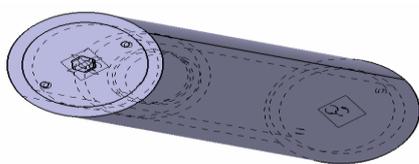


Fig 1: Single cylinder Hydraulic Accumulator

Here is a model of a piston-type single cylinder hydraulic accumulator. It has a double-layer compound cylinder, fluid connections, and a piston inside it.

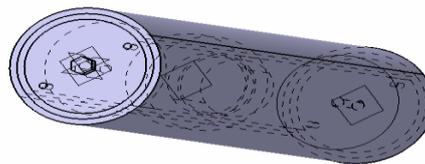


Fig 2: Compound Cylinder Hydraulic Accumulator

### 4.2. ANSYS Analysis Result

#### 4.2.1. Single Cylinder Pressure Vessel

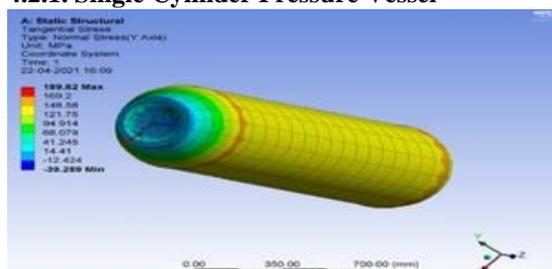


Fig 3: Tangential Stress

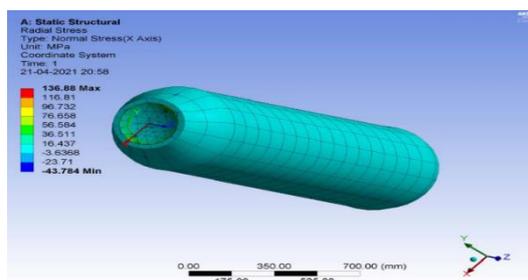


Fig 4: Radial Stress

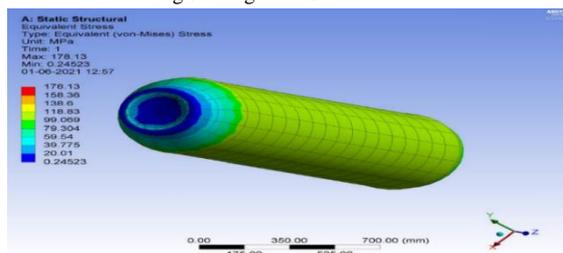


Fig 5: Von-Mises Stress

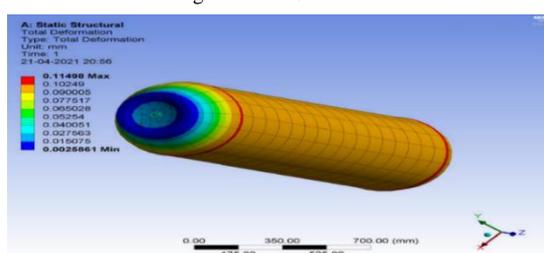


Fig 6: Total Deformation

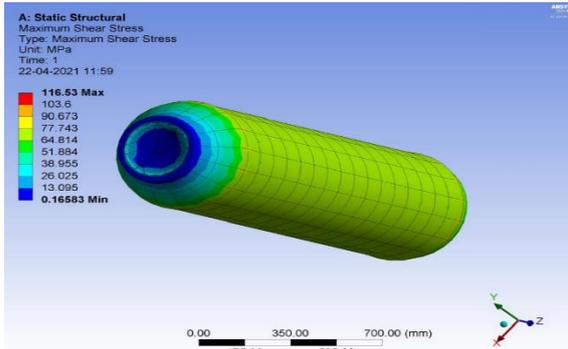


Fig 7: Maximum Shear Stress

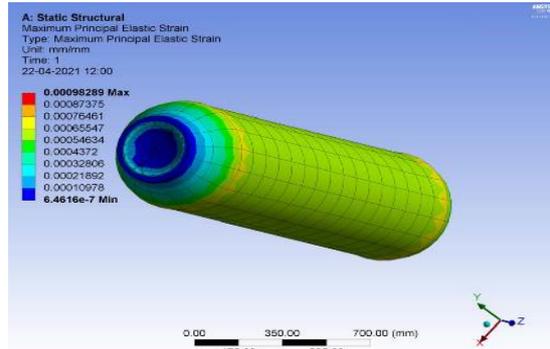


Fig 8: Max. Principal Elastic Strain

#### 4.2.2. Compound Cylinder Pressure Vessel

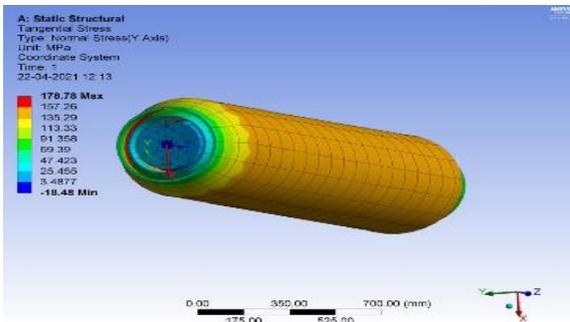


Fig 9: Tangential Stress

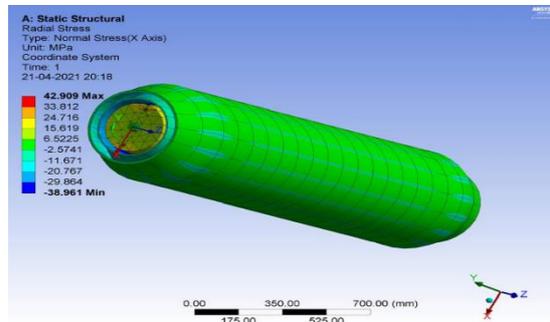


Fig 10: Radial Stress

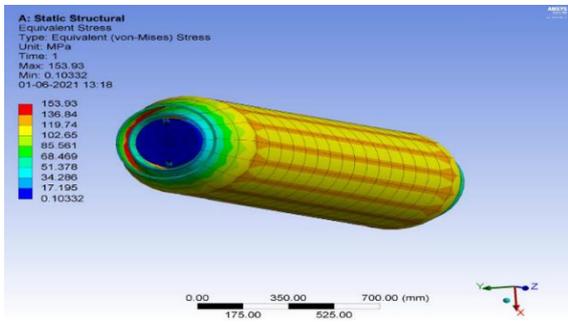


Fig 11: Von-Mises Stress

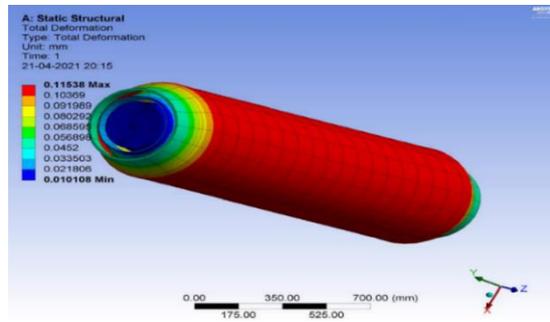


Fig 12: Total Deformation

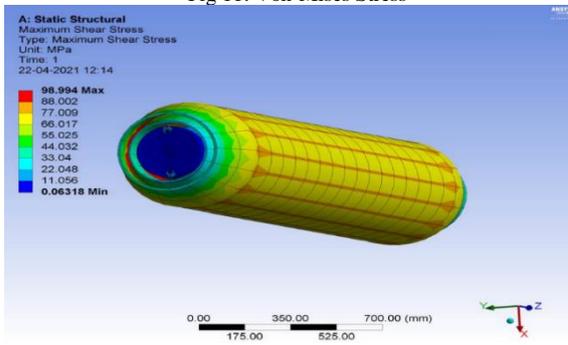


Fig 13: Maximum Shear Stress

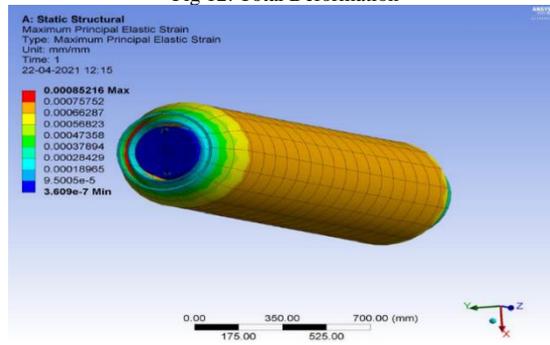


Fig 14: Max. Principal Elastic Strain

### 4.3. Calculations

Case 1: Hydraulic Accumulator made up of single cylinder pressure vessel

Data:-

Inner Diameter of the cylinder ( $d_i$ ) = 250 mm. So, Inner Radius ( $r_i$ ) = 125 mm

Outer Diameter of the cylinder ( $d_o$ ) = 310 mm. So, Outer Radius ( $r_o$ ) = 155 mm

Internal Pressure ( $p_i$ ) = 40 MPa

We know,

The tangential stress generated at the inner surface of the cylinder,

$$\sigma_{t(\text{inner})} = \frac{p_i(r_o^2 + r_i^2)}{r_o^2 - r_i^2} = \frac{40 \cdot (155^2 + 125^2)}{155^2 - 125^2} = 188.8 \text{ MPa}$$

The tangential stress generated at the outer surface of the cylinder,

$$\sigma_{t(\text{outer})} = \frac{2p_i(r_i^2)}{r_o^2 - r_i^2} = \frac{2 \cdot 40 \cdot (125^2)}{155^2 - 125^2} = 148.8 \text{ MPa}$$

From ANSYS Analytical result we got,

$$\sigma_{t(\text{inner})} = 189.82 \text{ MPa (Approx.)}$$

$$\sigma_{t(\text{outer})} = 148.58 \text{ MPa (Approx.)}$$

**Table 1:** Tangential Stress in case of Single Cylinder

Sl. No.	Parameter	Theoretical Result	Analytical Result	Absolute Difference	Percentage Difference
1	$\sigma_{t(\text{inner})}$	188.8 MPa	189.82 MPa	1.02 MPa	0.54%
2	$\sigma_{t(\text{outer})}$	148.8 MPa	148.58 MPa	0.22 MPa	0.14%

Hence, we got less than 1% difference in the theoretical and analytical results. So, the ANSYS analysis results can be accepted.

Case 2: Hydraulic Accumulator made up of compound cylinder pressure vessel

Data:-

Inner diameter of the inner cylinder ( $d_1$ ) = 250 mm. So, inner radius ( $r_1$ ) = 125 mm.

Junction diameter at the shrink-fit ( $d_2$ ) = 280 mm. So, junction radius ( $r_2$ ) = 140 mm.

Outer diameter of the outer cylinder ( $d_3$ ) = 310 mm. So, outer radius ( $r_3$ ) = 155 mm.

Difference in diameter at the junction ( $\delta_d$ ) = 0.03 mm. So,  $\delta_r$  = 0.015 mm.

Internal pressure ( $p_i$ ) = 40 MPa.

Elastic Modulus (E) =  $2 \cdot 10^5$  MPa

$$\begin{aligned} \text{Contact pressure } (p_c) &= \frac{E \cdot \delta_r}{r_2} \cdot \frac{(r_3^2 - r_2^2)(r_2^2 - r_1^2)}{2 \cdot r_2^2 (r_3^2 - r_1^2)} \\ &= \frac{2 \cdot 10^5 \cdot 0.015}{140} \cdot \frac{(155^2 - 140^2)(140^2 - 125^2)}{2 \cdot 140^2 (155^2 - 125^2)} = 1.145 \text{ MPa} \end{aligned}$$

Because of the contact pressure only,

Tangential stress at inner side of the inner cylinder,

$$\sigma_{t1} = \frac{-2p_c(r_2^2)}{r_2^2 - r_1^2} = \frac{-2 * 1.145 (140^2)}{(140^2 - 125^2)} = -11.58 \text{ MPa}$$

Tangential stress at outer side of the inner cylinder,

$$\sigma_{t2} = \frac{-p_c(r_2^2 + r_1^2)}{r_2^2 - r_1^2} = \frac{-1.145 (140^2 + 125^2)}{(140^2 - 125^2)} = -10.14 \text{ MPa}$$

Tangential stress at inner side of the outer cylinder,

$$\sigma_{t3} = \frac{p_c(r_3^2 + r_2^2)}{r_3^2 - r_2^2} = \frac{1.145 (155^2 + 140^2)}{(155^2 - 140^2)} = 11.58 \text{ MPa}$$

Tangential stress at the outer side of the outer cylinder,

$$\sigma_{t4} = \frac{2p_c(r_2^2)}{r_3^2 - r_2^2} = \frac{2 * 1.145 (140^2)}{(155^2 - 140^2)} = 10.14 \text{ MPa}$$

Because of the internal pressure only,

Tangential stress at inner side of the inner cylinder,

$$\sigma_{t5} = \frac{p_i(r_3^2 + r_1^2)}{r_3^2 - r_1^2} = \frac{40 * (155^2 + 125^2)}{(155^2 - 125^2)} = 188.8 \text{ MPa}$$

Tangential stress at outer side of the inner cylinder or inner side of the outer cylinder,

$$\sigma_{t6} = \frac{p_i r_1^2}{r_2^2} \frac{(r_3^2 + r_2^2)}{r_3^2 - r_1^2} = \frac{40 * 125^2}{140^2} * \frac{(155^2 + 140^2)}{(155^2 - 125^2)} = 165.6 \text{ MPa}$$

Tangential stress at the outer side of the outer cylinder,

$$\sigma_{t7} = \frac{2 * p_i r_1^2}{r_3^2 - r_1^2} = \frac{2 * 40 * 125^2}{155^2 - 125^2} = 148.8 \text{ MPa}$$

Resultant stress,

Because of both the internal pressure and contact pressure,

Tangential stress at inner side of the inner cylinder,

$$\sigma_{ti} = \sigma_{t1} + \sigma_{t5} = -11.58 + 188.8 = 177.22 \text{ MPa}$$

Tangential stress at outer side of the inner cylinder,

$$\sigma_{toi} = \sigma_{t2} + \sigma_{t6} = -10.14 + 165.6 = 155.46 \text{ MPa}$$

Tangential stress at inner side of the outer cylinder,

$$\sigma_{tio} = \sigma_{t3} + \sigma_{t6} = 11.58 + 165.6 = 177.18 \text{ MPa}$$

Tangential stress at the outer side of the outer cylinder,

$$\sigma_{to} = \sigma_{t4} + \sigma_{t7} = 10.14 + 148.8 = 158.94 \text{ MPa}$$

From ANSYS Analytical result we got,

$$\sigma_{ti} = 178.78 \text{ MPa (Approx.)}$$

$$\sigma_{toi} = 157.26 \text{ MPa (Approx.)}$$

$$\sigma_{tio} = 178.78 \text{ MPa (Approx.)}$$

$$\sigma_{to} = 157.26 \text{ MPa (Approx.)}$$

**Table 2:** Tangential Stress in case of Compound Cylinder

Sl. No.	Parameter	Theoretical Result	Analytical Result	Absolute Difference	Percentage Difference
1	$\sigma_{ti}$	177.22 MPa	178.78 MPa	1.56 MPa	0.88%
2	$\sigma_{toi}$	155.46 MPa	157.26 MPa	1.8 MPa	1.16%
3	$\sigma_{tio}$	177.18 MPa	178.78 MPa	1.6 MPa	0.91%
4	$\sigma_{to}$	158.94 MPa	157.26 MPa	1.68 MPa	1.06%

Hence, we got nearly 1% difference in the theoretical and analytical results. So, the ANSYS analysis results can be accepted.

#### 4.4. Comparative Result

**Table 3:** Equivalent (von-Mises) Stress, Maximum Shear Stress and Maximum Principal Elastic Strain in both the Single and Compound Cylinder from ANSYS Analysis Result

Sl. No.	Parameter	Single Cylinder case	Compound Cylinder case	Absolute change	Percentage change
1	Von-Mises Stress	178.13 MPa	153.93 MPa	24.2 MPa	13.58%
2	Max. Shear Stress	116.53 MPa	98.994 MPa	17.54 MPa	15.05%
3	Max. Elastic Strain	0.00098289 mm	0.00085216 mm	0.00013073 mm	13.3%

So, we got that there is nearly,

- 13.58% decrease in the Equivalent (von-Mises) stress,
- 15.05% decrease in the maximum shear stress,
- 13.3% decrease in the maximum principal elastic strain,

Generated in case of hydraulic accumulator made up of compound cylinder from the case of single cylinder for the same thickness in both the case.

As there is a decrease in stress and strain generated, we can conclude that we can accumulate more pressure in a hydraulic accumulator made up of a compound cylinder than that of a single cylinder.

## 5. SUMMARY AND CONCLUSION

### 5.1. Summary

In this project, we have designed a single and compound cylinder hydraulic accumulator and performed stress analysis of both the cases in the ANSYS Mechanical workbench. Finally, we found that the stress generated, in the case of the compound cylinder pressure vessel, is less than compared to a compound cylinder pressure vessel.

### 5.2. Conclusion

Finally, we got that the pressure accumulation capacity of the compound cylinder hydraulic accumulator is more than that of the single cylinder hydraulic accumulator. Hence we can conclude that a compound cylinder hydraulic accumulator is more effective than a single-cylinder hydraulic accumulator.



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## Commercial Product Development of Kinetic Sculpture Table

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### Abstract

Kinetic art technology has been combined with amazing meditative beauty in which a metal ball silently travels across the sand, endlessly making and erasing gorgeous patterns. The table is a moving work that has captured a number of users at its permanent installations in museums worldwide. The development of this table requires diverse skills such as interfacing of electronics, software and mechanical.

In Commercial Product Development of Kinetic Sculpture Table, a metal ball moves and creates a beautiful pattern on sand, the moving part and magnet are inside the table and the metal ball and sand are outside the table. The moving part created using two stepper motors, Arduino Uno, and a computer numerical control (CNC) shield. Motor movement is controlled by using Arduino and motor driver IC A4988. Creating a Graphical User Interface (GUI) using Python and PyQt5 software. Developed Graphical User Interface has a number of designs and the user can select any one design and start/stop the pattern generation process on the liquid crystal display screen. liquid crystal display has been connected to the Raspberry pi; Raspberry Pi serial communicate to the Arduino Uno. Arduino take g-code from raspberry Pi and sends it to motor driver IC A4988. Finally, the motor driver IC moves motor and draws the selected design.

**Keywords-** Graphical User Interface (GUI), PyQt5, ICA4988, Liquid Crystal Display (LCD), Commercial Product Development of Sculpture Table

### 1. INTRODUCTION

Art has been used since ancient period. In Indian festival rangoli is used as art in front of homes and it enhances the beauty of homes. A form of technological product that will be employed in various places as a piece of beauty as well as a commercial product in which Modern art, technology, and design all combine in magnificent meditative beauty. We designed a metal ball that travels silently in sand, forever creating and erasing beautiful patterns. The table is a dynamic art that has captivated millions of visitors in permanent installations in museums all over the world. In this project, Graphical User Interface created using python and PyQt5 software. In the development of kinetics sculpture table development aspects are, Development of GUI, X-Y plotter, G-Code Sender using Python code.

Now a days Office spaces are trying to include in-between spaces where employees or guests can claim as their own when they are between meetings or simply need a change of scenery. Considering both the review points the kinetic sculpture table can be installed on restaurant table for engaging the customers and at office in-between spaces as stress releasing device.

### 2. LITERATURE REVIEW

According to the researchers, at restaurants customer waiting time for the food after placing order is considered a major factor for a restaurant's rating. Customers are entertained in restaurants by playing TV shows, live music, and so on. This study's X-Y plotter is designed to record and display two-dimensional data in a rectangular coordinate system [1-6]. The mechanism's material was chosen with the cost and wide range of uses, such as servo motors, in view. The cost, peak torque capabilities, speed range to compromise the standard, and system application can all be used to differentiate servo motors as given by [7, 8]. Park, et al. [9]. The kinetics of both a servo system are examined, and an XY gantry model with motor driver for Y control and another motor rotating the gantry in the X direction is built. The design includes two parallel rails for Y-motion, with a bar across the rails to hold the system's end effectors. The precision of plotting, on the other hand, is the primary concern in the manufacture of an X-Y plotter. Few publications have been dedicated to plotters in terms of plotter accuracy and motion adjustment strategies. [10-14]. The X-Y plotter system is a simpler system than the CNC system since the CNC system is operating on three axes and requires more complicated programming [15]. According to case studies, the XY Plotter uses two stepper

motors, with the robot plotting the computer's input on the drawing board using an ATMEGA328P microcontroller on the Arduino accessible physical computing platform. Two axes of the XY plotter are powered and controlled by an Arduino compactable driver A4988.

Finally, an idea for designing the structure, studying Inkscape and Universal G-code Sender software methods, and producing the G-Code file, as well as learning about hardware and controlling boards. Design and manufacture of a mini-CNC plotter machine, as well as coding and basic circuit connections for an earlier plotter unit Design of a PCB design and drilling mini-CNC machine Obtaining the controller's G-Code file, and using the Inkscape extension to generate G-Code for the MakerBot Unicorn Pen Plotter. The Arduino Library for GRBL allows you to use the Arduino IDE to upload GRBL to your Arduino Board. The CNC plotter is being redesigned, and the drawing surface area on the document is being increased.. We keep the entire budget as low as possible while producing high-quality results.. Also change Arduino library for GRBL, and also create new code as per requirement.

### 3. OBJECTIVES

The main objectives are:

1. Development of a commercial product which could be used at meditating centres, restaurants or at homes as stress releasing or achieving thoughtlessness.
2. The development of kinetic sculpture includes learning and understanding of diverse skill sets.
3. The development takes dive in mechanical, electronics and computer science domains.

### 4. METHODOLOGY

In methodology, develop product in such way that, process steps are given below. Use Graphical User Interface to send G-code of the design to Arduino from raspberry Pi, In Arduino connected to CNC shield, In CNC shield Motor Driver IC are connected which supply current to Motor according to given instruction byuser and finally created a beautiful pattern on sand. In Figure 1 block diagram of methodology show execution flow of product. In this project for development of product require diverse skills, such as software, mechanical andelectronics. Simply can say require mechatronics skills. Execution of work is done by following steps:

1. Development of X-Y Plotter
2. Development of GUI
3. Automation of project using raspberry Pi
4. Development of table

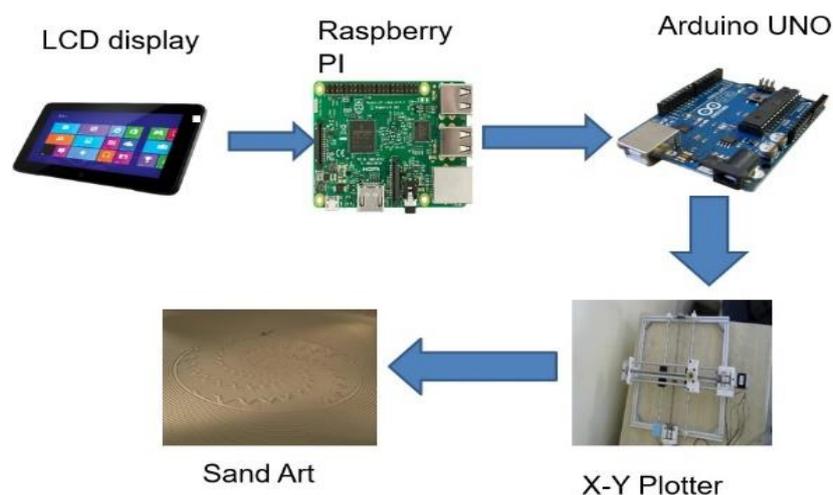


Figure 1: Block Diagram of Methodology

#### 4.1 Software requirement

Software is the most important part of this project. Project development requires different software for different uses. Some software used to upload programs. The following software used in this project

- 1) Arduino IDE: The Arduino IDE is a free piece of software that allows you to write code and compile it to be used with the Arduino module. The main code, referred to as the drawing, will eventually generate a hex file, that will be duplicated and uploaded to the board's controller.
- 2) Python IDE: IDLE stands for Integrated Development and Learning Environment. Its default software use for python programming.
- 3) Universal G-code sender: Its commonly known as UGS. Its UGS use for sending G-code and G-code file to the CNC shield and setting a parameter. UGS used in initial phase for trial purpose.
- 4) PyCharm: PyCharm is used for Python Programming similar to Python IDLE but PyCharm quickly write code to facilitate debugging. It reduces time help to coder for coding suggest instruction.
- 5) PyQt5: PyQt5 has used for Development of GUI. PyQt5 allow both language OOP as well as Python.
- 6) Inkscape: It is used for creation of G-Code. Using this software one can create G-Code of image.

## 5. DEVELOPMENT OF X-Y PLOTTER

Lead screw mechanism for the X-Y plotter. Development of X-Y plotter is completed by following the steps given below:

### 5.1 Components Selection

Component's selection is most important task in x-y plotter development. In this, the components divided into two types, which are Electronics Components and Mechanical Components.

#### Electronics Components

1. Arduino Uno
2. CNC shield
3. Motor Driver IC-A4988
4. NEMA 17 Motor
5. Limit Switch
6. Jumper and Wire

#### Mechanical Components

1. Lead screw (8mm \* 350mm)
2. Screw bearing ID - 8mm
3. Guide Rod 8mm
4. Guide Bearing 8mm ID
5. Guide Shaft 8mm ID
6. Guide Rod 8Mm OD
7. Motor Bracket NEMA 17
8. Aluminium Extrusion 2040T Slot

### 5.2 Electronics Construction

In electronics construction, Arduino Uno and CNC shield connected to each other. Motor Driver IC A4988 fit in the CNC shield, limit switch also connected to the Arduino Uno and CNC shield combination.

### 5.3 Mechanical Construction

In the mechanical construction, x-y plotter base created, based built using mechanical components. All solid work requires for x-y plotter created using 3D printer. x-y plotter work in 300mm\*300mm. Figure 2 represent the x-y plotter.

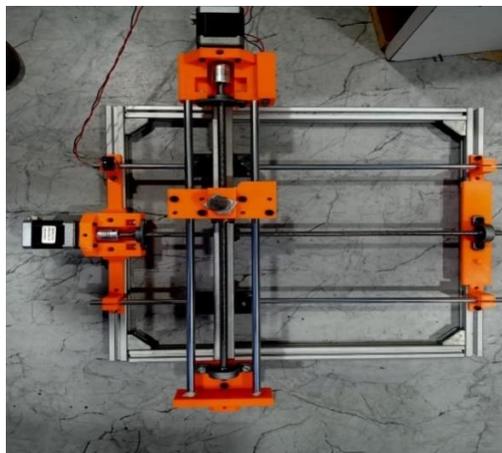


Figure 2: X-Y Plotter

#### 5.4. Homing and Parameter Setting

In homing and parameter setting, homing is defined reference position to particular position that is zero position. Calculate the step size and defined the parameter homing direction, maximum speed and other parameter.

\$0 = 10 (Step pulse time, microsecond)	\$27 = 20.000 (Homing switch pull-off distance, millimetres)
\$1 = 25 (Step idle delay, millisecond)	\$30 = 500 (Maximum spindle speed, RPM)
\$2 = 0 (Step pulse invert, mask)	\$31 = 0 (Minimum spindle speed, RPM)
\$3 = 0 (Step direction invert, mask)	\$32 = 0 (Laser-mode enable, Boolean)
\$4 = 0 (Invert step enable pin, Boolean)	\$100 = 400.000 (X-axis travel resolution, step/mm)
\$5 = 0 (Invert limit pins, Boolean)	\$101 = 400.000 (Y-axis travel resolution, step/mm)
\$6 = 0 (Invert probe pin, Boolean)	\$102 = 1600.000 (Z-axis travel resolution, step/mm)
\$10 = 0 (Status report options, mask)	\$110 = 500.000 (X-axis maximum rate, mm/min)
\$11 = 0.010 (Junction deviation, millimetres)	\$111 = 500.000 (Y-axis maximum rate, mm/min)
\$12 = 0.002 (Arc tolerance, millimetres)	\$112 = 600.000 (Z-axis maximum rate, mm/min)
\$13 = 0 (Report in inches, Boolean)	\$120 = 10.000 (X-axis acceleration, mm/sec <sup>2</sup> )
\$20 = 0 (Soft limits enable, Boolean)	\$121 = 10.000 (Y-axis acceleration, mm/sec <sup>2</sup> )
\$21 = 0 (Hard limits enable, Boolean)	\$122 = 10.000 (Z-axis acceleration, mm/sec <sup>2</sup> )
\$22 = 1 (Homing cycle enable, Boolean)	\$130 = 280.000 (X-axis maximum travel, millimetres)
\$23 = 0 (Homing direction invert, mask)	\$131 = 280.000 (Y-axis maximum travel, millimetres)
\$24 = 500.000 (Homing locate feed rate, mm/min)	\$132 = 500.000 (Z-axis maximum travel, millimetres)
\$25 = 500.000 (Homing search seek rate, mm/min)	
\$26 = 250 (Homing switch debounce delay, milliseconds)	

#### 6. DEVELOPMENT OF GUI

GUI is developed using PyQt5 software and Python programming language. The graphical user interface has eight different designs. Each design has start and stop button. User can click the required design button then GUI take input from user and send it to Raspberry Pi.

#### 7. AUTOMATION USING RASPBERRY PI

In automation most of code and programming used. In this project different programming languages are used for different application. Following type code develop:

1. Development of GUI python code
2. Development Python code for sending G-code file
3. Development of Python code for Modbus TCP protocol
4. Development Python code for automation and autorun in raspberry pi

#### 8. DEVELOPMENT OF TABLE

In development of table, construction of the final product is done as follows,

- 1) Selection of Sand
- 2) Selection of Metal Ball
- 3) Selection of Magnet

- 4) Power supply Construction
- 5) Construction of Table

Selection of sand, metal ball and magnet is proceed by trial-and-error method. Try on differen types of sand then fix one sand which is more suitable. Similarly this method uses for selection of metal ball and magnet. Sand used for the product is white aluminium oxide of 220 grit.

In this work power supply of components vary, such as Raspberry Pi required 5V, 3A DC power supply and motor driver IC required 12V, 4A DC Power Supply. Used rectifier which convert AC to DC Power, then Used buck converter 12V,3A for raspberry pi and connect motor driver IC before buck converter to rectifier.

Arduino require 5V power supply, we continue to use serial communication between Arduino and Raspberry pi so power supply for Arduino is going from Raspberry Pi, no need of other power supply.

## 9. RESULTS AND DISCUSSION

After carrying out the design and development of the sculpture table, the results obtained are presented in this section. Figure 3 shows the 8 different patterns as output on the GUI after execution of python script..

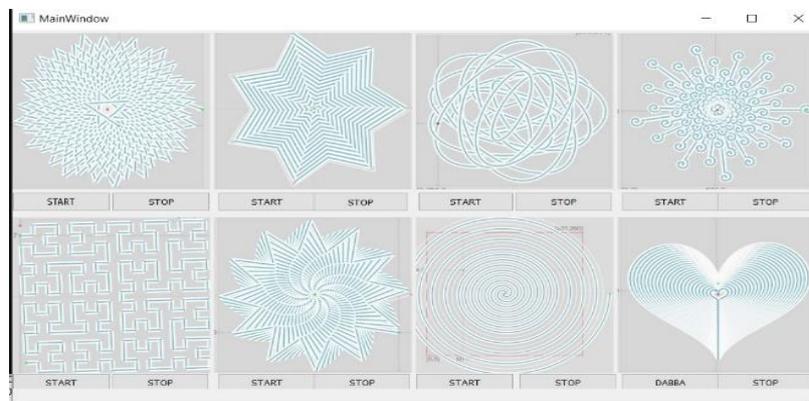


Figure 3: Output of GUI

Figure 4 is the output of sand art created using the metal ball. It is observed that very precise and pleasing art form is created using the developed table.



Figure 4: Output Art on Sand



Figure 5: Kinetic Sculpture Table

Figure 5, shows the developed final commercial product.

## 10. CONCLUSION

This paper highlights the development a commercial product which could be used at meditating centres, restaurants or at homes as stress releasing or achieving thoughtlessness.

1. Study of PyQt5 software and Qt designer and Developed Graphical User Interface which allows human input.
2. This work uses Raspberry Pi and use as microcomputer. Also python code is developed for automation.
3. For complex designs, the developed kinetic sculpture table takes maximum 20 mins to create the sand art whereas for simpler designs, 2-3 mins is the creation time.

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## Forecasting of Soft drinks Production

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### Abstract

In this paper the authors have proposed a methodology to predict the soft-drinks production using recurrent neural networks (LSTM). LSTM has a feedback connection and can be easily used in deep learning to map complex interdependencies. This method can be applied to any industrial case where forecasting is required. Data for this research has been assumed by the authors after analyzing variety of sources.

**Keywords-** Forecasting, Time series, LSTM, RNN

### 1. INTRODUCTION

Over the past few years, forecasting methods have been used to enhance the art of decision-making and predicting the future sales. Mostly statistical techniques are employed for this purpose, but nowadays artificial neural networks (ANN) are also in use (1). These methods are widely used in stock prediction (2), sales prediction (3), and construction cost prediction (4). Many researchers have used the historical demand information to generate autoregressive integrated moving average (ARIMA) models (5). Automobile sectors across the globe have adopted these methods to predict their sales (6). Many researchers have engaged themselves to predict the demand for electric vehicles using this approach (7). This method also proves to be beneficial for companies like Coca-Cola (8) and many fashion retailers (9).

### 2. RESEARCH BACKGROUND

In this study, the authors have used recurrent neural networks (LSTM) to prepare a forecasting model for soft drinks production. Long Short-Term Memory (LSTM) networks are upgraded version of recurrent neural networks, which makes it simple to recall previous data in memory. The vanishing gradient problem of RNN is resolved here. LSTM is convenient to categorize, process, and predict time series given time lags of unknown duration. It trains the model by using back-propagation. In an LSTM network, three gates are present as shown in figure 1. The input gate discovers which value from the input should be used to modify memory. The equation for the input gate is as follows:-

$$i_t = \sigma(w_i \cdot [h_{t-1}, x_t] + b_i)$$

$$x_t + b_c \quad \tilde{c}_t = \tanh(w_c \cdot [h_{t-1},$$

The forget gate discovers what details to be discarded from the block. The equation for gate 2 is as follows:

$$f_t = \sigma(w_f \cdot [h_{t-1}, x_t] + b_f)$$

Then finally the output gate decides the output of the block using the input and the memory of the block. The equation for the output gate is

$$o_t = \sigma(w_o \cdot [h_{t-1}, x_t] + b_o)$$
$$h_t = o_t * \tanh(C_t)$$

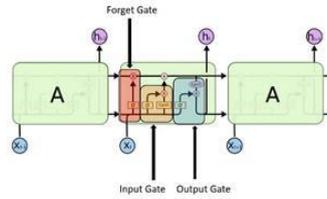


Figure 1: Three gates of LSTM

### 3. RESEARCH METHODS

Long Short-Term Memory (LSTM) is a type of recurrent neural network architecture that is developed to model sequences. These are machine learning models that take or give sequences of data and its vast range of dependencies more precisely than normal RNNs. To conduct this analysis the authors have taken data from 2007 to 2020 and then they have trained the data from 2007 to 2019 to predict the production for 2020. Later, the authors compared the actual value and the predicted value of 2020 for checking the performance of the trained model. This methodology can be extended in various industries for forecasting.

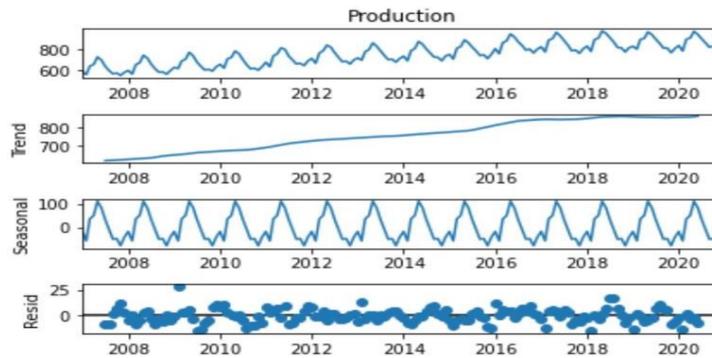


Figure 2: Seasonal decomposition

#### 3.1 Dataset

Month	2007	2008	2009	2010	2011
January	589	600	628	658	677
February	561	566	618	622	635
March	640	653	688	709	736
April	656	673	705	722	755
May	727	742	770	782	811
June	697	716	736	756	798
July	640	660	678	702	735
August	599	617	639	653	697
September	568	583	604	615	661
October	577	587	611	621	667
November	553	565	594	602	645
December	582	598	634	635	688

Data Table 1: This table shows the data collected for year 2007 to 2011 for year 2012 to 2016

Month	2012	2013	2014	2015	2016
January	713	717	734	750	804
February	667	696	690	707	756
March	762	775	785	807	860
April	784	796	805	824	878
May	837	858	871	886	942
June	817	826	845	859	913
July	767	783	801	819	869
August	722	740	764	783	834
September	681	701	725	740	790
October	687	706	723	747	800
November	660	677	690	711	763
December	698	711	734	751	800

Data Table 2: This table shows the data collected

Month	2017	2018	2019	2020
January	821	828	826	834
February	773	778	799	782
March	883	889	890	892
April	898	902	900	903
May	957	969	961	966
June	924	947	935	937
July	881	908	894	896
August	837	867	855	858
September	784	815	809	817
October	791	812	810	827
November	760	773	766	797
December	802	813	805	843

Data Table 3: This table shows the data collected for year 2017 to 2020

#### 4. RESULT DISCUSSION

In this research, the authors have forecasted the value of productions of soft drinks. Initially a model with dataset from 2007 to 2019 was trained and by using it the authors have predicted the production value of the year 2020 and later compared it with the actual value of production in 2020 presented in the dataset as shown in figure 3. The authors found that the predicted value is almost same as the actual value. Hence this method of forecasting is useful and gives better results.

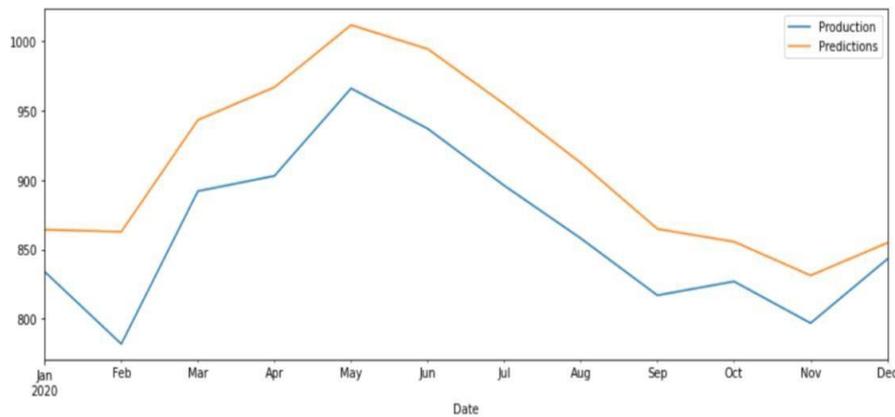


Figure 3: Comparison between Predicted value and the production value of year 2020

#### 5. CONCLUSION

In this research, the authors have done the forecasting of soft drinks production using LSTM. The authors have analyzed the result obtained and the output. It can be seen that both the values are nearly the same. Hence it shows that this method of forecasting is highly accurate and should be employed in the future to solve similar forecasting and decision-making problems. It provides better results as compared to conventional statistical techniques.

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## Nanomaterials: Aerospace Solution

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### Abstract

This chapter gives a brief presentation of nanomaterials for different applications, including features of material for different applications and technology used to process at nano level. Also, a general introduction of nano scale and materials are explained in it. Dimensions have very strong significance to relate things by their size in this universe [2]. In this sequence meter is the most significant unit to represent the daily life measurement. The Intergovernmental Panel on Climate Change (IPCC) reports that up to 15 per cent of total greenhouse gas emissions could be caused by aviation by 2050, it is important to review how the past, current and future use of advanced materials and design could help prevent this scenario. It is also noted that the flight usage will be doubled in terms of number of passengers on flight by the year 2036 by the International Air Transport Association (IATA). So, there arises a need to develop an advanced technology to fulfil the requirements of passengers and to meet their demands keeping safety in mind [8]. Sir David King, Dr Oliver Inderwildi and Chris Carey, of Oxford University's Smith School of Enterprise and the Environment, discuss improvements being made to existing materials, and review the new materials that we could soon see flying on aircraft. The defense and aerospace industry are considered to be an important part of the development. Many companies and units depend to deliver the products, services and humans with high speed that can only be undertaken by air. For achieving high performance and efficiency, the main parameter is aircraft design which includes the airframe and the payload. Some methods are used for achieving high efficiency which includes nanomaterials. Nanotechnology is considered to be an interdisciplinary branch that is the fastest growing technology over the past few decades. It is the technology which generates materials on a nanoscale with high accessibility and functions. Nanotechnology is a modern technology used in aviation and power generating techniques. [13] Nanotechnology is nowadays a leading technology and is having a bright future in defense and military. The main advantage of this technology is miniaturization which helps in increasing the system's performance on a large scale. The target of this nanotechnology is to control and hold the materials on the nanometer scale. The main factors that are required to be understood while using this technology is Time and Cost. Some meaningful routines and costs are needed to be undertaken while replacing this advanced technology with the conventional methods [4]. The primary task for the aerospace industry is to utilize these technologies in creating a qualitative impact to human society [2].

**Keywords:** *Nanomaterials, Aerospace, Manufacturing, Nanotechnology*

### 1. NANOMATERIALS:

Nanotechnology is a complete study of extremely minute particles falling in the range of 1 nm-100nm. Nanomaterials are simply those materials whose qualities are grabbed from the particles having size less than 100 nm. The existence of nanoparticles can be from sand, volcanic eruption or from various biological bodies. They also exist in biological specimens such as viruses, DNA, forms of lipids and proteins etc. [5]. Falling in the range from 1 nm-100 nm, many unique characteristics are shown by the nanoparticles. These characteristics are quite useful in terms of lattice structures, electrical and thermal conductivities, densities, surface areas and platforms etc. [5]. From aviation and space to medicinal fields and also in the fields of engineering, scanning techniques, environmental improvement Nanomaterials are widely used in this era. Nanomaterials are formed to develop the qualities same as the materials which are large in size (out of nanoscale size). Nanotechnology was firstly studied by Physicist Richard Feynman. There is a large impact of Nanotechnology today and will have a large impact tomorrow as well ranging in engineering applications to medicinal studies. From mechanisms of machines to humans, nanoparticles have contributed a lot.

Nano-functional is defined as a mixture of size and properties of material when created as a composite used for

the aerospace sector. Nanomaterials act as a resistance towards corrosion, thermal effects etc. which allows the aerospace products to withstand in any environmental conditions. With the increasing use of Nanomaterials, the roles and responsibilities for safety and precautions should also be taken into consideration. Nanoparticles can be observed under microscopes like TEM, SEM, AFM, STM etc. [15] The atoms present in the nanomaterials are mostly stuck to their surfaces increasing the surface area.[17] Nanostructures/materials are divided into two: 1) Bulk nanostructured 2) surface nanostructured

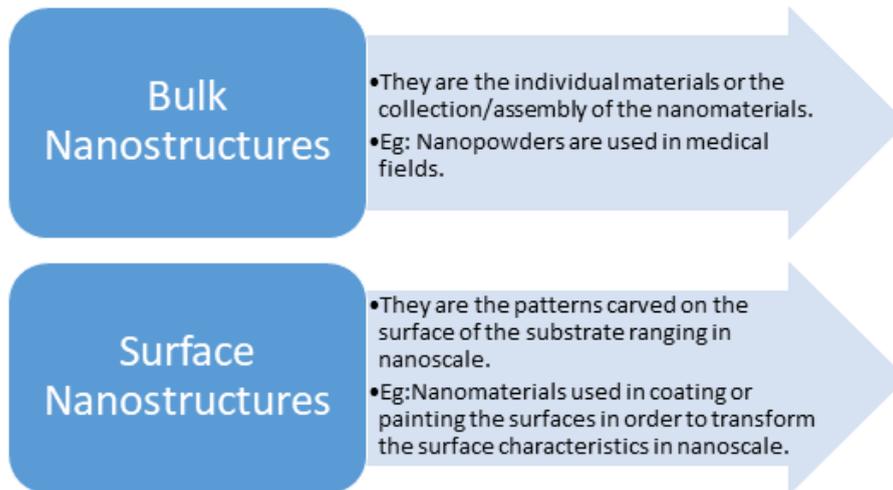


Fig:1 Classification of Nanostructures [6]

**Nanostructures: An overview [18]**

Nanostructures	Properties
1D Nanofiller (Nanoplate) 	Thickness <100 nm
2D Nanofiller (Nanofiber) 	Diameter < 100 nm
3D Nanofiller (Nanoparticle) 	All Dimensions < 100 nm

Table 1: Types of Nanostructures

**1.1 NANOMANUFACTURING PROCESSES: IN CONTEXT TO AEROSPACE**

The process which includes the manufacturing of particles in the range of 1-100 nm, 1D,2D,3D devices, specifications, for scales of measurement like micro, macro, meso is known as Nanomanufacturing processes. This process helps in development of

working products and equipment. This type of manufacturing falls under the categories like: “Bottom up” and “Top down”. Nano- Manufacturing also helps in improving the strength and effectiveness of Lithium-ion (Li-Ion) batteries. This also gives a promising factor of safety for usage.[9]

1) **Bottom-up method:**

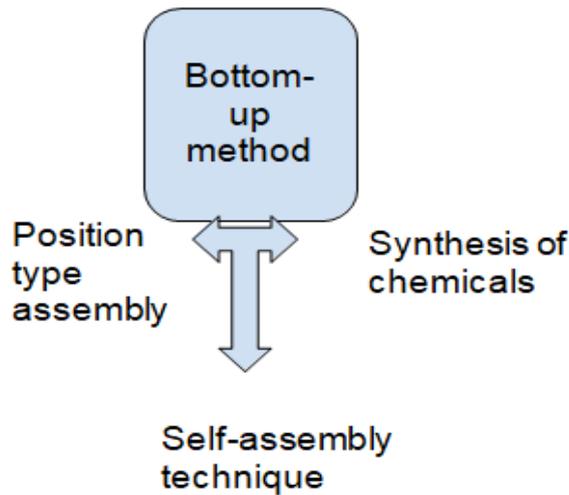


Fig 1.1 (a)

It is also known as a constructive method. It is the method in which the atoms/molecules tend to react with any compounds/elements either physically or chemically and tries to produce nanoparticles [9]. This method works by collecting the individual atoms and molecules in some particular shapes and configurations to develop products of high complexity. In this approach, the atoms/molecules will be put and joined the same as the process that occurs in living organisms. The examples include printing techniques, laser covering, assembly and joining techniques etc [19].

2) **Top-down Method:**

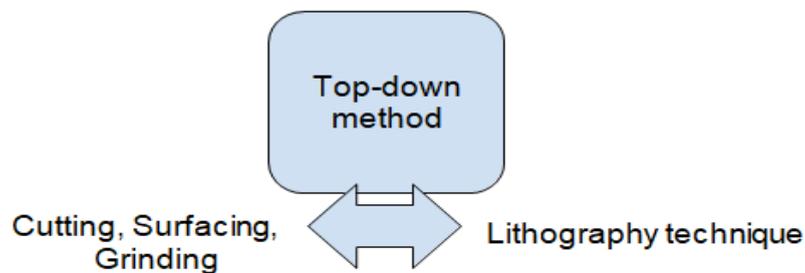


Fig1.1(b)

This method is also known as a destructive method. It starts with destroying the big bulk material until it comes to a nanosized particle. This destroying procedure is carried either physically or chemically [9]. This is known as an approach from larger to smaller. This approach was given by Taniguchi and hence is also known as the Taniguchi approach/method. The examples include mechanical events like machining, grinding etc, lithography techniques, electrochemical techniques etc [19].

1.2 **Types of Nanomaterials: 1.2a) Nanocomposites:**

Nowadays nanocomposites have drawn a large attraction due to their characteristics like thermal insulation, conduction and certain mechanical characteristics. Composites are the material which are made up of two or

more materials specially known as

hybrid composite materials with hybrid properties. If the materials merged are nanomaterials then they are termed as Nanocomposites. The nanosized particles have the quality of having large surface area which results in the increase in contact with other surrounding materials and hence increases the reactivity which generates a powerful material with light weight [11]. Nanocomposites are mainly having one of their phases belonging to the nanosize ( $10^{-9}$ ). The production of nanocomposites started due to their superiority in chemical, mechanical, structural and thermal properties in contrast to the conventional composites [17].

Types based on matrix	Types based on shape	Types according to dimensions
● Ceramic	● Spherical, tube	● Platelets (1D)
● Polymer	● Fibrillar	● Whiskers (2D)
● Metallic	● Lamellar	● Nearly Spherical (3D)

Table 2: Table showing types of nanomaterials

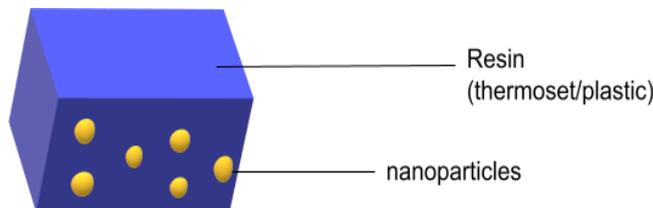


Fig 1.2(a) Resin with Nanoparticles

**1.2 b) Carbon Nanotubes**

CNTs are structurally cylinder-based structures made from one or more than one graphene sheets. They are integrated in polymer composite matrices due to their qualities like mechanical strength, thermal power etc. [11]. The synthesis and production of CNTs was reported by Iijima in 1991. He also mentioned about the capabilities of CNTs which can be scaled at the nanoscale for the applications. It is also proved that the CNTs are better compared to copper in terms of current carrying holder and also the thermal conductivity is approximately 20 times better than Aluminum.[16]

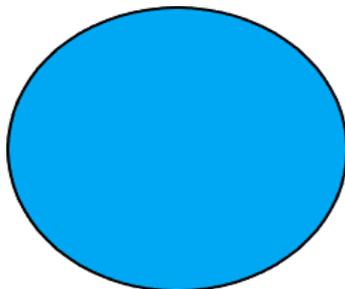


Fig 1.2b Old Macroparticle

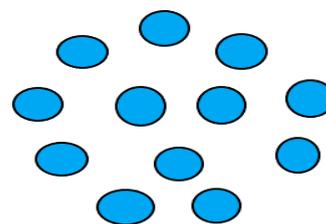


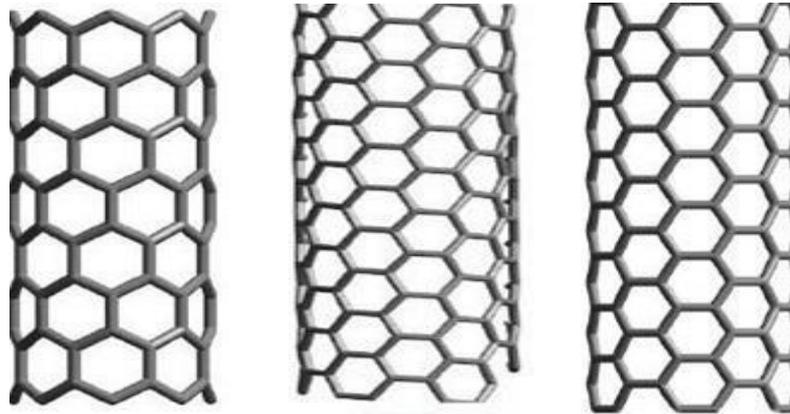
Fig 1.2b nanoparticles with increased surface area

The CNTs are of 3 types:

- a) Zigzag CNT: The line of carbon bonds is present down the centre.
- b) Chiral CNT: It shows the spirals or twists around the nanotube.

c) Armchair CNT: It shows the chain of hexagons just parallel to the neutral axis of the tube.

CNTs also exists like carbon nanotubes belonging to the nanotubes leading to the types Single walled and Multi walled Nanotube i.e., SWNT and MWNT [15].



Zigzag CNT

Chiral CNT

Armchair CNT

### 1.3 Characteristics of functional Nanomaterials [11,12]

Researchers have a prime interest in innovation in the field of nanomaterials in recent years. Nanomaterials being cheap and having more mass production results in the application in many sectors. The properties like high strength, stiffness, tolerance, ductility, stability makes the nanomaterials to be used in sectors like Aerospace, Automobile. Aviation, Sports etc.

For constructing wing panels of airplanes, properties like toughness and stability are required which is provided by the nanomaterials. They also provide properties like corrosion resistance which protects the airplane. Properties like fatigue, creep, wear-tear are also important parts of mechanical properties. Structural materials which are divided into categories like Polymer, Ceramic and metal based amongst which Polymer based is widely used in Aerospace applications. Polymer nanomaterials consist of nanofillers, copolymers, nanoclays etc. Multifunctionality is a term derived from this which suggests the serving of multiple functions by structural materials. Damage sensing is used in the aerospace industry just to sense damage using the structural materials to sense damage and prevent from any loss and hazard/malfunctioning. Sensors are implanted using this method and are used in detecting. But the drawback is it can decrease the mechanical strength of the structure.

Properties of Nanomaterials used in Aerospace sector

Nanomaterials	Functional Properties
• Nanoclays	Fire retardancy
• Nanoclays, ZrO <sub>2</sub>	Heat stability
• CNTs, Graphene, SnO <sub>2</sub>	Electrical conductivity
• Nanoclays, Graphene	Corrosion resistance
• Al <sub>2</sub> O <sub>3</sub> , SiO <sub>2</sub> , ZrO <sub>2</sub>	Scratch Resistance
• CaSiO <sub>3</sub>	Impact Resistance
• CuO, TiO <sub>2</sub> , ZnO	Antimicrobial property

Table 3: showing properties of Nanomaterials used in Aerospace sector In this topic, properties of Nanomaterials are widely explained below [5,11,12]

### 1.3.1) Reduction in weight [3,14,15]

To achieve more payload, supplies and devices in the power system there is a need for reduction in aircraft weight. Weight reduction also helps in less fuel consumption along with less emissions of gas and carbon compounds. Hence, weight reduction is still a big question in the Aerospace industry. As an alternative, the industry is using light weight composites in order to make less use of fuel. In comparison to Boeing 777, Boeing 787 is made up of 50% of composites. The voids present in composites can lead to material damage and can cause degradation of composite material parts. If nanomaterials are summed up to the pores, mechanical strength can be increased which results in the increase in mechanical load bearing capacity and can provide better durability. NASA is working to improve the features using aerogels. The mechanical properties of the insulated materials can be increased by incorporating nanofillers. Here nanofillers refers to CNTs, nanoclays and graphene. When the conventional materials are replaced with these nanofillers, mechanical strength is increased resulting in weight reduction of the airframe. Hence, the trend nowadays is to construct an aircraft or spacecraft with light weight properties and high endurance qualities.

### 1.3.2) Thermal insulation and fire stoppage properties

In regard to military appliances, electric aircraft and sensing systems there is a need for improved and flexible thermal and fire resistance characteristics. Power applications are also used in this case.

Nanoclays work as Thermal insulators which helps in increasing the overall thermal resistance of the aircrafts. But there is no change in fire stoppage properties when nanoclays are summed up. To increase the fire resistance, phosphorus flame retardation technique is used. CNTs have also shown their contribution in fire resistance. Nanoclay has become an important driving force for thermal insulation and fire redundancy properties. On researching it has been found that CNTs can even lead ahead of the nanoclays in fire retardation.

### 1.3.3) Optical Properties and Field Discharge/Emission

Field emissions based on CNTs are very much suitable for microsattellites which helps in reduction of mass, volume and power systems used for small satellites and subsystems of satellites. Shielding using Electromagnetic Induction has been majorly used in defense and military applications. For radar technology, MWCNTs have shown better results with increased stiffness and strength. Nanoparticles and the bulk materials have separate different colors. For example, Gold is yellowish in bulk while it shines as bright red on nano based.

### 1.3.4) Age factor and performance

Change in temperature and environments with UV rays can result in the damage of materials in physical, chemical or mechanical ways. These types of damages can reduce the age of the materials and hence the use of materials cannot be done. Nanomaterials such as nano ZnO, nano CeO<sub>2</sub> are used for absorbing UV rays. Being odourless, chemically stable, thermally stable they are widely used in UV shielding purposes.

### 1.3.5) Absorption of Energy and Impact Resistivity factor

Velocity varying with altitudes results in damage of composite materials and hence weakens the structure of the aircraft and can cause deformations like fire damage, cracks, and fibre damages. These damages lead to catastrophic accidents. By inserting nanofillers into matrices, damage absorption of energy can be increased. Particles mentioned in Table 1.2c also help in enhancing the impact strength. Compared to normal composites, nanostructured composites have eight times higher tensile strength and dissipation of energy.

### 1.3.6) Anticorrosion coatings

Nanocoatings in aircraft have increased the sustainability and durability of the aircrafts. Application of nanocoatings include turbine blades and other components which stops high temperature. Coatings are used to

prevent the part from being corroded. Many of the nanocoatings include compounds of chromium that cause heavy pollution to the surroundings. Nanocoating also includes traces of boron and cobalt oxides crystals. Also, many nanoscale coatings such as nitrides, carbides, ceramics etc work as friction modifying agents.

## 2 Nanomaterials: Different Areas of Aviation

Due to advanced aviation, there are some major characteristics which are taken into consideration i.e Light weight, multifunctional materials etc. The properties of multifunctional materials include the use of eco-friendly fuels, self- healers, efficiency in communication and electronics systems, high maneuvers, extra mechanical properties, intelligence etc.

Nanotechnology leaves a high impact on the aerospace sector as the nanomaterials having properties like low weight, high strength serve the small-compact planes, unmanned aerial vehicles for surveillance and aerial sensing purposes. The major three areas of aviation in context of the use of nanomaterials are mentioned below:

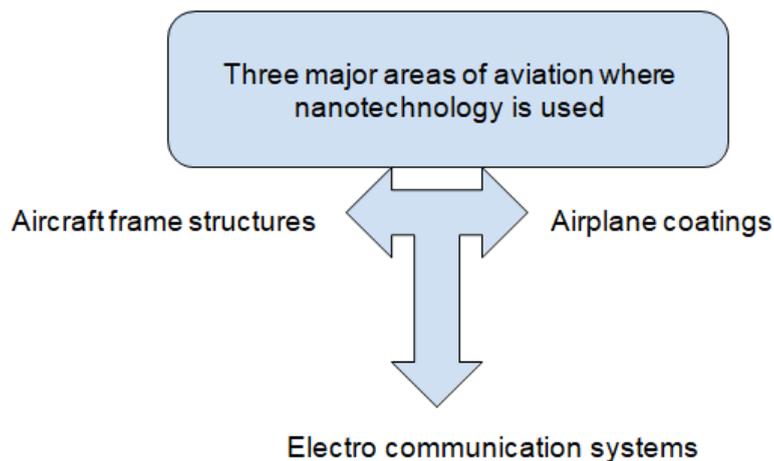


Fig 2: Classification of major areas of aviation based on nanomaterials

### 2.1 Aircraft Frame Structures

The manned aircraft was firstly developed by Wright Brothers in the year 1903 where the concept of light-weight materials for the airframes and the components was taken into effect. The material taken into use by this creator was the Aluminium alloy which shows the characteristics of heat resistance and toughness. Since 1903, this has been in continuous usage. With this, the birth of international flights was seen. Modern aircrafts require designs which include properties such as lightweight, high manoeuvrability, intelligent stealth systems and other extra mechanical advantages. The demands in high durable engine components and tensile parts which diminishes fatigue were seen. To fulfil the requirements, many types of aluminium alloys, Polymer Composites using CNTs, Nanoclays, Metal Nanoparticles integrated with Polymer composites were developed under observations.

#### 2.1 a) Aluminium nanoparticle alloys

Nowadays, there is a need for low-cost programs with new material inputs. The major task for this low cost program is to integrate different parts into a single structure to make it effective. A single structure in a basic language can be termed as amalgamation of two or more than two parts or machineries joined together via bolts or some other bonds. This amalgamation results in low weight, low cost opportunities because of the combination of all of the machinery and parts of different functions into a single structure giving a full pack of function. Also using all the parts into a single assembly helps in storage and production strategies too. The only thing to be kept in mind while opting for this amalgamation is that the single assembly should not limit the characteristics and functions of the raw materials used for combining. The performance characteristics should not reduce on integrating [8]. For several decades, aluminium alloys have served the aerospace industry with a

good handful of results. They have been in great use for aircraft structures since decades and are still in demand even today. The series of alloys found in today's aluminium is 2000, 6000 and the 7000 series. The 2000 series includes Al-Cu-Mg, the 6000 series includes Al-Si-Mg and the 7000 series includes Al-Zn-Mg-Cu. These three series of alloys make a pack of aluminium used in aircraft structures. All these three types have correct distribution of certain elements, mechanical properties on top scale, in a great strength-weight ratio and the best response to the environment. The assembly made up of these aluminium alloys are in a good response to heat treatment which allows them to be used in certain design needs [8]. Aluminium being an important element in propellant, aluminium nanoparticles play an important role to improve the efficiency and performance of the propulsion systems used in aerospace industries. A protective oxide layer can be coated on the nanosized aluminium particles to prevent the uncertain reactions and losses.[9]

### Types of Aluminium Alloys taken into use for the construction of heavy aircraft parts are mentioned below:[13]

- 1) AA 2024: This type of alloy is used for the construction of wings and fuselage of the air vehicle. The properties of this alloy are high tensile strength, maximum yield and also fatigue resistance. This type is considered as the high-grade alloy.
- 2) AA5052: As this type is easily mouldable i.e. can be converted into any shapes according to the need, it is used in fittings of aircrafts. It is also used for engine parts. It is resistant to corrosion and heat. Also, it is ductile in comparison to others.
- 3) AA 2014: This is considered as the strong and toughest amongst all. Due to this property, it is used for building internal structures and airframes of the aircrafts. It is resistant to arc and welding. But the drawback is, it is not corrosive- resistant.
- 4) AA 6061: This type of alloy is used for the construction of aircrafts in a homemade manner. Usually lightweight and strong in nature. It can be easily moulded and can be welded. Strongly recommended for wings and fuselage.
- 5) AA 7068: This is the strongest aluminium alloy which can withstand the difficult boundary conditions and attacks. AA7068 is used in military and defence aircrafts  
.AA 7050: As this alloy acts as a resistance to fractures, it is widely used in military aircrafts. Usually, skins of fuselages and wings are constructed using this.
- 6) AA 7075: This type of alloy contains some proportion of zinc which makes it fatigue resistant and also gives properties same as steel. This alloy was in high demand for the military aircrafts during World War 2.

Type of Alloy	Density(g/cm)	Elastic Modulus (GPa)	Yield strength (MPa)	Fracture toughness (MPa/m)
AA 7050	2.83	70.3	450	38.5
AA 7075	2.80	71.0	505	28.6
AA 2024	2.77	72.4	325	22.0
AA 2014	2.80	72.4	415	26.4
AA 2219	2.84	73.8	290	36.3

Source: Aerospace Materials and Material Technologies. Volume 1: Aerospace Materials. Indian Institute of Metals Series. N. Eswara Prasad, R.J.H. Wanhill. Springer Singapore.

Table: Mechanical characteristics of Aluminium Alloys used in Aerospace industries.

**2.1 b) Polymer Composites with reference to CNTs:**

The properties of CNTs used in polymer matrix are crash resistant, very high Young Modulus, Thermal shutdown, and very high specific strength. The airframe structures constructed using these polymers include CNTs integrated with Epoxy, Polyamide etc.

**2.1 c) Polymer Composites integrated with Nanoclays:**

They serve as a heat retardant substance to the airframe. They are the barriers between the heat and the airframes.

**2.1 d) Metallic Nanoparticles integrated with Composites:**

This type acts as a shield between the lightning and airframe structure. This type of composites has the property of EM shielding and electrostatic discharge which protects from thunder.

**2.2 Nanocoating [11,14]**

The object’s surface which is referred to as a substrate. A coating is implied to the surface which improves the properties of the substrate like appearance, resistance to wear and scratch, resistance to corrosion etc. Nanotechnology is used as an application in coating as nanomaterials used in this technology have different physical, chemical properties which improves and protects the substrate from corrosion. Nanocoatings are generally produced using nanoparticles having unique characteristics. They can either be nanocrystalline or the layers of nanocomposites and nanometers. The compound used as fillers is Silicon dioxide. Also, Nanomaterials act as friction modifying agents which are used for coating purposes. This includes carbides, nitrites, ceramics and also some metals.

The types of Nanocoatings are described below:

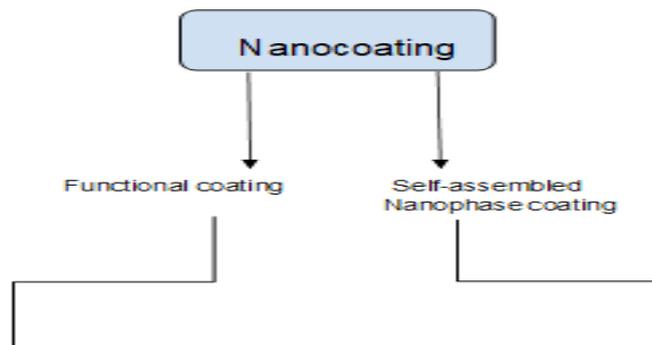


Fig 2.2a: Types of Nanocoatings

Table 4: shows the Nanomaterials coating applications in healing cracks, resistance to creep, high strength etc.

Nanomaterials coating	Applications
1) TiN	Low friction, wear-resistance
2) Nano graphite, Nano Aluminium	EMI shielding, Electrostatic discharge
3) TiN crystallites fixed in amorphous Si3N4	Wear-resistant coatings
4) Crystalline carbide, Diamond like carbide	Nanocomposite coatings

As no aircraft is fully invisible to the radar waves, to make it fully invisible, nano coating is done to stop the detection from the conventional radars. The aircraft surfaces are painted with the coat of Radar Absorbing Materials (RAM). Also, nanocoatings protect the aircraft from the heat rays and work as a heat insulator. The carbon emissions are also reduced up to an extent of 2% due to the application of nanotech coatings on the surfaces of aircrafts.

**SNAP Coating system [13]:**

SNAP stands for Self-assembled nanophase coatings which are the replacement for the surface coatings on the aircraft aluminium nanosized alloys. SNAP technique is used to generate a thin, protective and organic coated layer on the surface of the aluminium aircraft alloys. The coating formed by this method is used as a component of aircraft coating process in order to protect the Al aerospace alloys from corrosion when exposed to air.

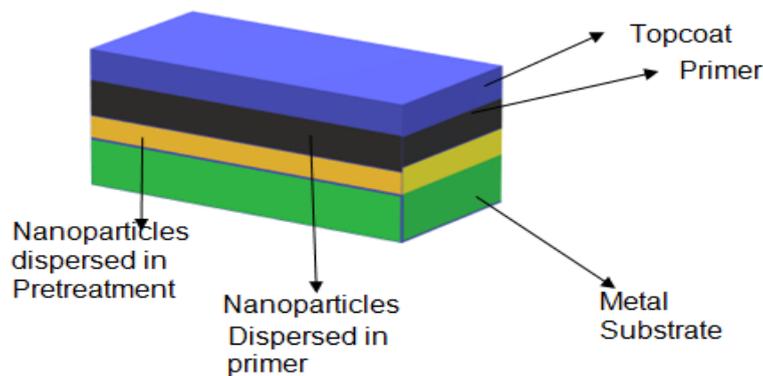


Fig 2.2b: Schematic diagram of SNAP system

**2.3 Electrocommunication systems**

With increasing demands of IT technology and services, there is a high need for data storage devices. After the invention and Research by Richard Feynmann and Eric, there arose a need for miniaturization of devices for storage and components. Hence, miniaturizing the components and devices for storing data came into knowledge to store and compress data in smaller areas, keeping the energy demand on lower levels. To fulfil the needs, nanotechnology has arrived in electrocommunication systems for energy saving purposes. The nanoparticles which are experimented for this system are mentioned below:

Nanomaterials used for Electro communication systems	Applications
Carbon Nanotubes (CNTs)	Huge current carrying devices
Magnetic nanoparticles of iron oxides	Patterning various data storage media
Template Assisted assembly	Growth and assemblies
Ceramic Nanoparticles	Supercapacitors
Metal oxide particles	Hard disks for data storage

Table 5: Applications of Nanomaterials used in Electrocommunications



### 3 Application of Nanomaterials in Aerospace:

#### 1) General:

The aviation industry is in need of materials which can sustain certain environmental conditions at high altitudes with varying temperatures and pressures. They are in search of technology which provides materials which occur on small scales and reduce weight[1]. The challenge nowadays for the defense sector in Aerospace is to design a quality product which has cheap material costs. If the defence sector lacks in using these nanotechnologies they will either suffer a great commercial loss or the Return On Investment(ROI) will be very low[2]. Nanomaterials are corrosion free and also act as a good resistance to the thermal flow which in turns help in flying the aircraft at high altitudes without material damage. Till now, the use of nanomaterials in the aerospace sector is quite low but surely will be in a good demand in the upcoming years. Composite is a type of material developed by amalgamating two materials with different characteristics which results in a material having different characteristics than both of them. Out of the variety of nanoparticles, carbon-based nanoparticles are in high demand all over the world. Carbon based nanotubes, buckyballs, carbon tubes and graphene are some kinds of carbon based nanoparticles which when amalgamated with a certain polymer matrix result in a good nanocomposite mixture. Hence this nanocomposite can be used in coating or painting for better sustainability. This type of nanocomposite materials formed gives better strength along with less weight and more amplified electrical properties[1]. Polymers being good in showing characteristics like middling cost, low point density and hostility to corrosion are used in aerospace materials very frequently. But polymers aren't used in their existing form in aircrafts due to their deformations on higher temperatures, less strength to size ratio and also the less heat capacity. So they are mixed with these materials and hence create composites which can be a great alternative to be used as materials in aircrafts. The parts of aircraft like wings, slats, flaps, stabilizers are built up from the polymer nanocomposites. Nowadays, these nanocomposites are also used in the parts of engines used for civil and military aircrafts and also in the structure(airframe) of the aircrafts consisting of 45-55% of the proportion of polymers in it. Boeing 787 Dreamliner is the first aircraft to use 50% proportion of composites. The maneuvers of F- 18 aircrafts is marked due to the partial use of composites in it[3]. If the nanocomposites are developed without the use of nanomaterials in the polymer matrix it can result in the devastating effect on the environment leading to damage to wildlife and natural things. Nanotechnology is a good scope of research in terms of aircraft engines. Alloys formed from metals like Titanium and Nickel are used as composites in the engine parts like exhaust ducts, nacelles etc.[1]. Nanomaterials were fabricated over a long time ago, but have been in use since the last ten years. Among all the types of nanomaterials, carbon nanotubes are the most used material in fabrication in the nano and macro systems [4]. The shielding of certain spacecraft and thunder light protection is also carried out by nanomaterials nowadays. The outcome of the study is to discover a new technology in science that is cost effective, which provides accurate efficiency and with increasing capabilities. These three requirements are mandatory to fulfill the needs. If anyone out of these is missing will lead to a loss [2]. Another area of aeronautics is Wiring which helps in direct weight reduction and less fuel consumption. Maximum usage of copper wires is seen in aircrafts. For example; wire named 1553B of CNTs can help in saving the weight by 69% and also avoids certain types of heating. The main requirement is lightweight in air vehicles, airplanes, rotorcrafts, space vehicles etc. Also with the light weight characteristic, increase in speed, thermal shieldings, smooth maneuvers are also concerned. CNTs plays an important role by minimizing the weight by replacing the airframe material with the nanosized material and wiring which also helps in less fuel consumption.[11]

Table 6: showing content for various requirements and its usages along with some effects.[8]

Requirements	Usages	Effects
1) Light weight	All types of aircrafts	-High strength to weight ratio. -Use of wood, composites as low density materials
2) Stealth technology	Military and defence	Stealth coated surfaces.
3) Safety of passengers	Carriers	-Crashworthiness testing. -Fire restrictive materials
4) Radiation and thermal shields	Vehicles in space	-Testing for different surroundings. -Damage issues
5) Weather	Air vehicles	Lightning protection and control
6) Exhaustion and corrosion	Air vehicles	Extensive testing for corrosion. ( eg: alloys)
7) Fly-By-Wire	Aircrafts	Use of computers and electronics
8) Multifunctional	All aerospace programs	Composites with various roles and functions.
9) Highly reliable	All aerospace schemes	Proof of design
10) Aerodynamic characteristics	Spacecrafts in the reusable format	Contoured shapes
11) Manufacturability	All aerospace schemes	Molding and machining
12) Nanomaterials	All aerospace programs	Coating, shielding, composition for the production of vehicles

## 2) Thermic shield

Nowadays to increase thermal stability and to strengthen the mechanical conditions at various aero thermic situations, Nanomaterials are being integrated. To shield the spacecraft from the turn back of heat into the atmosphere and so to protect it from space radiations, Thermal Protection System (TPS) came into existence. TPS was successfully given birth with the use of Carbon Nanotubes. CNTs help in raising the strength of the material by mixing some thread/knotty structure. Bulk Nanostructures play an inevitable role in TPS [7].

TPS: This system serves the inner structure by shielding them. TPS spreads through the whole surface of the spacecraft, space vehicles and also is a combination of different materials. This combination depends upon the heat incident on the surface. The materials used in TPS protect the vehicle by creating a layer/shield between the inner aerodynamic structure and the compartment for crew members. There are two main factors for TPS:

- a) Lightweight and b) type and thickness of material [13]

### 3) **Propulsion:**

Nanoparticles provide higher specific surface area which results in faster burn rates and increased reactivity with other elements. But along with this the storage of the materials is a major concern. Applications of nanomaterials in the field of propulsion include stabilization surfactants, dispersion elements and many more resulting in lower propellant (W0) weight fraction. In regard to this, due to increased reactivity negativity is seen in the performance which can be considered as a drawback. The performance of Combustion using (Al-H<sub>2</sub>O) Aluminum-water can be majorly increased with the help of nanomaterials and can be an important and primary driving factor for the aerospace materials also increasing the duration of flight in space.[7] Aluminum is considered as a major constituent of propellants. Metallic nanoparticles have special qualities like fast ignition rates and combustion in a shorter time period. Aluminum nanoparticles have been used to increase the characteristics of a propeller. Aluminum nanoparticles are covered/coated with protective oxide layers for unwanted ignitions.[11]

### 4) **Nanostructured alloys:**

Tensile strengths and maximum yielding results in the production of Nanostructured alloys. The most widely used production method amongst all is ECAE. It stands for Equal Channel Angular Extrusion. This method helps in the production of alloys in bulk. But there are certain drawbacks using the nanostructured alloys in the manufacturing of aerospace components. These drawbacks mainly include higher production cost rates, some of the mechanical properties are of low impact than the structural conventional alloys.[9] However along with the advantages, there are some disadvantages as well. They are:

- a) The mechanical properties such as fatigue, strength, ductility, fracture points are low as compared to the conventional structural alloys,
- b) The costs of manufacturing are comparatively high.
- c) The process to achieve highly ultrafine grain sized particles is lacking and hence are less producible. [11]

Also, Aluminum nanoparticle alloys are in high demand which is explained in detail in 2.1(a).

5) **Nano energetics:** The energetic materials are termed as the materials which release energy exothermically at higher rates in certain energy reactions such as detonation etc when initiated with a stimulus or certain input parameter. The applications of Nano energetic materials include space lift, propulsion systems of aircraft using air-breathing techniques etc. Nanotechnology is the primary responsible thing for the nano energetic structures to hold the production rates, energies released during reactions, and also the rate of reaction accordingly. Also, nano-structured propellants are capable of improving the thrust, specific impulse and the efficiency factor of the space lift engines throwing the advantages like low cost, safety, performances, and some properties.[10]

### 6) **Power, Energy and Storage:**

There is a need for a strong and reliable power system for aeronautics and space missions. The defined existing power systems are nowadays replaced with nanomaterial assembled power systems Nanomaterials based on graphene are continuously on improvement terms. Solar cells implanted with silicon having improved performances have been designed and developed. Also, fuel cells incorporated with nanomaterials have improved the performances drastically [7]. Harvesting energy through devices like thermoelectric and piezoelectric means are very much into application as power devices. Fuel systems incorporated with engineered nanomaterials having more increased efficiencies and self-powered structures holding the storage capacities leads to the development in power, energy and storage facilities.[10]

7) **Aerogels:** The composition of aerogels consists of 1% solid and 99% air. So, their weight is almost negligible. It has compositions of nanosized particles having covalent bonds [15]. Nanopores combined with Highly porous nanogels are super- efficient in terms of acting as a thermal insulator. Various combinations of materials like aluminium, silica, mixture of oxides, composites, titanium oxides with nanoparticles are in good use. Nowadays, aerogel is used as a thermic shield in aircrafts. The only drawback is the high-cost factor.



However, the commercial use is still low for the same. NASA carried out certain space missions using aerogels. The concept of cryogenic tanks in vehicles are also found to have the layer of aerogels for thermal insulation. [9] The first aerogel was generated by Samuel Kistler in the year 1931. They are used to produce supercapacitors because of the property of higher surface area.[15]

**8) Solid Lubricants carrying polymers:** Nowadays, Lubricant coatings carry nanoparticles or nanocomposites for better durability and enhanced performance under given conditions. Summing up to this, addition of nanofillers to the polymer matrix gives better mechanical properties with heat resistant qualities. Nanosized solid lubricant has vast use in space applications, aerospace industries, launch vehicles and satellites. These coatings include applications in gimbal bearing bolts, gears and pumps, telescopes for space, some components of satellite, slip and disc rings etc. Nanosized filler materials like graphite, Aluminium oxides, Titanium oxides, Zinc oxides are used in manufacturing of polymer nanocomposites. [11]

Table showing contents of Nanostructured coatings and its applications.

Coating compounds	Applications In
MoS <sub>2</sub> / Au	switches
Graphite	Ball Bearings in space Vehicles
Korolon	Punching and Piercings Foil
DLC	bearing in high degree
In/TiN	Dry machining of Carbon steel

**Insufficient Regulations in knowledge:**

The development of nanoparticles in the aerospace industry and the safety factor is quite impressive and long lasting than other industries. Due to the effective use of composites in the aerospace industry it has come to knowledge that composites combined with nanomaterials are highly observed in this field. Along with the use of nanomaterial technology, safety should be the primary thing that should be taken into consideration. The safety measures are as follows:

- a) Can be a protective environment.
- b) Well-equipped tool for testing
- c) Design processing under observation and many more.

So, in comparison to other industries, aerospace industries have a good hold in terms of safety [1]. Some censorious challenges include:

- a) Making the nanostructures absolutely healthy and fit to the health of humans.
- b) Long lasting reliability of nanomaterials.
- c) The production of nanomaterials without losing their inherent original properties.[11]



### **Conclusion:**

In this content, we have discussed about nanomaterials and their various properties which reflects certain impacts on Aerospace industry. We have also described the current technologies and types of nanomaterials which can be very useful in the defense sector. The versatile properties of nanomaterials allow the researchers and scientists to have a good hold and implement them for further technologies and arenas. Hence, more improvisations are needed in the practices of the nanomaterials so that the high and small scale accidents can also be avoided.

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## EEG Signal Classification for Neurological Disorder Detection

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### Abstract

Electroencephalography records electrical signals of the brain activity, any abnormality in human body that cannot be physically diagnosed, can be captured using brain signals. Thus the analysis of EEG signals is essential to make certain the correct assessment and treatment of neurological diseases. In this study, there were two classes in the dataset; first is the normal whereas second is abnormal types which represents the brain disorders, recorded for 5 seconds with 16 channels for 20 subjects (10 normal and 10 abnormal). Signal data from each subject is then optimized using Genetic Algorithm and Artificial Neural Network is used to classify the normal and abnormal neurological disorder. From the experimental results, the classification accuracy comes out to be 98.45% approximately.

**Keywords**—EEG (Electroencephalography), GA (Genetic Algorithm), ANN (Artificial Neural Network), Artifacts.

### 1. INTRODUCTION

EEG is becoming more and more important in the diagnosis and treatment of mental and cerebral neurodegenerative diseases and abnormalities. EEG is an electrophysiological measuring method used for recording electrical signals of the brain (al-Qazzaz et al., 2018). The analysis and classification of EEG signals are essential to substantiate the diagnosis of brain diseases and to help better understand the cognitive process (shirvan et al., 2018). The primary use of the classification is to break up the EEG signal segments and see whether people are healthy or estimate their mental state (zeynali et al., 2019). EEG generates a huge amount of data in the form of potential differences from the electrodes placed on the scalp, which can be recorded at a frequency of more few 100Hz and thus the visual inspection for distinguishing these potentials could be time-consuming, error prone and moreover expensive and insufficient to obtain reliable information. Therefore, the development of an automatic classification method for EEG is essential to assure the correct assessment and treatment of neurological diseases (Bhattacharyya et al., 2017).

Now since, the EEG records contain large amounts of data, a key issue is how to characterize the recorded EEG signals for the study (meisheri et al., 2018). First, it is important to extract useful features from the original EEG Signals, and then use the extracted features for categorization (son et al., 2016).

Due to non-stationary nature of EEG signals (lee et al., 2018), the conventional methods of frequency analysis are not highly successful in brain disorders classification (polat et al., 2016). In these days, classification of EEG signals is frequently used for the detection of brain disorders but the existing techniques for classification of brain disorders using EEG signal are not that efficient (kasahara et al., 2018). Thus in this work we used a combination of an optimization technique and a classification algorithm. Optimization technique being used is genetic algorithm and classifier as artificial neural network.

### 2. MATERIALS AND METHODS

#### 2.1 Experimental setup

The signal obtained during the process of data collection is called raw EEG signal (meisheri et al., 2018) which includes potentials from 16 channels of the brain i.e. FP1-F3, F3-C3, C3-P3, P3-O1, FP2-F4, F4-C4, C4-P4, P4-O2, FP1-F7, F7-T3, T3-T5, T5-O1, FP2-F8, F8-T4, T4-T6, T6-O2. Here the EEG recordings are made at the sensitivity of 70  $\mu$ V /cm, deflection of 100mm and time base of 30mm/sec. The frequency range used for low pass filter is 1Hz and for high pass filter is 70Hz. The notch filter of 50Hz is used to reject noise due to power supply. The values of potential are recorded at a frequency of 128Hz (garg et al., 2018). The recording of 5 seconds for 20 subjects (10 normal and 10 abnormal) is used as a dataset during the experiment.

Since the data collected was raw EEG data thus it comprises of some non-cerebral signals known as artefacts (chriskos et al., 2017). These are actually adulterations in the signal. These adulterations can be due to the movement related potentials, movement of facial muscles, eye blinks, etc. These are biomedical artefacts and are the most difficult to remove because of their resemblance to the actual EEG signal (luzheng et al., 2013). The other major cause of the problem is the extraction of best and appropriate feature sets from the EEG signals. To minimize these types of problems during classification, GA is best according to the survey and because of its Meta heuristic nature (pendharkar et al., 2009) for optimizing the collected data so as to reduce the effect of biomedical artefacts.

## 2.2 Genetic algorithm

Non stationary signals such as discontinuities, repeated patterns or trends can be efficiently interpreted using GA, which other signal processing technique becomes inefficient (hongqiang et al., 2017). Since EEG signals are non-stationary in nature, thus using genetic algorithm for optimizing these signals, transient features are accurately captured and localized in both time and frequency context so that the classification problems of brain disorders using EEG can be successfully solved. Also the process of Genetic Algorithm is fully involuntary and avoids home-grown minima (grefenstette et al., 1986).

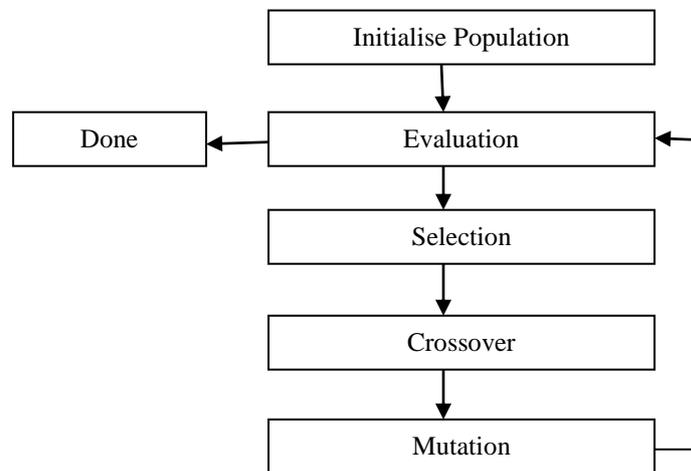


Figure 1: Flow Chart of Genetic Algorithm

Figure 1 shows the Flow Chart of Genetic Algorithm. Here the first step is to initialise the population of individual's randomly. Then, the individual fitness function is applied to measure the performance of the population. GA operates the genetic composition of a population through three basic operators, namely, selection, crossover, and mutation. Selection; On the basis of the fitness value, the most highly rated individuals are selected from the current population. Crossover; new individuals are created from their parents by exchanging information between the two parents. Mutation; on the basis of mutation rate, individuals in the population are selected for creating new individuals. After a series of iterative calculations with these operators, when the termination condition is satisfied, the optimal solution will be filtered (hongqiang et al., 2017). The parameters of GA used are as shown in Table 1.

Table 1: Parameters of Genetic Algorithm

Population size	50
Selection function	Stochastic Uniform
Crossover	0.8
Mutation rate	0.05

### 2.3 Neural network

ANN as a training algorithm, is used for final classifications of normal and abnormal EEG signals. Figure 2 shows the architecture of ANN used during training which includes input layer having 15 inputs (extracted features) hidden layer with 20 neurons and an output layer with one test output. Training parameters are shown in Table 2. Training halts when any of parameters are fulfilled. After training the ANN, the testing is done using different test sets.

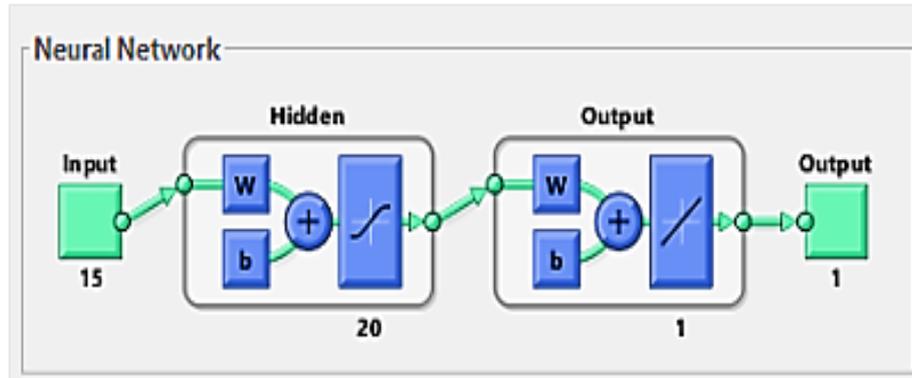


Figure 2: Architecture of the ANN

Table 2: Training Parameters used in ANN

Training algorithm	Levenberg-Marquardt backpropagation
Maximum no. of epochs	100
Minimum performance gradient	1.70
Performance	Mean squared error
Maximum validation checks	6

## 3. WORKFLOW

A GUI (Graphical User Interface) is created for the ease of access to the simulation environment. Figure 3 shows the flow chart of the proposed work. A simulation model is designed to depict the flow of the work undertaken to simulate the work. The flow of the research work is divided into two sections; first one is Training Phase and the other one is Testing Phase.

### 3.1 Training Phase

- Step 1. Initially, the raw data of neuro-patient is collected.
- Step 2. Pre-processing is applied on the collected data. The pre-processing steps includes: amplification, filtering etc.
- Step 3. Genetic algorithm is applied on the pre-processed data. GA helps to extract the optimized features using fitness function.
- Step 4. On the basis of the optimized features, neural network is trained for both normal and abnormal brain disease.

### 3.2 Testing Phase

- Step 1. Test data is loaded that could be normal or abnormal.
- Step 2. Genetic algorithm is applied to reduce the features of the test data using fitness function.

Step 3. ANN is applied to classify the Normal and abnormal neuro-disease. In this process, the test data is matched with the ground truth value. If the value of test data is more than the ground truth value, then the test data is considered as normal and denote by integer '1' otherwise denote the disease as value '2' that represents the abnormal brain disease.

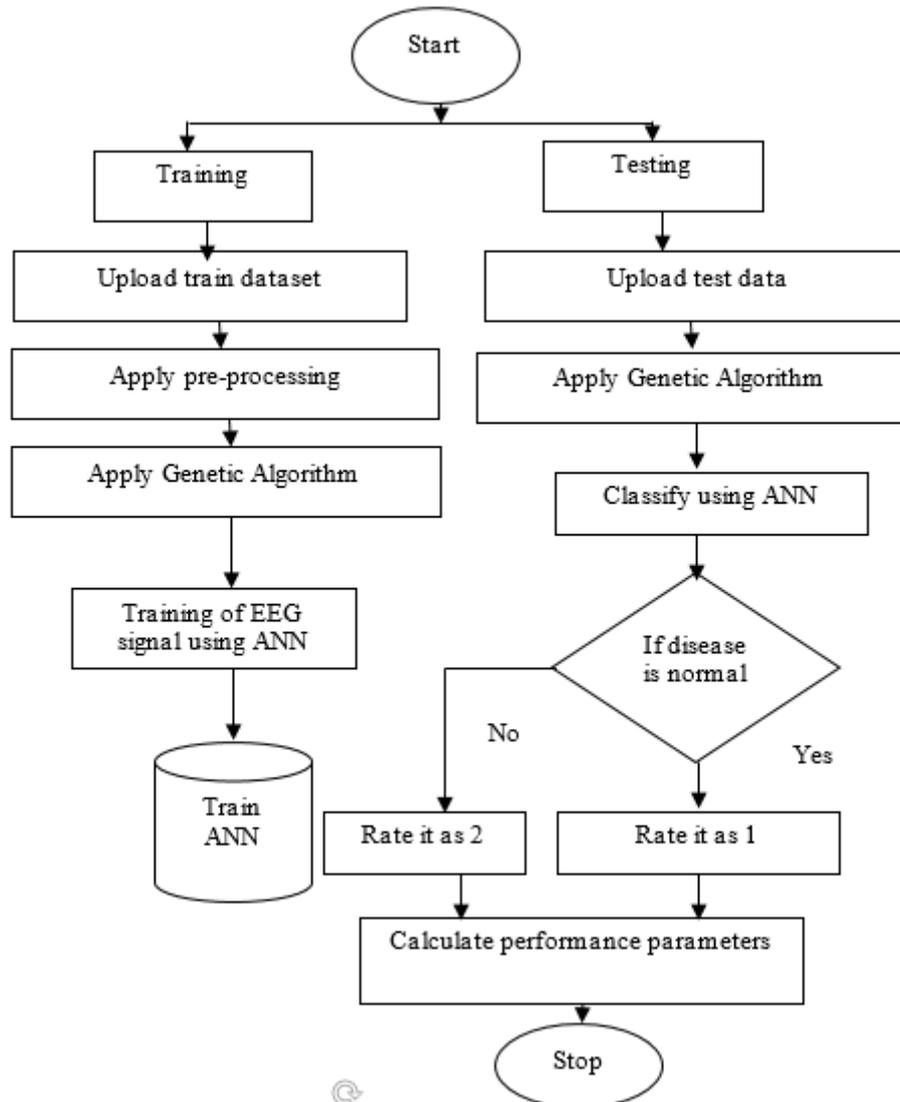


Figure 3: Flow Chart of the Proposed Work

#### 4. RESULTS AND DISCUSSION

The accuracy of the classification between normal and abnormal is calculated from classification parameters; true positive rate (TPR), true negative rate (TNR), false positive rate (FPR) and false negative rate (FNR).

$$Accuracy = \frac{TPR + TNR}{TPR + TNR + FPR + FNR}$$

Figure 4 shows a graph called ROC (Receiver Operating Characteristic) curve. Here the ROC is plotted between the true positive rate and the false positive rate for the different possible cut-points of a diagnostic test

(pendharkar et al., 2009). Since the curve completely coincides the y-axis i.e. area under true positive rate is 100%. Therefore, the ROC of the proposed work is 100%.

Seven trials with different test sets has been tested to check the average accuracy of the proposed system. Table 3 shows the accuracy and the values of TPR and FPR calculated during each trail. Thus, the average accuracy of the proposed work comes out to be 98.45 %.

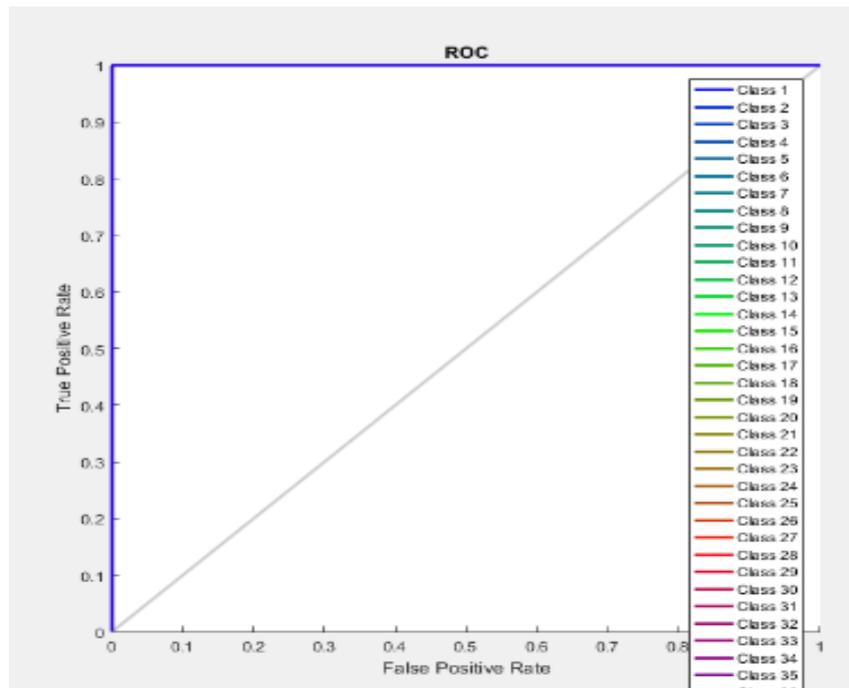


Figure 4: ROC Curve

Table 3: Results during Each Trial

Number of Trials	Accuracy	TPR	FPR
1	98.1208	0.8333	0.03915
2	98.6154	0.8333	0.028845
3	98.5128	1.1667	0.030983
4	98.7292	0.79167	0.026476
5	98.0951	0.79167	0.039685
6	98.5378	1.125	0.030463
7	98.5554	1	0.030096

Genetic algorithm used for data optimization has effectively represented the characteristics of EEG signals, regardless of their non-stationary nature, for which other signal processing approaches becomes less effective. Using GA 15 of the 16 channels were selected and given as input features to the neural network for the training of the network. During the classification various test sets were used to check the classification performance of the work. In this process, the test data is matched with the ground truth value. If the value of test data is more than the ground truth value, then the test data is considered as normal and denote by integer ‘1’ otherwise denote the disease as value ‘2’ that represents the abnormal brain activity.

After performing the experiment several times with different test sets, we got an average accuracy of 98.45%. Thus, in this work, we have dealt with a different method for analyzing the EEG signals using GA as optimization algorithm and classification using ANN.

### 5. CONCLUSION AND FUTURE SCOPE

The work describes the function of ANN for classification of brain disorders using EEG signals. This work embraces two stages: initially, GA is used as optimization scheme and then classification process is accomplished using ANN as a classifier. The performance of the proposed work is assessed in terms of training performance given by ROC curve and classification accuracies by calculated accuracy during each test performed. The results has confirmed that the work done has the potential in classifying normal and abnormal EEG signals. To illustrate the work, we have used recorded EEG signals with pre-processing steps. There are two classes in the database; first is the normal whereas second is abnormal which represents the brain disorders. Here, GA is used as an optimization algorithm with a novel objective function which helps to create a set of unique features for both classes. If the uniqueness of feature is more, then the probability of classification rate of ANN is high. From the experimental results, we have observed that the classification accuracy is 98.45% approximately.

In future, we can use another optimization algorithm such as Artificial Bee Colony, Particle Swarm Optimization along with ANN as classifier. Also, the performance of the proposed work can be compared with other classification techniques such as Support Vector Machines or fuzzy logic. For various features, PCA (Principal Component Analysis) can also be used.

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## Speech Recognition Approach for Under Resourced languages with reference to Sylheti

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### Abstract

A standard and labelled large vocabulary speech database has been the prime requirement for designing a learning-based model for a human language. The concept of globalization and the potential use of digital devices among people have led to the significant start-up towards the construction of speech database (corpora) and the automatic speech recognition system for under resourced languages in recent years. However, these issues are still to be considered the subjects of interest in many of the under resourced languages across the globe due to different practical constraints. Sylheti is an under resourced language with more than 10 million native speakers across various regions in the world. This language has its own distinct script and also unique characteristics. It is explored very recently reporting limited linguistics as well as scientific works. Focusing on this, this paper presents a typical review on the works reported on speech databases developed for the under resourced languages including Sylheti. Also, a comparative performance analysis is carried out for the proposed works in the field of speech recognition systems for under resourced languages especially considering the Sylheti language.

**Keywords-** Speech recognition, Speech database, Under resourced language, Sylheti, Human language technology

### 1. INTRODUCTION

Though speech application-based research has attained a notable height, yet it has been witnessed in recent years a high demand for designing automatic speech recognition (ASR) system for human-machine interface (HMI) in under resourced (UR) languages (also called low-resourced or less-resourced language). The importance of electronic technologies for UR languages is observed indispensable for ensuring language progresses and the use of digital content by the masses. Language barrier is considered one of the major factors in this scenario. Over the last decade, focus on research towards the development of ASR for UR languages has received significant attention for their preservation and making them attractive to their native speakers. Spoken language is the primary means of human communication and also fundamental to cultural identity and empowerment.

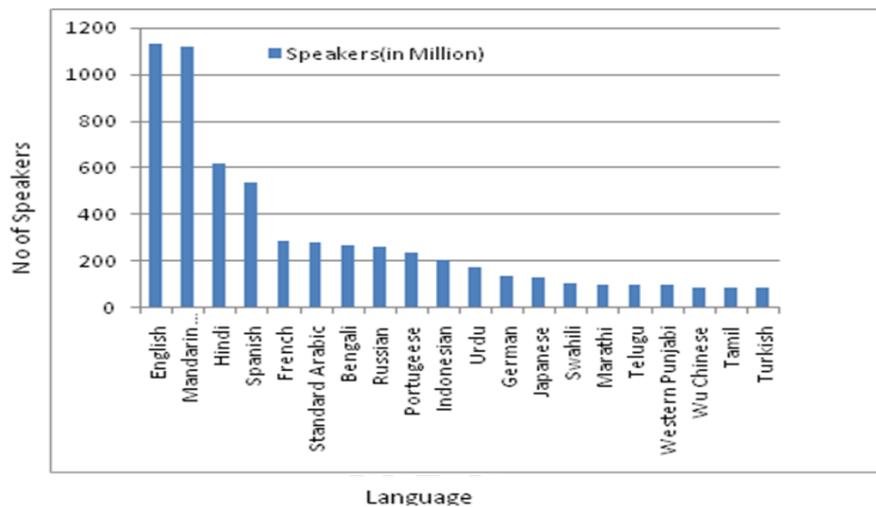


Figure 1. Top 20 most spoken languages in the world

As of 2019, SIL (Summar Institute of Linguistics) Ethnologue (a language center for language intelligence) has enlisted about 7,111 living spoken languages in the world. Out of 7111 living languages,

400 languages are considered to have more than 1 million speakers. In terms of native speakers, top 20 most spoken languages in the world with their total speakers are depicted in Figure 1 where English language stands in 1<sup>st</sup> rank followed by Mandarin and Hindi in second and third positions respectively. Very few fractions of the living languages have available linguistic resources which are necessary for Human Language Technologies (HLT). This small fraction called well-resourced languages are electronically well defined.

Further, Ethnologue enumerates around 41% of living languages as endangered across the globe. The remaining class of languages are considered as UR languages. The number of languages in India listed by Ethnologue is 461. Of these, 447 are living and 14 are extinct. According to the UNESCO Atlas of World's Languages in Danger 2010, around 197 languages are marked as endangered languages in India. Majority of such endangered languages are spoken in the North eastern part of India. In India, English is booming, and it is used commonly by the new generation, which is one of the reasons leading to the threat of extinction of native or regional languages. With these challenges, the research community has started their work by porting, adapting, or creating written and spoken resources or even models for UR languages. In this context, a set of workshops and special sessions are also been organized by considering UR language speech recognition challenge such as SLT (Spoken Language Technologies) workshop for UR languages in Hanoi, Vietnam in 2008, in Penang, Malaysia in 2010, in Cape Town, South Africa in 2012, in Gurugram, India in 2018, in Hyderabad, India, 2018, etc.

The Sylheti language is having its long literary tradition and rich cultural heritage. The alphabets of the Sylheti language are written in its own unique script Sylheti Nagari. It has been witnessed increased attention in academia very recently, thus opening numerous boulevards for the researchers to explore this language. Sylheti, which is marked as an UR language, has been explored with few linguistic discussions and scientific investigation on ASR technology for the language. It is found in Linguistics report that Sylheti contains a large part of its basic vocabulary common to its closest language standard Colloquial Bangla (SCB) [31]. Sylheti is therefore considered to be a dialect of SCB, but due to substantial differences in morpho-phonological context and limitation of mutual intelligibility separate Sylheti from SCB which results fixing the status of a language to Sylheti [31]. Under Indo-Aryan language class, Sylheti is used as their mother language by more than 100 lakhs people across the globe. Nonetheless, large section of Sylheti speakers resides in Sylhet part of Bangladesh and southern area of Assam, India. One of the linguistic studies presents that Sylheti shows some distinct phonetic characteristics such as de-aspiration, spirantization and deaffrication [11],[31]. Another acoustic experiment on the speech signal of Sylheti words establishes the presence of high tone in the Sylheti language due to the loss of breathy voice contrast [10]. As preliminary works in the field of ASR, set of ASR models are designed to investigate the speech signals of Sylheti words and sentences [8],[30]. It has been observed from these studies in the Sylheti language that it has enough scope to further explore this language in ASR applications which may help in designing HMI for Sylheti speakers.

### *a) Under resourced language*

While defining a language UR, some of the following shortcomings are observed [1]: deficiency of linguistic expertise, limited electronic and web resources, shortage of unique writing system or stable orthography, etc. According to Bermant's report, a language can be marked as UR language when it is having a mean score below 10/20 [1]. It is to mention here that UR languages can't be considered as endangered but the opposite is proved to be true [2].

### *b) Reasons to address UR languages*

As mentioned above, language acts as an important, fundamental and fastest communication tool among humans. The survival of a language depends on its number of speakers and respect shown by surrounding culture. Further, individual and community events, cultural activities, memories, ideas and experiences, etc. can be easily shared via language. Speech recognition and translation system have a lot of scope to revitalize and also to document a language. As a consequence, it creates a bridge between native and non-native speakers. From these perspectives, it can be summarized that the development of HLT should not concentrate only on considering well-resourced languages but UR languages also.

c) *Challenges to meet*

Designing an ASR system for a language needs bulk amount of transcribed speech recordings from many speakers (both male and female speakers be balanced) so as to use the speech data for training and testing the acoustic model. Processing a new language by adapting an existing model or by creating a new model becomes a challenging work for the specific phonological structure of the language. Finding native and educated speakers with minimum technical skills to provide speech recordings in their native language is also difficult for the researchers which are required to develop ASR systems. Further, very few linguistic literatures and electronic speech databases are available for UR languages. Hence, designing ASR systems for such languages sometimes have to borrow speech resources from similar type or closest languages. All of these multi-disciplinary challenges are to be resolved during the research in the field of ASR as well as on HLT for UR languages. The prime motive of this study is to disseminate our experience to research group by studying in UR languages across the world and also to motivate others to extend their work in speech technologies considering UR languages like Sylheti.

Apart from Introduction mentioned in Section I, remaining part of the paper is organized in the following way: Section II presents a typical review on speech corpus development for UR languages. In Section III, the research works carried out for the development of ASR systems for UR languages are introduced along with a comparative study of the ASR systems for UR languages with special reference to Sylheti. Section IV concludes the paper.

## 2. SPEECH CORPUS DEVELOPMENT FOR UR LANGUAGE

A standard speech database (or corpus) is the primary and integral requirement for the development of ASR system in a language. Due to the consequence of globalization and the promising use of digital technologies among masses during last two decades, it has been witnessed the significant startup towards the development of speech database and also the ASR system for UR languages in recent years across the globe. The Linguistic Data Consortium (LDC), USA acquired speech data from various sources such as broadcast news, telephone speech, etc. to construct several large databases for the UR class of languages especially focusing on Egyptian-Arabic, Lithuanian, Basque, Catalan, Czech, Greek, Hungarian, Haitian Creole, Lao Language, Swahili Language, Thai, Vietnamese, Turkish, Tamil, etc. Special Interest Group Under-Resourced Languages (SIGUL) provides the podium for constructing databases in multilingual languages with special stress on European languages [2].

In this line of research, the GlobalPhone project at Karlsruhe University, Germany designs a standard multilingual read speech and text database for 22 languages including UR languages such as Hausa, Polish, Swahili, Tamil, Thai, Ukrainian, Bulgarian, Turkish, etc. This speech database contains 450 hours of speech of more than 2000 native speakers who read various sentences from national newspapers. Construction of speech databases for the eleven South African official languages are also considered in recent years and few of these are relatively small in vocabulary size [3],[4]. However, some databases are found to be large like NCHLT corpus. Wide-band and telephone speech are incorporated in these databases for the official languages Ndebele, NorthernSotho, Sotho, SiSwati, Tsonga, Tswana, Venda, Xhosa, Zulu, Afrikaans and South African English. Further, speech data are collected from more than 200 speakers for each language. The main objective of constructing these databases is to design phoneme-based, speaker-independent ASR systems in those languages. In another exercise, a crowdsourced speech corpus in GALLU project is designed for the UR language Welsh which is largely spoken in Wales of United Kingdom [22]. The creators of this speech dataset have suggested that crowdsourcing proves to be a useful and efficient method of collecting speech for UR languages in the world, and also for developing resources for speech technology.

It is notable that Government of India has officially recognised 22 Indian languages namely Assamese, Bengali, Bodo, Dogri, Gujarati, Hindi, Kannada, Kashmiri, Konkani, Malayalam, Manipuri, Maithili, Marathi, Nepali, Oriya, Punjabi, Sanskrit, Sindhi, Santhali, Tamil, Telugu and Urdu even though India has about 1652 native languages/dialect [29]. Except the Hindi language (about 43% of total population of India), most Indian languages are still considered UR languages due to the lack of publicly available speech dataset. In recent years, researchers have emphasized to explore Indian languages in the domain of speech processing and natural language processing. The LDC specially for Indian Languages has introduced a collection of speech databases for segmented data, annotated data and pronunciation dictionaries focusing on these Indian languages in order to extend research in various domains of speech

processing. In Marathi language, a joint work by TIFR, Mumbai and IIT Bombay has constructed a speech database. This speech corpora includes speech data recorded from 1500 speakers by using two phone lines [21].

The construction of the multilingual speech corpora along with text corpora are reported by the authors for three UR languages of North-East India: Assamese, Bengali and Nepali [19]. In each of these databases, speech samples are recorded from native speakers by using two recording channels, narrowband and wideband. In another effort [20], an Assamese speech database is developed at Tezpur University, Assam which includes recording of 7 hours of speech in three forms: conversational speech, extempore speech and read speech. In this database construction, twenty-five speakers in the age range 20-40 years from different regions of Assam are selected. In a group effort, a small vocabulary Bengali speech database has been presented in 2016 at Bangladesh considering Bangla digits uttered by 102 number of speakers whose age range in between 19-25 years [21]. This database is used in the ASR system developed for connected Bangla digit recognition system. In [17], authors have designed a new speech corpus for Bangla considering connected words derived from newspapers. A total of 62 hours of recording has been taken from 150 speakers in the age range of 18-25 years in this work. A new continuous read speech corpus in Bangla is reported in [14] where a total of 110 speakers (70 male, 40 female) in two age groups of 20 to 40 years and 60 to 80 years are chosen to contribute their voices for a period of 26 hours. Considering this corpus, two ASR systems are reported by the authors to observe phoneme and continuous word recognition respectively.

A multilingual speech corpus at IIT Kharagpur has been constructed covering 27 Indian languages out of which many belong to UR language class [15]. Authors use this database for identifying language specific information in speech. A speech database in UR language Mizo (spoken mainly in the state of Mizoram, India) is reported in [23], which includes the speech data recording over phone from 782 native speakers (454 male, 328 female) considering 170 words of various items. This database is constructed mainly in order to develop an ASR system to facilitate a voice interface system to provide the prices of agricultural items to the farmers. The authors in [24] present a speech corpus development in an UR language Angami spoken in Nagaland, India and its use in the implementation of ASR system. In another UR language Manipuri which is spoken mainly in the state of Manipur, India, a large vocabulary speech corpus has been developed. This corpus includes read speech data of more than 300 speakers recorded for more than 90 hours [25].

As mentioned in Introduction section, Sylheti language is mainly spoken in the Sylhet division of Bangladesh as well as in the Barak Valley region of Assam, India and also partly in the northern part of Tripura, India. The research work in Sylheti is in infancy stage. As the first attempt, a Sylheti spoken medium vocabulary speech corpus including 40,000 Sylheti words collected from various sources has been reported in [12]. However, this corpus is not publicly available to use. The construction of a small vocabulary Sylheti speech database is reported in [30] which includes the labeled speech data of 30 Sylheti isolated words and 10 Sylheti sentences. In the development of this database, read speech data from 10 native Sylheti speakers are recorded for a period of 5 hours which accumulates 6000 utterances in the database. Both these two databases in Sylheti encompass the speech samples of normal speech. However, emotional Sylheti speech is yet to be considered to include in a speech database which is a challenge for the researchers to exercise.

From this review, it is highly felt that as far as India is concerned, still a lot of scope is witnessed to extend the works on speech databases for Indian languages which have different linguistics variations. In this line of research, people concentrate on designing ASR models for UR languages in recent years considering speech samples from the constructed databases. The following section presents a concise deliberation on the development of ASR systems in UR languages.

### 3. ASR SYSTEMS FOR UR LANGUAGES

The goal of ASR system is to generate the optimal word sequence subject to linguistic constraints. ASR systems are categorized primarily based on the vocabulary size from small (upto 100 words) to very large (>100000 words). Various machine learning models such as hidden Markov model (HMM), Dynamic Time Warping (DTW), Support Vector Machines (SVM), Artificial Neural Network (ANN) with one hidden layer, Deep Neural Network (DNN) with multiple hidden layers, etc. are being employed either in sole form or in hybrid form by the researchers to design speech recognizers for human languages. Several open-source and web-based toolkits such as KALDI, HTK, Sphinx, Julius, Rapid Language Adaptation Toolkit (RLAT), etc. for designing ASR system are freely available for technology developers to any target language.

In the context of ASR systems presented for UR languages in recent years, various methods are proposed for speech data collection, feature extraction and acoustic model creation. A number of adaptation methods including cross-language transfer, multilingual training, etc. have been introduced and compared by Ozgur Cetin et al. in [5] while developing a word recognizer in the Tamil language. Similar and extended approaches are also adopted by the researchers for Polish language [27] and Vietnamese language [26]. Considering Gujarati language, authors present ASR systems by using amplitude modulation (AM) features and two variants of DNN model i.e. long short term memory (LSTM) and time-delay neural network (TDNN) [29]. In [6], Amit Das et al. has considered three UR South African languages: Swahili, Amharic and Dinka to present ASR systems by employing mismatched crowdsourcing method for raw data collection and multilingual HMM and DNN probabilistic models for finding phone error rates (PER). Under research project AMODA [9], the contributors have tried to use cross-language acoustic data sharing between a well-resourced language Flemish (donor language) and an UR language Afrikaans (target language) to design an ASR system for recognizing phones of Afrikaans. In another ASR development work, the authors use a combination of convolutional neural network (CNN), TDNN and bi-directional LSTM to recognize an UR language Somali [7]. The authors in [13] have presented an ASR system by using TDNN model for the Indonesian language. A Marathi ASR system is presented by Supriya Paulose et al. to find the word error rate (WER) by applying HMM model on mel frequency cepstral coefficients (MFCC) acoustic features [28]. In an effort of designing an ASR system in Assamese language, speech signals are derived from a speech corpus developed for the Assamese language considering continuous speech [18]. In this work, authors employ three hybrid acoustic models to evaluate the performances of the systems. Considering the connected digit sequences, authors present an ASR system to evaluate and recognize Bangla digits [14].

In Sylheti language, as a preliminary work, two ASR systems are proposed by investigating the speech signals of isolated Sylheti words employing two swallow neural network classifiers: feed-forward and recurrent neural network (RNN) [8]. Both the systems are trained with MFCC features and present relatively satisfactory recognition performances. In continuation of this research, authors have presented another two trained models in ASR for recognizing isolated and connected Sylheti words by employing convolutional neural network (CNN) classifier [30]. These two models achieve better performances than the ASR models trained and tested by the classifiers presented in [8]. Table 1 presents a comparative study on the ASR systems developed for some of the UR languages reported in recent years as discussed in this section.

**Table 1:** Comparative results of the ASR systems developed for UR languages

Reference	Language	Features used	Classification model employed	System Performance
[18]	Assamese	MFCC	HMM-GMM	8.03% WER
			SGMM-HMM	6.58% WER
			DNN-HMM	5.65% WER
[28]	Marathi	MFCC	Context independent HMM	36.8% WER
			SGMM-HMM	21.2% WER
[29]	Gujarati	Mel filterbanks (FBANK)	TDNN TDNN-LSTM	15.58% WER 15.68% WER
		AM-CBANK (ConvRBM)	TDNN TDNN-LSTM	15.86% WER 15.97% WER
		AM-GFB (Gabbor)	TDNN TDNN-LSTM	15.72% WER 15.66% WER
		AM-GTFB (Gamm-atone)	TDNN TDNN-LSTM	15.66% WER 15.61% WER
[5]	Tamil	MFCC with delta and delta- delta MFCC	HMM (Unsupervised adaptation)	80.1% word accuracy
			HMM (Supervised adaptation)	82.2% word accuracy
[14]	Bengali	MFCC with delta and delta-delta MFCC	HMM	54.07% phone recognition accuracy 85.3% word recognition accuracy

[25]	Manipuri	Feature space Maximum Likelihood Linear Regression (FMLLR)	GMM-HMM	19.28% WER (best)
			DNN-HMM	13.57% WER (best)
[16]	Vietnamese	MFCC+ energy + zero crossing rate	HMM	36.6% Syllable Error Rate (best one) 42.7% WER (best one)
[13]	Indonesian	MFCC with delta and delta-delta MFCC	TDNN	17.54% WER
[9]	Afrikaans	MFCC with delta and delta- delta MFCC	HMM (with speaker adaptive training method)	78% Phone recognition Accuracy (average)
[7]	Somali	MFCC	TDNN (with adaptation)	58.05% WER
			LSTM (with adaptation)	60.23% WER
			BLSTM	57.91% WER
			TDNN-LSTM	58.05% WER
			TDNN-BLSTM	56.41% WER
			CNN-TDNN-LSTM	55.53% WER
[6]	Swahili	MFCC	HMM DNN	65.73% PER 61.17% PER
	Amharic	MFCC	HMM DNN	68.40% PER 66.53% PER
	Dinka	MFCC	HMM DNN	66.89% PER 64.78% PER
[8]	Sylheti	MFCC	FFNN	84.55% RR
			RNN	86.38% RR
[30]	Sylheti	MFCC	CNN	93% RR for isolated words, 95% RR for connected words

WER-Word Error Rate

PER-Phoneme Error Rate

RR-Recognition Rate

It can be concluded from this study that the recognition results as achieved by ASR models for Sylheti language are comparatively acceptable. However, these ASR models are to be further tested by applying more advanced classification models. In addition, to be compatible with real time application, a robust ASR model for Sylheti is very much essential to learn noisy speech data.

#### 4. CONCLUSION

Research in the domain of speech processing for UR languages tends to be significantly increasing in recent years which are analysed in this paper. This wave of interest in doing research in UR languages not only improves the portability of using these languages in multilingual applications but save them also from extinction. In this study, it is attempted to focus on recent studies carried out on speech corpora for UR languages, and presents a comparative result analysis on ASR systems designed for UR languages especially considering the Sylheti language. It can be concluded from this review that some new adaptive concepts such as crowdsourcing, cross-lingual, codeswitching, etc. are being employed for speech data collection and

recognition of very few UR languages which present effective performance. These new concepts along with various deep learning techniques are also required to be investigated in Indian UR languages including Sylheti.

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## Role of Circular Economy in Global Perspective

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### Abstract

Now a days the Circular economy is the eminent area of discussion among the many organizations and government and it is all about collection of different and unique thoughts from a distinguish field of organization. The main purpose of this article is to add the reasonable and unique thinking on CE. To begin with, we will describe the idea of CE from the view of sustainable development and concept of sustainability science, and secondly challenges in implementation in Circular economy has discussed in building advancement and improvement in sustainable development. CE is consider for its capability of uniqueness to draw attention in both the business system and strategy making system to supportability efforts, however it required to logical exploration to build right view about that the real biological impacts of CE run after manageability. The imperative pull capacity of circular economy in business strategy making and business networking makes it more supportability to work, and though logical explorations to get surety towards the actual biological consequence of circular economy run after manageability. The idea related to CE is generally formed by strategy creators, area specialists and business network. This piece of writing is having the main concern to begin constructing a logical reason for the CE idea and evaluate the CE idea with a basic examination. CE is all about the reliable ideas, because it has capacity to pull the any business network towards the sustainable progressed effort.

**Keywords-** Circular Economy, Sustainability, challenges

### 1. INTRODUCTION

Circular Economy (CE) is a vast area from the research point of view that has been attaining huge attention and importance from last some years, among researchers, managers, leader's scholars and managers of public as well as in private sectors, and become successful trend in a last many years. The various applications of circular economy in the monetary related frame work and reflexive cycles has higher to collaborate various attractions to commitment from different collection of idea that works on close cycles. An evidence of this, rate of fast development in the amount of circulation on the theme from few years. All along these lines, for example, the quantity of scholarly reviews distributed on CE and climate was just 371 out of 2017, 27 of every 2014, arriving at which speaks to an exploration of 1275% in simply three years. Additionally to being a burning area of discussion in western economy, CE is a swift development in different-different nations, like in China and many others countries, but China is the first nation on the earth to build up a legal law on 2008 that encourages the adoption and implementation of CE principles[1]. In a financial setting of trade advancement, CE is assumed as a vital passage to attain and maintain financial, ecological and biological improvement. Hence, the European countries made a CE package by expanding the prior waste order. CE does not have single or unique definition but it is collection of many more reciprocal and multidisciplinary in nature, and being characterized in various traditions and having a distinctive significance for different assembling of humans and situation [2]. In this way, it has to be concluded by many researchers and innovators that there is no generalize approved classification of CE. It may be a practical method through which financial improvement and losses can be enhanced and reduced respectively to prevent environment as well as human social life.

CE may non exclusive term including all exercises that hold 4R principles such as reduce, reuse, recycle and recovery of materials during the of first stage of production of product , distribution of products , and till its consumption[3]. CE has some more definitions like as an effectively use of energy during production and consumption of product with nominal materials losses by using the concept of 4R.

CE is consisting of majorly depicted as a grouping of many words such as reduce, reuse, and recycle actions. CE as “an economic system that is based on business models which replace the ‘end-of-life’ concept with reducing, alternatively reusing, recycling and recovering materials production/distribution and consumption processes, thus operating at the micro, level and macro level, with the aim to accomplish sustainable development”[6]. A circular economy based on different exercises whose main purpose is to save an energy, money , materials and human effort. It shows that how could be planning of materials or products remanufacturing and reuse can be done by using the concept of circular economy [4]. Circular economy makes use of circular frame work which is basically utilizes the bio based materials for allowing huge variety of services and maintain the balanced economy and regular frame work of CE[6]. In a concept of circular economy financial action constructs and remakes generally framework comfort. The thought sees the criticalness of the economy hoping to work effectively at all scales – for of every kind of associations, affiliations and individuals, worldwide and locally. It relies upon three principles:

- Design extract by contamination and waste
- Regenerate common frameworks
- Keep old and new products and materials in use

## 2. RESEARCH BACKGROUND

### 2.1. Overview of Circular economy

#### 2.1.1. Circular Economy

CE concept is not the new; it has been used drawn on many other different concepts, which has established from year ago, such as industrial ecology (2005 Daly), driving to growth (Meadows, Meadows et al., 1972) and cradle to cradle. (40) Whereas the CE concept draws the world wide attention recently only, due to need of society.

China is the first country who adopted the principle of circular economy before 2012 as a countrywide strategy. Now days Europe is the country where development of CE concept is currently on begin, variety of relevant literature, articles, documents are published and government and NGOs are also showing much interest in its development .The different descriptions of CE are found in literature review:

1. As a industrial economy point of view, materials are biological nutrients, they keep flow in circular pattern at high rate without much hampering the environment(7); For attaining an healthier industrial economy careful design of the products such as, using non toxic chemicals, based on renewable energy are required(8)
2. CE concentrates on three words; reuse, recycle, and re marketing(9)
3. In CE provides gives more focus on less wasted and more and more reuse for fulfillment of the purpose of economy for as long as possible(9)
4. CE suggests the concept of circularity based system which is based on reuse of products, end use materials, and natural resources with restorative capacity and also try to minimize the destruction of ecosystem as well as maximize value creation of the system (10).
5. Design and intension should be restorative from industrial system point of view. We should properly re use and use the products and its services rather than before the discarding them (11).

The Above list of definitions are not extensive ones, CE might be exist more definitions in the non-evaluated literature. Literature that represented in above 1-5 definitions is being analyzed from different commonalities and among the different approaches. The Overall summaries of above definitions are found to be minimized the use of non-renewable resources because it is limited and to try optimizing its usage with rule circularity i. e Material-design-manufacturing-distirbution-consumption-sharing-collecton-recycling-recovery.

Eco efficiency is another usual principle of CE which has been identified. It has been seems to be in different ways, which is based on unique way. Some of the common impacts pressure on eco efficiency as a aim of CE (12).Some other perspectives of CE beside with equanimity efficiency are creation of jobs,

economic value, reduction of pollution, decrease in price, resource security (13). Linear economy can also be used to increase the eco efficiency by the use of renewable and non-renewable resources that could affect to environment as well as industrialist with respect to capital cost, materials and pollution aspects. In reality Eco-effectiveness and Eco-efficiency both are the different terms which has been clarified by (14) “dematerialization, reducing the volume of material flow, deadliness in flow system of materials are comes under the approach of Eco- efficiency”, where as in eco-efficiency is the center of attraction in the future economic growth of country by entailing transformation of materials flow and their respective products to form supportive relationship with surroundings. The Main purpose of eco efficiency is to create and maintain the cradle to cradle mechanism and circularity not to reduce the cradle to grave material run that aid materials is to do proper maintenance of their position as resources (14). That’s why it is suggested by researchers, CE main aim is eco-effectiveness not eco-efficiency (14).

The Different approaches are used in context of CE where waste prevention is one of the important purposes of CE (15). The waste prevention is unique suggestion to save the earth limited resources and its limited capacity for preoccupancy of contamination, is commonly followed the concept of “cradle-to-cradle (16), planetary boundaries (17) and matter out of place (18). Stock optimization and waste prevention is another concept of achieving CE to keeping attention on environment strategies i.e. Reuse, Recycle and recover and remarketing the products and recycling for secondary resources (19) rather than throw away the materials or products, we need to understand how to reuse the product and use the product without hampering the ecosystem (20). The R-morphology is used in literature review including” Reuse , Repair, Refurbish, Remanufacture and Repurpose”(15).

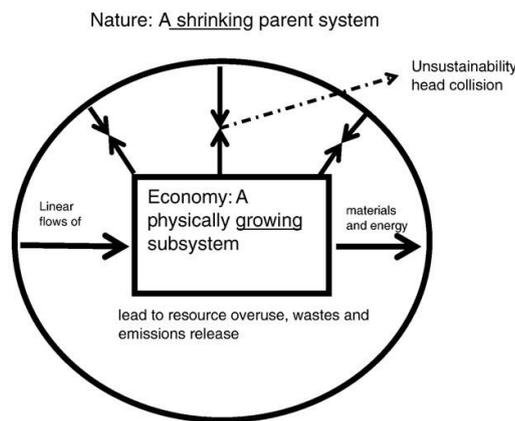


Fig. 1. The energy and material linear flow diagram [47]

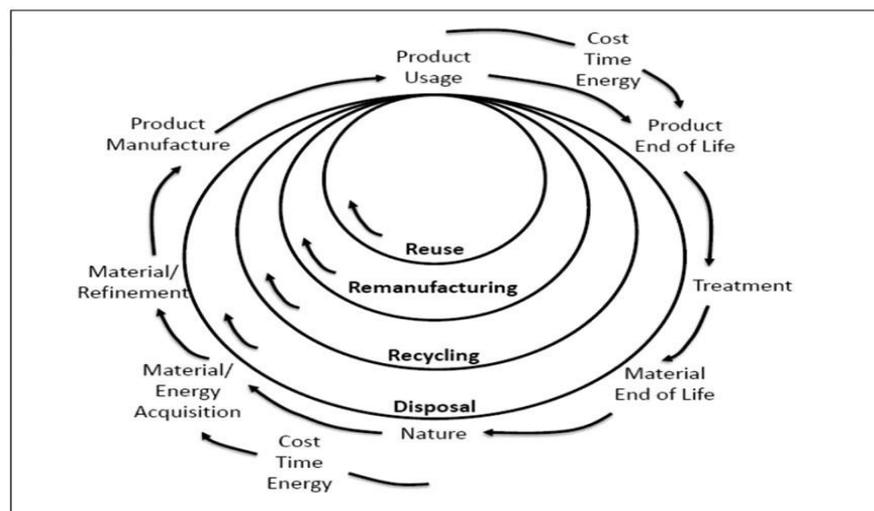


Fig. 2. The present circular economy concept [48]

## 2.2. The Circular Economy Components

CE is the multi-disciplinary field which consists of different components of distinguished disciplines and provides the good platform to doing research which has been found in literature review. CE works on different relevant theories and aspects which have been discussed here:

1. Transformation of business, marketing and gross economic structure
2. Constructive design and critical material
3. Conservation of resources
4. Industrial ecology system
5. CE initiatives taken by government

## 3. Concept of Circular Economy

### 3.1. Transformation of business, marketing and gross economic structure

After doing number of discussion on prevailing economic structure it has to be concluded that, now is time to move towards the closed system supplies rather than open system due to limited resources on earth. The 1966 was the year where the very first research towards the closed system has been discussed (21) and described in solar system earth as a spaceship which travels on a time consuming journey in presence of restricted availability of assets and this conversation was completely lying on interaction of environment and economy. Economic principles have been highlighted here in order to fulfill the demand of closed system and its nature. In this regards, it has to be seen that success of economic growth is not completely dependent on industrial production but also based on availability of resources on earth such as; quality of resource, complexity, extent, resource stock and also includes human as a workforce. For e.g. from 1981 onwards, economies of manufacturing industries are based on material and product curve consisting of use again, restore, recondition and recycling has been promoted (22). The sole aim of discussion was to increase the product life and reduce energy consumption flow, and to reduce the impact of damage of ecosystem so that it could support transition towards the linear to circular economy for the constitution of sustainable society, which could understand the limitation of limited resources. CE is the beneficial tool for fundamentals change in business model.

### 3.2. Regenerative design for critical materials

Constructive or regenerative design is not a new concept, strategies has been taught since the decades of 1970 and it has been observed that nature of regenerative design system are different from normal industrial systems, regenerative constructive design strategies which were expanded to carrying the take care of sustainable development (23). In the last some old preview has been shown that routine activities are rely on the limits of available venerable resources without harming the environment (24). The sole aim to maintain the biological balance of ecosystem among the circular ecological-economic which includes industrial and human supporting structures, and having requirements of energy sources which could be regenerate as well as material that have been consumed. To fulfillment of this purpose to lock the material loop by using the of unique concept of cradle to cradle path which have been already researched since 1990. The exclusive approach of cradle to cradle emphasis shifting from linear consumption of products to circular consumption of products or towards the close loop system rather than open loop by reusing, recycling, and reducing approaches (25). The incredible concept of cradle to cradle approach emerges light on the explanation of molecular mixture of materials. The "Biological nutrients and Technical nutrients" are the two main distinct categories of the end of product use life. This feature is made to clarifies that are materials able to re-enter the ecological and biological system from materials that could be remain still within the locked circle manufacturing cycles. Accordingly the drafting and design of the products and system are require to be made.

Additionally, design of any product is recognize as its important features in the innovative design point of view for fulfillment of sustainable circular system, particularly in correlation with material research. The life span of products or items have became continuously decreasing due to high flow and high usage of material by society as well as production of waste. (26). One of the best solution to improve product design approach as better alternative are such to improve the efficiency of material flow as well as its usage by lowering its processing time, enhancing its effective production, remanufacturing of products and reuse and products could be design with a reduction of natural resources (27).

### **3.3. Conservation of resources**

The approach of conservation of resources in manufacturing has played very significant role in the field of sustainable manufacturing (28). At the old time, design of the products, business based model, arrangement of supply chain network were based on closed loop system. For solving these problem new proposed approach has come into the existence in which healthy interaction among the product design, business model, customers and logistic chain are the treated as vital belongings and at the same time works as important element of manufacturing system.

The Concept of Res CoM encompasses unique idea of multiple product life cycles, materials and value added services for preventions of environment as combined parts of design of product design and product development strategy (29). Researchers has examined that Res CoM concept is robust in terms of operations and faces less problems related to quality of product. Product returns, less uncertainties in lead timing, quantity of product and mismatch of supply and demand in remanufacturing.

### **3.4. Industrial ecology system**

Now a today's time industrial ecology has proved that there is large scope of research while considering complex pattern of material flow, energy flow within and outer of the industrial based organization and in high technology. Industrial based ecosystem shows that in which human beings can support the environment technological expansion, cultural growth, and maintain the sustainability. The concepts explains that an industrial system cannot view as a alone from its surroundings, but it concern with surroundings. It is the sort of system where individual has to use all the parameters in materials circulation from its source to manufacturing to finished product to packaging to uttermost Disposal in optimized rate(30). Industrial ecology works on three degrees such as, factory, inter-firm and regional or global (31). On industrial point of view, attention is give on the concept of uncontaminated production i.e. protection of environment, reducing waste and minimizing pollution. On inter-firm level focused on collaboration among the industries and development of EIPs which encompass swapping of materials, fuel, energy, water, and by using and last part of product to attaining competitive profit as a combine approach(32).

### **3.5. CE initiatives from Government**

In the past, developed countries like Sweden, china and etc policy makers and their government has attempted to follow the principle of CE where the materials are recycled or close loop materials. There are many countries frequently works on research area of recycling waste reduction, towards recycling, and sustainable production. Example the concept of "extended producer responsibility" (33), the "Closed Substance Cycle and Waste Management Act" (34).

### **3.6. Circular Economy Challenges in Implementation**

The major faced challenge in CE is sustainable development which means without understanding and co-operating the need of upcoming future generation to fulfill their individual demand. The substantial flows of energy as well as material are the biggest challenge in CE. The main problem in development of CE either in worldwide or region wise is the linear concept not circular concept to flow of material and energy among the nature, human, environment and economy. It has to be seen that global system it going to be shrinking in volume as well as size (35). The global world is shrinking due many reasons such as active population, maximum utilization of materials, urbanization and so on, this could be solved by the sense of qualitative potential of the earth environment to offer life sustaining functions

The earth areas which carry human habitation are shrinking at elevated pace. Sea level is increasing, capita consumption is increasing, dessert is expanding, population is increasing, and economy is decreasing, biodiversity is descending at very fast rate as ever. This all mechanism is leading to high rate collision. A simple answers of all these problems are to adoption of circular or cyclic flow of material and energy rather than liner flow. As we know, by law of thermodynamic energy cannot be create nor be destroy or recycled, it can only be lying on use at low pressure along with high temperature levels, or simply It can state that in this way, energy cycling with materials can do for the point of simplification.

Table 1. Barriers in implementing CE [47] .

Technological	Product design
	Circular economy financial benefits
Pattern	Misplacing of information during exchange
	Awareness towards sustainability
Attitudinal	Hate Risk
Operational	Vague distribution of responsibility
	Infrastructure/ Supply chain management
Financial	Financial profitability
	Integration into production processes

### 3.7. Proposed solution of CE

The answers to the entire question are adoption of linear flow to circular flow of materials with sustainable manner i.e. called concept of circular economy. And this can be achieved by refurbishment, less demand of resources, remanufacturing, reuse as well as use of usual recycling of materials as raw materials with low rate. Material should be pull for refurbishment, reuse, and repair then merely send to remanufacturing. As per the concept of CE, ignition of energy or fossils should be second to last option while coming dump to land is the last option. The result of this the period of life cycle and value chain of the product would remain in the lofty possible stage and quality with providing and maintain for a long time and also would be energy proficient.

Once the unrefined material is withdrawal from earth purified and changed to final product with usual cost, it makes social, economic and business intellect to utilize the worth generate as long as possible. This results clean environment when compared to traditional linear extract to dump system (37). The currently famous CE approach prolong to conventional waste utilization, recycle, reuse of materials as value surrounded in materials where value of applications are most possible (38).

### 4. Circular Economy towards the Sustainable Growth

CE is a collection of many unique ideas which is derived from different fields which includes Industrial ecology (39), cleaner production (40), industrial symbiosis(41), product service system (42), eco efficiency (43), cradle to cradle design (43, 44) and others. The scenario of circular economy is not so much clear and difficult to understand, while above stated approaches have gave to important contributions in sustainability science. The scientific research on this area is still non-existent. All the quires which rise during the reuse and recycling of the product come under the determinate field of ecological economics. (45). The scientific work seems to be start by using concept of ecological economic. The cradle to cradle concept is one of the leverage concepts of “eco effectiveness” (46).It has to be studied that in the world about 75% production of energy are done by extraction of one time use sources from the earth which are ignited. Ignition discharges emanations to atmosphere in structures as well as fixations that nature can't endure or absorb. This is the apparent case of the straight all through economy and the finest case of cutoff points of the CE conception.

### 5. Conclusions

The imperative pull capacity of circular economy in business strategy making and business networking makes it more supportability to work, and though logical explorations to get surety towards the actual biological consequence of circular economy run after manageability. The idea related to CE is generally formed by strategy creators, area specialists and business network. This piece of writing is having the main concern to begin constructing a logical reason for the CE idea and evaluate the CE idea with a basic examination. CE is all about the reliable ideas, because it has capacity to pull the any business network towards the sustainable progressed effort. It creates common sense that on top of the off possibility that remove benefit from natural world and set to for it to revolve around the item or an support that has a financial esteem, to use this significance ordinarily, not now once.

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## A Review on Differentially Rotating Shells- Significant Geo dynamo Model

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### Abstract:

This paper examined quite enough number of papers to study the flow property in detail of the fluid, flowing in between the concentric rotating spherical shells. The difference between the angular velocities for both the spheres is considered, though a small one. In some cases outer shell is taken at rest. The governing equations are considered for different values of different flow parameters. Also those cases are considered where both the shells were distinctively heated. Solution for fluid flow is found in the presence as well as in the absence of magnetic field. Properties of fluid flow are worked out numerically and analytically.

**Keywords:** Differentially rotation, Concentric Shells, Magnetic Field, Dynamo, Core

### Nomenclature:

$v$  = fluid velocity

$\omega$  = vorticity

$B$  = axisymmetric magnetic field

$p$  = pressure

$J$  = current density

$\rho$  = density

$\Omega$  = potential

### 1. Introduction:

Fluid flow properties have been always played a vital role in technology, science and even day to day life. Most of the time turbulent flows are found of much interest. Although the laminar flow like fluid flow past a porous surface such as in groundwater, lubricated fluid flow in the operating parts of any machinery etc. is also found importance. Whenever a fluid flows past geometry, the features of flows especially the calculation of drag along with fluid velocity is something which is foremost required e.g. in sports. The fluid flows in annular regions of cylinders have its own significance, which can be seen while emptying liquid in the case of wells and pipelines. The fluid flow between the concentric spherical shells especially when both are moving can be considered as a replication of Earth's dynamo in the presence of magnetic field.

In 1956 Ian Proudman<sup>[1]</sup> considered two concentric spheres rotating with slightly different angular velocity. While rotating, the flow between the concentric shells generates a cylinder which touches the inner sphere. This study was followed by K. Stewartson<sup>[2]</sup> in 1966 and he studied the flow properties of the fluid, flowing between the differentially rotating spheres with little different boundary conditions. Later in 1968, Lawrence R Mack and Harry C. Hardee<sup>[3]</sup> studied the rate of heat transference, classification of velocity and temperature and arrangement of stream line for intuitive convection in isothermal spherical annulus at low Reyleigh number. J. Pedlosky<sup>[4]</sup> proposed linear theory for stable, axially symmetric motion of a layered fluid flowing in between two concentric spheres in 1969. But in this case both the shells are heated and rotating distinctively. In the momentum equation, just buoyancy effect of variable density is studied. S Ghoshal<sup>[5]</sup> examined in 1970 that



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non-viscous fluid flow over a sphere and spheroid in the presence of important part of magnetic field that is toroidal magnetic field. B. R. Munson and D. D. Joseph<sup>[6]</sup> found high-order analytic perturbation solution in case of low or medium Reynolds number for the viscous fluid present in between the two concentric spherical shells. S. H. Yin et. al<sup>[7]</sup> explored the native convection fluid flow between two concentric spherical shells. They too considered the case where the varying difference in temperature is considered with the case where inner sphere's temperature is more than the outer one. In 1975 Donald Greenspan<sup>[8]</sup> modified a numerical method which was evolved for the secondary flow in a curved tube, and then applied on the investigating fluid flow in spherical annulus. R. W. Douglass et al<sup>[9]</sup> (1978) examined viscous buoyancy driven flow of the fluid flowing in the annular region of spherical shells. Both the shells are kept at distinct temperatures and revolving with distinct angular accelerated speeds. S. C. R. Dennis and S. N. Singh<sup>[10]</sup> (1978) obtained the solution for the stream function and torque for the incompressible fluid carried in concentric spheres. The numerical solution for the same is found for Reynolds number upto 2000. David Schultz and Donald Greenspan<sup>[11]</sup> (1979) considered the same problem which was taken by D. Greenspan before. Koichi Nakabayashi et al.<sup>[12]</sup> (1981) explored the fluid flow in two concentric spherical shells where inner one is kept at rest and the outer one is rotating. The nature of the fluid is steady, viscous and incompressible.

Shamy Aleyas et al<sup>[13]</sup> (1986) examined invariable viscid stratified fluid flow flowing in two concentric spheres and the effect of temperature and eccentricity on this flow for smaller Reynolds numbers. Steve Schwengels et al.<sup>[14]</sup> (1989) developed a second order series procedure to get the solution of N-S equations after converting them in stream vorticity formation. The numerical solutions are found for the stream and vorticity functions for huge Reynolds numbers with big grid networks. Jen Kang Yang et al.<sup>[15]</sup> (1989) studied the structure's movement. The structure is made up of two concentric spherical shells and incompressible Newtonian fluid flowing in the annular region. Governing equations were converted to ordinary differential equations by finite difference method. D. Lloyd and D. Gubbins<sup>[16]</sup> (1990) found the incomparable fluid flow in the core by a numerical method - DVST (Discrete Vector Spherical Transform). Surface current at the top most layer of the core is not existing because of the core being an absolute conductor and it also permits usage of horizontal sections of secular variation (disparity). K K Zhang and F. H. Busse<sup>[17]</sup> (1990) worked out on the equations of motion for convection driven by buoyancy and also on the induction equations for fluid flow. For this magnetic field was considered and a very large Prandtl number was taken. Rainer Hollerbach and Chris Jones<sup>[18]</sup> (1993) gave time dependent results for models with finitely conducting inner core after including buoyancy force, which is geophysically practical in a better way. The diffusion of conducting inner core to the outer core's field takes some thousand years. David Deming<sup>[19]</sup> (1994) studied the top uppermost continental crust which is soddened with salty fluid and porous enough for the circulation of fluid flow and heat transportation. The structured procedure for heat and fluid flow is typographically driven flow which has typography gradients, sediment compaction, diagnosis and buoyancy force and because of all these factors, the nature of circulation is prevalent and constant. Rainer Hollerbach<sup>[20]</sup> (1994) explored the fluid flow in distinctively moving spherical shells numerically. J. Vanyo et. al<sup>[21]</sup> (1995) studied the precision of the solid mantle and found that the mantle moves slower than the core and acts like a rigidized fluid sphere. At high precession rate fluid moves turbulently. Gary A Glatzmaier and Paul H Roberts<sup>[22]</sup> (1995) found a numerical solution of magneto hydrodynamic equations. This numerical solution is time dependent, appropriate and three dimensional in nature.

N. Kleorin et. al<sup>[23]</sup> (1997) considered electrically conducting fluid in moving spherical shells in the presence of magnetic field along with dipole parity. The outer area of the shell is being kept as an insulator. Emmanuel Dormy et. al<sup>[24]</sup> (1998) found asymptomatic solution numerically with reduced values of Ekman number for the fluid movement which is produced in a rotating spherical shell. Inner core and liquid shell are electrically conducting after applying dipolar magnetic field which is not force bounded alongwith inner sources. Keke Zhang<sup>[25]</sup> (1999) explored linear and non linear convection in a rotating spherical shell in the existence of a toroidal magnetic field. Rainer Hollerbach<sup>[26]</sup> (2000) studied two distinctive cases in spherical shell. In the first case fluid flow is specified under kinematic dynamo theory. For the second case magnetic coquette flow is considered with the imposition of magnetic field. F H Busse<sup>[27]</sup> (2002) analysed the convection present in rotating spheres. The coriolis force applies a restriction that shows surprising properties like convection in a confined region, vacillations, disorganized composed oscillations. Julien Aubert et. al<sup>[28]</sup> (2003) gave a solution of three dimensional convection for distinctive heating over the usual two dimensional solution. To do so a quasi geostrophic model was formed. R. Simitev and F H Busse<sup>[29]</sup> (2005) analysed the impact of Prandtl number on dynamo operated by convection, over other parameters Rayleigh number R and Coriolis number. These parameters are not neglected but considered as fairly. Julien Aubert<sup>[30]</sup> (2005) described the convective

dynamo in a moving shell for prescribed ranges considered for Prandtl numbers, Ekman numbers, magnetic Prandtl number and Rayleigh numbers. H. C. Nataf et. al<sup>[31]</sup> (2006) described computation of electric potential at the top of the outer spherical shell and also found oscillatory movement close to the outer shell at small latitude. Michael A Calkins et. al<sup>[32]</sup> (2010) studied the fluid flow through axisymmetric numerical replica of rotating spherical shells, and rotation of outer spherical shell is time regulated. To get the solution Ekman number is changed with in the specified range. Omid Mahian et. al<sup>[33]</sup> (2011) considered incompressible fluid flow, movement of heat in between two concentric spherical shells and discussed the consequence of suction and blowing. Both the spherical shells are kept at unlike temperature and different angular velocities depending on time. V travinkov et. al<sup>[34]</sup> (2012) analysed linear steadiness of connective fluid. The fluid is electrically conducted and taken in between in the annular region of two spherical shells. To study this problem axial magnetic field is applied and inner spherical shell is kept at more temperature than the outer shell. Ratio of radii is considered for examining the numerically. M. Mohloul et. al<sup>[35]</sup> (2016) explored uncertainty modes which show between concentric spherical shells. To study this, outer shell is kept at rest while inner shell is kept on rotation. Ferran Garcia and Frank Stefani<sup>[36]</sup> (2018) calculated rotating waves which are diverging from spherical annular flow is magnetized. The outer shell is at rest while the inner shell is rotating. Krzysztof Mizerski<sup>[37]</sup> (2018) discussed two problems where MHD flow is considered (i) between two parallel planes (ii) between two concentric spheres. The fluid is viscous and conducting in nature. Krishna Prasad Madasu and Tina Bucha<sup>[38]</sup> (2019) examined the problem in which the flow area is divided into two parts – inner fluid area and outer fluid area. Both the flows are governed by Stoke's equations with distinct Hartmann number in the presence of transverse magnetic field. Ferran Garcia et. al<sup>[39]</sup> (2020) considered a problem where liquid metal is filled in the annular region of concentric spherical shells. They conferred straight numerical simulations. The flow is driven by the interaction between the moving inner sphere and imposed magnetic field externally which is calculated by Hartmann numbers. Ruben E. Rojas et. al<sup>[40]</sup> (2021) experimented a 40 cm fluid flow annular region with uneven boundaries of concentric spherical shells. To get the magnetic dynamo case, liquid metals are considered. Krista M. Soderlund et. al<sup>[41]</sup> (2012) studied the impact of magnetic fields in convective dynamo models by comparing them with non – magnetic fields. Masaki Matsushima<sup>[43]</sup> looked into the consequence of core electrical conductivity (particular range is considered) on core surface flow with the assumption that a viscous boundary layer appeared at the core–mantle boundary. S. M. Tobias<sup>[44]</sup> (2021) presented the basis of dynamo theory and also the governing equations along with the approaches that are necessary for dynamo theory. E.A. Ashmawy et. al<sup>[45]</sup> considered incompressible fluid flow between irregular spherical shells and examined the motion which is quasi – steady translational. For this non linear term was omitted from the governing equation after considering low Reynolds number. David Gubbins et. al<sup>[46]</sup> (2011) considered a replica of geo dynamo model and discussed the heat flow in the inner core due to the considerable sufficient transference of the lateral variations to the inner – core boundary. This explains the presence of the localized melting . The magnetic fields' generation in earth dynamo transmits heat and hence cool down the mantle. Aldo Figuero et. al<sup>[47]</sup> (2021) calculated the behaviour of the flow of electrolyte fluid in the presence of the electromagnetic force. The study is being done through experiments as well as analytically. A permanent magnet which is placed inside the inner spherical shell gave rise to the dipolar magnetic field and the Lorentz force was produced due to the infused AC at equatorial area.

2. **Geometry:** The considered papers are having more or less common geometry for their problems.

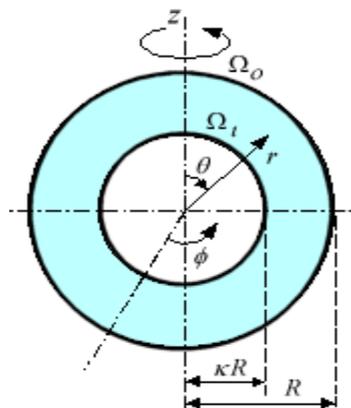


Fig. Fluid flow between two rotating spheres

### 3. Governing Equations:

The Governing equations for the fluid flow which are used in most of the cases with different set of flow parameters and boundary conditions are as follows:

Equations of motion

$$\frac{\partial \mathbf{v}}{\partial t} - \mathbf{v} \times \boldsymbol{\omega} = -\text{grad} \left( \frac{p}{\rho} + \Omega + \frac{1}{2} \mathbf{v}^2 \right) - \nu \text{curl} \boldsymbol{\omega} \quad (1)$$

Equations of Vorticity

$$\frac{\partial \boldsymbol{\omega}}{\partial t} - \text{curl}(\mathbf{v} \times \boldsymbol{\omega}) = -\nu \text{curl} \text{curl} \boldsymbol{\omega} \quad (2)$$

Along with Equation of continuity

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \mathbf{v}) = 0 \quad (3)$$

In the presence of Magnetic field, the magnetic field components are considered in equations of motion.

$$\frac{\partial \mathbf{v}}{\partial t} + (\mathbf{v} \cdot \nabla) \mathbf{v} - \nu \Delta \mathbf{v} + \frac{1}{\rho} \nabla p = \frac{1}{\rho} \mathbf{J} \times \mathbf{B} \quad (4)$$

There are many cases where induction equation is used where magnetic field is either time dependent or time independent.

$$\frac{\partial \mathbf{B}}{\partial t} = \nabla^2 \mathbf{B} + \nabla \times (\alpha \mathbf{B}) + \nabla \times (\mathbf{v} \times \mathbf{B}) \quad (5)$$

In the case of Earth's dynamo magnetic field  $\mathbf{B}$  is composed in two components – Toroidal magnetic field and Poloidal magnetic field. looked into the consequence of core electrical conductivity (particular range is considered) on core surface flow with the assumption that a viscous boundary layer appeared at the core–mantle boundary.

### 4. Methodology:

**4.1** The analytical method is used for few of the papers considered under review, where the governing equations with some changes as per the problems taken are solved for different boundary conditions analytically.

The methods which are used for analytic solutions are perturbation, series method till some specific order. Through these methods a development of boundary layer is explained.

**4.2** The numerical methods which are used for solving the above mentioned problems involve FEM (Finite Element Method), FDM (Finite Difference Method), FVM (Finite Volume Method), Adams Bashforth Predictor-corrector method, Legendre's Polynomial, ED method (Electro diffusion), DVST (Discrete Vector Spherical Transform).

Under FDM getting solution is easy in high order schemes. This method is good for turbulence flow models e.g. LES (Large eddy simulation). The FEM usually directs the problems which involve heat transfer, investigation of structures, fluid flow, electromagnetic potential, and mass transference. FVM can be applied on non uniform/unstructured grid; whereas FDM needs a particular type of grid. FVM is a better choice over these two for solving conservation laws with nonlinear terms.

## 5. Flow Parameters:

There is set of flow parameters which play vital role in the study of fluid flow in the annular region of concentric spherical shells. They are described as follows:

- i. **Reynolds number:** It is the ratio of inertial forces to viscous forces.

$$Re = \frac{\rho u L}{\mu} = \frac{u L}{\nu}$$

$\mu$  = Dynamic viscosity,  $L$  = Character linear dimension,  $\nu$  = Kinematic viscosity,

$u$  = Flow speed

- ii. **Magnetic Reynolds number:** It gives an estimate of the relative effects of advection or induction of a magnetic field by the motion of a conducting medium, often a fluid, to magnetic diffusion.

$$Rm = \frac{uL}{\eta}$$

$\eta$  = Magnetic diffusivity

- iii. **Prandtl number:** It is defined as the ratio of momentum diffusivity to thermal diffusivity.

$$Pr = \frac{\nu}{\alpha}$$

$\alpha$  = Thermal diffusivity

- iv. **Elsasser number:** It represents the ratio of magnetic forces to the Coriolis force.

$$\Lambda = \frac{\sigma B^2}{\rho \Omega}$$

$\sigma$  = Conductivity,  $\Omega$  = Rate of rotation

- v. **Ekman number:** It describes the ratio of viscous forces to Coriolis forces.

$$Ek = \frac{\nu}{2D^2 \Omega \sin \varphi}$$

$D$  = Characteristic length,  $\varphi$  = Latitude

- vi. **Hartmann number:** It is the ratio of electromagnetic force to the viscous force.

$$Ha = BL \sqrt{\frac{\sigma}{\mu}}$$

- vii. **Rosby numbers:** It is the ratio of inertial to Coriolis forces.

$$Ro = \frac{U}{Lf}$$

$U$  = Characteristic velocity,  $f$  = coriolis frequency

- viii. **Grashof number:** It is the ratio of the buoyancy to viscous force acting on a fluid.

$$Gr_c = \frac{g \beta (T_s - T_0) L^3}{\nu^2}$$

$g$  = Acceleration due to earth's gravity,  $\beta$  = Coefficient of thermal expansion

$T_s$  = Surface temperature,  $T_0$  = Bulk fluid temperature

ix. **Rayleigh number:** It is the product of Grashof and Prandtl number.

$$Ra = \frac{g\beta(T_s - T_0)L^3}{\nu\alpha}$$

## 6. Results:

Ian Proudman<sup>[1]</sup> developed direct solution for velocity distribution for large Reynolds number and also studies the shear layer mechanism for the cylinder. Later K. Stewartson<sup>[2]</sup> continued with the same work but the shear layer near the cylinder generated by the flow were divided into three different layers with different thickness in terms of Reynolds number. J. Pedlosky<sup>[3]</sup> observed that the Ekman layers on the surface loses its potential near the equator and also the effect of layers are progressively significant.

The problem taken up by Lawrence R Mack and Harry C. Hardee<sup>[4]</sup> has small scale difference in temperatures in spherical shells. The suitable comparisons are constructed with experimental outcomes. S Ghoshal<sup>[5]</sup> found in both the cases - sphere and spheroid, that field brings out a uniform current along the axis of symmetry. The field inside the sphere comprised of an electric dipole and in the case of spheroid, it's because of electric dipole and quadrupole, along with a steady electric field. B. R. Munson and D. D. Joseph<sup>[6]</sup> observed that for large Reynolds number, the governing equations are turned down into many non-linear ordinary differential equations by means of Legendre polynomial series. Torque that is needed to rotate shells is also calculated for different cases. S. H. Yin et. al<sup>[7]</sup> checked the velocity of fluid flow and also the pattern because of operating potential. The diameter of inner sphere kept varying to check the flow pattern due to varying width of annular region. Donald Greenspan<sup>[8]</sup> approached the governing equations are by diagonally dominant linear algebraic systems. It was found that the method is significant enough for random Reynolds number. And also on the increment of Reynolds number, the motion inclined to a tubular sheath. In R. W. Douglass et. al<sup>[9]</sup> study, broad solutions are found for modest Reynolds number by modified Galerkin approach. Primary and secondary flow patterns and the distribution of temperature are changed after escalating the buoyancy forces.

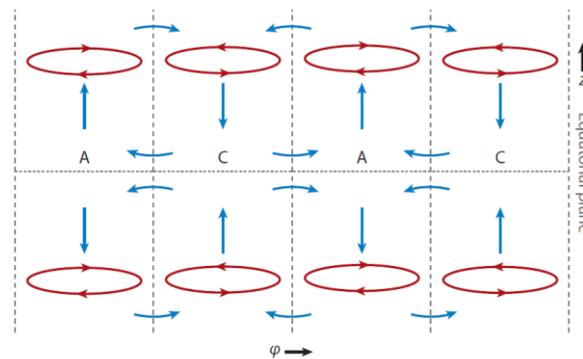


Figure 1

Illustration of the flow in the convective columns. The Primary (red) flow shows the cyclonic (C) and anticyclonic (A) rotation of the convective columns. The secondary (blue) flow shows the flow up and down the columns and its recirculation near the equator and the core-mantle boundary. Figure reproduced with the permission from Chris A Jones<sup>[48]</sup>

S. C. R. Dennis and S. N. Singh<sup>[10]</sup> developed the flow variables in series of orthogonal Gegenbauer functions. The result is also compared with the prior results and it's observed that the method used was satisfactory. David Schultz and Donald Greenspan<sup>[11]</sup> used small grid spacing to use numerical method and therefore better results were found. Koichi Nakbayanshi et al.<sup>[12]</sup> analysed many numerical methods and matched them for same boundary constraint. The impact of the increased Reynolds numbers on velocity profiles was studied. They considered the case when both the spherical shells were rotating. In this case velocity profiles, viscous frictional moment's coefficient, stream function's lines were taken up in terms of angular velocities. Shemy Aleyas et

al<sup>[13]</sup> computed power series expansion in physical quantities. It was observed that heat flow on the inner sphere and on the outer sphere is the same as the value of conduction and has symmetry around the equator respectively. Steve Schwengels et. al<sup>[14]</sup> compared the results were with the prior results for small scale Reynolds numbers and were found suitable. Jen kang Yang et al.<sup>[15]</sup> solved governing equations by Adams fourth order predictor-corrector method. Newton’s algorithm was applied to study state problems individually. Outcomes for stream function, angular velocities, torque, circumambient functions were obtained. D. Lloyd and D. Gubbins<sup>[16]</sup> used DVST which avoids long analysis and is quicker than other methods. It was observed that the toroidal core flow is applicable for more than 95% of the secular variation’s radial part at the core mantle boundary. Figure 1 shows that the secondary flow diverges at the equator in the anticyclones and converges in the cyclone.

K K Zhang and F. H. Busse<sup>[17]</sup> did not change the conditions for boundary were not changed and the outcomes were measured up with the previous results for the fluid with medium Prandtl number. It was observed that the amplitude of medium convection was either magnified or reduced by magnetic field depending on the dominant process. Rainer Hollerbach and Chris Jones<sup>[18]</sup> hypothesized that the turnabout of geomagnetic can be caused due to huge fluctuation and enduring to shift the field all over and also the inner core. David Deming<sup>[19]</sup> found that the nature of circulation is prevalent and constant. He also changed the conception regarding continental crust which was considered as a solid rock which can’t be changed to a body which is constantly developing through thermal, mechanical and chemical interaction of crystal fluid. In Rainer Hollerbach’s<sup>[20]</sup> work, observation shows that Ekman layer exists on the inner and outer spherical shells and Stewartson layer is seen on the cylinder when the field is feeble. But after increasing the strength of the field Ekman layer unites with Ekman Hartmann layer, and Stewartson layer comes down. Figure 2 shows that as  $\Lambda$  is increasing, stewartson shear layer was expanded in thickness and was more broaden outside the generated cylinder.

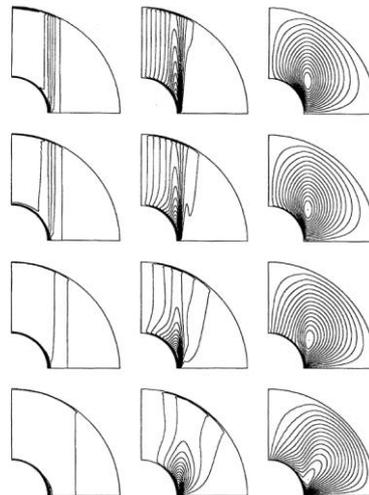


Figure 2

From left to right, contour plots of  $\frac{v}{r \sin \theta}$ ,  $\psi$ , and  $B$ . All at  $R = 10^4$  and  $Rm = 25$ , from top to bottom  $\Lambda = 0.01, 0.04, 0.16, 0.64$ . Contour intervals of  $1/15$  for  $\frac{v}{r \sin \theta}$ ,  $1.5 \times 10^{-4}$  for  $\psi$ , and 15 uniformly spaced levels for  $B$ . From top to bottom  $100/B|_{max} = 9.2, 7.0, 3.9, 1.9$ . Figure reproduced with the permission from Rainer Hollerbach<sup>[20]</sup> and the publisher.

$\Lambda$	$\tau$	viscous	ohmic
0.01	0.002 112	0.001 958	0.000 154
0.04	0.002 452	0.002 021	0.000 431
0.16	0.003 207	0.002 254	0.000 953
0.64	0.004 831	0.002 748	0.002 083

Table

The torque  $\tau$  as well as the viscous and ohmic dissipation, for the four identical values of  $\Lambda$ . Table reproduced with the permission from Rainer Hollerbach<sup>[20]</sup> and the publisher.

The table shows the result for torque, viscous and ohmic dissipation.

J. Vanyo et al<sup>[21]</sup> observed that the simulation of Earth’s liquid flow in the core influenced by luni - solar precession of mantle and in this simulation patterns of secondary flow were always considered. Gary A Glatzmaier and Paul H Roberts<sup>[22]</sup> observed that the solution is self assisted, very critical and it also preserves a magnetic field for three magnetic dispersal times. The model contains only thermal convection which gives united results of compositional and thermal convection. N. Kleorin et. al<sup>[23]</sup> found a solution of magnetohydrodynamics equations numerically in terms of small Ekman number and Elassar number. Emmanuel Dormy et. al<sup>[24]</sup> observed that Ekman layers are converted into Hartmann layer after increasing Elsasser number and even also shear at the internal sphere boundary. In figure 3, it was observed that near the tangential cylinder, the asymptotic behaviour was seen with the inner core rotation with the case when  $E < 10^{-6}$ . Three nested layers were highlighted in figure 4.

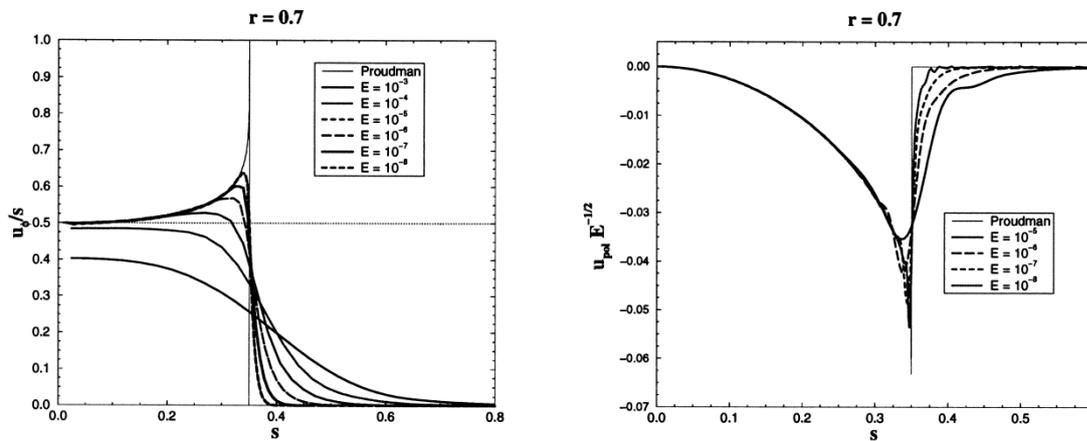


Figure 3

Comparison with the Proudman solution. Angular velocity  $u_\phi/s$  and poloidal scalar  $u_{pol}E^{1/2}$  versus  $s$  at  $r = 0.7$  for different Ekman numbers. The Proudman solution is shown with a thin solid line. The angular velocity solutions for  $E > 10^{-6}$  do not show the qualitative behavior of the asymptotic limit. Figure reproduced with the permission from Emmanuel Dormy<sup>[24]</sup>

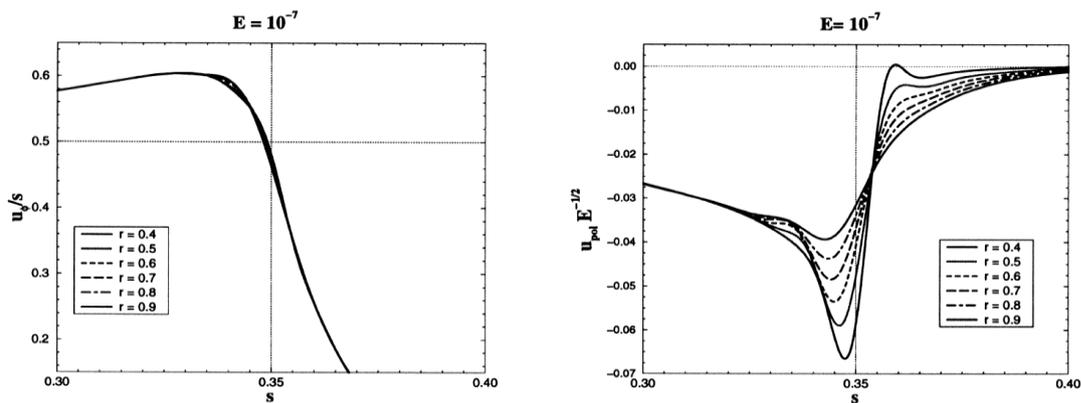


Figure 4

Comparison with the Stewartson asymptotics. Angular velocity  $u_\phi/s$  and poloidal field  $u_{pol}E^{1/2}$  versus  $s$  for different radius  $r$ .

The inner ageostrophic layer of width  $E^{1/3}$  is well distinguished from the outer layers where the azimuthal flow is geostrophic. Figure reproduced with the permission from Emmanuel Dormy<sup>[24]</sup>



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Keke Zhang<sup>[25]</sup> observed under the investigation that linear solution, convection was almost independent of small Ekman numbers. For nonlinear solution, two unlike solutions of convection were found. One communicates with fixed magneto convective waves in addition to equatorial and azimuthal uniformities. The second solution shows unreliability of fixed magneto convective wave that splits

Rainer Hollerbach<sup>[26]</sup> analysed both the case with the existing outcomes and also advanced outcomes were observed for the second case. F H Busse<sup>[27]</sup> found that the coriolis force applies a restriction that shows surprising properties like convection in a confined region, vacillations, disorganized composed oscillations. Julien Aubert et. al<sup>[28]</sup> has done study for non linear nature of structure. The outcome doesn't depend on the computer more and is still acceptable quantitatively. R. Simitev and F H Busse<sup>[29]</sup> discussed the dynamo in a rotating spherical shell developed by low Prandtl number and for the production of magnetic field, magnetic Prandtl number is needed. The limitations are considered on coriolis numbers as it has blocked the fulfillment of the dynamo. Julien Aubert<sup>[30]</sup> explored the dynamo which attributes stable zonal flow. H. C. Nataf et. al<sup>[31]</sup> found that electric potentials are deduced by azimuthal velocities which makes dynamo assessment attractive through this result of considerable meridional movement. Michael A Calkins et. al<sup>[32]</sup> described that the uncertainties last local spatially in equatorial area and it was seen that the zonal flow fundamentally non aligned with Ekman numbers doesn't confide in fluid's viscosity. It was observed that the zonal flow motivated by liberation in axisymmetric spheres, rarely yield compelling magnetic fields of planets, nevertheless it fairly achieves non-zero average torques on closed surfaces. Omid Mohian et. al<sup>[33]</sup> observed that the flow affect, temperature diffusion and heat transport are shown for numerous parameters rotational Reynold numbers  $Re$  and blowing/suction Reynold numbers  $Re_w$ . The reduction of the space between the spherical shells and the increment of eccentricity don't change viscous torque. Outcome is calculated for keeping eccentricity zero. V Travnikov et. al<sup>[34]</sup> have shown through their study that on the increment of  $\eta$ , the critical Grashof number  $Gr_c$  decreases in non appearance of magnetic field. And when  $Gr_c$  increases with Hartmann number  $Ha$  then a stable axial magnetic field is sustained. M. Mohloul et. al<sup>[35]</sup> used ED (electrodifusion) method to calculate barrier velocity gradients and time series of velocity gradients. Dimensionless gap thickness, an aspect ratio (ratio between height of the fluid and gap width) and Taylor number are considered to analyze the flow pattern. By Fast Fourier Transform time series of velocity gradient allowed exploration and description of the basic frequencies and their growth related with different cases of flow. Ferran Garcia and Frank Stefani<sup>[36]</sup> made use of Newton Krylov continuation approach for recurrent orbits and Floquet theory structure is used to explore their stabilities. The increment in strength of the magnetic field is found by Hartmann numbers within considered range and is also communicated for the medium values of Reynold numbers. The observations show that there are many areas of wave's multistability with different values of azimuthal wave numbers.

Krzysztof Mizerski<sup>[37]</sup> has done analysis for velocity field and the impact of the conductivity of the boundaries on the fluid motion. The construction of super speeding jet's structure is discussed which depends on powerful Hartmann currents. Krishna Prasad Madasu and Tina Bucha<sup>[38]</sup> calculated drag on the inner fluid sphere. They also found the features of creeping motion of the fluid which is taken like a fluid sphere confined in a spherical pouch. Ferran Garcia et. al<sup>[39]</sup> found flows for two or three self – sufficient frequencies and it was observed that the flows were stable for adequately big enough interval of Hartmann numbers. Ruben E. Rojas et. al<sup>[40]</sup> executed the examination of hydrodynamic for different baffle patterns – symmetric and asymmetric and also the height of baffles considered in terms of small percentages of radius. Due to different patterns, the changes in dimensionless torque are seen. This torque is a function of Reynolds numbers and Rosby numbers. The inclusion of baffles allows velocity calculation to express effective improvement in equatorial jet and poloidal flows. Krista M. Soderlund et. al<sup>[41]</sup> established that the dynamic Elsasser number parameterized the ratio of forces in a better way.

Ferran Garcia et. al<sup>[42]</sup> presented the complete explanation of modulated rotating waves (MRW) in the magnetized spherical coquette system for the varied magnetic field strength. Masaki Matsushima<sup>[43]</sup> observed that on increasing core electrical conductivity, there is no change in the magnitude of the mean toroidal flow is seen, but the mean poloidal flow increases. The outcome for the ratio of the magnitude of the mean toroidal flow and the magnitude of the mean poloidal flow is proposed, and observed that it's been changing with secular change of the Elsasser number. S. M. Tobias<sup>[44]</sup> gave elementary explanation for dynamo and also suggested that development in dynamo theory should be done with the help of recent discoveries in the field of neutral fluid turbulence. E.A. Ashmawy et. al<sup>[45]</sup> calculated drag by numerical method and observed that drag monotonously increases along with the increment in the radii ratio as well as with the increment in couple stress viscosity parameter. David Gubbins et. al<sup>[46]</sup> concluded that in the generation of the seismic irregularities in the inner core,



the freezing and melting give strong process. Aldo Figuero et. al<sup>[47]</sup> observed through experiments that the laminar flow with a given Reynolds number produced oscillatory Reynolds number. Azimuthal velocity's approximate and asymptotic results were calculated for small and big oscillatory Reynolds numbers. The analytical solution for oscillatory boundary layer was obtained.

### 7. Conclusion:

It can be concluded that the rotation of either any one spherical shell or both has impact on fluid flowing in the annular region. Differentially rotating shells in presence of magnetic field can very well sync with the model of Earth dynamo. Study of these models will help us in understanding the changes due to rotation of different layers of earth. It has been observed that there is lack of text considering this structure. There are definitely further improvements can be seen after considering this case with practical boundary conditions applicable to Earth's dynamo.

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## Overview of DSTATCOM for Power Quality Improvement

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### Abstract

As combination of voltage source converter and capacitor banks which is called Static Synchronous Compensator (STATCOM) or Distributed Static Compensators (DSTATCOMs) are the ac-dc and dc-ac grid-tied power converters that aim to compensate reactive currents (or reactive power) in transmission in addition with the distribution system. Power Quality (PQ) has an important and growing role in the Electrical and Electronic Industries, normally DSTATCOM which is a shunt Voltage Source Converter (VSC) connected in distribution system and has the capability of providing quick and continuous Capacitive and Inductive Mode Compensation. The IGBT is used as a power switch in DSTATCOM which combines the advantages of BJT and MOSFET. IGBT has low switching times as well as low power losses. This paper presents an overview of the objectives of DSTATCOM, and PWM Techniques used in DSTATCOM connected in the distribution side.

**Keywords-** Distributed Static Compensator (DSTATCOM), Power Quality (PQ), Pulse Width Modulation (PWM), Insulated Gate Bipolar Transistor (IGBT), Point of Common Coupling (PCC)

### 1. INTRODUCTION

Electrical Power Generation and Transmission is a system consisting of multiple electrical equipment and devices wherein different apparatuses are used to take full advantage of the output. Reactive power and voltage sag are the imperative power quality problems faced by utilities and many industries [1]. But in Transmission System, real and reactive powers play a major role. If any problem exists in either Transmission Side or Distribution Side related to sag, swell, skin effect, temperature effect, flicker, harmonics, noise, etc. then at that point of selection power loss becomes new. In these cases, DSTATCOM may be related inside the distribution system, and it will mitigate the electricity issues satisfactorily. DSTATCOM is used to generate or absorb reactive power. DSTATCOM has the advantage of optimized energy over DVRs [2]. The DSTATCOM gives much better performance and can have more components for operation while as compared to STATCOM. The primary purpose is to place the DSATACOM with a distribution system for a lossless gadget. The power quality holds issue along with voltage sag as it contributes more than 80% of PQ problems. Power Electronic Devices alternate voltage and modern-day waveforms in an electrical network, affecting electricity offerings and purchaser system. Harmonic voltages influence a lack of definitions in measuring apparatus and the run-down operation of relays and manipulate systems. Radio-Frequency Interference as a result of the noise of the high-frequency harmonics lofted from clout-digital circuits, distresses electronic gadgets used in business and enterprise and often encourages interfacing voltage in communication strains [3], [4], [5].

In a distribution machine DSTATCOM is used to lessen the Harmonics and high-frequency losses. DSTATCOM shows the main character in a distribution system during a power first-rate trouble occurring. If the supply is equitable then only the useful power will pass through the lines, when the supply is irregular at that time only reactive power might be biased through the machine known as VAR Compensation. In this paper, DSTATCOM with its objectives, PWM techniques are presented as an overview for compensating the Power System Problems.

## 2. OBJECTIVES OF DSTATCOM

Essentially DSTATCOM is based on new operating principles of power electronic equipment aimed at improving the PQ with reliability. Figure 1 shows the connection of DSTATCOM with the Distribution line

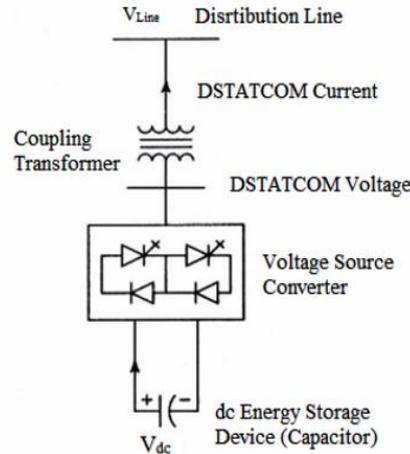


Figure 1 Connection of DSTATCOM with the Distribution Line

DSTATCOM consists of a thyristors-based voltage source converter, which converts a DC input voltage from the storage device into AC voltage output to compensate both active and reactive power, DC energy storage device, and coupling transformer[6], [7]. The shunt connected voltage source converter provides four different functions:

- A. Power Factor Correction
- B. Reactive Power Compensation
- C. Voltage Regulation
- D. Current Harmonic

Now a 900-1600  $\mu\text{F}$  capacitor is used in the DSATACOM to maintain dc voltage to the inverter and energy stored in the capacitor is proportional to the voltage of the capacitor, which controls the inverter voltage. The DSTATCOM is aberration related reactive power compensation device that can produce or absorb the reactive power at the PCC, applying IGBT as a consistent big speed switching component with its control based on Pulse Width Modulation. The device can produce and allure helplessly controllable real and reactive power at its output terminals when it is fed from a DC energy source. Some commonly used terminologies related to DSTATCOM are summarized below:

### 1. DSTATCOM Elemental Equations

$$\frac{di f_a}{dt} = \frac{1}{L_f} (-R_f \cdot I f_a + V_{ia} - V_{ta}) \quad (1)$$

$$\frac{di f_b}{dt} = \frac{1}{L_f} (-R_f \cdot I f_b + V_{ib} - V_{tb}) \quad (2)$$

$$\frac{di f_c}{dt} = \frac{1}{L_f} (-R_f \cdot I f_c + V_{ic} - V_{tc}) \quad (3)$$

Here  $V_{ia}, V_{ib}, V_{ic}$  are the output phase voltages from converter with respect to neutral and  $V_{ta}, V_{tb}, V_{tc}$  are the PCC bus phase voltages with respect to neutral

### 2. The converter output phase voltages are equal to

$$V_{ia} = V_{dc} \cdot U_a \quad (4)$$

$$V_{ib} = V_{dc} \cdot U_b \quad (5)$$

$$V_{ic} = V_{dc} \cdot U_c \quad (6)$$

Here  $U_a$ ,  $U_b$ , and  $U_c$  are switching functions generated by DSTATCOM controller

### 3. Reactive Power

Reactive Power is the power that flows back from a destination towards the grid in an alternating current scenario. Power as we analyze that it consists of two components active and reactive power [8]. The accretion of active and reactive power is called ‘‘apparent power’’. The energy is stashed provisionally in capacitive and inductive elements in AC circuits, which fallout in the periodic reversal of the way of the flow of energy between the source and the load [9]. In an inductive circuit, the instantaneous power can be written as:

$$P = V_{max} \cdot I_{max} \cos(\omega t) \cdot \cos(\omega t - \theta) \quad (7)$$

$$P = \frac{V_{max} \cdot I_{max}}{2} \cos \theta (1 + \cos 2\omega t) + \frac{V_{max} \cdot I_{max}}{2} \sin \theta (\sin 2\omega t) \quad (8)$$

Here

$P$  = Instantaneous Power

$V_{max}$  = Maximum value of the voltage waveform

$I_{max}$  = Maximun value of the current waveform

$\omega = 2\pi f$  (Angular Frequency)

$f$  = Frequency of the waveform

$t$  = Time Period

$\theta$  = Angle by which the current lags the voltage

The instantaneous reactive power is given by

$$\frac{V_{max} \cdot I_{max}}{2} \sin \theta (\sin 2\omega t) \quad (9)$$

and hence

$$Q = |V||I| \sin \theta \quad (10)$$

### 4. Operating Modes of DSTATCOM

DSTATCOM can generate reactive power and upon this, it works in four different modes. DSTATCOM also monitors currents and load side voltages and resolves the compensation amount for different disturbances. Through this active and reactive power is regulated by comparing DSTATCOM and distribution line voltages.[7] The below coming points illustrate different modes of working of DSTATCOM for the generation and absorption of reactive power. Figure 2 shows four quadrant operations of DSTATCOM

- A. Under Exited: In this mode, DSTATCOM works as an inductor and absorbs reactive power if the magnitude of the distribution line is greater than DSTATCOM voltage and hence known as inductive mode of operation.
- B. Over Exited: In this mode, DSTATCOM works as a capacitor and generates reactive power, if the magnitude of distribution line voltage is less than DSTATCOM and hence known as capacitive mode of operation.

- C. Normally excited: In this mode, DSTATCOM does nothing when distribution line voltage is the same as DSTATCOM voltage, and hence DSTATCOM work in Floating Mode.

Figure 3 shows the phasor diagrams. DSTATCOM with an energy storage device improves PQ of distribution systems by supplying real power also. This can be performed by setting phase angle of the distribution line and DSTATCOM. When leading the phase angle of VSC by phase angle of distribution line, DSTATCOM absorbs real power from the distribution line, on the other hand when the phase angle of VSC leads the phase angle of distribution line DSTATCOM supplies real power to distribution line.

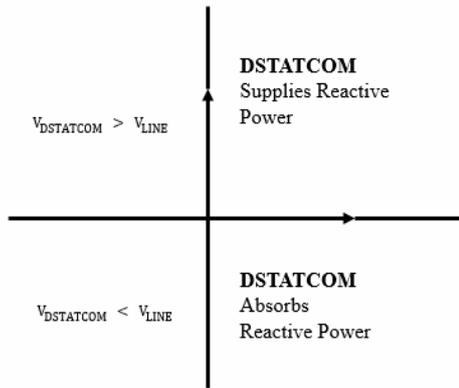


Figure 3 Four quadrant operation of DSTATCOM

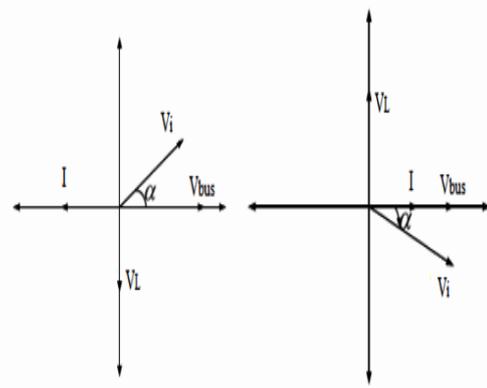


Figure 2 Phasor Diagram for DSTATCOM

### 5. Compensation model of DSTATCOM

DSTATCOM can be determined as a shunt current source, and by controlling the magnitude and phase angle of the VSC output voltage, both active and reactive power can be measured and transferred between DSTATCOM the load and the network, i.e., all 4VSC quadrant operations are used. Figure 4 shows the system diagram of DSTATCOM.

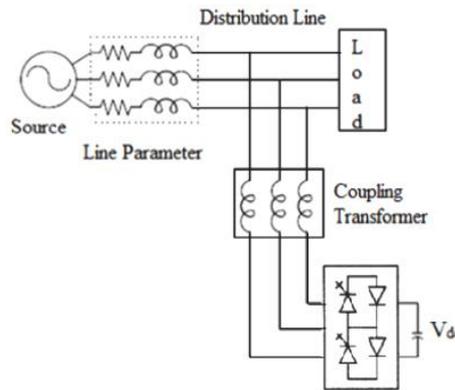


Figure 4 System Diagram of DSTATCOM

DSTATCOM circuit equation can be written as

$$L \left( \frac{di}{dt} \right) + R \cdot I = U_t - U_i \tag{11}$$

### 6. PI Controller for reactive power compensation

The PI controller provides stable voltage near to nonlinear loads which causes the disturbance. The controller will only measure the rms voltage as there is no need for the measurement of reactive power and

the voltage source converter switching scheme is based on PWM techniques which gives simple operation and good results.

### 3. PWM TECHNIQUE IN DSTATCOM

The advantage of using Pulse Width Modulation (PWM) inverters for DSTATCOM purposes is reducing the number of switching and switching losses. The Inverter topologies can generate AC voltage of different magnitudes and frequencies. Also, the output of the PWM inverter is improved while related to a square wave inverter [10], [11]. Depending upon PWM inverter implementations there are different types of PWM system benefits and are of distinctive types. In PWM inverters, voltage attains a very great acceptable sinusoidal form after filtering and after choosing fundamental frequency. Therefore, we have improved voltage for DSTATCOMs with the help of inverters and Harmonics can be eliminated by different PWM switching techniques along with different control algorithms. Different Modulation techniques are:

1. Single Pulse Width Modulation Technique (SPWM)
2. Modified Pulse width Modulation (MPWM)
3. Space Vector Modulation (SVM)
4. Multiple Uniform Pulse Width Modulation (UPMW)
5. Sinusoidal Pulse Width Modulation (Sin-PWM)

Among above mentioned techniques, Sin-PWM is widely used. In Sin-PWM, a sinusoidal control signal at the desired frequency is compared with a triangular waveform (carrier wave having frequency much larger than the control signal). The frequency of the control signal establishes the frequency of the fundamental component of the output voltage and the frequency of the triangular carrier wave establishes switching frequency. Then we define amplitude modulation ratio as

$$m_a = \frac{V_{control}(Peak)}{V_{triangular}(Peak)} \quad (12)$$

Industries use this method widely. The width of every pulse is modified proportionally to the amplitude of a sine wave calculated at the middle of the identical pulse. It has many advantages like low switching losses, the output has fewer Harmonics, and the scheme is simple to accomplish.

Since DSTATCOM is a low power application, PWM control will provide a more flexible operation than the conventional switching method occupied in the FACTS application. High switching frequency is used to improve the converter efficiency, with negligible switching loss. The rms terminal voltage and reference voltage provide an error signal and is given to the input of the PI Controller

### 4. Conclusion

DSTATCOM is an adequate mean for mitigation of power quality problems on the distribution side. DSTATCOM is a flexible device which can operate in current control mode for compensating unbalance, reactive power, and voltage variation. In voltage control mode DSTATCOM acts as a voltage stabilizer. Hence performance of DSTATCOM is always analyzed through design and simulation. Therefore, this paper has overviewed the objectives and PWM techniques used in connection of DSTATCOM.

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## Analysis of pH Value of Water for Treatment Plant of Kekri and Surajpura (Rajasthan)

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### Abstract

The basicity and acidity of a liquid are measured in terms of Ph value and natural pH value is 7.0. Water acid (Hcl) is added to reduce and carbon dioxide is added to increase the measured pH value. Temperature is one of the most important parameter that affects the equilibrium and pH value of water. The value of pH should be 6.5 to 8.5 in permissible drinking water, if its value is lower than 6.5 in the water then sodium carbonate and above than 8.5 then citric acid can be found. The pH value of blood in healthy people is more or less than 7.42. In the current research work three water treatment plants with size of 600MLD, 142 MLD and 132 MLD was used for treatment of raw water of a dam located in Tonk district named as Bisalpur. Poly aluminium chloride (PAC) was used in these water treatment plants as coagulant to accumulate suspended particles such as sand, clay and biological organic load. The results obtained nearby the neutralised pH value 7.0 in increasing trend between 7.35 to 7.45.

**Keywords:** Water; Water Treatment Plant; Poly Aluminium Chloride (PAC); pH Value

### 1. INTRODUCTION

Water treatment is a quit up to date practice. Firstly, different type of biological techniques is designed in the early of 19<sup>th</sup> century (Zajda & Kwaterczak, 2019). The increase of several industry branches has considered by enhanced people's life style in various modes. However, many plants growth having started to release a huge amount of polluted water so that pH value of water present in a source changes day by day (Proba & Nolny, 2013). The pollutants obtained from unprocessed agricultural industries and human being used (Domestic) waste water is responsible to water quality degradation (Liu et al., 2021). Therefore, it is necessary to find out new and efficient technique for water treatment to overcome above problems so that human life style improves. The various methods for water treatment are shown in Fig.1.



Fig. 1: Water Treatment Methods (Zajda and Kwaterczak, 2019).



The Acid and basic values of the water is measured by the pH value. The side effects of extreme pH value increase the irritation in eyes and rashes on the skin of body. Such side effect is appeared when the pH value more than 11. The problem of gastrointestinal and skin swelling is found when pH value of water found between 10-12 and when the pH of the water is falls below 4, irritation of the eyes and itching of the skin types disease occurs (WHO, 1986). pH value below than 2.5 can damage Epithelium. The corrosion resistance of metal and the ability to be corrosion potential efficiency depend on the pH value of water. pH of water can affect the corrosion of metals and disinfection efficiency. Its direction pact results on health of human and corrosivity of metal (Nodberg et. al.,1985; Tian and Zhao, 2011). PAC coagulant have been widely used in water treatment plants due to its strong, coagulant and sludge recycle to bio products likely titanium oxide (TiO<sub>2</sub>), PAC coagulant (Poly aluminium chloride) having strong coagulant property and sludge recycling to produce new titanium oxide (TiO<sub>2</sub>) by products (Tian and Zhao, 2011). Pollution reduction is the key component of the supportable improvement. It is necessary to clean water for that nowadays technology has changed the modern work place and revolutionized the complete working process to your more friendly to the environment (Qudafi et al., 2020; Legelier, 1996). Present research work is focused on water treatment method and comparative study on two water treatment plant of kekri and surajpura (Rajasthan).

## 2. WATER TREATMENT METHODOLOGY

Three unit of water treatment plants are considered for comparative analysis of pH value of water. The water treatment plant net purifying capacity 600 MLD located in Surajpura (Rajasthan) and two water treatment plant of Kekri with size of 142 MLD & 132 MLD are selected for this research work. Surajpura water treatment plant is based on modern pulsates clarifier Swiss Technology. Pulsates are installed composure in middle in clarifiers compressor pumps create vacuum (-ve pressure) and it is released after some fixed time in minutes as per pulsation of raw water and draw out sludge from pulsates. In Kekri Rajasthan two water treatment plants consist four clarifier with flocculate's, in each. In these WTD raw water enters at entry channel and after that it is distribute to all four clarifier flocculate's Poly-aluminium chloride (PAC) liquid. Similar PAC liquid is used in all three plants. Pre chlorination is done by means of chlorine gas is being adding at entry point of receiving raw water as well as PAC dosage and after settling of flocks in the bottom of clarifier, settling water impurities the clarifier raw water over topped in receiving channel for small V-notches fixed around the hole circumference of clarifier structure body. Aim of V-notches is increasing setting time in clarifier water collected from all clarifier which is enters in a common channel that spread water on open sky rapid gravity type filter beds. Filtered water enters in pure water channel with adding post chlorination dosage in water to make free from all microorganism and bacteria's and lowering pH value as required.

## 3. EQUATIONS

The negative common logarithm of the Hydrogen in activity represents the pH of any solution. it is obtained using equation (i) In the dilute solutions, the hydrogen ion activity is approximately equal to the hydrogen ion concentration.

$$\text{pH} = -\log(\text{H}^+) \dots \dots \dots (1)$$

In pure water, decrease in pH of about 0.45 occurs as the temperature is raised by 25 °C.

$$\text{pH} = \text{pOH ions} \dots \dots \dots (2)$$

## 4. RESULTS AND DISCUSSION

### 4.1 Control of pH of Raw Water

Raw water sources is taken some for each water treatment plant but 600MLD plant used direct water from raw water reservoir dam located 6 Km distance apart whenever 132 MLD and 142 MLD plant having raw water from reservoir to intermediate boosting located at village Thadoli at a distance of 35 km from kekri filter plant.

From reservoir to intermediate boosting station located at village Thadoli at a distance of 35 km from kekri filter plant. When the water has pH value less than 6.5, then such a water can be nenacing. In this way, the pipeline carrying such water and sources can generate dangerous metal from pipe etc. These deadly metals can be iron zinc of water treatment to raise the pH of water the natural level, sodium hydroxide and sodium carbonate is added to the water in excess, if the pH of the water is very less than sodium bicarbonate is added to raise the pH. Hence to control the pH level of the water, if the water is acidic to treatment of water than soda ash and sodium hydroxide used to increase the pH near to neutral value.

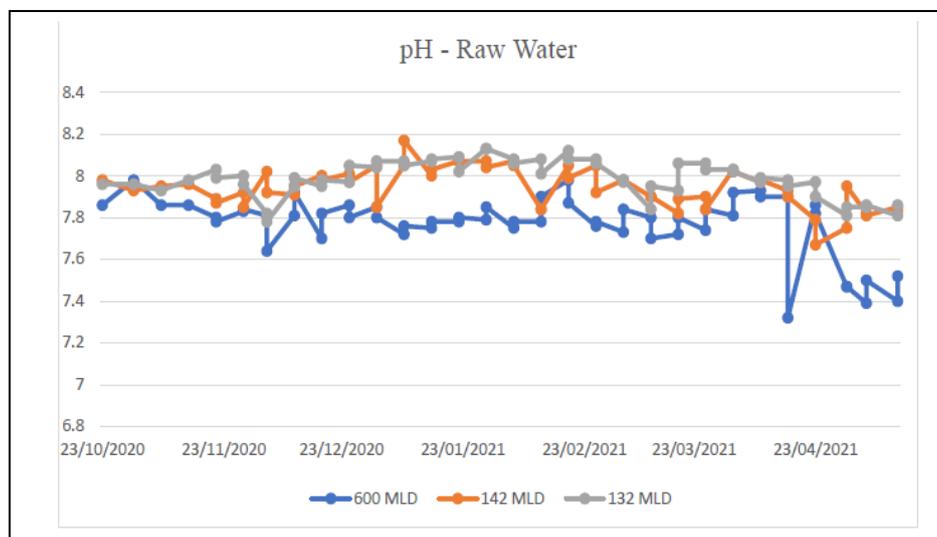


Fig. 2: Variation of pH value of raw water for 600 MLD, 142 MLD and 132 MLD water treatment plant.

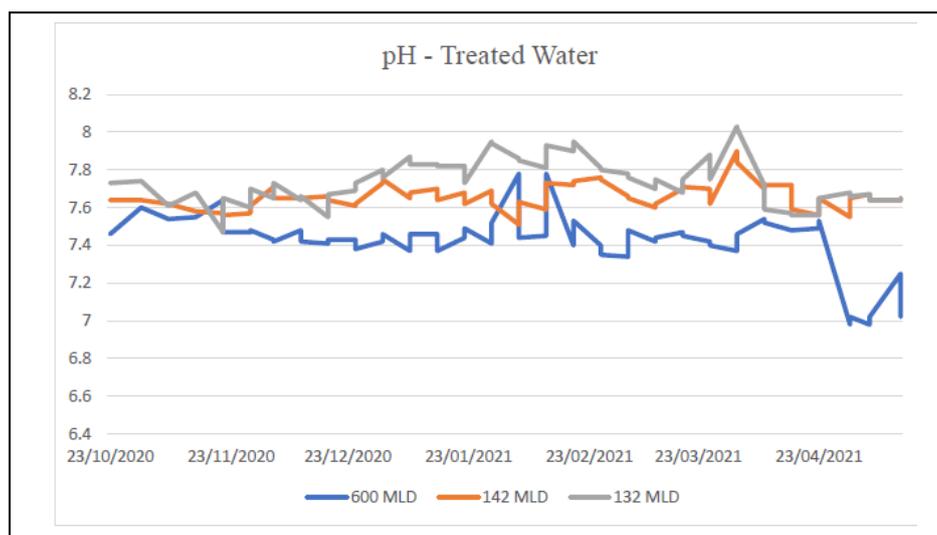


Fig. 3: Variation of pH value of treated water for 600 MLD, 142 MLD and 132 MLD water treatment plant.

pH balance in water naturally some amount of squeeze of lemon or lime to make water more alkaline as human being digest properly it. Baking soda is also added to lower the pH of the water after filtration treated water is collected in pure water for disinfection and removing micro-organism from pure water for disinfection and removing micro-organism from filtered water. PAC coagulant is added to control pH value of water. The correct of PAC coagulant is decided with the help of JAR test shown in Fig. 4 (APHA, 1989; ASTM, 1976). The optimized value of PAC coagulant dose is found 22 mg/l for 600 MLD and 30 mg/l in 142 MLD & 132 MLD water treatment plant. pH should be 6.50-8.50 for drinking water. The variation of pH value of Raw water and treated water are shown in Fig. 2 for 600 MLD, 142 MLD and 132 MLD water treatment plants. From fig. 2 it is observed that 600 MLD water treatment plant, treated water pH value having nearer to neutral and 142 MLD water treatment plant, treated water pH results are higher than the 600 MLD water treatment plant more efficient reducing the pH value of treated water the region behind to get different value of pH its used technique and place from which raw water is entered into the plant. 600 MLD water treatment plant is based on swiss technology. In this pulsator is used instead of flocculator but 142 MLD & 132 MLD water treatment plant is based on flocculator technique. In general fig. 3 shows at point sudden increase and decrease in pH value is due to vegetation and temperature effect. The chemical analysis was found satisfactory in water sample of raw water taken from Bisalpur Dan and shown in Table-1.

**Table-1:** Characteristics of raw water and treated drinking water.

S. No.	Characteristics of water	Values of Dam Raw Water	IS Code 10550-2012	
			Acceptable limit	Permissible limit
1	pH	7.90	6.50-8.50	No relaxation
2	Colour (Hazen)	5.00	5.00	15
3	Chloride (as Cl.) mg/l Max	60	250	1000
4	Fluorides (as F/mg/l) Max.	0.3	1.0	1.50
5	Nitrates (as NO <sub>3</sub> ) mg/l Max.	2	45	No relaxation
6	Total dissolved solids (as TDS) mg/l Max.	320	500	2000



**Fig. 4:** Flocculator model for JAR test.

### 2.3. Effect of Temperature on pH Value

It is observed that pH value is reduced with raising the temperature. In this study, clean (pure) water having equal concentration of Hydrogen ions and Hydroxide ions. Now the water is just neutral at 100 °C, if the pH interchange. pH of 6.13 is the new neutral value on the pH scale at the oppressive heat. Sweltering heat (temperature) plays a significant character in pH measurement. The pH value through variation in temperature is not a mistake the new pH level.

**Table-2:** Variation of pH with temperature.

S. No.	Temperature (°C)	pH
1	0	7.46
2	25	7.01
3	50	6.64
4	100	6.13

**Table-3:** pH values of a solution at non-identical temperature.

S. No.	Property of liquid	pH at 0 °C	pH at 25 °C	pH at 50 °C
1	Acid	2.00	2.01	2.01
2	Neutral (water)	7.46	7.02	6.64
3	Basic	13.84	12.81	12.16

Table no 2 shows the variation of pH with temperature. From the table 2 it is understandable that the pH of water at 0°C is 7.46 and at 100°C has a pH of 6.13 for same water, if the pH decreases with increase in temperature, in other words water becomes acidic as the temperature rises, in this case hydrogen ions can be less than hydroxide ions. The amount of hydrogen ions and hydroxide ions are equal that at 25°C temperature pH of water is neutral 7.01. A solution with a pH 7.0 at 0°C is a bit acidic because its pH is just lower than the neutral value of 7.46 pH values of a solution at different temperature shown in table no 3.

### 4.3 Effect of Variables on pH Value

When carbon dioxide gas is mixed with water to form weak acid, if acidic and alkaline rocks, coral and soil mixed with organic debris adversely affect pH level, sodium and calcium hypochlorite will have a minor effect on pH level. Calcium hydrochloride is frequently used in treating potable water treatment plants. Air-borne can affect pH of water as can rock and clay. Chlorine gas radically also lowers the pH of water.

## 5. CONCLUSION

pH is one of the parameters of water quality. pH quality of water. Water purification in water treatment plants, clarification measurement of pH is essential in the process of water purification. Coagulant is used for water treatment like poly aluminium chloride (PAC) chlorine is used for disinfection. Chlorine is being used in the Surajpura and Kekri water treatment plants. 6.50 to 8.5 pH value is acceptable for drinking water. In 600 MLD water treatment plant the value of pH is found in the range of 7.0 to 7.20 and both plants of Kekri (142 MLD & 132 MLD) its value range of 7.73 to 7.75. Treated water obtained from all three plants is potable, non-corrosive and not harmful to the consumer.



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## Feature Optimization Methods: A step towards improvement in Medical Image Processing

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### Abstract

In the area of machine learning and pattern recognition, features are essential for forecasting, classification of the image, medical imaging, and a few other applications of features that are well-known. Health agencies are gathering vast amounts of data by virtue of the rapid growth of knowledge expenditures in medical data archives and health care procurement. These data repositories hold a wealth of knowledge that can help doctors to make better diagnoses and develop a better quality of patient responsibility. On the contrary, this expansion has endured more crucial to understand and use this information for a variety of purposes. Because of the presence of extraneous features in larger datasets, the findings of imaging data can become skewed. Feature selection allows for a reduction in the number of constituents in these large datasets. Using selection techniques, the insignificant features are eliminated, and a fragment of components is chosen that yields high characterization fidelity. A precise grouping model is generated by making the right agreement to asset a good virtue, which improves learning speed and forecast control. An analysis of feature choice strategies and attribute choice steps for medical field imaging is presented in this paper. This survey aims to explain feature selection strategies in the medical domain, as well as their advantages and disadvantages, and to demonstrate their use in imaging data and data mining algorithms. The study presents the flaws in current multi-sourced data features and attributes selection methods. Furthermore, the influence of feature selection for the proper distribution of medical infections is discussed in this study. Finally, critical reviews and recommendations for the future are presented.

**Keywords:** Attribute selection, Data mining, Feature selection, Imaging data, Medical imaging, Medical challenges, Future directions

### 1. INTRODUCTION

To eliminate non-essential features, feature selection method is to be used and choosing a fragment of constituents that produces high characterization precision. Data mining algorithms or inductive machine learning are both concerned with determining an attribute's quality. When insignificant properties are included in the forecasting method, effective mining is not possible. In a research problem, such properties are expressed as features. The general feature selection process is depicted in Figure 1. A subset of features is created from the original feature set using a search approach. Already the subset gets created, all of these features must pass the enlargement criteria and then these are aggregated in the eventual feature set to continue the evaluation process. It is used in many applications of medical domains and also useful in a wide range of applications. It's helpful when there's a lot of trivial and insignificant data mixed with high-dimensional data. These methods have recently been used in a variety of regions like image retrieval, image recognition, bio-informatics data analysis, skin cancer, lungs cancer, brain cancer, and name a few more. Computations are speed up and time is saved when the right attributes are chosen. The importance of function selection in various medical fields such as in image recognition the need for these selection methods is more critical than before, even though decades ago, image processing researchers first recognized the need for knowing which features needed to be extracted from every pixel. Image analysis encompasses a broad range of applications and, as a result, various techniques [1]. For image retrieval, feature selection on the base of two developmental computations, namely the Genetic method and also Binary Bat method are used to find out the optimal features analogous to estimate the calculation on ranking base for the reduction in dimensionality and also to refine the best features from a

comprehensive feature set[2]. As for Bio-informatic data analysis has a long history of sequence analysis. The content analysis examines a sequence's broad characteristics, such as its proclivity for coding for proteins or its ability to perform a specific biological role [3]. To optimize pattern recognition systems in use, feature selection is a must to detect skin cancer [4]. The utility of feature selection methods is primarily actuate by an event that occurs when the classifiers are equipped with a constrained number of training samples. After a peak, the classification rate of the classifier reduces as the number of features is increased. Moreover, while developing a recognition system, the need for reducing the number of features is often motivated by computational considerations. Cellular breakdown in the lungs is the main disease executioner among the two people [5],[6]. The indications of cellular breakdown in the lungs don't show up until the malignancy spreads to different zones, accordingly prompting disease location of just 24% in beginning phases [7]. It needs an exact early recognition of cellular breakdown in the lungs, for expanding the endurance rate. Different techniques such as Computed Tomography (CT) scan, microarray information examination are utilized for the cellular breakdown in the lungs discovery [8]. CT scan is a promising technique used for the chest mass screening for the cellular breakdown in the lungs identification. Anyway, this strategy isn't suggested because it is exorbitant and the long haul wellbeing of this technique isn't set up because of the danger of openness to radiation [9]. The utilization of microarray information for malignant growth is examined in [10]. Anyway, the utilization of microarray information is an expensive methodology and approaches. An expanding death rate among various age classes is brought about brain cancer [11]. This sickness is showed by the development of unusual cells inside or over the brain[12]. There exist different kinds of brain cancer like cancerous and non-cancerous. Quick revelation in brain cancer is of incredible significance and a significant test for additional examinations. Hence, image processing equipments are utilized in dissecting cancer and the cancer territory.[13]

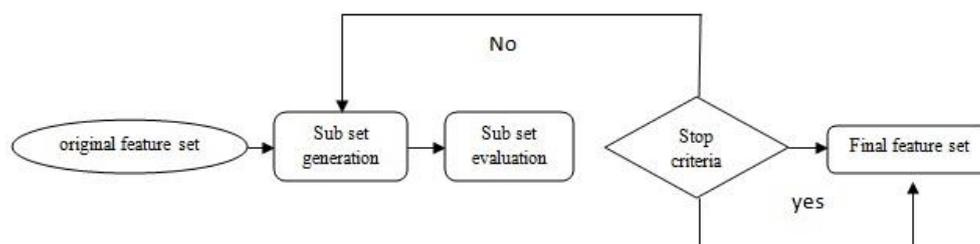


Figure 1: Irrelevant redundant feature detection

To make a Computer-Aided Detection (CAD) framework, different image handling strategies, for example, segmentation, feature extraction and feature selection, and classification are coordinated. Feature selection addresses a functioning examination space in pattern detection [14], machine learning, and also data mining [15]. Insignificant and repetitive features appeal to further hunt as to make design with less noticeable and rules essential for anticipating or characterization less clear, notwithstanding the high over fitting hazard. The choice of feature subsets requires deciding the desired feature to expand the precision of forecast or order. A significant point of this paper is to decide an ideal element subset. Selecting features is typically founded on the boundaries of computational time and the nature of the produced includes subset arrangements. Fast and accurate classification, utilizing the minimum number of features is regularly settled on. This can clearly be obtained through feature selection. A brief literature survey is described in section 2. Various feature selection methods are investigated in Sections 3. In Section 4, research challenges and future direction has been described. The conclusion is being discussed in the last section.

## 2. LITERATURE REVIEW:

The uttermost fundamental step in image processing is the feature selection process. This feature selection algorithm is utilized to determine the most applicable feature from the element feature vector and assists with giving up the undesirable ascribe. Furthermore, this is essential for research territory in machine learning method as well as in and pattern recognition [16]. Several images are being taken for the process of recognition in clinical medical imaging [17]. There are several pictures with high resolution and comprises of more ascribes

which are utilized for research work [18]. Because of this huge information, a more noteworthy dimensionality vector set is acquired in the feature extraction technique. These techniques are used to decrease the extensity along with lessen the expenses of evocation of data and comprehension of the model[19]. Genetic Algorithm (GA) is a typical component choice strategy utilized these days. GA can give the specific or assessed best arrangements. This depends on the hypothesis of enlargement and the genetics of universal selection [20]. A different aggregate hypergraph method [21] is presented for an arrangement of given Alzheimer's contamination. A cross-breed-directed feature selection technique [22] is suggested for the grouping of brain tumors from MRI examine. Besides, other distinctive methods are being created for the perception of experimental medical images [23]. Recent procedures and operations are efficiently attainable to produce an enormous extent of information [24]. It may be represented in design visuals or other format [25,26]. The expansion in the extent of datasets forge it hard to understand and use the information for different pursue [27]. High-geometric data is gathered in online medical images databases to make it more impose [28]. In Data Mining, observation is found from recorded information. Information is broke down, and Information is figured out how to extricate information [29]. With regards to information from the executives, revelation is made on information to discover significant examples. Knowledge observation is not essential in databases and demonstrated its scientific effectiveness for data inquiry [30]. This feature selection is finished by setting a couple of standards that evaluate the worth of each contender quality [31]. Numerous words are utilized for quality assurance like feature selection, feature reduction [32]. While, trait choice, is a numerical portrayal inside which a rule is determined against which quality is assessed [33,34]. The sorts of information that are dug in clinical utilization for finishing up one of the previously mentioned measures incorporate microarray information [35], information identified with heart issues [36], clinical imaging information [37], and others. The information utilized for examination in the clinical area is typically thick and scanty, for instance, the information might be as straightforward and complex pictures, clusters, X-beams, radiotherapy data, and immune histo-chemistry [38]. The insufficiency of data increases the number of features and can cause oath of extent [39]. Another significant impediment to the utilization of selection methods on medical image is numerous of the calculations which are all firmly identified with one another [40]. As referenced before, feature selection methods are additionally utilized on pathological information for genome examination [41]. A productive analysis of selection technique is represented by [42] employed in bioinformatics. This scientific categorization of selection techniques along several benefits based on filter method, wrapper method, implanted techniques is introduced in [43]. A few ensemble feature selectors are likewise evaluated in [44]. A bit of feature selection methods are utilized for the investigation of biomedical signal [45]. These biomedical signals are conspicuously examined in this survey with regards to Electroencephalogram (EEG) beacon examination [46], heart cancer forecast [47]. Many grouping examination techniques endeavour to perceive short, pretty much- monitored signs to indulge protein procession. One more citable endeavour is identified with the use of any feature selection method on microarray information [48]. Microarray data sets are utilized for tumour differential analysis [49]. These genetic techniques are likewise famous for the selection of features from microarray information [50]. A survey of various feature selection methods utilized over medical care datasets is introduced in [51]. Various feature selection methods are utilized on this given information for examining significant features only.

### 3. VARIOUS FEATURE SELECTION TECHNIQUES

Systems are assembled in three orders dependent on choice standards [52]. Various Filters, Wrapper and Embedded algorithms has been described with some advantages and disadvantages.

**3.1 Filter Algorithms:** These techniques need to assessment norm across which each attribute is computed and filter out insignificant aspect before the enlistment action begins. The way towards to choose trait cease when each trait is calculated in contrast to some allowance. Some attributes are chosen with the finest assessment criteria. These filter algorithms are portrayed in a way.

**3.1.1 LVF Algorithm:** LVF algorithm [53] irregularly does an arbitrary pursuit with any assessment method. In this algorithm, consistency is utilized as an assessment measurement. With every emphasis, best subset is chosen as a set apart. It can deal with small scale noisy dataset. It has high time complexity. The selected attributes is normally larger in number for accomplishing always a steady arrangement [54]

**3.1.2 B&B Algorithm:** This algorithm is exponential pursuit in a reverse way with a part of monotonic method for the assessment in clinical purposes [55]. It is an excellent search algorithm where a fixed value is characterized. Nodes with lesser fixed values are not investigated as a result of monotonicity supposition which

expresses that its sub hubs won't create an ideal arrangement. The algorithm finds important ascribes by doing fanning of the dataset. This algorithm stops when the chance of expanding finish. It is highly expensive in nature.

**3.1.3 RELIEF Algorithm:** This algorithm has an irregular inquiry in the recommended pursuit space and appoints loads to the property that are close to the ideal worth [56]. Distance is assessment parameter in this calculation. It picks a property haphazardly and discovers its closest hit and miss. The closest hit is viewed as the nearest occurrence of that trait with the same class through the closest miss is the nearest occasion with an alternate class [57].

**3.1.4 MRMR Algorithm:** This algorithm chooses ascribes based on two assessment estimates reliance and pertinence [58].

Importance implies firmly associated. Pertinence among credits is settled based on common data divided among property and class esteem. It selects those highlights just whose significance is greatest and reliance is least [59].

**3.1.5 Joint Mutual Information Maximization Algorithm:** The JMIM algorithm chooses applicable attributes based on mutual information [60]. It utilizes joint information over a greedy methodology by accepting ascribes as a feed-forward structure [61]. From this information, it very well may be reasoned that firmness quality evaluator is uttermost noticeably utilized in filter. This evaluator retain just those ascribes in the image dataset which is the justification for accomplishing always predictable arrangement. Mutual information and monotonicity are additionally broadly utilized in filter feature selection algorithms.

**3.2 Wrapper Feature Selection Methods:** This algorithm needs rigid data mining technique and utilizations its exhibition as a computation basis and satisfy some conditions with enhancing properties and profoundly computationally effective.

**3.2.1 SFS Algorithm:** This method utilizes heuristic inquiry in forward way. It is known as Successive Forward Selection method. It begins with a vacant set and compute one component in the main emphasis [62]. In the following emphasis, some existing and new features are used to make a complete set and the perfect one is chosen. It gives the best outcomes with little information. [63]

**3.2.2 SBS Algorithm :** This algorithm is known as sequential backward selection algorithm and entire features are at first combined to the list of capabilities [64]. An assessment measure is utilized which gradually eliminates features individually based on some rule. The exhibition of this algorithm might be ideal [65].

**3.2.3 SFFS Algorithm:** It is known as Sequential floating forward search method. It starts compute with one property to the rundown of abilities as SFS method. The credits are taken out dependent on appraisal measures. SFFS ensures that no huge quality is cleared out from the feature set [66].

**3.2.4 SFBS Algorithm:** This algorithm is known as sequential floating backward search method that begins with a total rundown of features. In each cycle, forward and backward following are in process until the fulfilment of the most extreme target work. The worldwide list of capabilities is advantageously gotten because it investigates of highlights which are adding to accomplishing target work [67].

**3.2.5 ASFFS Algorithm:** This method is named as Adaptive Sequential Forward Floating Selection method [68] is a granular perspective. It is high coordinated inquiry that entirety the forward way. The previous one advises the number of features that should be included incorporation stage and the horizontal one advises the number of traits to be taken out in the prohibition stage. This method closes in a lesser number of repetitive features and additionally works precisely. It is more unpredictable and its functions admirably on more modest datasets.

This wrapper methods has some advantages which are as follow (a) It is smooth in nature and collaborate with the classifier (b) It is less computationally comprehensive than randomized method. (c) It is limited prostrate to local optima

Some disadvantages are (a) It has high risk of over fitting (b) It is more prostrate than randomized algorithms to getting fastened in a limited optimum.

**3.3 Embedded Feature Selection Methods:** This method attempts to exploit both filter method and wrapper method by the modification in assessment allowance at various stages. This strategy needs to lessen the overabundance computational season of covering method. A few calculations of the implanted technique are examined underneath.

**3.3.1 Boosted Decision Stump Feature Selection Algorithm:** It utilizes data acquire standards to choose features. The selected number of various features is allowed to a irregular parameter k. At each progression, it disregards every one of the features that were chosen beforehand. Thus the main target is on inspected features with the most noteworthy data acquire [69]. The characteristic of this method effectively forecast class worth with most

noteworthy weight. It is an endless supply of a trait. It gets credits that have more data by playing out the avaricious pursuit.

**3.3.2 SVM-RFE Algorithm:** This method is based on the linear discriminate function of weights [70]. The new target work is arranged by utilizing SVM to perform recursive element end. It is utilized for twofold class grouping. It utilizes standardization for the minimization of the SVM issue. Discovering ideal target work is troublesome in SVM-RFE.

**3.3.3 Lazy feature selection algorithm :** This algorithm chooses and wipes out selected features from include space with some expectations. It utilizes the K-NN technique to anticipate the bench mark of given trait for the most part utilized in the text arrangement issue. Dissipating properties are taken advantage of and utilized as a component choice strategy. It is a classifier subordinate [71].

These methods with some advantages It is used to interact with the basic classifier (b) It is lesser computationally complexity in nature as compare to wrapper method. There is a drawback is to select classifier dependent.

From these methods, it is clear that the embedded method has superior computational complexity as compare to wrapper. This method is not dependent on the classifier but the wrapper method and also embedded both are dependent. These feature selection methods can be applied on the segmented images using ISIC and PH2 datasets [72].

#### 4. RESEARCH DESCRIPTION & FUTURE CHALLENGES

The feature selection accepts a pivotal part in the clinical imaging space for characterization tasks. Considering the ongoing focuses, the feature selection strategies will be deliberated in future examinations.

(a) The method to election the robust features is used to improve the conjecture precision level and also for life span calculation of different skin lesion characterization.

(b) Nevertheless, in light of commotion and a couple of different elements, the eliminated features don't design the particular sore domain. Consequently, the segment decision techniques are employed to pick simply significant features to identify exact injury or lesion identification.

(d) The usage of feature optimization method provides a great success depending on scarcely any new articles.

(e) The determination of deep learning feature to know capabilities likewise upholds higher acknowledgment exactness with inside the clinical area, especially for a big measure of imaging information.

(f) As entropy-primarily established totally techniques restrained the computational time of CAD framework and also improves acknowledgment exactness.

(g) The overall enforcement of each determination strategy relies upon at the fitness characteristics. The fitness characteristic may be more suitable using higher strategies such as Neural Network or many more.

#### 5. DISCUSSION & CONCLUSION

Health service Institutes are massing widespread quantities of information because of the speedy increase of information prices in scientific information repositories and fitness care provision. These information repositories maintain a wealth of information that may assist medical doctors make better diagnostic selections and enhance the quality of patient care. The information, on the opposite hand, is multidimensional, with feature numbers weighing in greater closely than samples. In the scientific field, rapid and specific machine learning structures are needed. Most machine learning algorithms want a massive range of samples for training due to the fact small samples can lessen generalization functionality and cause over fitting. Due to the motives related to the curse of dimensionality, the use of traditional strategies to cope with such information isn't good idea. To attain higher accuracy, the choice of vital functions is required. The choice of vital feature is essential to reap higher accuracy. Before sample classification, feature selection is one of the maximum a success techniques for doing away with redundant and unimportant functions. Different strategies to scientific feature selection implementations are studied in this paper. It has been proven that the feature selection technique now no longer reduces the range of features however additionally improves the accuracy rate, supporting within side the comprehension of diseases' root causes. Feature extraction, feature selection, dimensionality reduction, and characteristic choice have been all discussed. Filter, wrapper and embedded techniques are general strategies to feature selection techniques which might be described in detail, along with their algorithms. The measures for characteristic assessment are covered, in addition to a few beneficial facts approximately the pros and cons of these feature selection procedures. Both, feature selection method and reduction algorithm techniques are to be



discovered for the beneficial to improve accuracy and execution time of scientific imaging. Furthermore, it is concluded that deciding on suitable features reduces a CAD system's universal complication.

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## MODELLING OF STEM DETACHMENT MACHINE FOR TOBACCO LEAF

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### Abstract-

The processing of tobacco leaf requires removal of stem which impart an irritating and unpleasant taste to the smoke. The removal of stem from tobacco leaf by manually is a time-consuming process. In large industries it is done by shredding machines where the stem is cut into pieces along with the blend and removed by many techniques. There is demand for removing stem in a straight piece without cutting into pieces in medium, small scale contractactors. In these present stem removing is done manually by daily wages system which is not an economical. This drawback leads to modelling of stem detachment machine. The main principle involved is Sharp Edge Cutting Cone (SECC) which removes the stem in a straight form from the leaf by shearing action. By using more SECC the greater number of stems can be removed at a time this increases the production rate and reduces the cost of stemming process. Therefore, modelling of "Stem Detachment Machine" is highly recommended for small, medium tobacco processing factories.

**Keyword-** SECC, CONE GRIPPER, HOLDING PLATE

### 1. INTRODUCTION

Tobacco, *Nicotiana tabacum*, is an herbaceous annual or perennial plant in the family Solanaceae grown for its leaves. The tobacco plant has a thick, hairy stem and large, simple leaves which are oval in shape. Tobacco plays a significant role in the Indian economy. India is the world's second largest producer of tobacco and also the second largest consumer of tobacco. The demand of tobacco in India is yearlong continuously. Tobacco leaves of the type employed for the manufacture of cigarettes and like Smoking products generally contain about 20 to 35% or more stems. In earlier pair of flexible endless cutting members [1] are used having adjacent cutting edges arranged to receive the stem of a tobacco leaf between them, and further this was replaced by pair of flexible cutting disks [2] having their axes inclined to Wards each other, arranged to receive the Stem of a tobacco leaf between then and cut the laminae there from as said leaf is progressed past their cutting edges. The presence of stems in cut tobacco is detrimental to cigarette quality [3], resulting in problems during production particularly on today's high-speed makers. Incomplete threshing and the use of un threshed semi oriental tobaccos can increase the stem content in the cut tobacco considerably. However, tobacco leaf-stripping machine has been invented to increase production efficiency, reduce lab our and waste, increase production speed [4] it is suitable for green tobacco leaf only. Tobacco leaves harvesting in per leaf way, using a roller-type separating device [5] acting on object of harvesting with rolling cutter having cutting flanges forming leaf-separating cells in working area. The subject of these studies is highly specialized and relates to field of agricultural engineering. Stemming tobacco leaves, means to provide a stem guiding and shearing mechanism [6] of simple construction, which will be very easily adjusted to shear or cut of the stems of tobacco leaves at predetermined lengths. Tobacco leaf flue-curing process consumes large amounts of energy. Comparing to the traditional heating approach using coal, the heating source like heat pump [7] would be more energy efficient

and environmentally friendly. Tobacco played a very important role in the mystical, social and medical rituals [8] of the American natives. Based on the medical applications of the herb by the natives, European herbalists believed that most herbs of the New World possess some medicinal virtues.

## 2. RESEARCH BACKGROUND

W. B. Bronander and Montclair [1] used a combination with a pair of flexible endless cutting members having adjacent cutting edges as shown in Fig 1. arranged to receive the stem of a tobacco leaf between them to cut the laminae from the stem. It has a drawback that the great variations in leaf structure in tobacco, especially in the several varieties of tobacco can't be handled. George w. Gwenn and James w. leary [2] used the combination with a pair of flexible cutting disks as shown in Fig 2. arranged to receive the stem of a tobacco leaf between them and cut the laminae there from as said leaf is moved past them, driving means for rotating cutting disks to impart cutting movement to disks, and a suction guide table upon which said leaf is Spread and moved. It has a drawback that A portion of leaf lamina is wasted along with the stem removal. D. zielke and r. liebeet al [3] has used the separation of particles in an air stream is based on the principle that particles of different density and shape fall at different speeds as shown in Fig 3. The process relies on the presence of individual particles which can be surrounded by the air stream without hindrance.

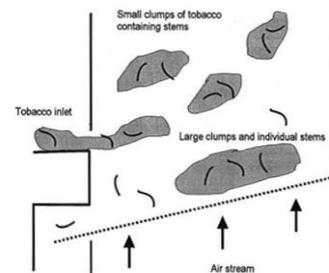
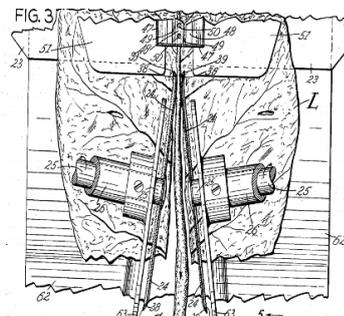
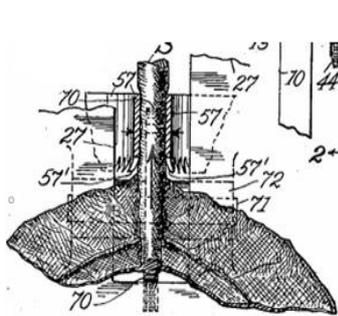


Fig. 1. Endless cutting members      Fig. 2. Endless cutting disks      Fig. 3. Removal of stem by density difference

## 3. DATA OF TOBACCO LEAF

The tobacco leaves are available in various size and shapes. The leaf should not be in dried position during stemming. The leaves are not in exact straight position as green leaf. Cross section of stem at the end is not a perfect circle.

Specifications of tobacco leaf

- Maximum height of leaf = 450mm
- Minimum height of leaf = 250mm
- Thickness of stem at the end = 5-10mm
- End of stem free from leaf = 2-3 cm

## 4. PRINCIPLE

The idea is to remove the stem in a straight piece for this there are many ways i.e. by pulling, pushing, cutting, shearing etc. After considering merits and demerits of various processes under the domain of required conditions pulling is concluded. The stem should be pulled from a small equipment named as sharp edge cutting cone. Technically frustum of cone as shown in Fig. 4a.

Pulling of stem through minor diameter of frustum of cone from inside. When the initial end of the leaf sheared because of sharpness of cone and remaining portion of leaf is simply sheared by vertical downward force as shown in fig. 4b. In this way stem is detached from tobacco leaf practically shown in below Fig. 5. The separation of stem from tobacco leaf is shown in Fig. 6.

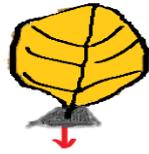


Fig. 4a. Inserting of tobacco leaf in SECC



Fig. 4b. Pulling of tobacco leaf through SECC



Fig. 5. Removal of stem from tobacco leaf in a straight manner



Fig. 6 Separation of stem from tobacco leaf

## 5. MODELLING

The modelling of stem detachment machine involves parts that are designed in Catia v5 software the parts are Cone Gripper, Base Plate, Holding Plate, Rubber Gripper, Tension Springs.

### 5.1.1 CONE GRIPPER

It is a joining of two curved surface that has a radius gradient by means of tension springs (Fig8). Cone gripper is used to hold the leaf stem end of 20-30mm which is free from leaf. It is made up of high strength steel. At minor diameter the rubber grips are provided to hold the stem firmly. In this one is fixed to the grabbing plate and another is movable by means of lever. And when the lever operated it closes the grips together very tightly as shown in Fig. 7.a. The gripping force/pressure depends upon the type of material used for gripping

### 5.1.2 HOLDING PLATE

Plate is one of the most important part of the device. It contains a sharp edge cutting cone that is a frustum of cone in each corner on its four corners shown in Fig. 7.b. The number of sharp edge cutting cones can be increased according to the requirement of the customer.

### 5.1.3 RUBBER GRIPPER

Rubber exhibits unusual sliding friction. When rubber is slid on a hard, rough substrate, the surface asperities of the substrate exert oscillating forces on the rubber surface leading to energy “dissipation” via the internal friction of the rubber. Rubber gripper that can be used is shown in Fig. 7.c.

#### 5.1.4 TENSION SPRINGS

Extension springs, also known as a tension spring, are helical wound coils, wrapped tightly together to create tension as shown in Fig. 7.d. Extension springs usually have hooks, loops, or end coils that are pulled out and formed from each end of the body. The function of an extension spring is to provide extended force when the spring is pulled apart from its original length.

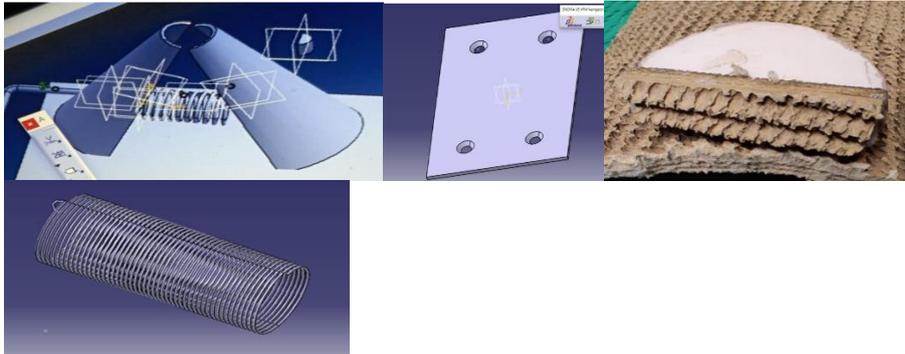


Fig. 7.a. Cone gripper      Fig. 7.b. Holding plate      Fig. 7.c. Rubber gripper      Fig. 7.d. Tension springs

### 6. MOTIONS REQUIRED

The proper action of implementing principle depend upon the implementing the desired motion to the assembled parts and the it should be done in many ways like human power, electric power, pneumatic energy, hydraulic energy etc. The motions involved are reciprocating motion between top plate and holding plate, Angular motion in cone gripper by means of spring.

#### 6.1.1 RECIPROCATING MOTION BETWEEN TOP PLATE AND HOLDING PLATE

This motion is achieved by means of compression springs placed between top plate and holding plate in such a way that the one end of spring is fixed to the top plate and other end is hooked to the holding plate as shown in Fig. 8.a.

#### 6.1.2 ANGULAR MOTION IN CONE GRIPPER BY MEANS OF SPRING

This motion is achieved by the proper positioning of cone gripper so that the base of one-half cone gripper is offset to the base plate and the pivot must be incorporated to provide angular movement around it as show in Fig. 8.b. For all placed cone grippers this motion will be created by means of lever mechanism.

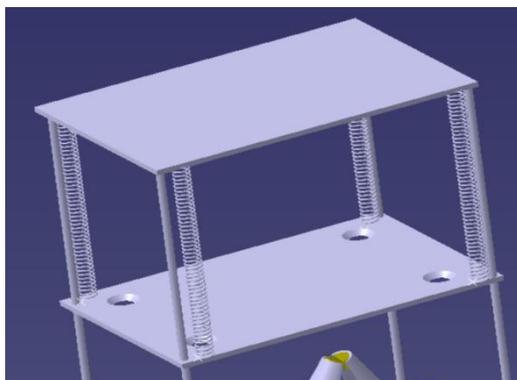


Fig. 8.a. Reciprocating motion

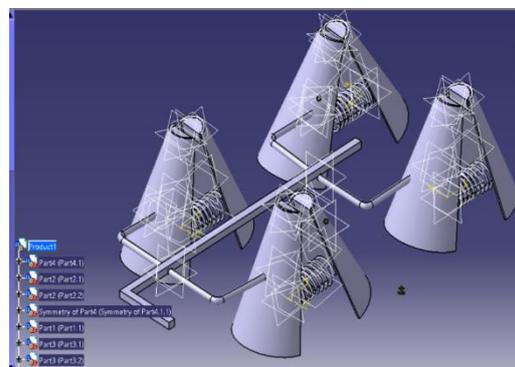


Fig. 8.b. Angular motion in cone gripper by spring

### 7. RESULT

The main parts of the stem detachment machine is cone gripper, base plate, holding plate, rubber gripper and top plate are assembled in such a way that the required motion is obtained by using of user is shown below Fig. 9. There should be minimum clearance between holding plate and plane of cone grippers top side.

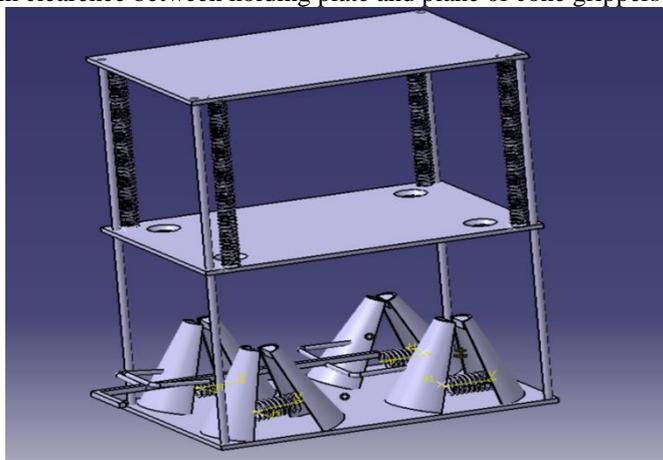


Fig. 9. Assembled view of stem detachment machine

## 8. CONCLUSION

The modelling of stem detachment machine for tobacco leaf is successfully done. Main Mechanism involved in stem detachment machine is the sharp edge cutting cone which is mounted on the base plate by the welding technique. it should be held in such a manner that it will be able to gripping the stem so that the more grip force will be applied on the end of the stem that is 1-2 cm available. In this mechanism the two plates are fixed and one plate is movable by means of a compression spring attached on the top plate so from this it is concluded that the stem removal from the tobacco leaf is done because of the shearing action takes place at the end of the leaf by means of SECC.

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## PNEUMONIA PREDICTION ON CXR IMAGE DATASET USING MACHINE LEARNING

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### ABSTRACT :

Pneumonia is an acute respiratory infection which affects the alveoli of the lungs. When a person has pneumonia, the alveoli get infected and inflamed with pus. Due to this the breathing becomes painful and even limits intake of the oxygen. This disease is caused by viruses or bacteria or fungi. In severe cases, this may even lead to death. Predicting pneumonia at early stages and undergoing medication can prevent mortality and also can control severe conditions of pneumonia. For this problem a Machine Learning model has been created that can predict whether a person has pneumonia or not with given input images of chest X-rays. We took a dataset of around 5000 images and made an attempt to predict and visualize using charts and graphs based on two classifier Machine Learning models such as logistic regression and k- nearest neighbours.

**Keywords : Pneumonia prediction , chest x-ray images , logistic regression , k-nearest neighbours.**

### 1. INTRODUCTION

Machine Learning has reached a great height in recent trend words. Machine Learning is being used in various fields like finance, marketing, medical science and other industries. At the current scenario, this new technology has been a great help for the medical practitioners. In medical sectors, Machine Learning model algorithms smartly discover the patterns in the data that is provided. These models are of great help in predicting the abnormalities in the human bodies by examining the x-ray images of various parts of the body.

In this paper, an attempt to predict pneumonia by using different Machine Learning models is made. Pneumonia has been a deadly disease since ages. This disease affects the lungs and causes inflammation in the alveoli. Pneumonia is the core reason for the death of 15% of children under the age of 5 across the world.

Usually, machine learning models using image data as input uses Neural Network for image classification. But here, we have tried to classify images using basic models such as Logistic Regression and k-nearest neighbours. The goal of this work is to showcase that image classification can also be done using basic models with good accuracy other than Neural Network.

### 2. LITERATURE SURVEY

Findings say that viral pneumonia is similar to that of covid-19. So, using transfer learning, the model used for predicting viral pneumonia can also be used to identify covid-19 [1]. Creating efficient deep learning models, trained with chest X-ray images, for rapid screening of COVID-19 patients using publicly available X-ray images of COVID-19 patients [2]. new hybrid deep learning framework by combining VGG, data augmentation and spatial transformer network (STN) with CNN. This new hybrid method is termed here as *VGG Data STN* with *CNN* (VDSNet). The new model is applied to NIH chest X-ray image dataset collected from Kaggle repository [3]. Present the use of deep learning for the high-accuracy detection of COVID-19 using chest X-ray images. Publicly available X-ray images were used in the experiments, which involved the training of deep learning and machine learning classifiers [4]. A novel approach based on a weighted classifier is introduced, which combines the weighted predictions from the state-of-the-art deep learning models such as ResNet18, Xception, InceptionV3, DenseNet121, and MobileNetV3 in an optimal way. This approach is a supervised

learning approach in which the network predicts the result based on the quality of the dataset used [5]. Using supervised models such as Logistic Regression, Principal Component Analysis along with Deep Convolutional Neural Networks for predicting pneumonia. Comparing and analysing results of the various models [6]. Proposes the machine learning-based classification of the extracted deep feature using ResNet152 with COVID-19 and Pneumonia patients on chest X-ray images. SMOTE is used for balancing the imbalanced data points of COVID-19 and Normal patients [7]. A detailed comparative study of various machine learning algorithms namely Random Forest, Logistic Regression, and Support Vector Machine. These models are trained with features extracted by a pre-trained deep convolutional neural network (DCNN), VGG16 for the diagnosis of pneumonia from chest x-rays [8].

### 3. METHODOLOGY

The method followed to predict the pneumonia using the chest x - ray image using machine learning model is shown in Fig 1:



Fig 1: Methodology

### 4. DATASET

The dataset was collected from the Kaggle website. The dataset is organized into 3 folders train, test and val with subfolders for each image category of Pneumonia and Normal. There are 5,863 X-Ray images of JPEG format. These x - rays were selected from retrospective cohorts of paediatric patients of 1 - 5 years old from Guangzhou Women and Children’s Medical Centre, Guangzhou. Fig 2: shows the sample chest x-ray images from the dataset.



Fig 2: Sample Training Dataset

### 5. DATA PREPROCESSING

Data pre-processing technique is the most important part of a Machine Learning model. This technique prepares the data for the model building phase. The data pre-processing techniques used for this problem are described below: The images from the dataset are of shape (277, 277). These images are first resized to the shape of (80, 80) images. The resized images are then converted into grayscale images. These grayscale images are again transformed into arrays with a stream of float values. Each value in the arrays represents the pixel values of those images. These processes are done using the Python Imaging Library (PIL). Fig 3: shows the image after the above pre-processing technique.

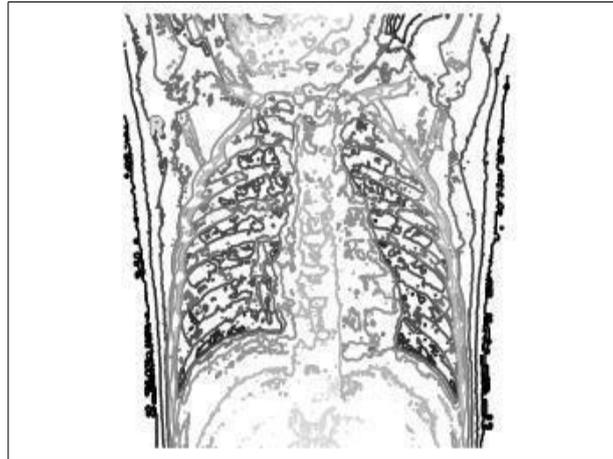


Fig 3: Pre-processed image

### 6. DATA VISUALIZATION

A histogram plot was created for a random x - ray image of both normal and pneumonia to compare the pixel values. The histogram is a kind of plot which shows the pixel value distribution of an image. Fig 4: shows the histogram plot of a random image from the dataset.

Now, these transformed arrays are of shape (80, 80). Then reshaped these two-dimensional arrays into a one-dimensional array to adapt into the model. So, each image has been converted into numbers of shape (1, 6400). A sample data of the arrays after reshaping is shown below in Fig 5: In the same way, all the images of the folders are converted into arrays.

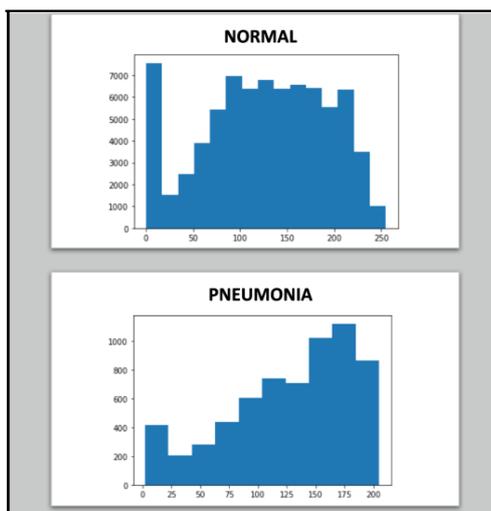


Fig 4. Histogram plot

```
[array([[131, 149, 147, ..., 0, 0, 0]], dtype=uint8),
array([[ 38, 99, 215, ..., 218, 232, 216]], dtype=uint8),
array([[61, 78, 84, ..., 0, 0, 0]], dtype=uint8),
array([[21, 25, 27, ..., 0, 0, 0]], dtype=uint8),
array([[67, 45, 73, ..., 0, 1, 21]], dtype=uint8),
array([[35, 40, 53, ..., 43, 51, 50]], dtype=uint8),
array([[20, 27, 37, ..., 0, 0, 0]], dtype=uint8),
array([[33, 33, 33, ..., 40, 41, 40]], dtype=uint8),
array([[34, 47, 48, ..., 8, 7, 6]], dtype=uint8),
array([[ 14, 15, 15, ..., 26, 53, 121]], dtype=uint8),
array([[50, 56, 81, ..., 21, 9, 13]], dtype=uint8),
array([[38, 34, 37, ..., 98, 73, 54]], dtype=uint8),
array([[20, 24, 26, ..., 0, 0, 0]], dtype=uint8),
array([[ 2, 12, 32, ..., 13, 24, 18]], dtype=uint8),
array([[83, 62, 57, ..., 16, 18, 19]], dtype=uint8),
array([[71, 76, 77, ..., 16, 24, 25]], dtype=uint8),
array([[ 3, 20, 39, ..., 2, 2, 5]], dtype=uint8),
array([[36, 44, 53, ..., 32, 1, 2]], dtype=uint8),
array([[48, 51, 55, ..., 20, 25, 43]], dtype=uint8),
array([[26, 31, 35, ..., 6, 5, 4]], dtype=uint8),
array([[ 81, 84, 89, ..., 114, 86, 56]], dtype=uint8),
array([[129, 38, 14, ..., 73, 59, 41]], dtype=uint8),
array([[36, 44, 48, ..., 26, 26, 26]], dtype=uint8),
```

Fig 5. Reshaped array



## 7. DATAFRAME CREATION

A data frame was created with the array values of those images using the python pandas library. Then added a target column as the last column of the data frame. The target column depicts 1 for pneumonia and 0 for normal images. Fig 6. shows the data frame of the pixel values of the images along with the target column. That is the final refined dataset to proceed further with the model building phase.

	0	1	2	3	4	5	6	7	8	9	...	6391	6392	6393	6394	6395	6396	6397	6398	6399	target
157	134	134	134	134	134	135	137	143	149	151	...	128	75	22	4	4	2	1	0	0	0
17	11	11	13	15	14	11	10	10	11	12	...	149	126	102	70	33	9	13	18	19	0
279	23	26	27	27	25	23	18	14	12	38	...	29	3	8	11	13	12	14	22	42	1
252	200	57	28	35	40	46	54	60	59	59	...	14	11	16	18	18	14	107	57	15	1
69	0	2	11	21	23	24	24	23	23	24	...	178	155	131	95	53	21	11	2	0	0
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
16	86	87	88	90	89	88	85	82	78	76	...	91	87	82	66	42	23	12	2	0	0
58	0	5	23	43	61	80	93	95	97	109	...	68	38	9	2	4	6	8	9	10	0
43	85	154	91	83	138	137	175	88	58	66	...	61	57	30	5	14	17	18	18	18	1
21	217	215	224	215	196	59	4	11	12	12	...	13	14	14	16	16	16	16	16	17	1
86	221	210	196	172	153	149	148	128	140	118	...	15	20	23	24	25	25	23	54	82	1

Fig 6: Data frame

## 8. MODEL BUILDING

The first step in the model building is to split the dataset into train, test and validation data. Then import the model using the necessary libraries. After splitting the dataset, fit the data into the model. Next, train and validate the model using the respective dataset and then test the performance of the model. Here, two Machine Learning models are used for this classification problem. First model is a logistic regression model to classify the images as normal (0) or pneumonia (1)

### 8.1. LOGISTIC REGRESSION

Logistic regression is a statistical analysis method used for classification problems. This method is exclusively used for binary classification. It comes under supervised machine learning algorithms. This model predicts a dependent data variable by analysing the relationship between one or more existing independent variables. This model determines the probability of an event between 0 and 1. Here, the sigmoid function is used to map the predicted values to the probabilities.

### 8.2. K - NEAREST NEIGHBORS

This is an unsupervised machine learning algorithm model. This model assumes that similar data exist in close proximities. The k value here determines the number of data points to be nearer to that given data value for the prediction. That k value is optimized by the elbow curve method where we plot a curve between the error and the k values from which we find the lowest point of the curve (least error) to be the optimal k value for the problem.

## 9. MODEL EVALUATION

This is also an important part of machine learning. In this we will compare the results of various models used and choose the model with good accuracy as the best model that fits our problem. Accuracy is one of the most common evaluation metrics that is used. Confusion matrix and classification reports are the two popular methods used to find the accuracy and also to visualize how well our model works with new data points. Fig 7: shows the classification report and confusion matrix over the test data of the logistic regression model. Similarly

Fig 8: shows the classification report and confusion matrix over the test data of the k - nearest neighbour model

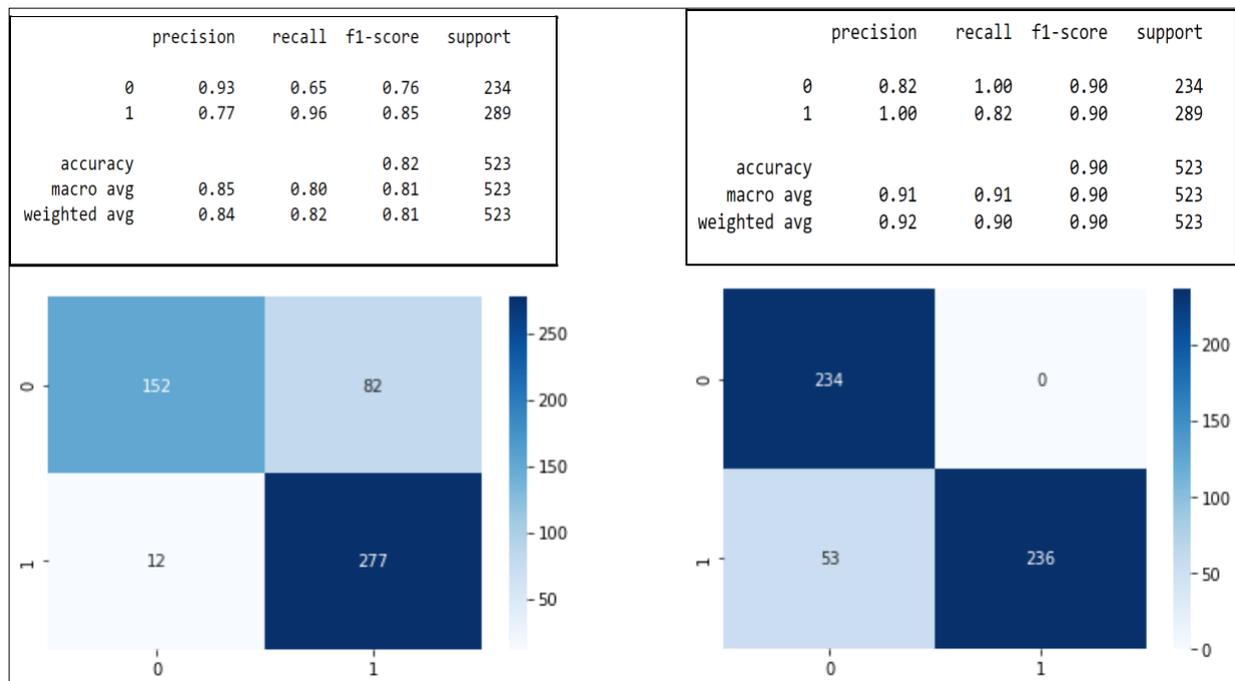


Fig 7: Model evaluation of logistic regression

Fig 8. Model evaluation of k - nearest neighbors

### 10. MODEL COMPARISON

Table 1: Comparison of two models

Criteria	Logistic regression	K-nearest neighbours
F1 - score	76	90
Accuracy	82	90

From Table 1 it can be observed that the accuracy as well as the F1 - score is higher for the knn model. Among the two models k - nearest neighbour model performs better for this problem.

### 11. CONCLUSION

For proper medication and to avoid severe conditions, disease prediction is very important. In this work we have done a pneumonia disease prediction using the chest x - ray images. We collected the dataset from Kaggle , then pre-processed the data according to the requirement of the model. Later, two Machine Learning models were also created, logistic regression and k - nearest neighbours. After model building model evaluation and model comparison were also done and from the later it was inferred that k - nearest neighbour model gives a higher accuracy value of 90%.

Recently, Neural Networks hold a higher position for image classification problems even though neural networks remain a black box due to their unexplained functionality. To conclude, the only drawback with basic models could be that it may run quite slower on working with larger dataset but basic models have also been proved to give better results for image classification.

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## Designing Parameter Optimization for Manufacturing of Masks

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### Abstract

The pandemic has introduced a new essential in our lives, a face mask. The ongoing increasing demand for masks has led the mask manufacturing companies to step up their game and come up with masks that fight the virus and are also environment friendly and reusable. In order to promote the significance of masks considering aspects such as their sales in the market, looks and comfort, the response factors were selected. With the help of the Design of Experiments Taguchi Method, this experiment intended to attain a set of suitable parameters in a mask that would provide protection as well as give the maximum comfort. Using the ANOVA table as provided by Taguchi Method, 39.11% contribution was shown by Adjustable ear loops followed by 38.79% by a cotton cloth mask. The analysis of variance also showed that for all factors suggested that the average of all mask preferences combinations under consideration are equal.

**Keywords-** Taguchi Method, ANOVA, S/N Ratio, Parametric Optimization

### 1. Introduction:

When the news of a deadly and rising virus hit the tabloids, masks came to be known as a necessity. Every other store in the street had their own fair share of masks stocks ready. For people still going up and about their work, it became essential they couldn't take a chance for it to be of poor quality. With such urgency, the need to produce masks that aided not just the prevention of COVID-19 but also breathability and durability became important.

The authors of [1] explained how parametric design is a cost-friendly technique when improving product quality (1985). A systemic guide on how to correctly carry out this experiment was provided by authors of [2] (1993). W.H. Yang et al. searched for an alternate approach to optimize cutting parameters for more efficiency [3] (1997). Authors of [4] (2012) have given insights on how the Taguchi Method aids in uplifting the quality of the design. Karna et al. pointed out that when practised on human-focused quality evaluation, the Taguchi method is exceptionally compatible [5] (2012). The authors of [6] (2012) carried out an experiment using the Taguchi Method, which saved the researchers 88% of their cost and time.

Design of Experiments (DOE) was initially proposed by Sir R. A. Fisher to detect ideal conditions for growing the best crop. In the coming years, in order to make this process a little more time and pocket friendly, Dr Genichi Taguchi came up with a new experimental design [7] (2013). Ranganath et al., with the help of the Taguchi method, analyzed values for parameters needed to maximize surface finish [8] (2015). This particular parameter construction makes use of Orthogonal Array, Analysis of Variance, Signal-to-Noise ratio and main effects. With these techniques, the procedure of carrying out parameter optimization becomes easy and more lucid.

The primary intent of this paper was to help mask manufacturing companies boost their sales by designing masks that are of good quality and cater assistance in fighting against the coronavirus. Moreover, people have been facing breathing problems when it comes to wearing masks for an extended period of time. It was essential to produce masks with a more relaxed and comfortable fabric that did not irritate the mask wearers. Since the pandemic, there have been instances where the consumers have denied wearing masks because of how they look with it. Considering how much our looks add to our personality, the look of the mask was also considered. Hence these factors were studied in order to encourage people to wear masks more often.

### 2. Methodology:

Following the rise of the coronavirus and the usage of masks, authors of [9] discovered that face masks aided in lessening the transmission of this deadly virus to susceptible individuals (2020). Phan et al. wanted to provide a solution to the manufacturing companies on how to produce reusable masks [10] (2020). The authors of [11] conducted an empirical analysis on preferences of masks in this pandemic (2021). Srivastav et al. presented a mathematical model studying the impact of quarantining, usage of face masks and hospitalization of infected

people in India (2021). The main objective for finding optimized parameters for the manufacturing of masks is to curate a combination of masks that is most sought by people. In order to do so, we have performed a Design of Experiments for manufacturing snug and pleasant looking masks considering three response data and three factors. These response data include comfort, look and itchiness whereas the factors include the type of cloth used for making the mask, type of slings used to hook the mask with our ears and kind of design of the mask.

While selecting response factors, elements such as how much people find their masks convenient, how well the masks suit them and how well is business booming for the mask manufacturing companies were intensely studied. The first response factor, comfort, was aimed at how satisfied the respondents felt. The second response factor, look, was targeted towards how pleasant do consumers find their masks visually. The third response factor, itchiness, was directed towards how well they found to wear masks for a long duration without getting irritated. To draw more conclusions, three major parts of India were targeted.

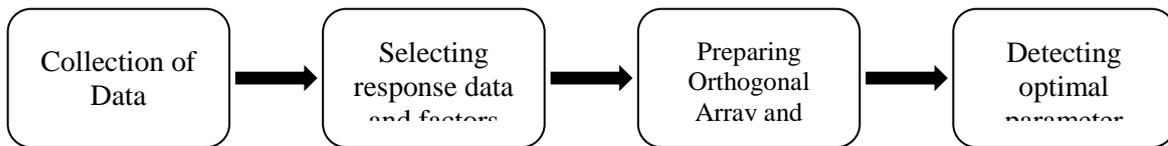


Fig 1: Methodology Flow Chart

### 3. Results and Discussion:

Not limiting this study geographically, data was collected from three major parts of India i.e., North, Middle and South Indian regions. A survey was circulated and looking at the data, Taguchi Method was the most preferable among all Design of Experiments techniques.

The respondents were given different combination sets of factors as arranged by the L27 Orthogonal array. The respondents were asked to rate on a scale of 1 to 5, 1 being the lowest and 5 being the highest, which set of combinations did they like the best when put against the response factors.

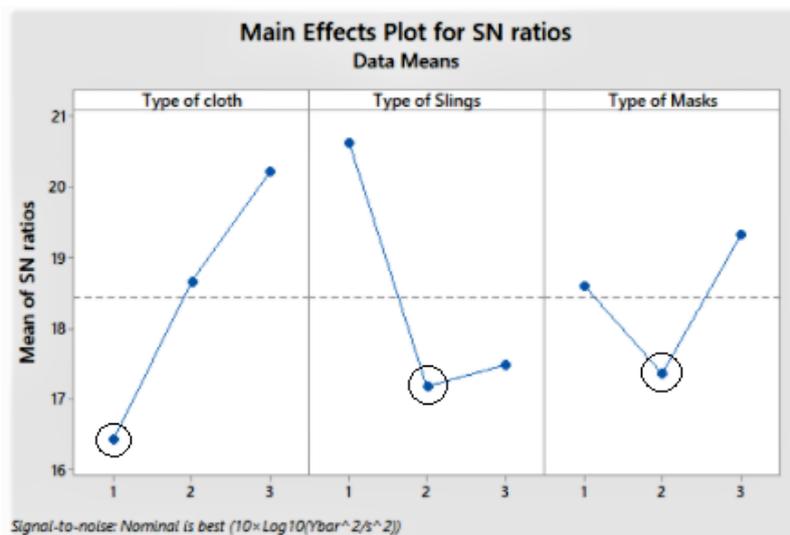


Fig 2: Mean Effects Plot for S/N ratios

#### 3.1 Main Effects Plot

In order to get the desired plots and results, the data was analyzed in Minitab software. With the Main Effects plot, we aim to assess the importance of each factor along the same scale. From the Mean Effects Plot for S/N Ratios we make the inference that if the line is horizontal, there is no main effect. The combination is found by looking at the least Mean of S/N ratios of each factor. As seen in Figure 2, we can infer the best combination which can be adopted by the mask manufacturing organizations. This combination is **C1S2M2**.

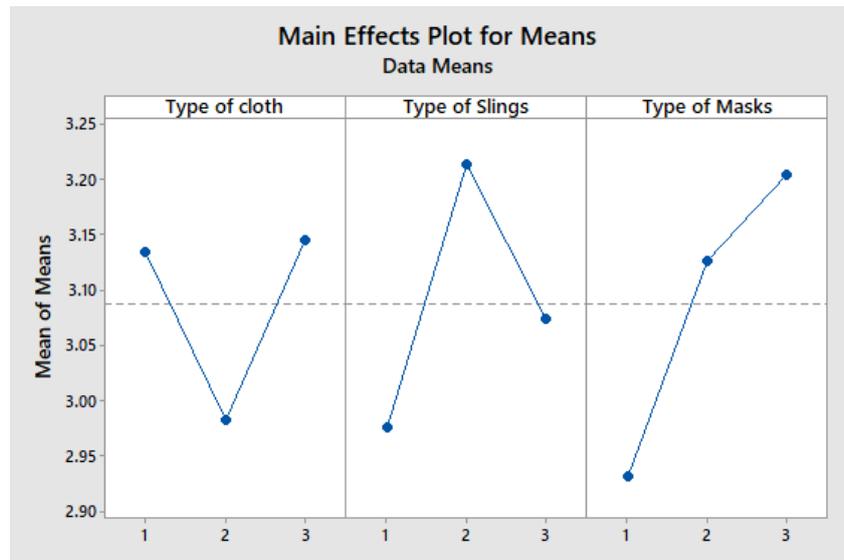


Fig 3: Mean Effects Plot for Means

Figure 3 shows the mean value for each response factor. With response factors 1 and 2, Comfort and Look, we need a high mean value. But when thinking about the itchinness response factor, we certainly do not want this factor to have a high mean value. Hence we look for low means in only the third factor.

### 3.2 ANOVA

With Analysis of Variance (ANOVA), we determine if there is a difference between average mask preference as well as calculating the contribution of each factor. A null hypothesis along with an alternate hypothesis is defined in order to assess the significance of factors. The hypothesis is defined as follows:

**H<sub>0</sub>**: There is no significant difference in the average of all combinations of mask preferences under consideration.

Against

**H<sub>1</sub>**: There is a significant difference in the average means of all combinations of mask preferences under consideration.

Analysis of Variance for SN ratios

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Type of cloth	2	21.932	21.932	10.966	3.41	0.227
Type of Slings	2	22.117	22.117	11.059	3.44	0.225
Type of Masks	2	6.061	6.061	3.030	0.94	0.515
Residual Error	2	6.430	6.430	3.215		
Total	8	56.540				

Fig 4: ANOVA Table

Using Table 1 ANOVA Table data inference, the p-value for all factors is greater than the significance level, 0.05. Hence we do not have enough evidence to reject the null hypothesis. We can say that the combinations of mask preferences under consideration are equal. Using the total sum of squares given in Figure 4 ANOVA Table, we can find the percentage of influence of each factor.

Table 1. List of Factors and their Influence Percentage

Factor	Sequential Sum of Squares/Total Sum of Squares	Influence Percentage
Type of Cloth	21.932/56.540	38.79%

Type of Slings	22.117/56.540	39.11%
Type of Masks	6.061/56.540	10.71%

As seen in Table 1, Type of Slings is most influential 39.11%, followed by Type of Cloth 38.79% and then Type of Masks 10.71% when manufacturing masks. From Taguchi Analysis, we found that a mask made out of Cotton with Adjustable Ear Loops which can be washed for multiple uses are considered to be the optimal parameters for an ideal face mask.

#### 4. Conclusion

The main agendas of this paper, sales of masks, comfort, and look, were satisfied. The three factors used in this study, Type of Cloth, Type of Slings and Type of Masks were found to have no significant difference in the average of all combinations of mask preferences under consideration. It was found from the Main Effects Plot of S/N ratios and the Main Effects Plot for Means that a washable mask made out of cotton with adjustable ear loops is the best combination. Analysis of Variance (ANOVA) supported our results. It was found out that 39.11% of the influence is shown by the factor Type of Slings followed by 38.79% contributed by Type of Cloth, and 10.71% contributed by Type of Mask. It is recommended that this result can be adopted by mask manufacturing companies to manufacture masks that will target a larger audience and also encourage more people to wear masks for a longer duration as comfort is a parameter considered.

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## Finite Element Simulation of Laser Beam Bending Process

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### Abstract

Laser beam assisted bending is generally an advancing expertise, comprehensively deployed for bending of worksheet by practice of precised laser radiations. Worksheet is bent with the aid of thermal stresses carried by means of laser beam radiations instead of outer source load in laser beam assisted bending. Unique characteristic of laser beam assisted bending is that it takes less time to complete process as special tooling is not essential. Due to this unique quality, this method has been widely deployed in manufacturing world like shipbuilding, autovehicles and space-crafts etc. In present paper, shipbuilding steel (D36) workpiece is operated for bending. Simulation is completed with the aid of ANSYS workbench at several velocities of scan & laser power. These simulations are conceded with combined thermal and structural study. Afterwards, the outcomes were matched with available experimental facts. The attained outcomes demonstrates that there is certain reduction in angle of bending with the rise in velocity of scan which are in decent assurance with issued experimental records. Added, impact of beam diameter & depth of workpiece have too scrutinized on bending angle; possessing extra constraints continual and engaged from the similar experimental records. Simulation outcomes depicts that angle of bending lessens by way of rise in depth of workpiece and span of beam used.

**Keywords:** Laser Beam Bending, Gaussian Heat Source, Thermal-Structural Analysis, Finite Element Methods.

### 1. INTRODUCTION

The laser beam assisted bending process is the type of the laser materializing process that has extraordinary applications in sheet metal formation process Vollertsen, F. (1994). In laser beam assisted forming, forming is attained via driven thermal induced stresses into the worksheet surface by accurate radiation of laser beam. Profile and location of bend is basically reliant on scan velocity, beam diameter and controlled laser beam Z. Ji, S. Wu (1998). In the old-style forming, substantial outsource load is continually applied by weighty tools i.e. punches and die. However in laser beam assisted bending there is no such necessity of outsource loads. Thus, laser beam assisted bending has copious pluses over outdated means of forming.

Presently, three mechanisms are present for laser beam assisted bending that are Temperature Gradient Mechanism (T.G.M), Buckling Mechanism (B.M.) and Upsetting Mechanism (U.M.). TGM commences just the when beam diameter is closely equivalent to depth of worksheet and velocity of scan is opulent. Now in BM, the diameter of beam is supplementary as compared to depth of worksheet & scanning velocity is lesser. In UM, beam diameter is lesser as compared to depth of worksheet [Kyrzanidi et al. 1999, Hu, Z., Wang et al .2001, Y. Shen et al. 2007, William et al. 2010).

### 2. LITERATURE REVIEW

The practice for laser beam assisted worksheet bending was main presented by Kitamura reported in 1980. First investigation was broadcasted by Namba & Scully. Researchers accounts that laser beam assisted bending possibly attained by three approaches: Experimentation Work, Analytical Approach and Mathematical Simulation Vollertsen, F. (1994).

Tentative model has been introduced by T. Hennige et al. (1997) depicts the accurateness of operation of laser beam assisted bending via closed-loop control methods; M.L Chen et al. (2007) which provides effective report of laser bending Diode laser was operated for bending two dimensional low carbon steel; P. J. Cheng et al. (2000) gave rigorous effort in analyzing then calculating the laser bending method and P. M Bhuyan et al. (2014) considered the study listed bending nature of aluminium worksheet & for the purpose of bending they make use of parabolic irradiations.

Vollertsen in 1994 derived an analytical model for approximating the value of bending angle for temperature gradient mechanism but his model does not consist of yield stress of the material Vollertsen, F. (1994).

P.J. Cheng, S.C. (2000) established analytical model for three dimensional temperature fields. They presented that analytical models were considering less time as compared to FEM models. P.J. Cheng et al. (2001) derived analytical model to find bend angle by laser beam. The bending angle measured here is equal to the summation of angle bend throughout heating and during cooling. A.Eidah et al. (2014) derived simple analytical method to study bending angle & the model was based on elastic & plastic concept for bending of worksheet. FEM models for laser bending given by Zhong Ji. Et al. (1998) established a simple model and studied the technique of laser forming specified by thermal stresses. Kyrsanidi et al. (1999) gave set of rules for the finite element. Proposed procedure capable to measure temperature, stress and strain. R. Kant and S.N Joshi (2016) developed a numerical representation for coupled thermal-structural analysis procedure. In this current study, simulation is conceded by using ANSYS software by thermal and structural coupled analysis. Then this ANSYS simulation is compared with experimental published data. The effects of sheet thickness and beam diameter on bending angle are also studied by using same parameters which are used in experimental published data.

### 3. FINITE ELEMENT FORMULATION OF STRAIGHT LINE LASER HEATING

Fig. 1. Depicts the representation of laser beam assisted bending procedure. The worksheet is fastened at one edge and heating of worksheet surface occurs via laser beam radiations. The softening of material surface is escaped by correcting the process constraints. The worksheet becomes extended in heated region and because of this reason thermal stresses are stimulated in worksheet. These thermal stresses are accountable for bending of worksheet.

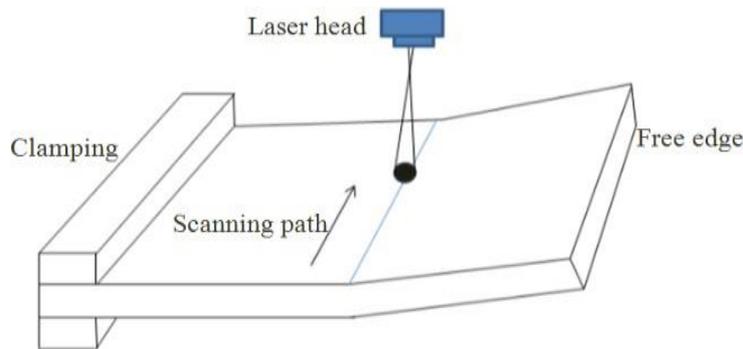


Fig 1. Diagrammatic representation of laser beam assisted bending process.

Parameters which are used in the simulation as per Kyrsanidi et al. (1999). Diameter of beam that is used is 16 mm, laser power of 2kW & velocities for scanning are 0.1 m/min., 0.15 m/min., 0.3 m/min. and 0.5 m/min. correspondingly. Material used for simulation as per published data is Shipbuilding steel (D36) with dimensions of 300mm length, 150mm width and 6mm of thickness of sheet. Properties of material used in this study are: Laser power used is of 2kW. Specific heat=427J/(Kg°C), density of material= 7860kg/m<sup>3</sup>, coefficient of thermal expansion =12\*10<sup>-6</sup>, thermal conductivity = 35.1W/(m °C), coefficient of absorption= 0.3, poisson's ratio = 0.3 & young's modulus = 200GPa.

#### 3.1. Heat Flux as an Input

Gaussian heat source is used as input load which generally follows the normal distribution. The heat flux can be shown as:

$$q = \frac{2AP}{\pi R^2} \exp\left(-\frac{2r^2}{R^2}\right) \quad (1)$$

Where, q=heat flux at top irradiated surface of material (watt/mm<sup>2</sup>), A = Coefficient of absorption, P = laser power (watt); R=Diameter of beam (in mm) and r = Distance commencing centre of beam (in mm)

#### 3.2. Thermal Model for Analysis

Temperature was produced in worksheet by means of radiation of beam which was evaluated by the support of non-linear equation of finite element i.e. three dimensional heat conduction equation:

$$k \left( \frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} + \frac{\partial^2 T}{\partial z^2} \right) = \rho c \frac{\partial T}{\partial t} \quad (2)$$

Boundary circumstance consists of loss of heat from worksheet's surface by natural convection

$$q_c = h(T_s - T_0) \quad (3)$$

### 3.3. Structural Model

The results from temperature based analysis is deployed as input for structural investigation. Sheet is clamped from one side as shown in Fig. 1 so that zero displacement and rotation was applied to the sheet.

Elasticity is calculated by Von-mises principle shown as:

$$J = \frac{1}{6} \left[ (\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2 \right] = K^2 \quad (4)$$

Where,  $\sigma_1, \sigma_2, \sigma_3$  are principal stresses in x, y and z direction respectively.

$$\frac{1}{3} \sigma_y^2 = K^2 \quad (5)$$

Where, K is the property of material. Equation (5) indicates that when  $J > K^2$ , the strain is elastic & while  $J < K^2$ , strain will be plastic.

## 4. SIMULATION RESULTS

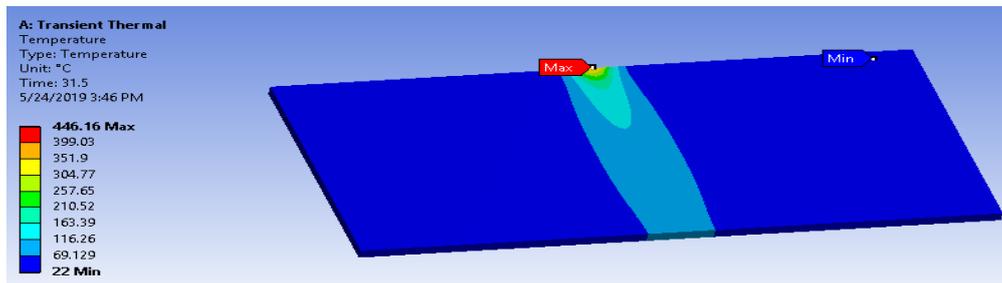


Fig. 2. Overall distribution of temperature for 2kW of laser power at scanning velocity of 0.3 m/min.

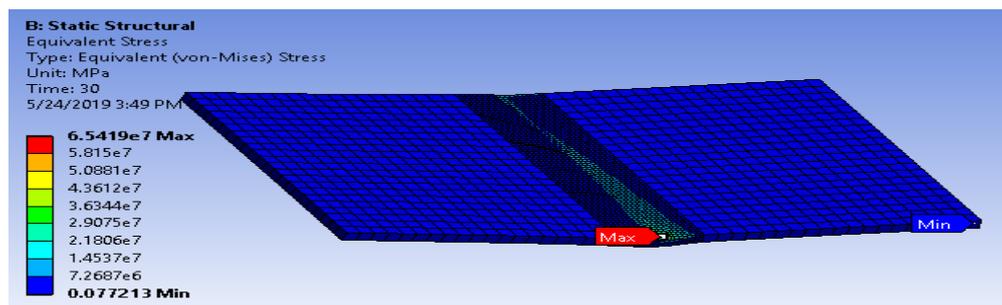


Fig. 3. Overall distribution of stress for 2kW of laser power at scan velocity 0.3m/min.

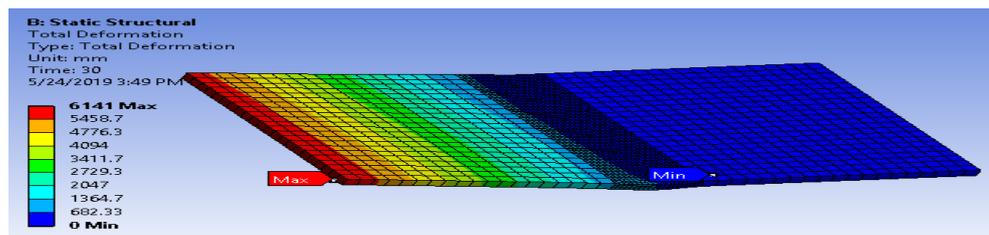


Fig. 4. Total displacement for 2kW laser power at scan velocity 0.3m/min

## 5. RESULTS AND DISCUSSIONS

For validation of the model, simulation outcomes have been matched with published investigational data of Kyrzanidi et al. (2000). Table 1 shows that at, 2kW laser power, the predicted bending angle is in decent promise with the issued experimental records.

Table 1. Assessment among experimental outcomes of Kyrzanidi et al. (2000) and FEM model for 2 kW laser beam power.

Scanning Velocity(m/min.)	Experimental bending angle	Predicted bending angle	% Error
0.1	1.1	0.98	10.9
0.15	1.15	1.06	7.8
0.3	0.96	0.76	20.8
0.5	0.34	0.30	11.7
Overall deviation:			12.8%

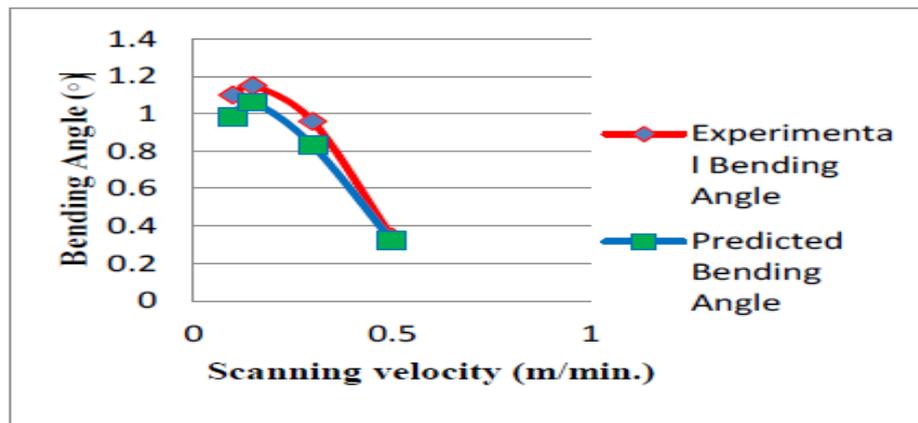


Fig. 5. Bending angle deliberated at several velocities of scanning in investigated model. [6] and forecasted model for 2kW laser power

Table 1. depicts comparison between the bend angle predicted by FEM model and published experimental data. Fig. 5 shows the variation between scanning velocities and bending angle at scanning speed of 0.1 m/min., 0.15 m/min., 0.3 m/min. & 0.5 m/min. Variation depicts that the bending angle increases upto certain value and then starts decreasing with increase in scan velocity. Variation indicates that bending angle of FEM model are in good agreement with the published experimental data with percentage error of 12.8%. This may be due to little interaction time b/w material of worksheet & beam of laser. Hence, fewer heat is attained which is inadequate to attain adequate bending angle.

### 5.1. Simulation results for bending angle at various sheet thickness for 2kW laser power

Table 2. Bending angle values at various sheet thickness at 2kW laser power

Sheet thickness	Bending Angle
1	3.8
2	1.2
3	0.3
4	0.153

Fig. 6. displays that bending angle values diminishes by rise in worksheet thickness which may be due to the fact that the heat induced on the uppermost surface is less and it give hint that there is reduction in temperature gradient lengthways and because of this reason bending of worksheet diminishes.

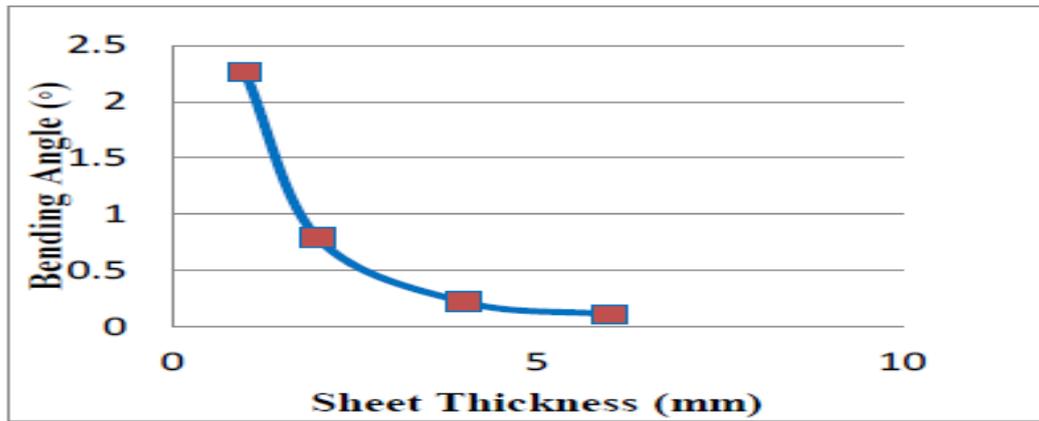


Fig. 6. Effect of sheet thickness on bending angle for 2kW laser power

### 5.2. Simulation results for bending angle at various beam diameter for 2kW laser power

Table 3. Bending angle values at various beam diameter at 2kW laser power

Beam diameter	Bending Angle
2	0.61
4	0.52
8	0.46
16	0.32

Table 3. shows the angle of bending values at various diameter of beam and Fig. 7. shows that bending angle falls with rise in diameter of beam of laser. It mainly governed by laser compactness. As diameter of laser beam rises there is drop in laser compactness and therefore, it leads to decrease in bending angle.

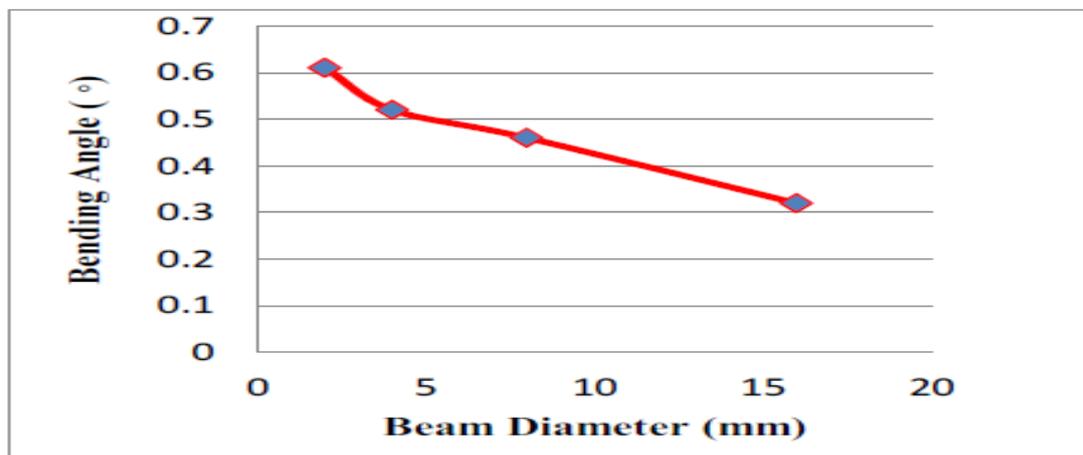


Fig. 7. Effect of beam diameter on bending angle for 2kW laser power

## 6. CONCLUSIONS AND SCOPE OF FUTURE WORK

Conclusions from our present work are given as follows:

1. Bending angle which we attained from our presented model is validated with experimental published data of Kyrzanidi et al. (2000) and the results indicates that the angle of bending drops by increases in velocity of scanning.
2. Results from simulation shows that with the increase in worksheet depth, there is decrease in bending angle of the worksheet.
3. Simulation outcomes also illustrates that angle of bending diminishes on increasing beam diameter of laser.

The simulation presented in this paper for laser beam bending process is a very useful tool and can be used in the development of the manufacturing world. Experimental setup can be developed for verifying the effects of process parameters on bending angle.

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## Thermal Analysis in Friction Stir Welding

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### Abstract

Friction stir welding is a solid state joining process which is used to join two workpieces without the use of consumable tool and without attaining the melting temperature of the workpieces. Friction stir welding process is used to join aluminium, magnesium, copper, stainless steel and titanium alloys. Experimental analysis of friction stir welding takes more time and also costlier. Numerical simulation of friction stir welding has eliminated these problems and is used in the last few years. This research investigates a thermal analysis in FSW process using Abaqus software. In this research, FSW is performed on different workpiece materials and these materials are aluminium AA6082, magnesium AZ31B and pure copper alloy. Also, this research analyzed the temperature distribution in different materials at various rotational speed of the tool pin that are 600 rpm, 650 rpm, 700 rpm, 800 rpm and 1000rpm. This research also compared the peak temperature on the center region of the weld at different rotational speed of the tool and also compared the peak temperature on advance side and retreat side of the workpiece at different speed of the tool. Results clearly indicates that at the same conditions, same rotational speed and same welding speed magnesium workpiece material generates more heat as compared to aluminium and copper workpiece.

**Keywords-** Friction Stir Welding, Abaqus, Numerical Simulation

### 1. INTRODUCTION

There are two different types of weldings, one is solid state welding and another one is fusion welding. In fusion welding, the material is welded and the temperature of welded workpiece passes the melting temperature of the materials whereas in solid state welding, the material is heated below the melting temperature of the materials as there is no melting in solid state welding. The major problem occurs in fusion welding during the solidification is hot cracking and because of melting in fusion welding process problem of porosity also occurs in fusion welding. To eliminate these defects, welding conditions and parameters must be carefully selected W.Tang et al. (1998). To overcome these problems, Wayne Thomas developed one of the solid state welding method that is friction stir welding in 1991. After that, various research has been done on FSW primarily concerned on strength of the welded joints H.Schimdt et al. (2004).

A rotating cylindrical tool comprises of two main components, one is tool pin and second is tool shoulder. Tool shoulder has a higher diameter than tool pin. A cylindrical tool with a profile probe is delivered into the workpieces which is to be joined, until the shoulder touches the workpiece. Tool is rotated for some time to increase the temperature of the workpieces that soften it. After that, the tool moves along the weld path gives strong weld joint Kallee, S. W. (2006). Heat rises because of relative motion between tool and workpieces and heat is also present within the material. All these heats are responsible for softening of the materials without melting. These heats melts the metal plastically. After that metal gets plasticized the downward force made a robust weld.

### 2. RESEARCH BACKGROUND

This chapter summarizes previous work of thermal analysis in FSW process. C.M Chen and R. Kovacevic et al. (2003) studied the thermal behavior of the welded material through the three dimensional model using FEA of friction stir welding using ANSYS software. Aluminium 6061 T6 alloy workpiece material is used in this model. Longitudinal stress, lateral stress along with temperature distribution were numerically simulated. The residual stress of the specimen is calculated through X ray diffraction technique. The relationship between the specimen residual stresses and parameter like tool traverse speed is observed. H Zhang, J H Huang and S B Lin et al. (2006) studied the thermal distribution of preheating time of FSW using simulation. Magnesium AZ31B work material is used in the simulation of FSW. To evaluate the necessary preheating conditions, thermal histories and distribution at various plunge speeds and rotational speeds are calculated and determined. This simulation of friction stir welding proves that the temperature or heat generation generated by the pin tool can not be neglected and nearly 14 % of the heat is produced.

Ahmed O, Al-Roubaiy & Saja M. Nabat et al. (2014) investigates FSW of aluminium and copper alloy by experimental and numerical simulation. In this experiment, two dissimilar metals are joined and thermal properties are studied. 5083- H116 aluminium alloy and pure copper were used as the workpiece material. The temperatures are forecasted by the inverse heat transfer method. The temperature was observed not only on the centre of the weld but also observed at the surroundings of the weld zone. Mechanical properties and microstructure is also studied for this model. Finite element analysis is completed by COSMOL Multiphysics.

Mahmoud Abbasi, Behrouz Bagheri and Rasoul Keivani et al. (2015) studied the thermal distribution during FSW process that was evaluated using ABAQUS software. For modeling and simulation of aluminium AA 6082 T6 in friction stir welding, ABAQUS software is used. Johnson cook coefficient was used in the abaqus software. This modelling also investigates the impact of tool pin on thermal distribution. Results shows that spherical pin generates the highest temperature at workpieces as compared to cylindrical and tapered pin.

M Iordache, C Badulescu, E Nitu et al. (2016) uses a ABAQUS software to simulate the friction stir welding process. Basically, there are two methods of simulation in abaqus software, one is ALE and another one is CEL method. In this simulation of abaqus software, coupled eulerian lagrangian (CEL) method is used. This model simulate the FSW process of aluminium AA 6082 T6 alloy. The model is also validated with the experimental results and the comparison between the simulated results and experimental results are satisfactory.

C.L. Yang et al. (2018) modelled a friction stir welding process of dissimilar alloys of aluminium and magnesium by numerical simulation. The material used for welding is aluminium 6061 T4 and AZ 31BZ4 magnesium alloy. The cutting tool material is H13 steel. In this model, magnesium alloy kept on the advance side whereas aluminium alloy kept on the retreat side. The laminar and local turbulence model is observed and then compared with each other. This model also clearly differentiate the temperature difference between the advance side and retreat side.

Bahman Meyghani, Mokhtar B Awang and Marina Rynkovskaya et al. (2019) uses the combined eulerian and langragian method for the simulation of the friction stir welding by abaqus software. Temperature distribution of the friction stir welding is evaluated in this research paper. Experimental model is also completed for comparison of the temperature distribution with the numerical simulation (using abaqus) results. The result of comparison of temperature between the experimental and simulation clearly shows the effectiveness of the simulated model.

Pankaj Sahlot and Amit Arora et al. (2019) investigates the friction stir welding process of copper alloy. In the past, a lot of research has been done on aluminium alloy so this research is focused on different workpiece material that is copper. This journal presents a numerical model of FSW process of copper. This paper finds out the temperature distribution, tensile strength of the welded joint.

Bahman Meyghani, Mokhtar B Awang et al. (2019) simulated the FSW process of aluminium 6061 T6 alloy using abaqus software. This model uses the arbitrary lagrangian eulerian method of the abaqus software. In the past studies, constant friction values are taken but that is not a realistic case. This research focused on the effect of the applying temperature on friction coefficient and results compared among different model. Results shows that the simulation where temperature dependent values of friction coefficient is given is the more realistic one.

M A Constantin, M D Iordache, E L Nitu1, M Diakhatw and Y Demmouche et al. (2020) investigates the effective simulation way to simulate the FSW of copper alloys using CEL method FEM. This paper aimed to decrease the simulation time of the friction stir welding using ABAQUS software.

### 3. RESEARCH METHOD

#### 3.1 Simulation of Friction stir welding

This section describes the simulation of FSW process. Friction stir welding is simulated using ABAQUS software by coupled eulerian lagrangian method.

##### 3.1.1 Assumptions made for thermal analysis

- Tool is considered as rigid part and isothermal.
- Workpiece material is considered as homogenous and isotropic.
- Friction coefficient of workpiece is considered as constant during the friction stir welding.
- Initial temperature of whole model is taken as room temperature (25°C).

### 3.1.2 Simulation Steps

Table 1. Simulation steps in friction stir welding

Step number	Step time(sec)	Description
1	0.02	Tool plunges down into the tool
2	0.01	Tool rotate for preheating workpiece
3	1.97	Tool moves forward along the weld path(traverse)

### 3.1.3 Meshing used in Simulation

A uniform meshes has been generated on tool and workpiece. Figure 3.3 shows the meshes that are made for simulation of FSW process. Tool consists of 954 meshes and workpiece consist of 1800 meshes.

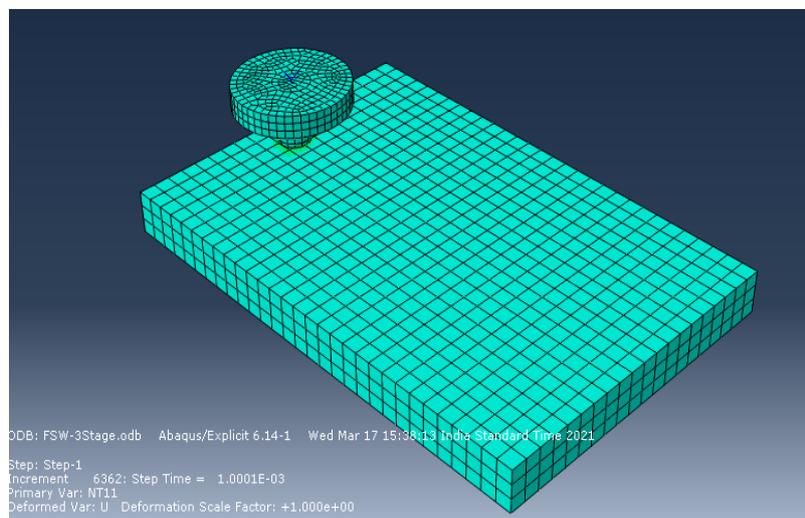


Figure 1. Statistics of meshes used in simulation of FSW

### 3.1.4 Material properties

Friction stir welding simulation completed on three different materials and these are aluminium AA6082 T6 alloy, magnesium AZ31B alloy and copper alloy. The johnson cook model of the aluminium alloy needed for simulation is taken from table 2 of M Iordache et al. (2016) [20]. The physical properties of magnesium Mg AZ31B is taken from table 3 of C.L Yong et al. (2018) [21] and johnson cook coefficients taken from table 2 of F.Abbasi et al. (2016) [26]. The physical properties and johnson cook coefficient of copper alloy are taken from table 1 and table 2 of M A Constantin et al. (2016).

### 3.1.5 Boundary conditions

The whole model is kept initially at room temperature (25°C). The workpiece is fixed coefficient of friction of material is kept constant at 0.3. Three different materials are simulated in abaqus software at five different rotational speeds of 600rpm, 650rpm, 700rpm, 800rpm and 1000rpm. The welding speed is 0.3 m/min.

Table 2. Dimensions of tool and workpiece

Tool shoulder diameter	Tool pin diameter	Tool pin height	Workpiece length	Workpiece breadth	Workpiece thickness
15mm	4.8mm	4.8mm	60mm	20mm	5mm

## 4. Numerical Simulation

Three different materials are used as workpiece and these are aluminium, magnesium and copper. Peak temperature of different material at different rotational speed of tool are compared. Five different rotational

speed of tool are 600rpm, 650rpm, 700rpm, 800rpm and 1000rpm. The welding speed is kept constant at all cases is 1.5m/min. Total simulation time is 2 second.

Table 3. Different cases in simulation of FSW process.

Workpiece material	Rotational speed(rpm)	Welding speed (m/min)	Workpiece thickness (mm)
Aluminum	600	0.3	5
Copper	650		
Magnesium	700		
	800		
	1000		

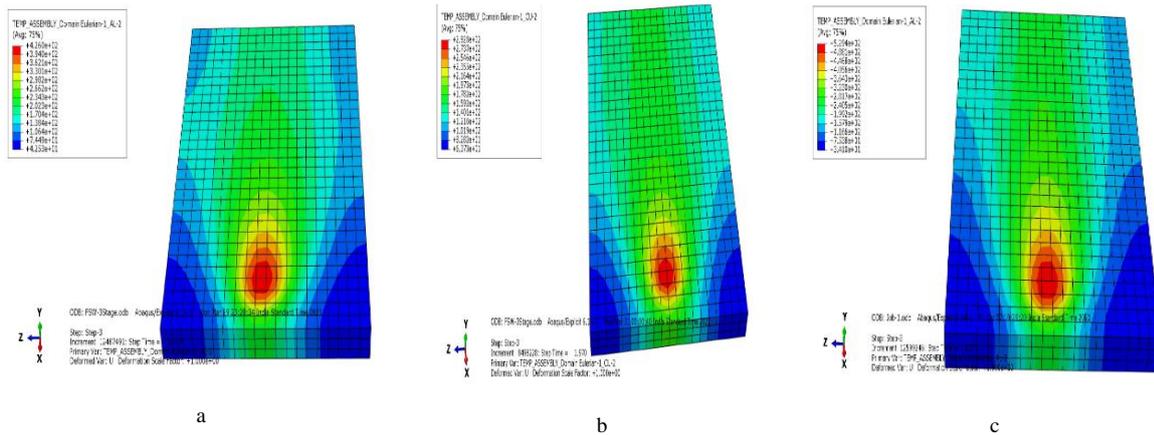


Figure 2. Temperature distribution in aluminium (a), copper (b) and magnesium (c) alloy at tool speed of 600rpm and welding speed 0.3m/min.

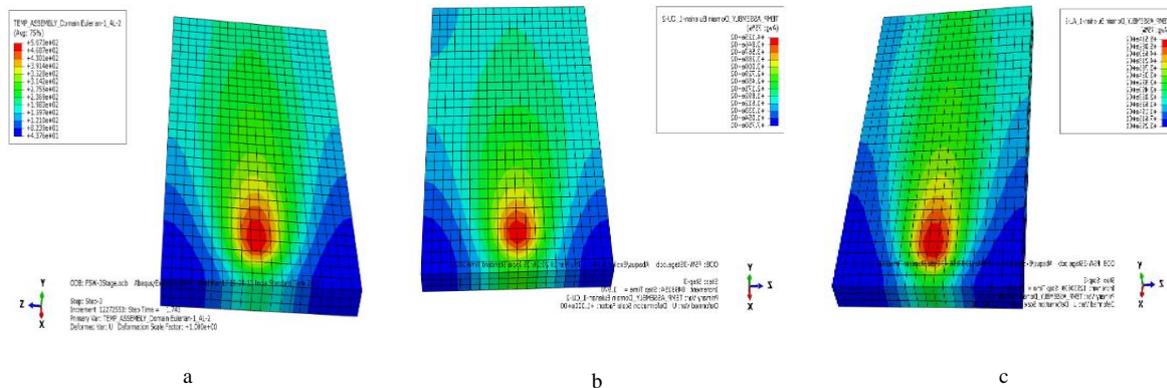


Figure 3. Temperature distribution in aluminium (a), copper (b) and magnesium(c) alloy at tool speed of 1000 rpm and welding speed of 0.3 m/min.

## 5. RESULT DISCUSSION

### 5.1 Comparison of temperature profiles of different materials at specific rotational speed

From figure 4 is clearly seen that magnesium shows a highest peak temperature of 521°C in the center region of upper surface of workpiece. This indicated that magnesium material is more sensitive to heat generation as compared to aluminium and copper alloys. Same results are obtained from the different rotational speed of tool of 650rpm, 700rpm, 800rpm and 1000rpm.

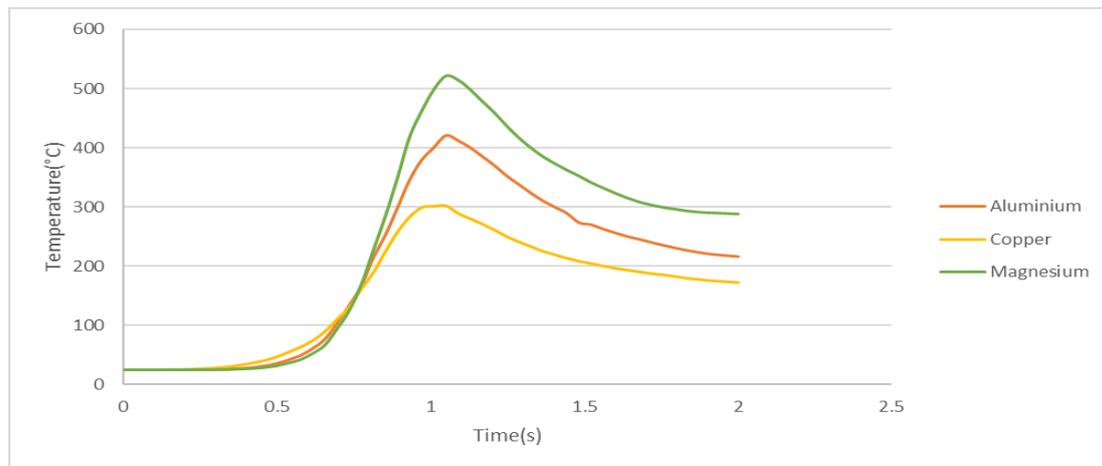


Figure 4 Temperature profiles of welded joint in the center of upper surface of different workpiece materials at 600 rpm.

Table 4 Peak temperature of different material in center region of top surface at 600rpm

Workpiece material	Rotational speed of tool(rpm)	Peak temperature(°C)
Aluminium	600	420
Copper	600	303
Magnesium	600	521

## 5.2 Comparison of temperature profiles of materials at center, 5mm on advance side and 5mm on retreat side

Figure 5 shows that the peak temperature on the center is higher than the advance and retreat side. As tool passes from the center, it increases the peak temperature at the center higher as compared to the advancing and retreating side. This also indicated that heat generation on the advancing side during FSW process is more than that on the retreating side.

Table 5 Peak temperature of aluminium at center region, 5mm from center on advancing side and 5mm from center on retreating side under 1000 rpm.

Temperature profile location	Rotational speed (rpm)	Peak temperature(°C)
Center region on top surface	1000	515
5mm from center on advancing side	1000	392
5mm from center on retreating side	1000	331

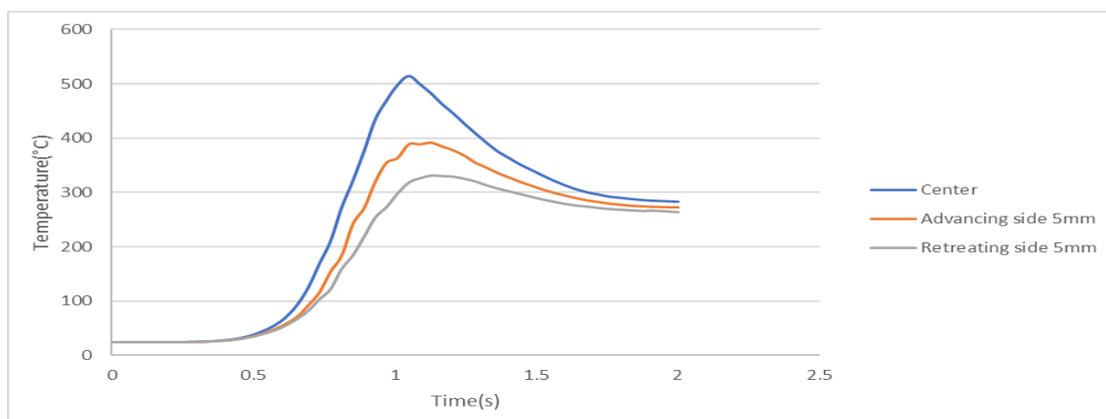


Figure 5.2 Temperature profiles of welded joint on the center, advance side and retreat side of top surface of aluminium at 1000 rpm.

### 5.3 Comparison of temperature profiles on center of specific material at different rotational speed.

Figure 6 clearly shows that if the rotational speed of the tool increases, it increases the peak temperature. The peak temperature at rotational speed of 600 rpm is 420°C and at 1000 rpm is 515°C which is higher than that of 600 rpm rotational speed. Similar results are obtained if the workpiece material is changed to magnesium and copper alloy. This clearly concludes that if we increase the rotational speed of tool, it raises the temperature distribution in the workpiece material.

Table 6. Peak temperature of aluminium 6082 T6 workpiece on center of weld at different rotational speed.

Rotational speed of tool(rpm)	Workpiece material	Peak temperature(°C)
600	Aluminium	420
650	Aluminium	433
700	Aluminium	447
800	Aluminium	472
1000	Aluminium	515

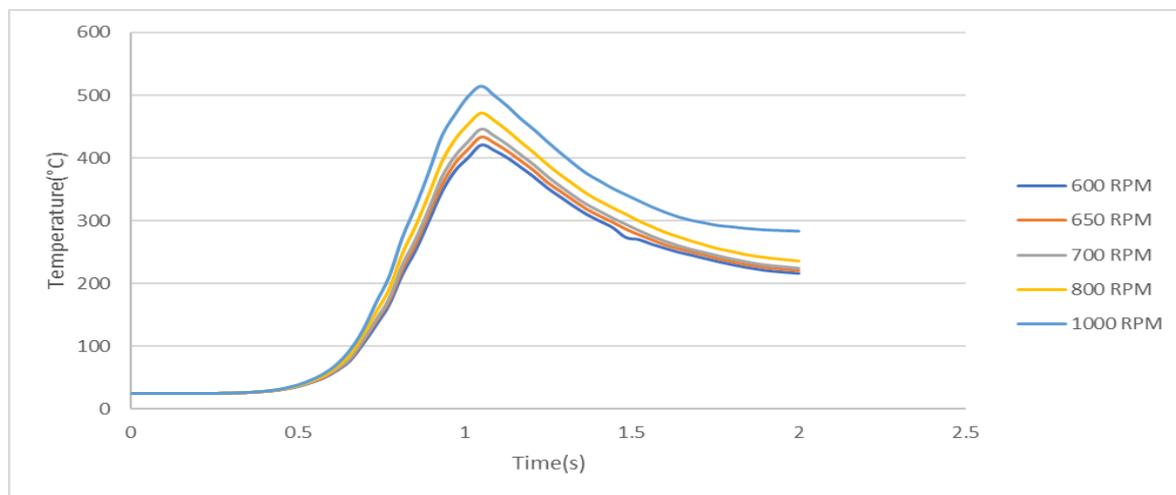


Figure 6 Temperature profile on the center of aluminium workpiece at different rotational speed.

## 6. CONCLUSION

At the same conditions, same rotational speed and same welding speed magnesium workpiece material generates more heat as compared to aluminium and copper workpiece. Also temperature generation on the advancing side of the workpiece material is more than retreating side of the workpiece material. Peak temperature increases as the rotational speed of tool increases and the increased temperature depends on the value of increased rotational speed.

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## Experimental Investigation On Tensile Behavior Of Sugarcane Bagasse Filled With Rice Husk Epoxy Composite

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### Abstract

Nowadays fabrication of natural fiber composites increased in various field due to their properties like eco-friendly, recyclability and biodegradability. These fibers also have good mechanical and physical properties and we can utilize it more effectively by fabricating composite for various industrial and many other applications. In this study we try to fabricate rice husk and sugarcane bagasse hybrid composite and deals with their mechanical properties. These fibers are chemically treated with NaOH and chopped very fine before fabrication of composite. Samples are fabricated with varying 10%, 15%, 20%, 25%, 30% volume of sugarcane bagasse with 10% volume of rice husk. After preparation of composite their tensile strength is observed.

**Keywords-** Sugarcane bagasse fiber(SCBF), rice husk fiber(RHF), tensile strength, alkali treatment.

### 1. INTRODUCTION

Natural fiber composites are one of the best alternative to replace synthetic composites for producing eco-friendly domestic and industrial component [1]. Now most of the country uses natural fiber rather than synthetic fiber due to their properties like biodegradability and recyclability for healthy environment[2]. Natural fibers are cheap, easily available and eco-friendly, it can be used as a composite materials for technological and industrial applications due to their great potential [3]. Natural fibers further minimise the mass of the composite due to their low density [4]. If the fibers are residues from agro industrial processes, and their raw qualities are suited for composites, this is very significant[5]. Natural fiber polymer composites can be employed as structural materials because they have better mechanical qualities than polymer resins, and they are not only inexpensive but also simple to make [6]. The mechanical and chemical qualities of natural fiber are determined by the amount of cellulose present on the fiber, which varies from fiber to fiber, the amount of cellulose present on the fiber determines the mechanical and chemical properties [7]. Sugarcane bagasse is a agricultural waste and is easily available. A very less effort have beendone to use sugarcane bagasse, to develop disposable plates and cups etc. Mostly it is used as a fule in the sugar plant, many places bagasse is used as a construction material [8][9]. Sugar cane waste is composed of 38% cellulose 28% hemicellulose and 24% Lignin [10] India produce large amount of rice husk (approximately 840000 tons per year). Mostly it is used as a filler material for fabrication of biodegradable composites due to its properties like toughness lower weight and weathering resistance [11]. In this study, sugarcane bagasse is combined with rice husk as a reinforcement material to create a hybrid composite with improved mechanical properties. Hybridization of composites improves the mechanical, electrical, and thermal properties of the material, making it ideal for custom engineering applications [12]. One technique to improve natural fiber's mechanical and thermal qualities is to chemically treat it. To boost the strength and adhesion of sugarcane bagasse fibers, they are treated with a sodium hydroxide (NaOH) solution. In natural fiber reinforced composites, alkali treatment is an effective approach to improve fiber matrix addition [13]. Alkali treatment changed the composition structure and characteristics of sugarcane bagasse fiber. The cellulose content of sugarcane bagasse fiber increases when it is treated with an alkali solution, whereas hemicelluloses and lignin content decreases [14].

Table no. 1 chemical properties of SCBF and RHF

fibers	Cellulose%	Hemicelluloses%	Lignin%	Moisture%
SCBF	34-38	23-28	20-24	12-17
RHF	35-40	15-20	25-30	10-15

## 2. RESEARCH BACKGROUND

Composite materials are compatible with metals particularly for use of structures and engineering applications, they have amazing stability and physical behavior, Z. Sun (2016). Reddy investigated the mechanical characteristics of kapok/sisal/polypropylene composites with various fiber volumes. He discovered that increasing the amount of seashell in the material gradually reduces the tensile and flexural characteristics, T. S. R. G. V. Reddy and S. V. Naidu (2008).

## 3. EXPERIMENTAL PROCEDURE

### 3.1 Materials

A local sugarcane processor provided raw sugarcane bagasse for the composites. To remove its moisture bagasse was dried in sunlight for 24 hours. rice husk where received from nearest rice mill. To remove its impurities like bran rice, send dust it was cleaned with fresh water and after then it was dried in sunlight for 48 hours. Epoxy resin, Alkali(NaOH) were purchase from nearest local retailer. The ratio of hardener and epoxy is 1:1.

Table no.2 Composition of specimen

SAMPLE NO.	COMPOSITION (IN VOLUME)
1	Epoxy(80%)+RH(10%)+SCB(10%) Epoxy(75%)+RH(10%)+SCB(15%)
2	Epoxy(70%)+RH(10%)+SCB(20%) Epoxy(65%)+RH(10%)+SCB(25%)
3	Epoxy(60%)+RH(10%)+SCB(30%)
4	
5	

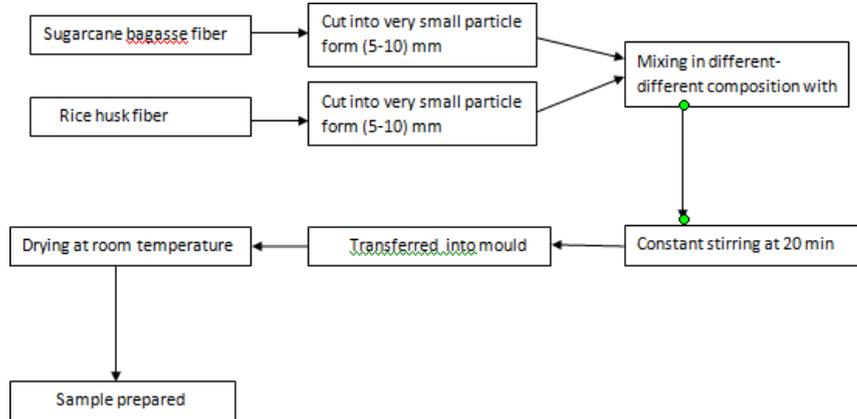
### 3.2 Chemical treatment

Before fabrication of composite rice husk and sugarcane bagasse where treated with a solution containing 5% (NaOH). The fibres were merged in (NaOH) alkali solution for 6 hour. Then the fibers were dried for 24 hours at room temperature. Chemical treatment improve the compatibility and bonding between the fibers.

### 3.3 Fabrication of composite

Composites were made by using a wooden mould the dimension of the Mould was (250×25×5) mm<sup>3</sup> Length, width and thickness. Composites were prepared with varying volume of fibers shown in table no.2 and the ratio of hardener and epoxy is 1:1.

### Diagram of composite preparation



#### 4. TEST

##### 4.1 Tensile test

In tensile test the sample is fixed between two fixtures called grip which clamp the material. Then begin to apply weight to the one end of fixture. Tensile test is destructive in nature. Which provide tensile strength of the materials. It is used to predict how a material will react when subjected to a tension load. A sample is tugged to its breaking point in a simple tensile test. The amount of force applied to the sample and elongation of sample are measured. Dimension of mould for tensile test was (250×25×5) mm cube as per ASTM D3039 standard.

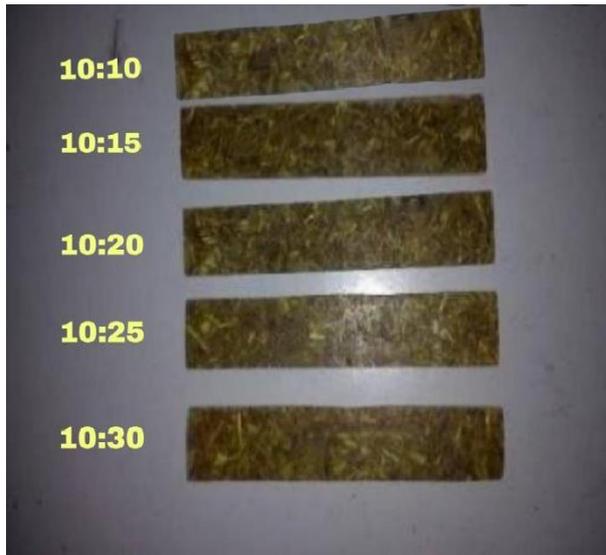


Fig.no1-Tensile test specimen



Fig.no.2-Universal testing machine

#### 5. Result Discussion

In this paper an attempt is made to improve the mechanical properties of sugarcane bagasse and rice husk fiber. Improve the bonding and addition properties fibers are treated with 5% of (NaOH) solution. Tensile strength of hybrid composites were evaluated for different different composition of sugarcane bagasse and rice husk fiber. From the result obtained we observed that while increasing the amount of sugarcane bagasse fiber tensile strength increasing up to 25% of sugarcane bagasse fiber. This is due to uniform mixing between the fibers and their bonding and addition property for this composition.

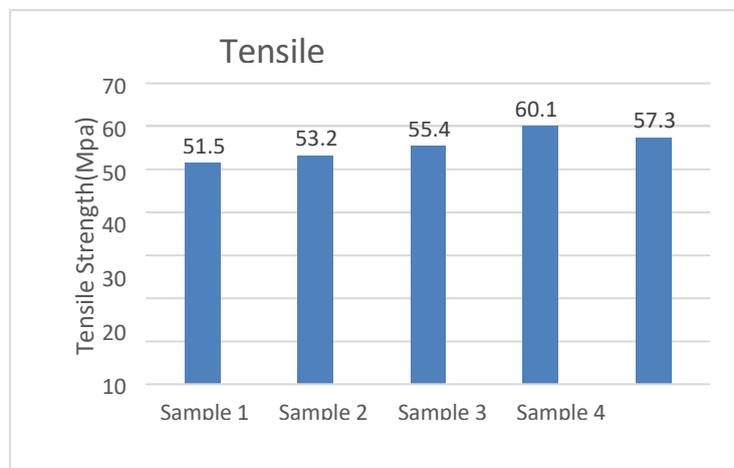


Fig. no.- 3 tensile test result of composite



## 6. Conclusion

After successfully study of sugarcane bagasse and rice husk hybrid composite we can conclude following points.

- Improved tensile strength was observed by sample number 4 which containing 10% volume of Rises and 25% volume of sugarcane bagasse.
- Mechanical property achieved with composite is adequate for industrial and domestic applications.
- The natural fiber composites are very cheap, easily available and eco-friendly we can utilize it for healthy environment.

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## **Wanderer: Mars rover prototype with a modified four-link suspension system**

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### **Abstract**

In this paper, we have discussed the wanderer – a four-wheeled mars rover prototype. A newly small robotic rover is presented because of its advantage in weight and ability to move through the dust alien track of mars. The aim was to design a prototype that used fewer parts and provided similar functionality to that of the conventional rover design. We have designed a custom four-link suspension that is inspired by the suspension system used in formula one cars. The rover could sense the temperature and humidity of the surroundings. It will also be able to map the surface using depth-sensing using a stereo camera. A brief description of the wheel design, control system architecture, components selected, facts and features, and techniques to be used for the development of the rover are discussed below.

**Keywords-** planetary rovers, four-link suspension system, Navigation systems, Rover Electronics

### **1. INTRODUCTION**

Since ancient times, humans have been curious about their position in the universe. Thanks to the curious human beings and their efforts in space exploration, today we are equipped with technologies such as GPS, accurate weather reports, the camera on phones, CAT scan, scratch-resistant glasses, LEDs, etc. But, the artificial satellites sent to space are not capable of providing precise information about the environment, soil composition, climate conditions, etc. To collect this information, rovers are sent to extra-terrestrial bodies. Rover is a planetary exploration device designed to land on different terrestrial bodies and provide information about its weather, humidity, temperature, soil composition, search for minerals, or even find the existence of life on the planet. The rover chassis and suspension system are specifically designed to withstand landing impact, survive extreme weather conditions, move over rugged terrain, and secure the components such as cameras, microcontrollers, sensors, communication systems, power units, etc. A rover comprises of a body (to protect vital organs), computer (to process information), sensors (to collect data), arm (to perform tasks and to position cameras), wheels/legs (for mobility), power unit, communication system (to send data to earth), and temperature controls (to maintain internal temperature). Through this paper, we have introduced a custom-designed four-wheeled suspension system for a mars rover. We have also implemented depth-sensing (to give the best possible path for travel), SLAM (for navigation), custom build battery (for power), and different sensors to collect data.

### **2. RESEARCH BACKGROUND**

Exploration of planetary surfaces by rovers has been researched at JPL since the early 1960's [2]. According to the features of the mobile mechanism of robots, the rovers can be wheeled, legged, tracked, etc [5]. The wheel-step locomotion is produced by changing the distance between the middle and front wheel [3]. A thorough study on rovers based on rocker-bogie mechanism is discussed in [5,12]. A rover configuration with asymmetric mobility system was proposed to analyze its motion performance [6]. A wheel step design has also been proposed by [14]. The wheel-step locomotion is produced by changing the distance between the middle and front wheel. The angle-adjusting mechanism is used to change two joints between the rocker sections and the body, which makes the wheelbase change [14]. The rover has four independently driven wheel-legs which are based on a double half-revolution mechanism [8]. It has been observed that the larger the friction feasible region, the better the obstacle-climbing ability [8]. A brief overview of a rover MAYA has been given in [10]. It discusses the design architecture and rover mechanics, electronics, communication, live streams, software usage, tasks and features alongside with experiments of the rover [10]. Power supply is a crucial part for every Mars mission. [11] demonstrates that a two triple-junction deployable solar panel are efficient for rover surface operations. The batteries can supply power at night for at least 90 Mars days and can also supply power during

launch. A thorough review of major steps for navigation systems, Path-planning, obstacle-avoidance, and terrain analysis is given in [13].

Based on the literature mentioned above, we have inferred that the rocker-bogie suspension systems are widely used for the rovers because of their excellent obstacle avoidance capabilities. This simple design can climb obstacles twice the size of wheel diameter. Some papers have also proposed a modified version of rocker-bogie suspension to improve the rover's stability at high-speeds. Apart from this, there are many papers who has proposed different suspension mechanisms such as, wheel-step rover, asymmetric design for mobility, double half-revolution mechanism, and simplified four-wheeled mechanisms. The results and observations of all these papers have helped us to define parameters for rover analysis. We have also modified our design several times based on the ideas and perspective of the literature. The study on different control systems and navigation systems have helped us to define the structure of the control and navigation system. It has helped us to understand the integration of SLAM (Simultaneous Localizing and Mapping) for navigation, cameras for depth-sensing, communication system, and different sensors for rover functions.

We have concluded that for better performance of the rover following parameters are necessary:

1. Weight reduction of the rover is important for better mobility.
2. The rover designed should be tested on different types of soil and should withstand extreme conditions.
3. Path-planning, obstacle avoidance and terrain analysis capability of a rover is very important for selection of best possible path of travel.
4. Fast and accurate processing of data provided by the sensors should be preferred.

### 3. DESIGN AND ROVER MECHANISM

The paper proposes a modified four-link suspension system for a mars rover. As shown in fig.1, the four-link suspension system consists of an upper link and a lower link mounted directly to the chassis on one side and interconnected using a connecting link.

Four link suspension system generally are of two types:

- i. Triangulated
- ii. Parallel.

In triangulated four-link suspension system, the shorter upper links are built at an offset with respect to the lower link such that when viewed from the top, the distance between the chassis-side upper link mount and wheel-side upper link mount are different. Whereas in the parallel four-link suspension system, the upper and the lower links are more or less of the same length and in-line when viewed from the top.

We have used a form of parallel four-link system where the upper and lower links are of different lengths but in-line. The reason being that the system acts as a single link extending from the wheel assembly to the instantaneous center of rotation (IC) as shown in fig.1. The parallel arrangement gives us higher wheel travel and minimizes wheel-base variation. The wheels remain grounded even if it hits a rock as the links of one -side are independent of the other.

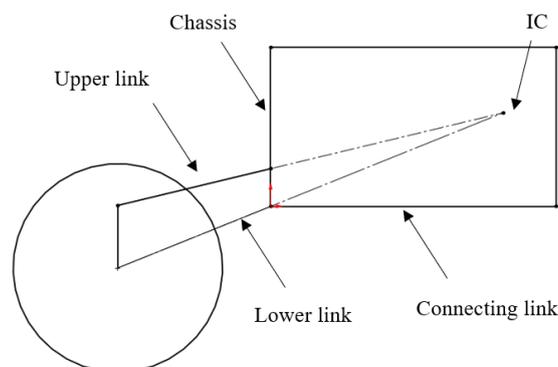


Fig. 1 Side view of four link suspension

This paper proposes a method to interconnect the front and rear four-link suspension system on either side. Basically, a pushrod connects the upper link with rocker-shock up assembly. As the upper link and push rod

pivots along the x-axis, the rocker rotates through the corresponding angle, hence loading the spring. Since the other end of the spring is connected to the corresponding longitudinal set of links (front-rear connection), some part of the displacement in the spring is transmitted to the other wheel in the opposite direction. Therefore, as the front wheel jounces the rear wheel is pushed down negating body pitch by up to 50%.

Following are the parameters considered while designing:

A. Motion ratio

The ratio of the displacement between the point of interest (in this case wheel) and other point(spring) is known as the motion ratio of a mechanism. Hence it is a crucial design parameter when it comes to determining the available wheel travel in a suspension system. The mechanism discussed here manages motion ratio using three methods,

- i. location of mounting point for connecting link on the lower link.
- ii. Location of push rod mounting point on upper link.
- iii. Ratio between push rod-rocker arm and spring-rocker arm.

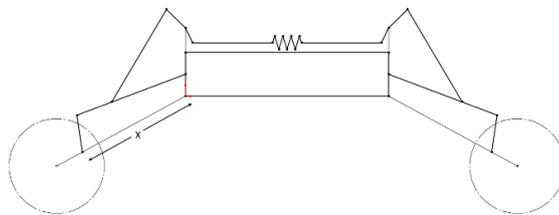


Fig 2.1 Position of connecting link

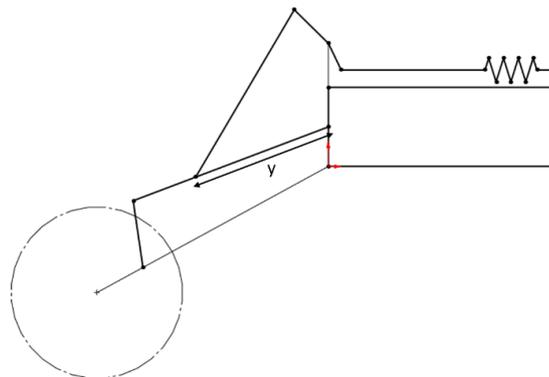


Fig 2.2 Position of push-rod

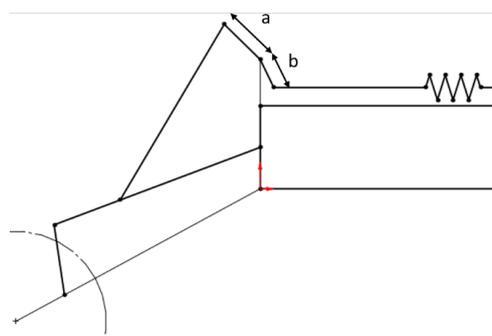


Fig 2.3 Ratio of rocker arms

### B. Anti-squat and anti-dive

Anti-squat is the percentage of the rear squatting under acceleration and anti-dive is the percentage of the front diving under braking.

In this case the body pitch can be controlled using three methods:

- i. The distance between chassis side pivots of upper and lower link compared to the distance between wheel side pivots of the same.
- ii. Friction in joints
- iii. Distance between rocker pivots

## 4. ROVER ELECTRONICS

### A. Communication Systems

The communication between the Jetson Nano and a laptop was essential so a USB Wi-Fi Adapter was connected to the Jetson Nano. The Wi-Fi Adapter used was the TP Link TL-WN725N. The Jetson Nano was set as the edge device and a laptop was set as the main device. Both devices were connected to a common Wi-Fi network which allowed communication between the devices. Always AI was the software used to receive the camera feed from the Jetson Nano with the processing data.

### B. Power Systems

We decided to implement buck converters for the power circuit. The input voltages were set using a digital multimeter and the converters were put in a test circuit for flaws. The required voltages to be used as inputs ranged from 3.5V -12V. Overheating is not an issue for the buck converter and the voltage can be varied according to the requirements.

### C. Sensor

The rover is fitted with a variety of sensors, each having an essential purpose. The STM32F3 Discovery Kit is fitted with ST MEMS motion sensor, 3-axis digital output gyroscope, 3D digital linear acceleration sensor and a digital magnetic sensor which are used for the purpose of navigation and positioning of the rover. A DHT 11 sensor is attached to check for the humidity and temperature in the environment. An additional camera is fixed on a turntable powered by a motor at a height of 30 cm to get a 360 view of the surrounding. The MPL311A2 was used as a barometer to measure the pressure and it also provides the altitude. For additional obstacle detection, the front was fitted with an ultrasonic sensor, SFR05, which was used as a backup in case an object was not detected by the camera.

### D. Encoders

OE-775 Hall Effect Two Channel Magnetic Encoder is attached on each of the four motors used for the driver. It helps ensure each motor is moving as it is supposed to. One of the main advantages that when the rover is instructed to move in a straight line, the four encoders will match the values to ensure all the motors are rotating at the same speed. Also, it will help to stop the rover on a slope, if necessary, since the encoders can detect the backward and with the help of the code the rover can be programmed to counter the value achieved when it starts moving back.

## 5. CONTROL SYSTEMS

We use two boards to operate our mechanism- A STM32F3 Discovery Kit and the NVIDIA Jetson Nano.

The NVIDIA Jetson Nano is used for the main processing. The sensors, stereo camera and the STM32F3 Developer kit is connected to the Jetson Nano. The stereo camera serves the purpose of depth sensing while autonomous driving. This helps in the rover to understand which obstacles it can overcome and which to avoid. An additional webcam is connected to provide a wide view of the rover's surrounding.

The STM32F3 Developer kit is connected to the motor drivers and hence is responsible for the motion of the rover. It communicates with the Jetson Nano on which path to take and hence enables the motors to take the decided path. The onboard sensors are also used for the navigation of the rover.

## 6. SIMULATION AND RESULTS

The simulation was performed on MSC Adams which is a multibody dynamics simulation software that accepts inputs such as different linkages, joint variables, gravity, contact variables and forces/motion to run the simulation and record the results for future analysis.

To test the vehicle on a rough extra-terrestrial terrain, a sample terrain was designed that represented various geographic features commonly found on the Martian surface such as rocky flats, sand dunes and sudden drops.

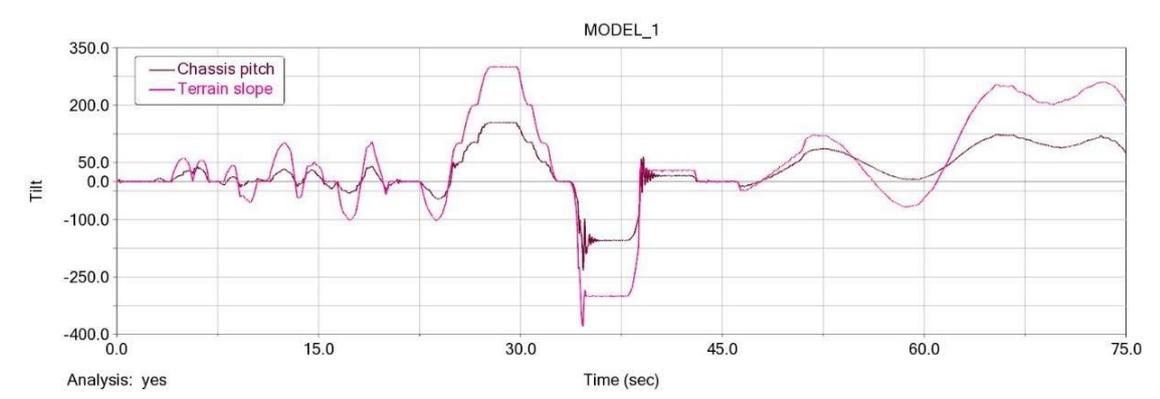
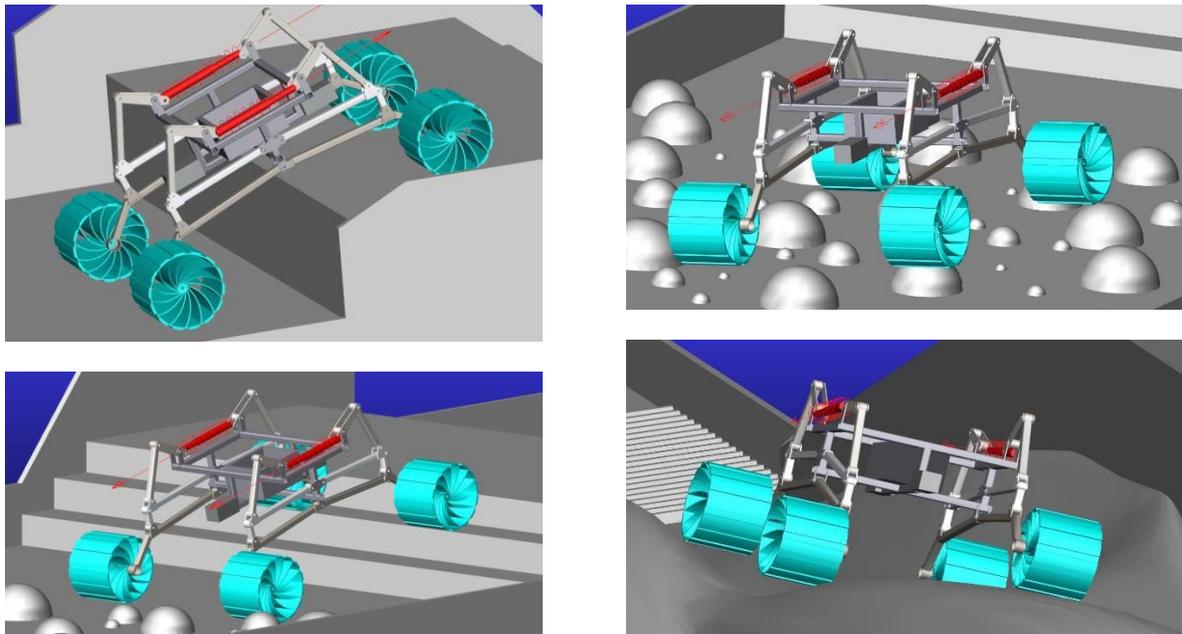


Fig.3 Simulation

Through the simulation, we observed that:

1. All the four wheels always remained in contact with the ground.
2. The body/chassis counters the tilt given due to the terrain trying to stay horizontal.
3. It dampens the oscillations caused due to bumps using the spring damper system and friction caused in the joints.

## 7. CONCLUSION

Through this project, we are proposing a custom four wheeled suspension system which can form a base for a Mars rover. This report comprises of the design and simulation results of the prototypes made for the project. Jetson Nano has been used for object detection and path planning. The rover can be further developed for



advance functions such as soil composition, testing and drilling. An additional arm can also be attached with the rover for various other functions like positioning, typing, extended and 360 view of the surrounding. As the rover is based on a four-wheeled mechanism, it requires less motors, motor drivers, and tyres, compared to six-wheeled mechanisms. This also results in reduction of the overall weight of the rover for better mobility. This mechanism has its applications for various other autonomous vehicles such as: Wheelchairs capable of travelling through rough terrains, Military Unmanned ground vehicles to provide medical aid in the war field, Firefighting to enter the dangerous zones without the risk of health hazards, bomb diffusing squad, etc.

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## Process modelling of Electrical Discharge Machining by Artificial Neural Networks: A review

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### Abstract

Electrical discharge machining (EDM) has emerged as a promising unconventional method to machine electrically conductive parts irrespective of their hardness. It finds applications in numerous sectors such as aerospace, die and mould making, medical and miniature parts. Various techniques such as regression is used for process modelling. However, due to the complex and stochastic nature of the process and also the underlying non linear interactions, soft computing techniques such as artificial neural network (ANN) is utilized to model the process as well as to predict the responses. ANN draws its inspiration from human nervous system. In this work, the applications of ANN in the field of EDM have been detailed. It may serve a ready reference for researchers who are planning to use this soft computing technique in the field of EDM.

**Keywords – EDM, ANN, SR, MRR, MLP**

### 1. INTRODUCTION

ANN can be referred to as a processing unit that has wide distribution parallelly. It comprises of neurons [1]–[3], which are the units of processing, and are naturally capable to figure out and store experimentally related information to be credible for usage [4], [5]. ANN possess admirable attributes such as robustness [6], [7], adaptiveness [8], capability related to mapping [9] and these are responsible for making ANN a strong and clever tool instrument used for modelling and prediction in practical applications of non linear nature [10]–[14] and resulting in saving time and expenses [15]. Generally, the model of neuron applied to design large number of ANN model comprises of connection link groups, possessing their own weights [16]–[18], referred to as synapse. These are multiplied by individual inputs and all summed up, along with bias. Later on, an activation function gets applied to this (Fig. 1) [19].

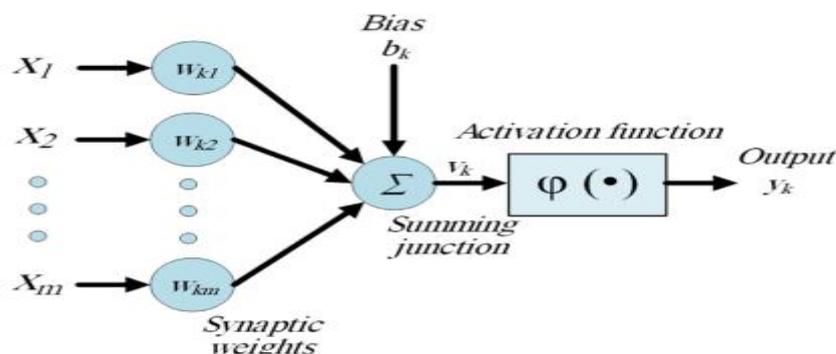


Fig. 1. Neuron's non-linear model [19]

ANNs belong to the category of machine learning and draw their inspiration from the functioning of human brain [20]–[22]. These primarily consist of input layer, hidden layer and output layer [23]–[33]. ANN does the learning of relations in between the parameters and understanding of the situation being investigated [34].



Hidden layer comprise of undetected nodes which perform transformation of input [35]. The number of input parameters corresponds to the count of neurons in input layer. Finally, collection of processed signal in output layer forms network output solution [36]. This iterated learned model produced gives assistance for making of decision [37]. ANN developed model represents appreciable prediction results [38]–[40]. ANNs are generally classified into recurrent and feedforward neural networks. The latter include radial basis network, multilayer perceptron, single layered perceptron and the former include Hopfield and competitive type, alongwith other type of networks [41]–[44]. The cause-effect diagram related to ANN model’s performance is depicted in Fig. 2 [7].

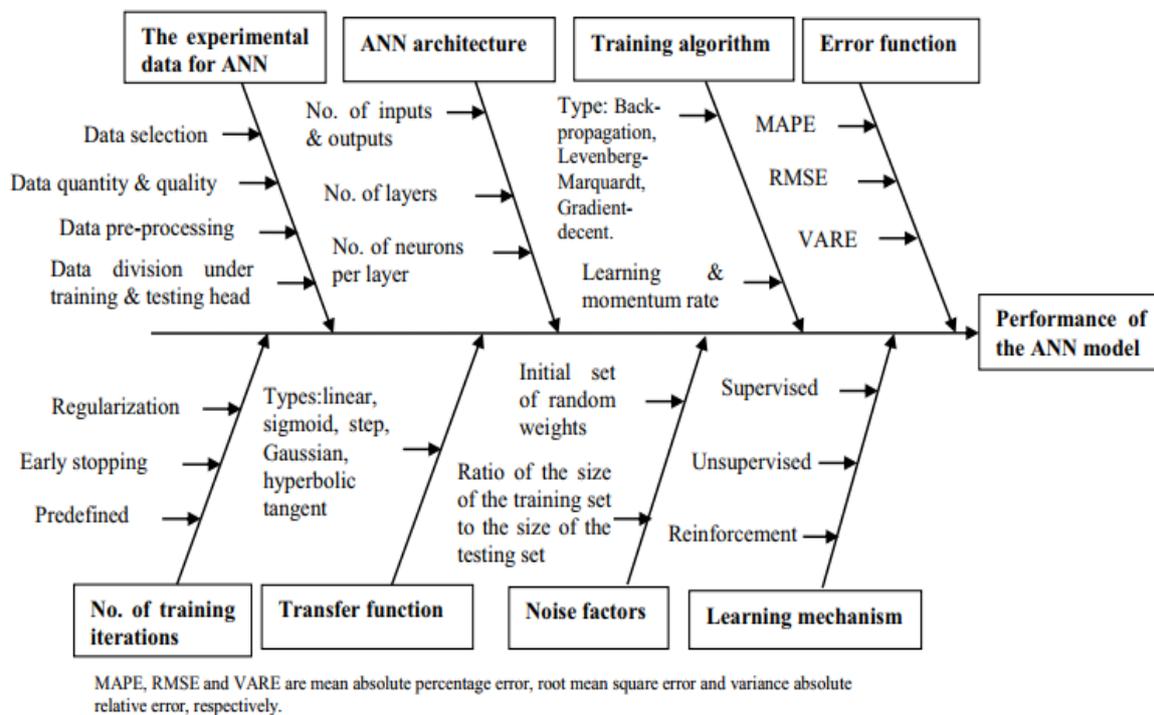


Fig. 2. Cause-effect diagram [7]

Electrical Discharge Machining (EDM) is a widely popularized non-conventional machining process applied for machining electrically conductive materials (Fig. 3). While carrying out the experimentation, various control factors are associated and performance variables are obtained. Due to the stochastic-complex nature of the process, non-linear modelling needs to be carried out most often and soft computing techniques such as ANN are a befitting solution for process modelling in many cases, in comparison to other modelling techniques [45]–[55].

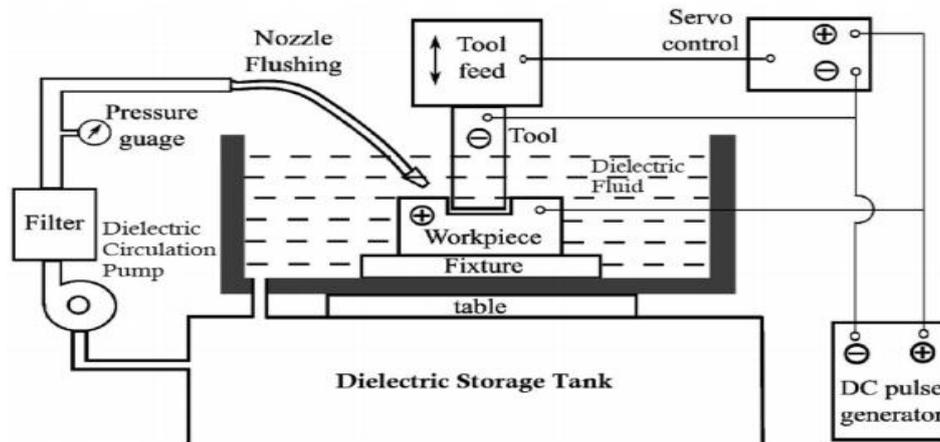


Fig. 3. Components of EDM system [55]

This work is a review of the ANNs employed in the field of EDM for process modelling. The work may be a reference for the new researchers to select a particular type of ANN for the process modelling of EDM.

## 2. ANN MODELLING OF EDM EMPLOYING BPNN (Back Propagation Neural Networks)

Thankachan et al. [47] applied ANN for process modelling in WEDM of alloy of aluminium. A comparison amongst the prediction results of regression, experimentation and ANN was made (Fig. 14-15). Figure 3 shows the comparison for MRR with respect to experimental runs whereas Figure 4 shows the comparison for SR with respect to experimental runs, respectively. ANN predicted data was found to be better amongst these. Levenberg-Marquardt (LM) training algorithm was employed along with hidden layer tan-sigmoid transfer function and output layer puelin transfer function, respectively. Count of hidden layer was considered as one. As per practise, normalization of all data was also performed. For selection of the count of nodes in hidden layer, different models were trained for one thousand epochs, considering mean square error as their evaluation parameter. 98.51% and 99.42% were the obtained values for ANN models of SR, MRR respectively.

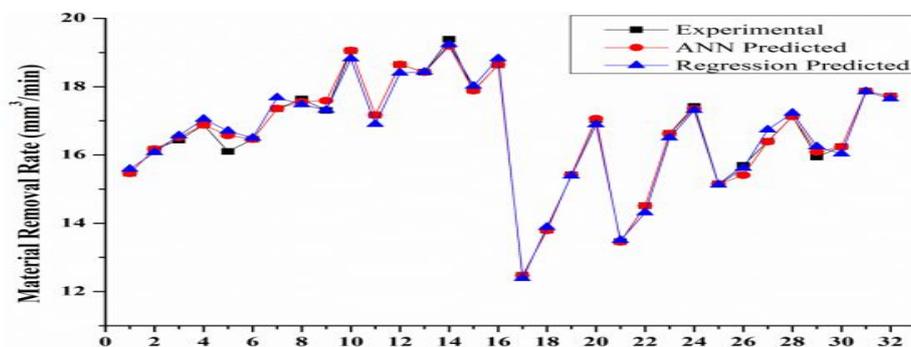


Fig. 14. Comparison amongst values of MRR with respect to experimental runs [47]

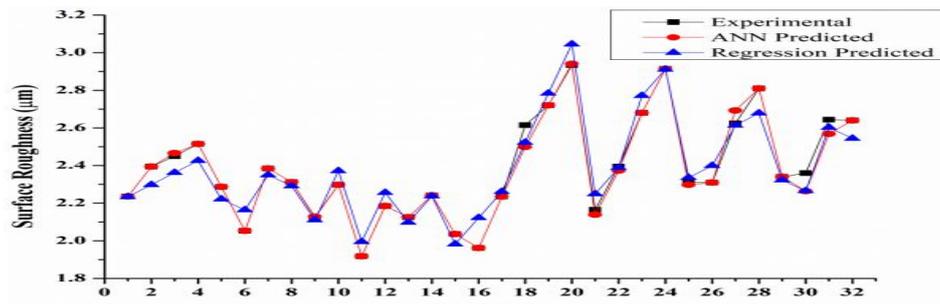


Fig. 15. Comparison amongst values of SR with respect to experimental runs [47]

Goyal et al. [56] performed the ANN modelling in WEDM of shape memory alloy considering MRR as the performance variable. Comparison of experimental values with prediction values of ANN was performed, as indicated in terms of the plot for training data, validation data, testing data respectively and the respective R value being 0.9995, 0.9953, 0.9965. Based on trial and error, ten hidden layers were considered (Fig. 16). Prediction model using ANN signified greater accuracy.

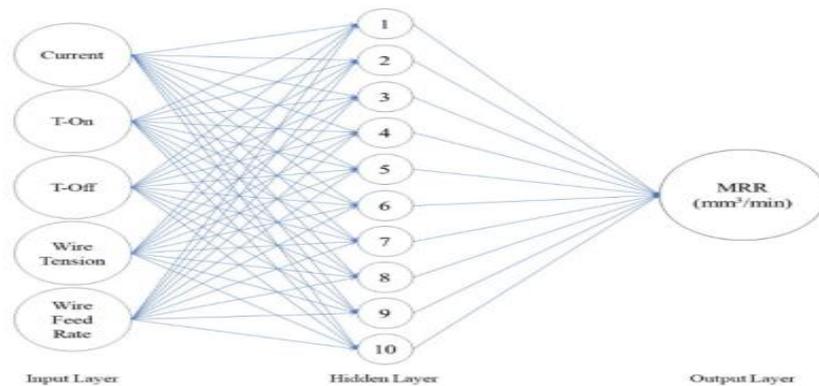


Fig. 16. Optimum ANN model selected [56]

Vishnu et al. [57] performed ANN modelling in EDM of Inconel 718 and the fitness value for the same was found to be decent. ANN predicted values were found to be much better as compared to the experimental values. LM training algorithm was utilized. One hidden layer with five neurons were considered based on hit and trial. Momentum constant and learning rate used were 0.9, 0.05 respectively. Hyperbolic tan activation function was considered. Twelve experiments were utilized for ANN model training whereas six experiments for validation.

Ubale et al. [58] developed ANN model while considering MRR as the performance parameter. LM training algorithm was considered. Thirty six experiments were considered for ANN model training whereas eight experiments for testing and validation, respectively. Logsig and tansig transfer functions were utilized.

Chalisingaonkar et al. [50] utilized ANN for modelling and prediction in WEDM of pure titanium, adopting LM training algorithm and gradient descent, respectively. As a part of pre-processing, normalization was performed.

One hidden layer was considered. R values for training were obtained to be 0.9679, 0.9832 respectively (Fig. 17).

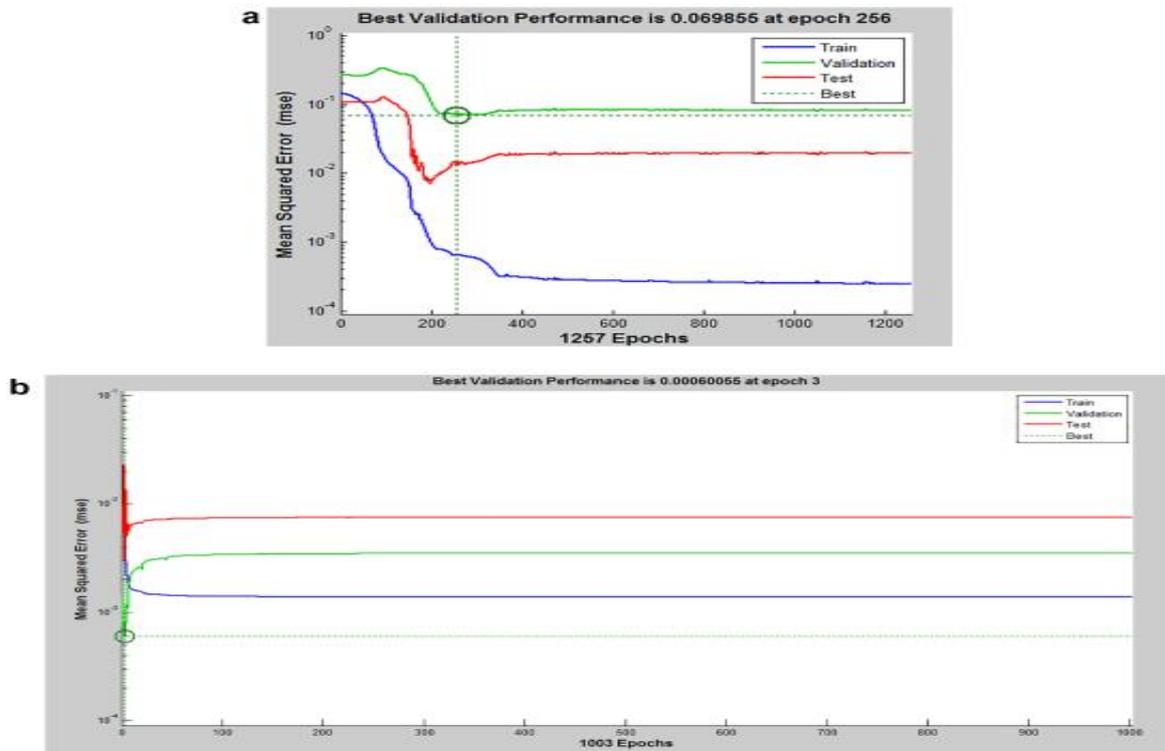


Fig. 17. Variation of MSE with epochs for different performance variables [50]

### 3. ANN MODELLING OF EDM EMPLOYING DIFFERENT LEARNING ALGORITHMS

Vel murugan et al. [59] employed a different set of training algorithm for ANN model – quick prop, incremental back propagation, batch back propagation. Amongst these, batch back propagation and incremental back propagation were considered. Variation in count of neurons in hidden layer was from five to twenty. Twenty neurons were selected while considering MSE as the comparison parameter. Training of ANN was performed for eighty percent data.

Palanisamy et al. [60] employed LM algorithm for training ANN model and R value of 1, 0.9995, 0.9958 was obtained for training, validation and testing, respectively.

### 4. CONCLUSIONS

EDM is a popular non traditional machining technique which finds wide applications. It is stochastic in nature and the process modelling often requires a suitable soft computing technique and ANN is fitting match for the same. ANN, consisting of a network of neurons, is inspired by the working of human brain and possess worth-mentioning attributes such as robustness and mapping capability, to name a few. BPNN applied in the field of EDM is reviewed with details:



- a. Various algorithms have been used for training of ANN network, out of which, LM algorithm is widely used. Different transfer functions such as tan-sig, purelin, logsig are utilized.
- b. Number of hidden layers and nodes are decided based on trial and error or literature survey or on MSE basis or MAE basis.
- c. Normalization of data using normalizations equations is carried out so as to transform the values in between zero to one.
- d. Mostly, MATLAB is applied for carrying out the ANN modelling and prediction. ANN modelling consists of training, testing and validation.
- e. The value of R of the model is a measure of the adequacy of the model.

The details reported in this work may present as a guiding force for various researchers who have an aim to employ ANN modelling to the EDM process data.

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## A systematic review of TMJ (Temporomandibular joint) Prosthetic: Dysfunction Index, Design and Success Rate

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### Abstract

The temporomandibular joint is a very complex joint that is formed by mandibular and temporal bones. In the USA, approximately 2-4% of the population have suffered from TMJ disorder. TMJ prosthetic is used when there is TMJ disorder which is not cured by other means like therapies, medicines etc. This systematic review aimed to introduce about design and success rate of TMJ prosthetic systems which are available in the market (USA). A systematic review was conducted to identify all the relevant papers. Mean principal stresses on the surface of the condyle as well as mean principal stresses on the surface of genoid fossa were found. These stresses are used to design a safe TMJ prosthetic system taking the factor of safety 15. Three total prosthetic systems TMJ Implants, TMJ Concepts, Biomet/Lorenz and their design's characteristics of TMJ prosthesis devices were taken into study. It was found that TMJ implant got an average success rate of 93% for fixing 383 numbers of joints. In the case TMJ concept, we got an average success rate of 88% for fixing 1028 numbers of joints. Data showed that Lorenz-Biomet got an average success rate of 69% for fixing 530 numbers of joints.

**Keywords:** TMJ Dysfunction, TMJ Prosthetic, Stresses in TMJ, Design of TMJ Prosthetic

### 1. INTRODUCTION

The temporomandibular joint (TMJ) regulates the movement of the jaw (Fig. 1). The temporomandibular joint (TMJ) is the most used joint which connects the mandible (lower jaw bone) to the temporal bone. The important functions of the TMJ are chewing, speech, respiration, mastication etc. It is a bi-condylar joint in which the condyles rotate and translate in fossa with the help of the disc to get desired opening and closing of the mouth. Forces are provided by muscle and ligament constraining motion of TMJ. The TMJ in the human body is one of the most complex joints. (Dimitroulis et al., 2018)

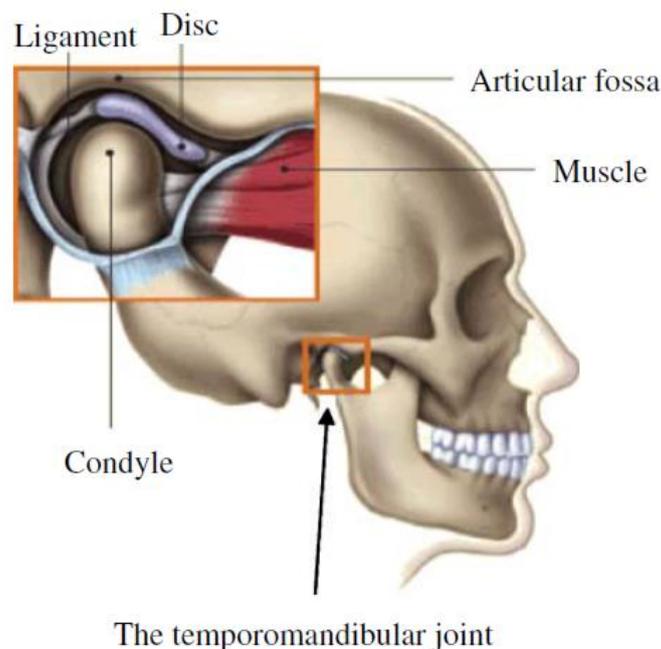


Fig 1. TMJ anatomical structure. source: (Dimitroulis et al., 2018)



Many diseases such as arthritis, ankylosis, hypo or hyperplasia, others related to TMJ can affect the functioning of TMJ (Vignesh et al., 2020). TMD-related arthralgia, myalgia, myofascial pain, disc displacement disorders, degenerative joint disease, subluxation, and headache are among the most common TMJ disorders (temporomandibular dysfunction). The specific aetiology of TMJ issues is unknown, osteoarthritic alterations may be linked to hard tissue damage caused by proteolytic enzymes and inflammatory mediators. TMJ inflammation may be linked to oxidative stress caused by the accumulation of free radicals produced by various metabolic circumstances. Failure of enzymatic and nonenzymatic antioxidative processes to eliminate free oxygen radicals might result in an imbalance that causes oxidative stress. In the TMJ, stable aldehydes such as malondialdehyde (MDA) are produced, which can harm cell membranes. In TMJ problems, mechanical stress may exacerbate the pathophysiological cascade triggered by oxidative stress. (Demir et al., 2018)

Due to the potential of biological injury to the joint, experimental tests to assess stresses and strains in the articular disc during loading is difficult to execute. For studying stress and strain distributions in the TMJ during mastication, the FEA is now the most suited method. Physiological mandibular motions or prolonged teeth clenching were reproduced in certain investigations. (Ferreira et al., 2017). The Finite Element Method TMJ (FEM) can be used to understand the mechanical stress that occurred in TMJ. To better understand the biomechanical reactions of functional appliances, FEM studies on the human temporomandibular joint (TMJ) are becoming more common. FEM is a non-invasive, in vitro, very advanced approach. It explains the qualitative nature of compressive and tensile stresses in a complex biological system like the TMJ, as well as their relative patterns. The advantages of functional appliances in the TMJ remodelling process are well known, although there are differing viewpoints on the construction bite employed to protract the mandible (Shrivastava et al., 2015).

Many prostheses have been created during the last few decades to repair the TMJ and restore its natural movements. The biomechanical aspect of the contralateral joint might be affected by the replacement of a TMJ with a whole joint prosthesis, as well as the complicated mandibular movements, which include both rotational and translational components. TMJ replacement seeks to improve function as well as the quality of life. The main outcome measures reported in various medium and long-term studies include pain, maximum mouth opening, and the capacity to eat a normal diet. (Merema et al., 2021).

Nowadays, advanced manufacture processes such as DLMS (Direct Metal laser sintering) (Sharma & Soni, 2020), SLM (selective laser melting), other 3D printing processes are used in the manufacturing of TMJ prosthetics. Also, advancement in the field of rapid prototyping enables us to make low-cost TMJ prosthetics. Custom-made total joint prostheses can be produced using CAD/CAM (computer-assisted design/computer-assisted manufacture) (Dela Coleta et al., 2009). Using x-ray, MRI or CT scans information enables us to make patient-specific TMJ prosthetics easily and quickly. Other means like Finite element analysis (FEA) is an analysis tool to mimic the biomechanics of TMJ which also helps in designing. For clinical diagnosis and surgical planning, design and development of prosthetic devices, and to precisely characterise TMJ stresses and strains, contact mechanics, accurate temporomandibular morphometry is crucial. (Coombs et al., 2019)

The selection of proper materials and a TMJ replacement system is critical to success. While other domains of expertise, like as orthopaedic surgery, have a long history of arguing the benefits and drawbacks of various materials, the literature and research on material selection for TMJ prostheses are comparatively scant (De Meurechy et al., 2017). Current study shows a few parameters of the design of TMJ prosthetics and their success rate. In this literature, we have considered three TMJ prosthetic designs and presented their designing parameters such as stresses, material required etc. (Tanaka et al., 1994).

The objective of this study was to combine the knowledge of signs and symptoms of TMJ dysfunction (Oikarinen et al., 1991), designing parameters of TMJ Prosthetic with its success rate. We have presented three company designs - TMJ Implants, TMJ Concepts, Biomet/Lorenz and their success rate (Guarda-Nardini et al., 2008a; Ingawalé & Goswami, 2009; Leandro et al., 2013; Westermark et al., 2011).

## 2. MATERIALS AND METHODS

Information about TMJ prostheses was gathered from multiple databases. We retrieved information from Google Scholar, PubMed Central, Science Direct. The heading which was used to perform the search was TMJ dysfunction, Design and success rate. We have identified all the relevant papers related to our study. This led to a total of 51 articles. All articles were read carefully. We found 10 articles were duplicates that were removed.

Articles related to our topic were selected for analysis. Finally, 28 papers were considered for this review. The flow diagram showed a summary of article selection.

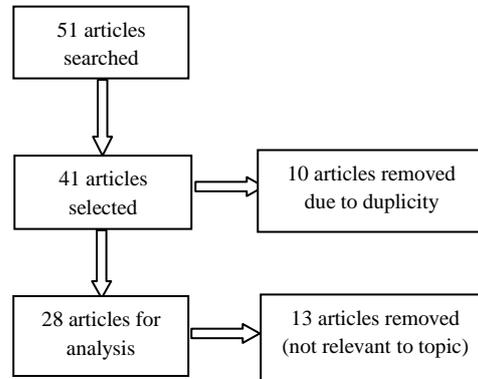


Fig 2: Flow chart for selection of articles

Selected publications were read and examined separately for the purposes of this study. Author names, journal, publication year, simulation aims, the software utilised for bone geometry and TMJR device modelling, simulation software, kind of TMJR device, and outcomes were collected for this review.

### 3. RESULT

#### 3.1 TMJ stresses

The biomechanical behaviour of joint replacement devices, including the distribution of stress and strain across component materials and the host bone, can be studied using finite element modelling (FEM). Despite the growing body of knowledge in this field, FEM has limits when it comes to generating geometry, modelling, and biomechanical evaluations of these devices. As illustrated in figure 3, FEM simulation begins with the computer development of geometry to generate a bone model. (Rodrigues et al., 2018)

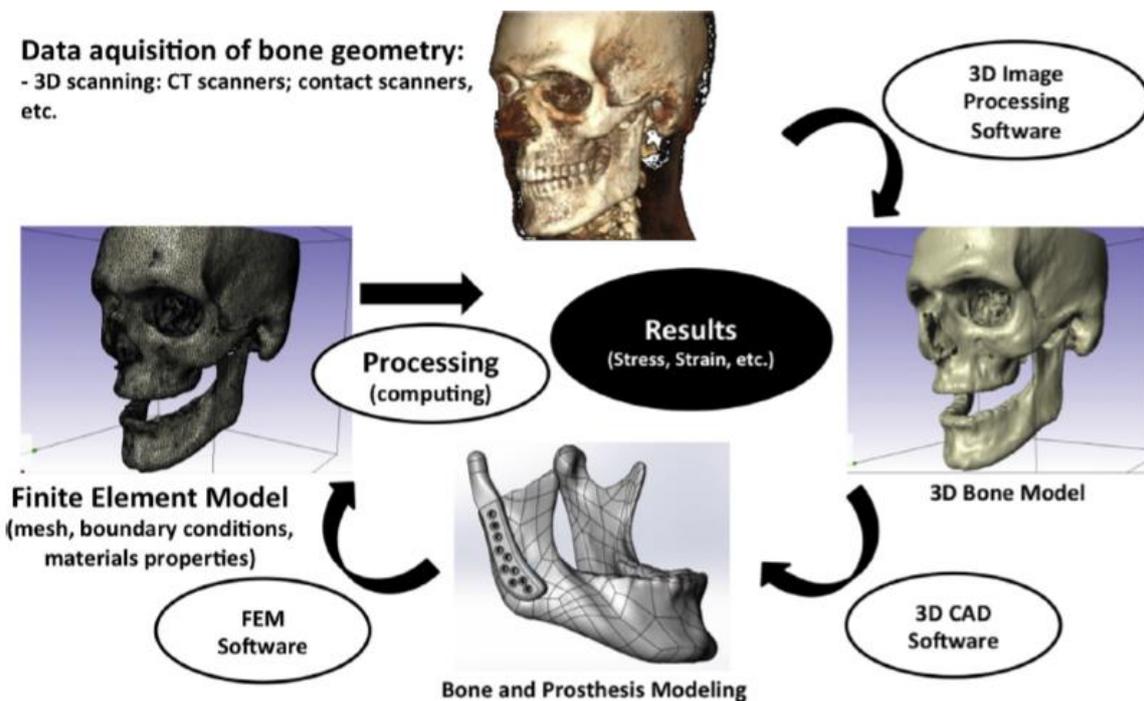


Fig 3:FEM approach to calculate stress. source: (Rodrigues et al., 2018)

The bone geometry may be produced using CT scans and then processed using 3D image segmentation and processing tools. MIMICS (Materialise NV), InVesalius, 3D- DOCTOR, 3DSlicer, GIMIAS and OsiriX are some of the software programmes that can convert DICOM files (CT images) into 3D models. The TMJR and fixation screws are designed using specialised CAD software or even FEM software with embedded CAD modules after the programme generates the mandible(bone) model. Finally, boundary conditions may be used to execute computer simulations. (Pinheiro et al., 2021)

FEA model is made to mimic the stress developed in TMJ. It is found that mean principal stresses are anterior - 1.642 MPa, middle -0.543 MPa, posterior 0.664 MPa, lateral -1.017 MPa, medial areas 0.521 MPa on the surface of the condyle and mean principal stresses on the surface of genoid fossa are anterior -0.440 MPa, middle 0.410 MPa, posterior 0.445 MPa, lateral -0.351 MPa, medial areas 0.103 MPa (Tanaka et al., 1994). The middle to the anterior zone of the disc had higher stress concentrations, with maximum values above 2MPa (Ferreira et al., 2017).

FEA model can also be used to understand the effect of the geometry of fixing screws for TMJ on surrounding bone stress concentration. The stress observed in geometry as all screwed like a commercial was critical, with a maximum value around 750 MPa for screw and suggested the use of a bigger diameter than 2.4mm for condyle fixation of Biomet/Lorenz. (Ramos et al., 2013)

### 3.2 TMJ dysfunction Index

TMJ dysfunction, also known as temporomandibular disorders, is a prevalent occurrence in both medical and dentistry practice. TMJ problems, which include myofascial pain and dysfunction, may be classified as a broad category of non-specific generalised muscular aches and pains that impact various muscle groups across the body. (Yucel, 1993). Temporomandibular joint (TMJ) disorders are a group of symptoms caused by changes in the structure or function of the articular and periarticular tissues. It is a prevalent ailment that affects 5 to 12% of the population, and around 15% of all patients develop chronic TMJ issues, lowering their quality of life. (Demir et al., 2018)

The Helkimo index is a simple, fast and effective method to assess TMJ dysfunction. Mandibular Condyle Fractures can be categories into 3 groups in the Anamnestic dysfunction index. Clinical Dysfunction Index made by Helkimo in 1974 divided TMJ Dysfunction into three groups named as mild dysfunction, moderate dysfunction, and severe dysfunction. For every sign causing dysfunction of TMJ, three criteria are given. The normal range is assigned with 0 units, slightly dysfunction with 1 unit and severe dysfunction with 5 units. There was a total of 25 points. The group having total points between 0 and 4 points was defined as Mild dysfunction group; moderate dysfunction group was defined between 5 and 9 points. The severe dysfunction group was defined as between 10 and 25 points. (Oikarinen et al., 1991)

Table 1: Anamnestic dysfunction index, Ai

Symbols	Symptoms	References
AiO	There are no subjective signs or symptoms of masticatory dysfunction.	
AiI	Mild symptoms include clicking and crepitation of the temporomandibular joint (TMJ), jaw tightness, and weariness.	(Helkimo, 1974)
AiII	Severe dysfunctional symptoms. In the anamnesis, one or more of the following symptoms were mentioned: difficulty expanding the mouth wide, locking, discomfort while moving face and jaw pain	



Table 2: Clinical dysfunction index, Di

Symbols	Symptoms	References
DiO	The lack of the clinical symptoms that are used to create the index.	
DiI	Mild symptoms of dysfunction. TMJ noises, deviations of the mandible in opening and/or closing movement >2 mm from a straight (sagittal) line, and other symptoms were noted (clicking or crepitation). Discomfort to palpation of the masticatory muscle in 1-3 locations, tenderness to palpation laterally across the TMJ, pain associated with 1 mandibular movement, maximal mouth opening 30-39 mm, horizontal movements 4-6 mm	(Helkimo, 1974)
DiII	At least one severe symptom in addition to 0-4 minor symptoms, or 5 minor symptoms alone. Any of the following might be a serious symptom: Tenderness to palpation in four or more locations of the masticatory muscle, tenderness to palpation posteriorly of the TMJ, discomfort in two or more jaw movements, maximal mouth opening of 30 mm, one or more horizontal movements of 4 mm	
DiIII	2-5 severe symptoms, perhaps in combination with any of the moderate symptoms	

Table 1 described symptoms for the Anamnestic dysfunction index which are very helpful to divide the group into three categories. Table 2 showed possible symptoms which are used to generate the clinical dysfunctional index.

### 3.3 TMJ Prosthetic system

The majority of TMJ-TJR on the market now are made with computer-aided design and manufacturing (CAD/CAM) techniques, allowing for virtual patient-specific modelling. In general, designs are based on two commercially available prostheses that include a skull and a mandibular component that is attached to the glenoid fossa and mandibular ramus independently. These pieces can articulate relative to one another, allowing for movement between a concave and convex body. However, in certain situations, the designs of these prostheses do not appear to appropriately simulate normal TMJ movement. Because of the tight fit of the prosthesis, which increases osseointegration, the usefulness of patient-specific prostheses has been well acknowledged and should increase treatment predictability and improve long-term success. Several CAD/CAM prostheses have been implanted with the use of surgical guides, allowing the virtual surgical plan (VSP) to be translated to the operating room. (Merema et al., 2021)

#### 3.3.1 Total temporomandibular joint prostheses

The Biomet/Lorenz Microfixation TMJ Replacement System and the TMJ Concepts Patient-Fitted Total TMJ Replacement System have both acquired FDA clearance as of this writing. The first approach, like the Christensen system, relies on a stock prosthesis that comes in a variety of standard sizes. During surgery, the optimal fit is determined based on the patient's anatomy, and the components are joined with screws once the host bone has been altered. The TMJ Concepts system, on the other hand, is a custom-made and patient-fitted prosthesis. First, a maxillofacial computed tomography image of the patient is used to create the prosthesis utilising CAD/CAM technology. The next step is to build a stereolithographic model of the patient's skull, from which the final components are designed and manufactured. The prosthesis may be customised to the patient's individual anatomy, including jaw anomalies and jaw position, thanks to its bespoke design. Furthermore, the fixation screw placements can be adjusted by considering the patient's anatomical features, such as the inferior alveolar nerve. Optimizing the prosthesis's location and contact with the bone can considerably increase the prosthesis's stability. (De Meurechy et al., 2017)

The researchers looked at two types of complete TMJ TJR prostheses: stock prostheses, which need the surgeon to alter the patient's anatomical characteristics, and custom-made prostheses, which are built specifically for each clinical case. In this review paper, we have covered three Prosthetic systems named as TMJ Implants (Fig.6), TMJ Concepts (Fig.5), Biomet/Lorenz (Fig 4). Standard or total stock TMJ TJR consists of a mandibular component in three sizes (55, 50, and 45 mm) as well as a prosthetic articular fossa in various diameters (wide, medium,small) whereas as custom-made TMJ prosthetic system is specific to patient. Custom-made TMJ TJR prosthesis operates better than stock TMJ TJR prostheses. Biomet/Lorenz is a widely utilised standard system that has received FDA certification. (Pinto-Borges et al., 2021)



Fig 4: Biomet/Lorenz prosthetic system source: (Pinto-Borges et al., 2021)

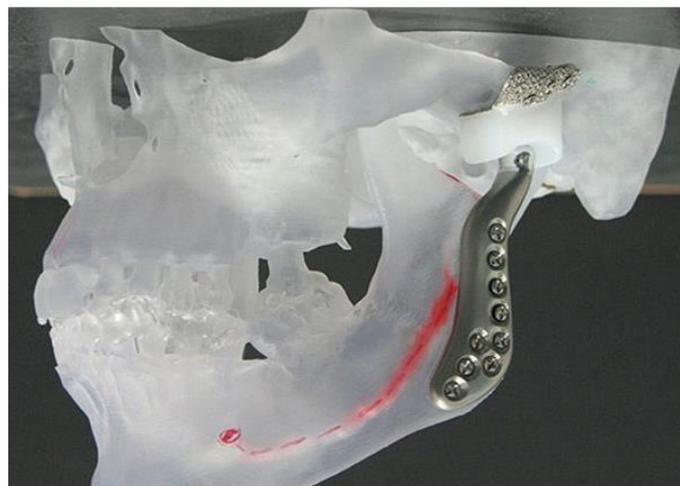


Fig 5: TMJ Concepts prosthetic system source: (Pinto-Borges et al., 2021)



Fig 6: TMJ Implant prosthetic system. source: (Ingawalé & Goswami, 2009)

Prosthetic is divided into three parts Fossa, Condyle and Ramus. Condyle and Ramus combined by manufacturing process to behave like one part and Fossa made another part of TMJ-TJR system. These two parts are fixed to the bone with screws. Table 3 showed material used for these TMJ prosthetic systems.

Table 3. Characteristics of TMJ prosthesis devices of USA

Prosthetic System	Design	Fossa material	Condyle material	Ramus material	Screws (titanium alloy)	References
TMJ Concepts	Custom	Titanium (UHMWPE surface)	Co-Cr-Mo alloy	Titanium alloy	For Fossa: 3-4 No. (Dia. 2.0 mm) For Ramus: 7-10 No. (Dia. 2.0 mm)	(Elledge et al., 2019; Guarda-Nardini et al., 2008b, 2008a; Ingawalé & Goswami, 2009)
Biomet/Lorenz	Stock/Custom	UHMWPE	Co-Cr-Mo alloy (titanium surface)	Co-Cr-Mo alloy	For Fossa: 4-7 No. (Dia. 2.0 mm) For Ramus: 7-11 No. (Dia. 2.7mm)	
TMJ Implants*	Stock	Co-Cr-Mo alloy	Co-Cr-Mo alloy	Co-Cr-Mo alloy	For Fossa: 3-4 No. (Dia 2.0 mm) For Ramus: 6-8 No. (Dia. 2.7)	

Note: Co: cobalt; Cr: chromium; Mo: molybdenum; UHMWPE: ultra-high molecular weight polyethylene

\*This device is no longer available on the market

### 3.3.2 Biocompatibility

Biocompatibility, originally defined as a material's ability to come into contact with and interact with the tissues of the human body without causing any adverse effects at the implant site (locally) or in the patient as a whole, is a requirement for any successful clinical application of an implant. As a result, a substance and its breakdown products must be non-cytotoxic, promote cell survival, and preserve particular biological activities while avoiding inflammation and allergic responses (hypersensitivity). Advances in medical technology, such as the discovery of biodegradable implant materials and tissue engineering, have prompted a review of the biocompatibility edict to include not just biological safety but also the material's unique functioning. (De Meurechy et al., 2017)

### 3.3.3 Success rate

CT scans and DICOM data can be used for virtual planning and production of prostheses before surgery. The mandibular component was made of titanium alloy, while the fossa component was made of ultra-high molecular weight polyethene (UHMWPE). Fossa was created to entirely encompass the condylar head, including a posterior lip to prevent the condyle from dislocating posteriorly. Polyamide surgical guides, in addition to the tailored prosthetic design, enabled for intraoperative surgical bone resection and prosthesis installation, matching preoperative design and individual anatomy with surgical osteotomies, screws, and prostheses placement (Fig. 7). (Sembronio et al., 2019)

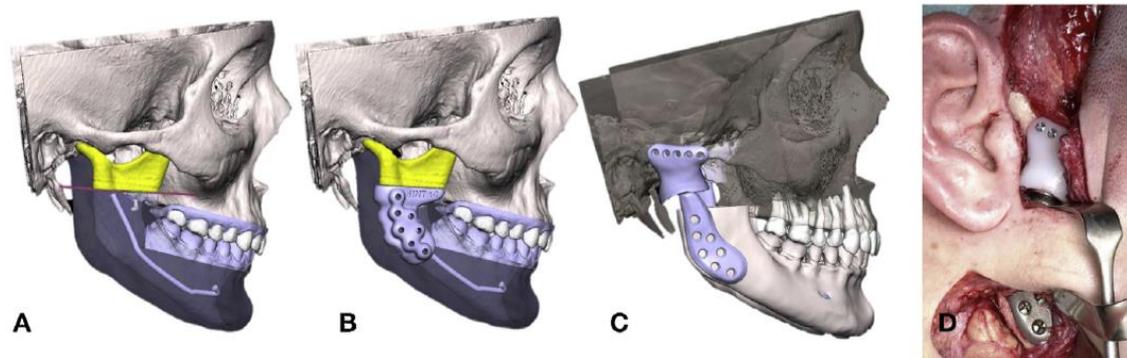


Fig.7: (A) Cutting plane position. (B) Screw fixing positions. (C) Prosthesis design.

(D)Fixing TMJ prosthesis. source: (Sembronio et al., 2019)

For all three total prosthetic systems taken in this study, results were shown based on reduced pain and improved function, the period from 14 months to 108 months and ability to masticate. Data were summarized below table for these prosthetic systems.

Table 4. Clinical studies on TMJ total replacement: success rate

Device	Joint	Success rate	References
TMJ Implants	109	92 % success rate	(Ingawalé & Goswami, 2009)
TMJ Implants	26	82% had a pain improvement	(Ingawalé & Goswami, 2009)
TMJ Implants	60	97% had overall functional improvement	(Ingawalé & Goswami, 2009)
TMJ Implants	34	100% success rate (patients)	(Ingawalé & Goswami, 2009)
TMJ Implants	86	100% success rate	(Ingawalé & Goswami, 2009)
TMJ Implants	68	88% success rate for TMJ	(Guarda-Nardini et al., 2008b)
TMJ Concepts	65	90% overall success rate	(Ingawalé & Goswami, 2009)
TMJ Concepts,	97	76% had reduction in mean pain scores	(Ingawalé & Goswami, 2009)
TMJ Concepts	102	85% had improved quality of life	(Ingawalé & Goswami, 2009)
TMJ Concepts	363	91% success rate (patients)	(Guarda-Nardini et al., 2008b)
TMJ Concepts	69	84.2% success rate	(Ingawalé & Goswami, 2009)
TMJ Concepts	332	100% success rate	(Guarda-Nardini et al., 2008b)
Lorenz–Biomet	69	32 % success rate for longer than 3 years	(Ingawalé & Goswami, 2009)
Lorenz–Biomet	399	85% of the patients scored the optimal condition after the first year	(Leandro et al., 2013)
Lorenz–Biomet	62	91% success rate	(Boyo et al., 2019)

We took the average success rate for each TMJ prosthetic system. It was found that TMJ implant got an average success rate of 93% for fixing 383 numbers of joints. In the case TMJ concept, we got an average success rate of 88% for fixing 1028 numbers of joints. Data showed that Lorenz-Biomet got an average success rate of 69% for fixing 530 numbers of joints.

#### 4 DISCUSSION

In today world, we are using analysis tools such as FEA extensively to understand the biomechanics of TMJ (Vignesh et al., 2020). FEA also helps in analysing the stability of TMJ by predetermined stress calculation. There is also stress concentration in the bone while fixing the TMJ prosthetic with the help of the screws. The study showed that the geometry of screws can also affect stress concentration in bone. (Ramos et al., 2013)

In this literature, three designs have been analysed. Results show that a large number of patients were treated with TMJ concept prosthetic as compared to other prosthetic systems. Currently, the USA has approved only the TMJ Concepts system and Biomet/Lorenz prosthetic systems for the treatment of patients suffering from TMJ disorders. These three systems show reliable short-term results but for the long-term, results are not fully understood.

Moreover, Twenty-seven TMJ replacement systems have been developed by 15 countries (Elledge et al., 2019). It revealed that 21 are custom made designs and 6 have the stock design. Stock prosthetics are cheaper than



custom made and are readily available in the market. The study showed that 74% (178/241) of the stock prosthesis have achieved success which helped to reduce cost and uncertainty for TMJ stock prostheses. It helped surgeons to use a stock prosthesis instead of a custom made prosthetic system (Brown et al., 2021). Recent advancement in technologies enables us to make custom design prosthetic. Processes like 3D printing, SLM(Selective laser melting), DMLS(Direct metal laser sintering) can produce a low-cost product. DMLS can effectively be used to produce TMJ prosthetics for large population countries like India. Although, the use of 3D printed patient-matched or custom-made replacement components may cause warping of the ramus' baseplate, as well as other issues that raise the risk of mechanical failure and loose screws. So, A custom-made system's strong primary stability (the "gold standard" biocompatibility of high-grade titanium alloy and UHMWPE), design and manufacturing procedures should be built to minimise surface roughness and porosity to increase the device's lifetime. (Elledge et al., 2019).

#### 4.1 Future directions for temporomandibular joint materials

##### $\beta$ -titanium alloys

Although Ti alloys have proven to be highly corrosion-resistant and biocompatible, there are growing concerns about long-term implantation due to the release of potentially toxic alloying elements such as Al and V, as well as the risk of stress shielding due to their elastic modulus values being relatively high compared to bone's elastic modulus. These constraints have prompted the creation of more biocompatible, low-modulus  $\beta$ -Ti alloys that include nontoxic  $\beta$ -stabilizing alloying elements including Nb, zirconium (Zr), Mo, Ta, and iron (Fe) rather than Al and V. (De Meurechy et al., 2017)

##### Polyetheretherketone (PEEK)

PEEK was first employed in the field of spine surgery in 1998 when it was launched as a biomaterial. PEEK offers some beneficial biomaterial features, including biocompatibility and the ability to create bone (De Meurechy et al., 2017). Chen et al., 2020 studied the Effect of PEEK coatings in fatigue performance of the dental implant. PEEK coatings have the potential to increase the durability of implant threaded connections while also reducing implant internal thread wear. PEEK coating might be a good technique to keep screws from loosening and retaining screw joints (Chen et al., 2020)

##### Surface modifications

A biomaterial's surface can be a critical aspect in determining its long-term success. Surface changes of Ti have been the subject of much investigation, with the goal of either eliciting an adequate cell response to increase osseointegration or inhibiting bacterial adhesion to reduce infection rates. (De Meurechy et al., 2017)

This literature provides overall knowledge of TMJ prosthetics. The limitation of this study is that here we analyse a few numbers of literature and we are encouraging its use as optional to get more knowledge about TMJ design and reconstruction.

#### 5 CONCLUSION

We concluded that the TMJ total replacement system should be used to patients with severe TMJ dysfunction who have failed conservative treatments. There are the presence of 2–5 severe symptoms, perhaps in combination with any of the moderate symptoms for TMJ dysfunction. Computer-aided designs and manufacturing can be used to create and design an accurate implant which helps to enhance masticatory function and has been linked to better quality of life. Furthermore, they save surgery time and provide a better scope for problems that can be understood by doctors to convey the treatment goals to patients. As surgeons and engineers increasingly utilise the technology's benefits, the demand for flexibility in the production of medical items is increasing. So, Computer analysis softwares like ANSYS(FEA) are used to mimic the biomechanics of TMJ. FEA based design and calculation of stress help to make patient-specific TMJ. We have also concluded that three TMJ prosthesis systems which are taken into this review are not equal in terms of material composition, way of manufacturing and design. The success rate also varies for these three systems.



### Funding

None.

### Competing interests

None.

### Ethical approval

Not required.

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## PHYSICAL RISK AND MUSCULOSKELETAL INJURIES ASSESSMENT AMONG WORKERS IN CLEANING OCCUPATION

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### Abstracts

Cleaning is vitally important in everyday life and practice every day in all aspects of places. Cleaning workers are an important group who experience physical risk and injuries during cleaning activities i.e. heavy, statics or monotonous work, extreme or constrained postures, repetitive movements, unsuitable workplaces and equipment, forces, etc. The present study was aimed to describe musculoskeletal disorder risk arising through various cleaning activities i.e. problems arising through manual handling tasks such as lifting and lowering heavyweight, loading, and unloading, etc, a problem arising through awkward posture (wiping, mopping, etc), problem arising through work organization. This study was conducted on 36 cleaners of various educational institutions from UT Chandigarh, India. Physical risk and intensity of MSDs were investigated by Modified Nordic questionnaire and visual analogue scale. Awkward posture and rest pattern was accessed by the OVAKO Working Posture Analysis System(OWAS). Results concluded that the causes for risk in manual handling tasks were poor lifting methods, poorly designed workspace, poor equipment maintenance. The causes for awkward repetitive posture were unsuitable work heights, rapid hand movements, static posture, etc. Poor work organization combined with the requirement to adopt awkward postures while conducting strenuous work can contribute to the development of musculoskeletal disorders.

**Keywords:** musculoskeletal disorders, cleaners, physical risk, awkward posture, OWAS.

### 1. INTRODUCTION

The physical risk associated with Musculoskeletal disorder (MSD) is most typical of health concerns in cleaners. Cleaners working in various organized and unorganized sectors such as manufacturing, transportation, construction, institution, etc. Cleaners used their bare hands to work with tools, machinery is often prone to awkward postures, repetitive movement. This can lead to strain, musculoskeletal and physical risk(Battenvi et al, 1998). The impact of the above risk and injury are absenteeism from work, injury care cost, etc. Work-related musculoskeletal disorders (WMSD) are muscular injuries/pain, that occur while doing work i.e. tendonitis, carpal tunnel syndrome, thoracic outlet syndrome, tingling in hands, etc. Above mention, WMSD affects our various body parts, muscles, nerves, and joints. In the cleaning occupation, there is a lot of manual hard work has to be done that includes wiping, mopping, polishing, buffing, swabbing, etc(Clark et al, 2012). While performing the above cleaning task, repetitive nature of various body parts, awkward posture are observed which leads to various WMSD. In India, ILO official statistics show that around 4.75 million workers are employed in cleaning occupations but the true number to be more than 20 million

to 40 million. The main purpose of cleaning is to remove dust, marks, and unwanted items from useful areas. Cleaning work should be done without exposing cleaners to the possibility of injury or physical hazard (Burdorf et al. 1991). Cleaning work plays an important role in ordinary work and the public sphere as it improves the employee's / community's sense of health and well-being. Clean workplaces also promote productivity and product quality (Habin et al, 2015). Dirty areas can lead to accidents, and without cleaning there is a high risk of exposure to irritating substances that can lead to problems such as allergies and respiratory infections. The purpose of cleaning can be defined as contributing to the maintenance of sanitation and community facilities (Hopsu et al, 1994). Cleaning includes such things as dusting, scrubbing, sweeping, and cleaning. Cleaning work can also include additional tasks such as handling garbage, lifting / moving furniture/equipment (Johansson et al., 1989).

## **2. INJURIES AND PHYSICAL RISK IN CLEANING**

Cleaning jobs can be physically demanding and should be done without putting workers at risk of accidental injury or work-related illness. Numerous studies have shown, however, that cleaners are at risk of developing musculoskeletal disorders (MSDs) of the back, neck, shoulders, elbows, hands, and lower limbs as a result of their work (Chang et al, 2012). MSDs are disorders of the body's structures such as muscles, joints, tendons, nerves, bones, and the local circulatory system, which are largely caused by work and the effects of the immediate environment in which the work is performed (Dahlberg et al 2004).

Low back pain is a major work-related problem in almost every body-care activity. It can be described as chronic or severe pain in the lumbar or buttock area (sometimes called lumbago), or in the region of the upper leg (sometimes called sciatica). Low back pain can result from muscle or ligamentous pressure, degeneration of the joints or discs of the spine, or pressure on the nerve roots within the spine. Muscle stress is perhaps the most common cause of back pain (Esen et al, 2015). Lifting and carrying heavy loads is a major cause, but pushing and pulling or the need to adjust to a flexible or twisted posture is also dangerous. Other parts of the body and organs can be affected. Neck and upper limb disorders are caused by deformities of body structures such as tendon, nerve, muscle, joint, bursa, or local circulatory system, which are mainly due to the function of the work and the environmental effects when the work is done (Garnaue et al, 2012). They include many types of inflammation as well degenerative conditions such as shoulder injuries caused by prolonged working with hands overhead height or injury to the wrist caused by repeated work. Symptoms include pain and/or decreased ability to function normally. This can affect any region of the neck, shoulders, upper arms, elbows, arms, wrists, and hands. Some cleansing activities require prolonged standing, which can cause varicose veins in the legs (Habin et al, 2015).

Various studies on cleaning method describe that most higher risk factor is associated with lower back and lower limb (Buchholz et al, 1996). There are lots of hard-working body postures during mopping, wiping, surface cleaning, polishing, etc. The cleaners faced so many problems/pain during all these activities like lower back pain, neck pain, upper limb and lower limb disorder more. While cleaning they have to do one step in a quite repetitive manner, which leads to wrist joint pain. (Clark et al, 2012).

Lower back pain is defined as the accurate pain which occurs in a lumbar area called lumbago, and an upper area called Sciatica(Corletta et al, 1999). Neck and upper limb are defined as the disorder or pain in muscles, joints, or in the localized shoulder area. These above-mentioned injuries and pain occurred due to awkward postures, repetitive movement or insufficient rest period, and also working in unorganized space(Hagberg et al,1995).

Cleaners adopt different awkward postures while performing their jobs. Sometimes some postures are very harmful, even they continuously do their work for a long time. Various work postures which are performed by workers are physiological demanding and time-consuming. Although the women cleaner performing the job in forwarding bending and squatting postures, these postures can cause serious physical risk and injuries(clark et al 2010).

### 3. METHOD

#### 3.1 Subjects

In this study, a total of 36 cleaner were participated from UT Chandigarh, India. Out of which 27 are female and 9 are male . The Sociodemographic characteristic are shown in Table 1.

Table 1: Sociodemographic characteristic of cleaners

Subject Characteristic	Mean	Standard deviation	Maximum	Minimum
Age(yrs)	38.21	5.87	49	29
Height(cm)	165.21	3.53	180	152
Working years(yrs)	11.01	5.09	21	3
Weights(kg)	62.60	5.5	80	49

#### 3.2 Musculoskeletal Disorder Injury

The Musculoskeletal disorder injury of the cleaner was evaluated by modified Nordic Questionnaire which contain question on individual detail, work type, intensity of pain in various region of body. The awkward body posture were identified by using OWAS technique in Technomatix software.

#### 3.3 Intensity of Pain rating

The intensity of pain was evaluated by 10 levels visual analogue scale. In scale, level '0' termed as no pain and level '10' termed as severe pain. The visual analogue scale shown in figure 1.

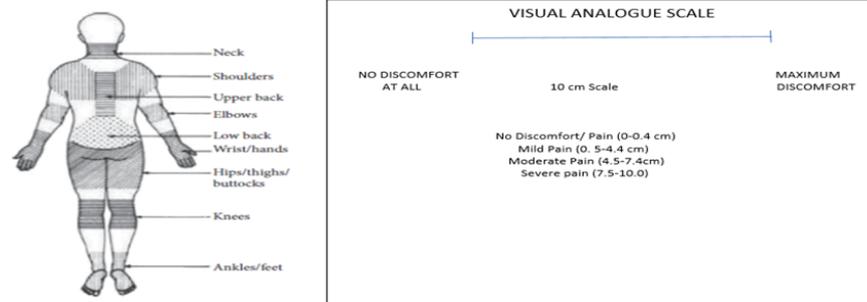


Figure 1: Various body parts of humans and visual analogue scale

### 3.4 Identify Posture Pattern

Posture stress and strain were evaluated and observed by direct observation method. Working posture during cleaning activities of all cleaner were noted carefully and also duration of time also were noted. Posture of the various cleaner were shown in figure 2.



Figure 2: Cleaner performing mopping task on the floor

### 3.5 Posture analysis

Posture of cleaner were analysed by OWAS method an ergonomic assessment technique. Body angle and posture were created in Technomatix software then simulation of the same cleaning activities were done. On this simulation OWAS report created of each and every postures of the cleaners.

## 4. RESULT

The result of this study shows that there were high musculoskeletal injuries among cleaners. The most injuries in low back injuries ( 77.7% ), followed by wrist( 63% ). The frequency of pain in various body part during cleaning activities shown in table 2. The perceived rate of MSD pain in lower back region was higher followed up by wrist and upper back and so on, Intensity of MSD pain rate of cleaners were shown in table 3.

Part of Body	Frequency(%)
Neck	9(25%)
Shoulder	14(38.8%)
Elbow	16(44.4%)
Upper back	21(58%)
Low back	28(77.7%)
Wrist	23(63.8%)
Hip	19(52.7%)
Knee	21(58.3%)

Table 2: Frequency of pain during cleaning activities

Table 3: Rate of MSD pain in various parts of body

Part of Body	Mean +/- SD	Discomfort Level
Neck	2.9 +/- 2	Mild
Shoulder	3.6 +/- 2.1	Mild
Elbow	4.5 +/- 2.32	Moderate
Upper back	6.9 +/- 1.97	Moderate
Low back	7.8 +/- 1.56	Severe
Wrist	7.4 +/- 2.01	Moderate
Hip	5.6 +/- 2.34	Moderate
Knee	4.5 +/- 2.45	Moderate

Owas posture analysis report shows that, left hip flexion and left ankle extension was more enough which is the main reason for pain and injury, although wrist flex was of higher degree as shown in table 4 during mopping the surface. Technomatix owas report showing that owas action category 2 required for correctness for the posture as shown in figure 3.

**TECNOMATIX OWAS(Jack)**

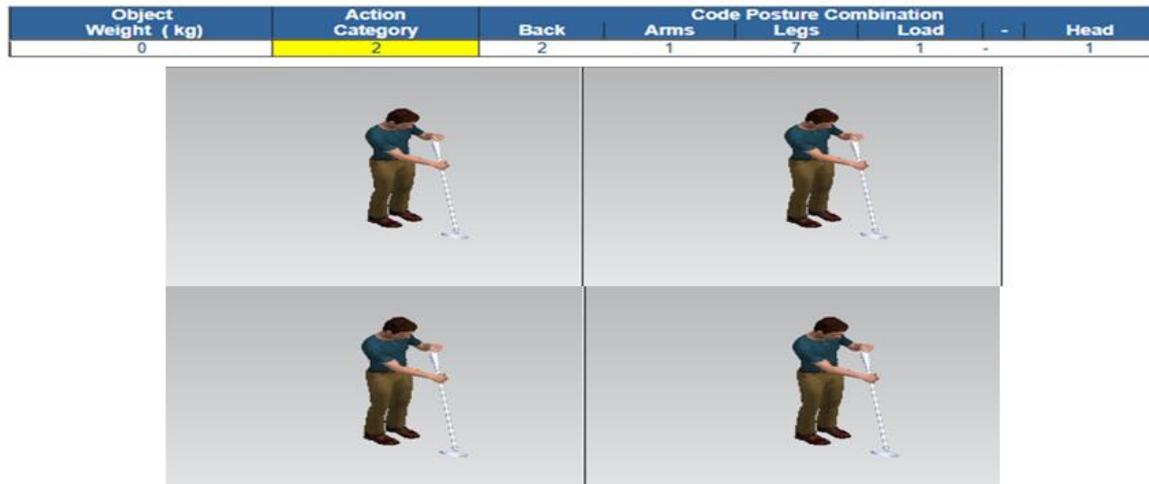


Figure 3: OWAS posture of mopping in simulation

While mopping various problems are identified when cleaning under furniture, cleaner was squatting forward over 65<sup>0</sup> and also, the cleaner had to stretch to access some areas which adopt awkward shoulder posture.

## 5. DISCUSSION

The finding of the study are below

1. MSD pain and injury are higher in intensity in low back and wrist.
2. cleaner were in most awkward posture when they work underneath the furniture.
3. Before purchasing the cleaning tool, tool must be trailed with the cleaner.
4. Time to time training must be provided to cleaners, so that the will do self care of there health
5. Before coming to work they must do some exercise for back.

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## A Systematic Review on Color Homography Estimation System

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### ABSTRACT

This paper gives an overview of homography estimation system which is a central part of geometric methods and can be used to associate the picture elements of two images. This association is required to calculate the variation between two images which is computed by finding the difference between each pixel in each image. An integrated framework is presented which explains the different phases of homography estimation system. Two approaches are directed which can be used to work with this system. Benefits and Issues are discussed which can help to analyze this research area. This paper survey all the application areas such as Mosaicking, Image Registration, and three dimensional camera pose reconstruction, collision Avoidance, Image Stitching, video color Grading etc. Finally, the findings of this paper states that solving the color homography problem lead the way to more précised evaluation.

**Keywords-Homography, Photometry, mapping, illumination, Calibration, Chromaticity, Color models, Geometric methods.**

### 1. INTRODUCTION

Homography proves to be a fundamental theorem of projective geometry. With the help of homography, it is straightforward to define projective coordinates, also known as homogeneous coordinates. Homography plays a vital role when a relationship has to be established between geometric figures and images. The task of homography can be implemented by using a homography matrix that relates coplanar image space points. In contrast, another matrix known as the essential matrix can also be used to relate images, but it requires more points to calculate. If we use a homography matrix, it also abolishes the necessity to measure the internal and external parameters of the camera [1]. Homography is defined by its countless excellent applications such as image rectification, image registration, image rotation and translation etc. One most extensive applications of homography are wall-climbing robots. They can even take the place of human beings while working with threatening events tasks such as analysis of storage tanks in petrochemical facilities, nuclear power plants, constructing and examining tall buildings, keeping the maintenance and welding to ship hulls and application in open-pit mine walls [2]. It can be seen that wall climbing robots are also used in a variety of engineering applications.

In the sphere of computer vision, any two images of the same planar surface in space are associated with a homography. Homography provides the results with error-free calibration and presents a new way of working with color correction algorithms [3]. The color homography problem is solved with the help of at least four non-planar rays. To find the solution for homography problem, the planar homography associates the transformation [4] between two planes:

$$8 \begin{bmatrix} x' \\ y' \\ 1 \end{bmatrix} = H \begin{bmatrix} x \\ y \\ 1 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} & h_{13} \\ h_{21} & h_{22} & h_{23} \\ h_{31} & h_{32} & h_{33} \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix} \quad (1)$$

The equation 1 makes it clear that homography matrix (H) is a 3X3 matrix [5] that maps the points in one image to the analogous points in the other image but with 8 degrees of freedom. In analytical methods, the number of degrees of freedom is that number which is not bound for any change in the final results and calculations. The homography matrix is generally normalized with  $h_{33}=1$  or  $h_{11}^2+h_{12}^2+h_{13}^2+h_{21}^2+h_{22}^2+h_{23}^2+h_{31}^2+h_{32}^2+h_{33}^2 = 1$ .

## 2. BACKGROUND STUDY

In this section, we have presented the framework of the Homography Estimation System, which explains its functionality with the help of different phases. The system has two approaches, i.e. Direct and Feature-based approach. Homography has various applications in different zones, such as collision avoidance, Image stitching, video color grading etc. We also talked about various Benefits and Issues related to it.

### 2.1 Framework of Homography Estimation System

The Framework of Homography Estimation System consists of different phases. In the Input Phase, it takes the source picture as input from a database of colorful objects [6] where its chromaticity distribution represents the color content of each image. Chromaticity is an accurate description of the quality of color despite its lighting effect. After this, the source picture passes through a Color correction Homography Model. Whereas in the Process phase, the source picture taken as input is inserted into the homography model, which generates an immediate (close) estimation picture, i.e.  $P=H(I, O)$ , where homography  $H$  plots the  $I$  image to estimate  $O$  image. In the Result Phase, the output picture results with a similar segment as the I/P picture but with divergent radiance and illumination. Speed Calculation Phase provides the result of the whole process with a quick calculation speed.

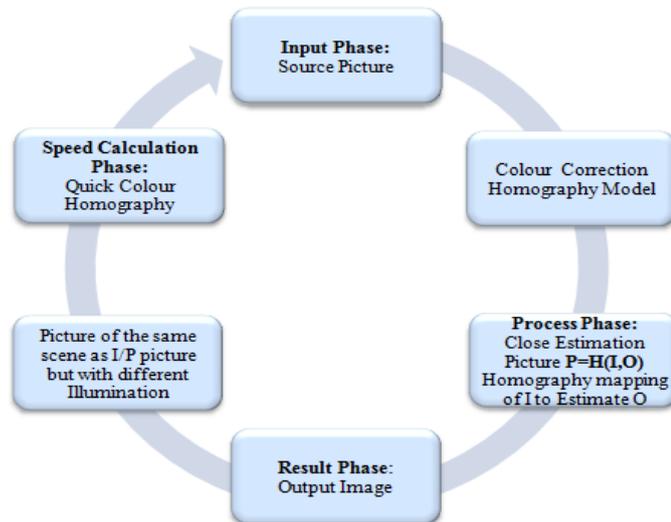


Fig. 2 Phases of Homography Estimation System

Fig.2 describes the Phases and directions of the study; here a methodological approach in the shape of block diagram for the homography estimation model is explained in Fig. 3. This approach is used to solve a color homography problem.

### 2.2. Approaches to Homography Estimation System

As part of a tradition, there are two approaches for homography estimation such as a direct method or pixel-based method approach and a feature-based method approach. Fig.4 shows both approaches and their schemes used for Homography Estimation System. The explanation of both approaches is as follows:

#### 2.2.1 Direct Method Approach

The direct Method approach [7] is based on the Seminal Lucas-Kanade algorithm, which uses pixel to pixel correspondence. The performance of the direct method can be enhanced by using a different adequate criterion such as the Fourier domain, enhanced correlation coefficient (ECC), incorporating direct method with the feature-based method, and using different parameters under image alignment schemes. These parameters are error metric, Hierarchical Motion Estimation, Fourier Based Alignment, Incremental Refinement and Parametric Motion. The first parameter error metric works based on squared differences (SSD) for relocating and twisting

similar images. It makes use of gradient descent optimization [8] technique to minimize the error function. The Error Metric is used to calculate the error in the upcoming models.

### 2.2.2 Feature Based Approach

Feature based approach is used to extract important features from an image. Feature based approach for homography estimation makes use of a Scale Invariant Feature Transform (SIFT) for retrieving the key information of each image. Then feature matching is established to create a correspondence between the two sets of key information and Random Sample Consensus (RANSAC) [9] is used to get the accurate homography results. Feature based approach [10] gives better output in comparison with the direct approach because the homography parameters [11] are linearly connected to the simple functions of the feature coordinates but this approach can be imperfect if it fails to find the enough key information. Feature based approach does not perform well even in the presence of illumination [12]. It makes use of different parameters for better results such as Key point detectors, Feature matching, Geometric Registration. The earlier methods under the feature based approaches, works after detecting the “corner-like” features of an image. But now key points are used to detect the salient features such as interest points or salient points. Key point detectors have number of applications such as three dimensional reconstructions, function localization [13]. After detecting the features or key points under the Key point detector scheme, they must get matched. Matching means to find those features which arises from analogous locations in different images. The Error Metric Scheme covered under direct Method Approach can be used to compare the intensities in small-scale dots around each feature point for the completion of matching process [14]. Once the matching process is complete, the next is to evaluate the motion parameters that are owned to register the two images. The usual way to perform Geometric Registration [15] is done by using Least Square method. It is a procedure to fit a unique curve through the given points. This method follow three steps for implementation: Form Normal equation, Solve to get constants, put constants in curve equations.

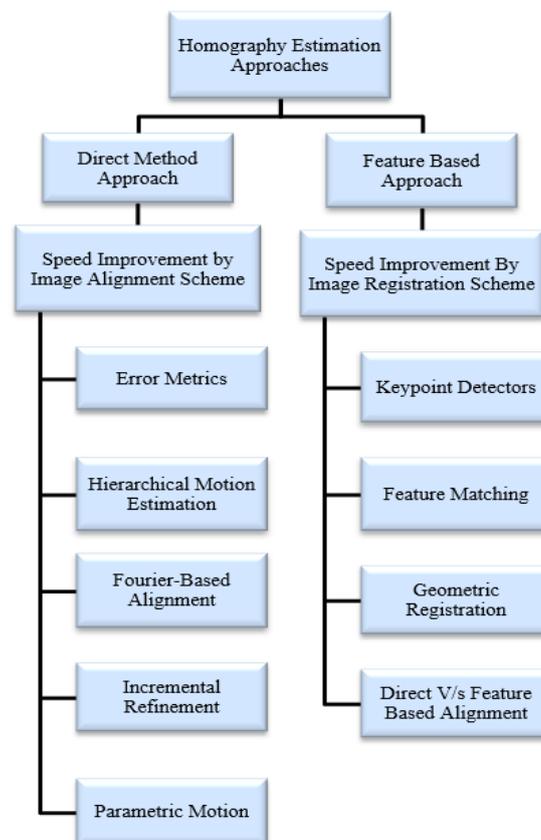


Fig.4 Approaches to color homography estimation system

Mostly, direct based approach is used for the purpose of Image Alignment because they make appropriate utilization of every pixel present in the image. Whereas feature based approach does not proves well in those sectors which are either too textured or not textured. Sometimes, the features are not distributed uniformly above images so it gets difficult to match image pairs under feature based approach.

### 2.3 Benefits & Issues of Color Homography Estimation System

Homography plays a vital role in many computer vision applications and robotics issues [16], especially where artificial environments are established using planar surfaces [17]. In this section, the Benefits and Issues of the Homography Estimation System are discussed. The essential benefits of Color Homography Estimation system are:

- It allows different error metrics to be used, not just least-squares error [18].
- Homography plays an essential role in robotics and computer vision applications.
- Wall-climbing robots are one of the applications of homography estimation. They can be used for performing complex tasks where the involvement of human beings can be avoided/minimized.
- Wall-climbing robots can be used for assessing the storage tanks in petrochemical premises.
- Homography is based on two approaches-Direct Methods and Feature-based Methods. However, Feature-based methods are very beneficial because of considerable advancements in feature extraction algorithms such as SIFT, SURF, ORB etc.

#### **Different problems and troubles involved in constructing and executing the Homography Estimation System are:**

- One of the methods for Homography Estimation is RANSAC [19], its computation cost rises when the outliers are at a high proportion rate.
- It is challenging to address the accuracy for multiple homography estimation [20] as almost all multi-model estimation algorithms are based on stochastic model creation, which does not work with random sampling, and proves to be deterministic.

Theoretically, one can rightfully claim that homography estimation from point correspondences has been solved as many linear and non-linear approaches are available. The tradeoffs of accuracy versus computational complexity are well known, and developers of vision applications [21] can decide the correct for them depending on the nature of their problem.

### 2.4 Application Areas of Color Homography

Here, we have mentioned many applications of this innovative approach for Color Homography System. We here confidently assume that homography is one of the inspirational and demanding field in computer vision. Various application areas for the Homography Estimation system are as follows:

- **Mosaicking:**  
Mosaic means a view or vision which is created by collecting small pieces of stones, seeds, bricks, slates etc. In Homography, Mosaicking can be used to build a smooth presentation of image surface after joining together a collection of images
- **Image Registration:**  
It is the process to line up the multiple images of the same site in order to get more information. Image registration has big application in the field of medical images because it registers the medical images by upgrading its quality.
- **Monocular (SLAM)**  
Homography Estimation process has two approaches i.e. direct and Feature based approach. Simultaneous Localization and Mapping algorithm plays very important role in image feature matching.
- **3D Camera pose reconstruction**  
Pose reconstruction is a powerful approach towards homography which results with good image matching accuracy and camera poses. It creates three dimensional models from a collection of images.



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➤ **Collision avoidance**

Collision avoidance is a very important application of homography as it assists systems to discover obstacles and check the collisions. For this purpose, a hybrid stereo vision –based method [22] is used that integrate Stereo matching and transformation methods based on homography.

➤ **Image Stitching**

It is the process of joining multiple images to produce a high-resolution image. In Homography, an image [I] is taken to select some feature points and then homography matrix derives and align different pairs of images from neighborhood.

➤ **Video color grading**

Color grading application is used to apply technical and creative changes in images or videos such as environment, feelings, reactions, excitement etc. It produces results in one run without implementation of extra steps to remove artifacts. Color grading tools are not perfect so lookup tables are used to achieve the results[23]. With color grading the image can be manipulated in a required format.

### 3. CONCLUSION AND FUTURE DIRECTION

This survey paper illustrates the very important aspect that image chromaticity is well related by homography even if changes are observed in surroundings such as shading, camera, changing light intensity, radiance and illumination. We demonstrate that the homography estimation system is capable to deal with huge displacements and large illumination variations in images that are a challenging task. We have also discussed about various approaches, applications, issues, benefits. Our findings also provide additional evidence for applying homography to various robotics perception problems. One of them is wall climbing robots, they can even take the place of human beings while working with the threatening events tasks such as analysis of storage tanks in petrochemical facilities, nuclear power plants, constructing and examining tall buildings, performing the maintenance and welding to ship hulls and application in open-pit mine walls. It can be seen that wall climbing robots are widely used in a variety of engineering applications. Exact location detection is important in the controlling of wall-climbing robots. In future, researchers can work on this system to find the obstacles in designing the safe walking route for the wall-climbing robot.

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## A Review on Advancements and Characteristics of Cryogenic Propulsion Rocket Engine

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### Abstract

Future space exploration missions will require the synergistic integration of potentially lightweight, high thrust producing, and environmentally sustainable rocket engines. This article guides through one such capable rocket engine, the cryogenic propulsion rocket engine and some cutting-edge characteristics and novel engineering advancements affiliated with it. A typical cryogenic-propulsion rocket engine works similarly to all other LPRE's (Liquid Propellant Rocket Engines), in which the primary fluid (Cryogenic fuel 1) reacts chemically to get vaporized and get ignited by an oxidizer to provide extremely hot rocket thrust that escapes the engine nozzle and generates thrust from the combustion process. Considerable efforts have been made to optimize the engine's performance and reliability in order to utilize the most desirable output from it. Therefore, a brief overview of the different models and research approaches associated with it to provide predictions and results about the stability, dynamics, and cooling characteristics of the given engine configuration is presented.

**Keywords-** Propulsion, Cryogenic propellant, Liquid rockets, Cryocooler, Combustion, Regenerative cooling

### 1. INTRODUCTION

Effective human exploration of the solar system in the future will only be possible with engines capable of producing high thrust and specific impulse due to the ever-growing payload mass demands, and an engine that accommodates these requirements efficiently in the current industry is a cryogenic propulsion rocket engine. In 1877, Louis Paul Cailletet and Raoul Pictet experimented with liquefying oxygen gas, in which this liquefaction process prefigured the beginning of low-temperature science, the cryogenic technology. During World War II, however, this technology was further explored for propulsion applications with the development of the V2 rockets, which used cryo-fuels liquid oxygen/kerosene. Finally, with the deployment of the world's first cryogenic rocket engine, the RL-10 engine for NASA's upper-stage Centaur space launch vehicle in 1963, cryogenic rocket technology's possibilities in the aviation sector became more prevalent. As a result of the RL 10's remarkable range of spin-offs and phenomenal confidence level in the design, construction, and handling of cryogenic systems, as well as due to its feasibility in rocket technology, several space organizations and companies around the world became engaged and started building these systems indigenously for sustainable exploration beyond the Earth (Mohite et al. 2012; Thakur and Pegu 2017)

Cryogenic fluids are those fluids that are gaseous at room temperature but are preserved at low temperatures below their boiling point (below approximately -150°C), and a conventional cryogenic-propellant rocket engine operates similar to LPRE's (Liquid Propellant Rocket Engine), but instead use at least one cryogenic fluid to propel. It consists of i) separate tanks for storing different cryo-propellant(s) and oxidizer, ii) an axisymmetric nozzle with iii) a combustion chamber, iv) a system for injecting propellants into the combustion chamber, v) a nozzle throat and vi) a convergent-divergent section (Olivier Dobek and Daniel Le Dortz 2015). The primary fluid (Cryofuel 1) is vaporized and get ignited by an oxidizer to provide typical hot rocket thrust, i.e., they (primary fuel and oxidizer) react chemically to produce a super-hot stream that escapes the engine nozzle and generates thrust from rapid expansion from this liquid to gaseous state.

The behaviour of cryogenic fluids gives rise to plenty of phenomena that take on a different significance when compared to the actual behaviour of fluids at room temperature. Therefore, several problems are likely to occur from an experimental perspective during the development of these engines until their successful launch. Due to the cryogenic quality and after-effects associated with these propellants, causes difficulty in operating it in multiphase conditions. Therefore, understanding the experimental setup and test conditions of this engine, in aligning with the selection of proper measuring approaches to extract quantitative facts about its properties is vital, so that it would be easy to devise strategy for avoiding the potential risks (Scurlock 1990; Esposito 2020).

## 2. PROPELLANT COMBINATIONS

The fuel and oxidizer used to produce the propellant in a LPRE like cryogenic engine are extremely cold, liquefied gases. These liquefied gases are actually super-cooled gases used as liquid fuels and the reason why it is referred to as super-cooled is because they remain in liquid phase, despite that they are below the boiling point. It is very critical to understand the characteristics and properties of these liquids (the non-reacted fuel and oxidizer liquids) and those of the hot gas mixture released by the combustion chamber reaction. The properties and characteristics however, depend on the chemical composition of the propellants, i.e. a high chemical energy content per unit of propellant mixture and a low molecular mass of resultant gases is preferred and ultimately has a significant impact on obtaining high engine performance. This resultant performance of the engine can be examined by analysing and calculating the propellant density, the specific impulse, mixture ratio and certain other parameters under operating conditions with high degree of accuracy (Sutton and Biblarz 2001).

Table 1. Characteristic of Few Cryogenic Fluid Combinations (Oskar J Haidn 2008)

Oxidizer	Fuel	Mixture ratios ( $r_{of}$ )	Specific Impulse ( $I_{sp}$ )	Density (in $kg/m^3$ )
Liquid Oxygen	Kerosene	2,77	358	820
	LH <sub>2</sub>	4,83	455	700
	LCH <sub>4</sub>	3,45	369	430

See Table 1, this comparative analysis helps understand the properties of frequently used cryogenic propellant combinations such as their mixture ratios, specific impulse and densities. Out of these propellants, currently LOx (Liquid Oxygen) /LH<sub>2</sub> (Liquid Hydrogen) combination is used in most cryogenic engines to utilize the relatively high thrust and delta velocity, especially in their upper stages. So here in this article this particular propellant combination is focused while compared to others.

### 2.1 LOX - LH<sub>2</sub> Propellant Combination

The hydrogen gas and oxygen gas are super cooled to a temperature of -423 degrees Fahrenheit (-253 degrees Celsius) and -297 degrees Fahrenheit (-183 degrees Celsius) respectively into liquid states (LOX and LH<sub>2</sub>) to accommodate in a smaller, lighter tank. The LH<sub>2</sub> and LOX are fed into the combustion chambers of the engine once they are in the tanks as the launch countdown approaches zero. The hydrogen in the propellant interacts rapidly with oxygen to produce water when it is ignited. A tremendous amount of energy is produced along with superheated water (steam) in this "green" process. As a result, a lot of heat is produced which significantly causes the water vapour to expand and escape through the engine nozzles at about 10,000 mph or more. Thereby the force that drives the rocket to rise off is created by all of that fast-moving steam. Cryogenic LH<sub>2</sub> - LOx however, isn't simply a great combination because of the ecologically friendly water reaction, whereas it's all about due its incomparable specific impulse (Isp) capability (Perry 2016). Behind the scenes, there is a major influence of propellant combination and their mixture ratio on the specific impulse of an engine and when looking at the Fig 1, it is almost clear that LOx-LH<sub>2</sub> when blend together results in producing peerless specific impulse effect.

Notardonato (Notardonato 2012) has claimed that the LOX/LH<sub>2</sub>-based engine is the only engine in the industry so far that outperforms any practical chemical propellant mixture there-by operating at the highest efficiency. Apart from propulsion point of view, he also described that, long-term cryogenic storage will also be possible with these cryo-fluids, due to its advancements in active and passive temperature management, thus making these propellants nearly as "storable" in space as hypergols. The propellant combination analysis performed in NASA's Titan Orbiter Polar Surveyor (TOPS) mission (Mustafi et al. 2016) set forth that a LOX/LH<sub>2</sub> propelled missions saves 43% launched mass over Methyl hydrazine (MMH) and Nitrogen Tetroxide (NTO) hypergolic propelled missions (used in LPRE's before cryo-propellants) due to their notable specific Impulse. In addition to this, during the development stages of ISRO's in-house GSLV Mk 3 project (Praveen et al. 2017), its LOX/LH<sub>2</sub> based upper stage engine(CE20) was revolutionary at the time to operate in the gas generator cycle and was sufficient to attain a specific impulse of 443 seconds in a vacuum and operating thrust range between 180 kN to 220 kN, which was indeed a ground-breaking news to the aerospace community. All key elements like as atomization, vaporisation, reaction, mixing, thermal loads, nozzle performance, and engine stability were taken into consideration while designing the CE20's thrust chamber. Similarly, the advancement of this combination is even observable in commercial sea launch technologies and projects. For example, the medium-lift Chinese rocket CZ-8A/RH (SONG et al. 2021) was launched at sea and contained a second core or

upper stage process operating with LOX/LH<sub>2</sub> engines, resulted in the improved feasibility and commercial value of launching cryogenic liquid-fuelled rockets at sea.

These cryo-fuels (LOx and LH<sub>2</sub>) typically have a lower volumetric energy density than most other fuels, and being bulky, large volume tanks are necessary for accommodating these propellants, which significantly arises drag penalties. These penalties aren't however significant enough to surpass its high specific impulse and thrust generation capability (Arnold et al. 2006). However, the possibilities of substitutes like LCH<sub>4</sub>/LNG combo surpassing the LOx/LH<sub>2</sub> in the near future cant be neglected.

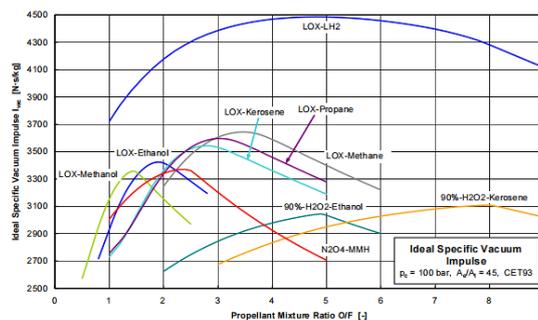


Fig 1: The influence of the propellant combination and the mixture ratio on the specific impulse (Oskar J Haidn 2008)

## 2 COMBUSTION DYNAMICS & INSTABILITY

Combustion dynamics and control are already pressing priorities in energy and propulsion technology. Along with the origin of cryogenic rocket engines in the early 1950's, former Soviet Union and the US's were fundamentally dependent on manual experimental-trial and error procedures, and primitive analytical tools, because the optical imaging, computing power, numerical approaches and other modern techniques were all in their infancy at the time (Haidn and Habiballah 2003). However, there came a point when manual approaches like trial and error procedures, etc. became impractical and economically unfeasible, such that computational simulations and other state of the art diagnostic techniques were necessary to evaluate the realistic conditions of the system undergoing combustion. Since then, a substantial deal of progress was achieved and combustion analysis methodologies of a cryogenic engine progressed from a basic science to a more complex art.

In a typical combustion chamber, the resultant flow due to chemical reaction is turbulent, reactive, and fluctuates between subsonic and supersonic speeds. As a result, combustion instabilities are likely to arise due to the system's combustion, resonant modes and fluid dynamics combination and have long been recognised as a major concern in cryogenic engine development. Usually, the high-frequency (HF)-thermo-acoustic (chamber instability) instability that results from the interaction between the combustion process and the chamber acoustics are portrayed as the most detrimental. These instabilities result in extremely unstable heat transfer rates, accelerates the combustion process by shortening the flame, leading to local burnout of the combustion chamber walls, injector plates, and severe damage to the propulsion system. In fact, the unsteady heat release during combustion may be regarded of as an acoustic source that transfers sound disturbances throughout the combustor. When these pressure waves transiting away from the source encounter an acoustic boundary, they start reflecting towards the flame, causing acoustic pressure and velocity perturbations in the proximity of the injector plate. This results in modifying the incoming propellant flow and cause local fluctuations to the unsteady heat release rate. If these acoustic oscillations affect the burning rate with the appropriate phasing, the severity of the instabilities inside the reaction slot increases and causes enhanced flame oscillations. As a result of this unstable heat release fluctuations, increased amplitude acoustic disturbances are developed, accelerating the build-up of instability (Bennewitz and Frederick 2013). Considering all these complex phenomena inside the engine, adding baffles, resonators or cavities was initially thought to be viable enough to decrease the oscillation level and make the system stable. Using these devices however were just a partial fulfilment for a broad subject like this.

Woschnak et al. (Woschnak et al. 2003) studied thermal transfer characteristics in a LOx/H<sub>2</sub> combustion chamber containing longitudinal mode HF instability. During the study, it was observed that raising the chamber pressure above critical affected the relative strength of particular transfer functions in the measured oscillation spectrum substantially. These findings were helpful in understanding that injection of fuel into a supercritical environment has a significant impact on the interaction of acoustic waves with the atomisation and combustion processes.

In support to this, DLR facility (Smith et al. 2004) performed a comprehensive analysis of injection settings in a sub-scale combustor known as 'Combustor C' (BKC). Here, a hydrogen injection pressure dropped less than 20%

of chamber pressure enabled different modes of unstable combustion to evolve at subcritical conditions. The first longitudinal (1L) acoustic (HF) mode within the chamber was observed along with an injection coupled Low Frequency (LF) mode. When operating at or over the critical pressure of oxygen, however, there was no evidence of instability. Later, a similar experiment (Lux and Haidn 2009) was conducted using the same BKC probe. This time LOx/CH<sub>4</sub> combinations was used and OH\* emission patterns with and without recess were contrasted within subcritical and supercritical chamber pressure conditions. Changes in the shape of the jet and emission intensity, soon after injection were noticed to be apparent during functioning with a recessed injector and were found to be sharper at supercritical pressure than for subcritical. Additionally, no such fluctuations were detected when used with a non-recessed injector. More accurate and validated results were obtained when probe setup Combustor H and Combustor D were used to study the thermo-acoustic instability. These setups are considered as a more potential successor of Combustor C (BKC). Combustor H is a multipurpose subscale rocket thrust chamber that exhibits spontaneous acoustic resonance of an engine running on LOX/LH<sub>2</sub> propellants, while Combustor D evaluated the resultant flame under forced acoustic interactions and perturbations (see (Hardi et al. 2018) for detailed information). A wide variety of theoretical and pragmatic methods, such as setting up a Lattice-Boltzmann model, CFD simulations, Shadow-graphic Imaging, and Lumped parameter modeling, were used to visualize the instability pattern in these simulated probes and these approaches were convenient in evaluating the combustion instabilities and the behavior of the cryogenic propellant under realistic LPRE conditions (transient, injection, and ignition), thereby delivering better, sharper results. The multiple injector combustor (MIC), which utilizes five coaxial injectors to construct a thermo-acoustical environment and monitor flames at subcritical or trans-critical conditions, was regarded as a potential contender to investigate if contact between flames from adjacent injectors might be a key mechanism for supporting combustion instability. The propellant mixture LOx/H<sub>2</sub> was first employed, but this was later replaced with LOx/CH<sub>4</sub> (Richecoeur et al. 2006) to utilize the advantage of obtaining lower injection velocities and hence flames that are more responsive to acoustic oscillation. The oscillation level, which reached roughly about 8% of the chamber pressure, however wasn't sufficient enough to approximate the extremely high oscillation amplitudes found in engine thrust chambers. Therefore, a more advanced, very high amplitude modulator (VHAM) was integrated with the MIC and was used to stimulate transverse, thermo-acoustic modes and investigate their effects on flame dynamics under intense fire conditions (Méry et al. 2013).

In regard to the above-mentioned state of the art studies and approaches, a lot of vital experiments were/are being put into trying to learn and regulate the combustion dynamics of the engine's combustion chamber, so-as-to reduce the likelihood of combustion instability. After validating each of those methodologies, most of their experimental data and preliminary results were found to be in good agreement. However, despite decades of study, the ability to forecast each mode of combustion instability empirically based on physio-chemical parameters, engine and its operating characteristics has yet to be achieved.

#### 4 COOLING SYSTEM

Usually during operational conditions, it is observed that the thrust chamber of a cryogenic rocket engine is subjected to severe conditions, with elevated pressures of up to 30 MPa and temperatures reaching 3500K, such that an increased heat transfer rates is resulted in the thrust chamber (as high as 100 MW/m<sup>2</sup>). i.e. the oxygen combustion produces extremely high temperatures and pressure in the thrust chamber and these high thermodynamic circumstances combined with diffusion flames burning near stoichiometric ratio can result in concentrations of burned gases exceeding this 3500 K range (Grenard et al. 2019). When such hot concentrations approach the combustion chamber walls, intense heat fluxes and extremely high temperatures occur, which may transcend the material's thermal resistance. Local heat flux values fluctuate throughout the thrust chamber wall depending on geometry and design factors, however the highest heat flux is seen proximal to the nozzle - throat area. Figure 2 illustrates a typical heat flow pattern along the thrust chamber wall.

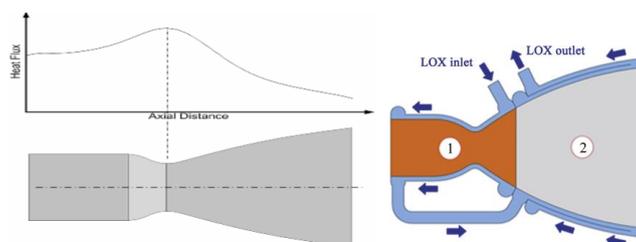


Fig 2: a) Heat flux variation at thrust chamber (Vinitha et al. 2013) b) Regenerative cooling

Meanwhile studying the post-launch conditions, the heat from the Sun and other celestial bodies near the spacecraft (such as Earth, the Moon, and Mars), as well as the heat conducted to the cryogenic storage tanks from other sources on the rocket, is predicted to cause the cryogenics(fuel) to pressurize or boil off (i.e., change state

from liquid to gas). As a function of these different venting process, the propellant quantity would be inadequate for running the engine during long-duration missions.

Considering these two significant scenarios that could cause the engine to be inefficient, or may be destructible, there has been a necessity of an effective cooling techniques and systems for enhanced reliability and reusability of the engine. For heat management of cryo-rocket engines, a variety of cooling techniques such as regenerative cooling, film cooling, ablative cooling, and radiative cooling are employed in order to keep the wall temperature of engines within the material limit. However, regenerative cooling (see fig 2.b) and film cooling are two of the most used methods.

On the other side, using passive and active insulation systems seems to be a less complex technique to reduce heat flux. The passive insulation systems that meet these requirements includes multi-layer insulations and active heat removal systems such as Cryocoolers, Thermodynamic Venting System (TVS) can manage and reduce the fluid temperature and heat leaks respectively (Taylor et al. 2015). Since the early space programs (which began in the 1950s) and after the development of 80K Stirling long life coolers, used in the Improved Stratospheric and Mesospheric Sounder (ISAMS) and Along-Track Scanning Radiometer (ATSR-1) instruments (Ross and Boyle 2007; Ross 2015), countless experiments have been performed to come up with a feasible state of the art technique. However, maintaining the temperature of the cryo-fuels as low as possible while still holding the Zero Boil Off (ZBO) point was extremely difficult. An efficient TVS can control the pressure in the propellant tank and at the same time reduce the thermal stratification and eliminate environmental heat leakage. By allowing indirect venting of vapor through heat transfer between the discharged fluid and the fluid stored in the tanks (Mustafi et al. 2016), this phenomenon of attaining ZBO can be achieved. Correspondingly, NASA's Cryogenic Boil Off Reduction System (CBRS) and 90K -20K cryocooler setups (Plachta et al. 2018) provided the scientific community with prolific test results in maintaining an exploration vehicle's propellant mass parameters by minimizing the thermal gradients and further allowed robust pressure control in the propellant tanks. Using Highly Effective Heat Insulation (HEHI) materials such as polyethylene terephthalate film and glass wool lining on the sides of the tanks, along with the cryo-pump designs using CaE-4B, Ca-H, carbon fabric adsorbents to limit boil off in reservoirs was suggested by Gorbaskii et al. (Gorbatskii et al. 2002). They also developed a new system that avoids clogging of the mixing chamber, so that the issue of storing the propellants for an extended period could be effectively solved.

Similarly, the strategy by using a recirculation chill-down mechanism for cooling the turbopump for long-duration space explorations have been addressed in (Kinefuchi et al. 2020), where a cryogenic pump extracts propellant from the tank into the engine via feedlines and thereby the enthalpy of the propellant rises considerably to chill down the turbopump. Then this extracted propellant is recirculated back to the tank without getting vented outside to recover the radiant energy vented from the engine. This recovered heat can be substituted to heat the inert fluid for pressurizing one or more propellant tanks and is advantageous in limiting the use of additional devices (electro-thermal systems) required to heat the inert fluid, thereby reducing the onboard weight of the launcher.

## 5 CONCLUSION

Since the beginning of this low temperature technology, it has been apparent that the theoretical and practical study of cryogenic characteristic engine is highly challenging and often falls short during each development process. This review has examined the characteristics and research activities associated with the cryogenic rocket engine and have summarized the potential of using this engine for fulfilling the ever-growing payload mass-thrust demands, with sustainable methodologies. In summary it was found out that, when a suitable, state-of-the-art analyses and techniques comes into place, the engine is expected to rise off incredibly with reduced drag penalties and desired performance and efficiency. Therefore, a need for constant improvement in the efficiency and durability of current LPRE's, such as a cryogenic engine and the development of a new propulsion technology; but without jeopardizing the environment's sustainability is vital.

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## Effect of Working Posture, Feed Force, and Drill Speed on Productivity and Perceived Discomfort

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### Abstract

Work-related musculoskeletal discomforts are prevalent in industries. The purpose of the research was to identify the effect of drilling height, feed force, and drill speed on productivity and worker discomfort for a drilling task. Right-handed male subjects completed 27 drilling work exertions stratified by drilling height (at shoulder height and 15 cm above and 15 cm below it i.e., H<sub>2</sub>, H<sub>3</sub> and H<sub>1</sub>), feed force (4.5, 6, and 7.5 kg) and drilling speed (2400, 2600 and 2800 rpm). A non-parametric ANOVA on rank test revealed that drilling height had a significant effect on the productivity and perceived discomfort score. Feed force had a significant effect on the perceived discomfort score of shoulder and productivity. Drilling speed significantly affected perceived discomfort score in wrist. The results support evidence-based approach to horizontal drilling tasks for the industry.

**Keywords-** Industrial ergonomics, Drilling, Shoulder height, Feed force, Drill speed, WMSD, Productivity.

### 1. INTRODUCTION

About 20–33% of individuals across the globe, live with painful musculoskeletal conditions [1]. Work related musculoskeletal disorders (WMSD) have been reported widely over the last few years. WMSDs are usually associated with the use of hand held tools, especially those with an un-ergonomic designs [2] which results in muscle fatigue [3]. Hand held such as drilling tool is one such example which finds high utility among carpenters and industrial workers. In a drilling task, feed force and drilling speed are two major factors that affect productivity and fatigue rate. Feed force usually have a significant effect on the discomfort score and productivity [4] [5]. While higher feed force is generally associated with more discomfort and higher productivity [6] [4]. However, Muzammil et.al. reported no significant effect of feed force on heart rate and blood pressure of subjects for a drilling task [7]. Similarly an increase in drilling speed reduces machining time, thereby improving productivity [8]. Drilling speed also has a significant effect on the discomfort score [9]. Subjects perceived discomfort score was found to be least for a combination of highest drilling speed and lowest task duration [9]. Further, working posture such as shoulder flexion angles also affects muscle fatigue and subject's discomfort perceptions [10]. Shoulder flexion angle also affect the ability to generate feed force, higher the flexion angle usually provide lower the feed forces [10].

Productivity is a major concern for employers and employees alike. It may be worth noting here that worker's health, fatigue, and productivity are closely related [11]. Studies have shown that fatigue leads to a substantial loss in productivity [12]. Subjective measures such as body discomfort charts have been used extensively in ergonomic studies, for assessing fatigue, as perceived by the worker [13]–[15]. The modified Bishop Carlott scale, which Dimov et al. utilised to quantify physical discomfort in a carpentry work [16], was also used in the current investigation. On the basis of the literature reviewed, it was decided to examine the effect of drilling height, feed force, and drilling speed on productivity and perceived discomfort. Null hypothesis framed was that shoulder posture, drilling speed, and feed force have no significant effect on productivity and perceived discomfort of a worker performing a drilling task.

### 2. EXPERIMENT

The above hypothesis was tested through a series of experiments. Drilling was performed at three levels of shoulder posture [15 cm below shoulder level (H<sub>1</sub>); at shoulder level (H<sub>2</sub>) and 15 cm above the shoulder level (H<sub>3</sub>)], 3 levels of feed force [4.5 kg (44N), 6 kg (59N), 7.5 kg (73N)], and 3 levels of drilling speed [2400, 2600 and 2800 rpm]. Drilling heights corresponded to shoulder flexion angles of approximately 60<sup>0</sup> (H<sub>1</sub>), 90<sup>0</sup> (H<sub>2</sub>), and 120<sup>0</sup> (H<sub>3</sub>). Worker fatigue in terms of perceived discomfort score (modified Bishop Carlott scale), number of holes drilled and time were monitored as the dependent parameters. Productivity was then calculated in terms

of the number of holes drilled per unit time. Each participant performed 27 randomized combinations of experiments (3 levels of drilling height \* 3 levels of feed force \* 3 levels of drilling speed). The whole set of readings was taken across several weeks to give the participants ample rest. The study included five healthy right-handed male students from Aligarh Muslim University's Zakir Husain College of Engineering and Technology. To eliminate any acclimatization or bias, volunteers were chosen who had no experience in drilling. They had no prior musculoskeletal issues. The table 1 illustrates the participants' characteristics.

Table 1. Characteristic of subjects who took part in the study

Characteristics	Mean	Std dev	Range
Age (years)	24.00	0.81	23-25
Weight (N)	70.07	12.82	60-92
Height (cm)	170.27	5.05	165.2-192

The experimental setup consisted of a load cell, a wooden block of Acacia Arabica tree (Babul tree), a handheld drill machine, an electronic display unit, a stopwatch and EMG sensors. Drilling was done on a plank of babul wood. The load cell was calibrated on the ground by using 1 kg, 5 kg, and 10 kg weights. The zero reading of the electronic display unit included the weight of the wooden plank. The wooden plank was fastened to a load cell, which in turn was mounted on an iron plate. The iron plate was fastened to a wall. The load cell was placed in the vertical direction [13] to prevent it from bending from the weight of the wooden plank. A similar setup has been used in many studies earlier[5] [17] [18]. Since the setup was fixed to the wall, a platform was used to adjust the different drilling heights. The platform was steady and wide enough to allow the subject to stand comfortably [6] [19]. A stopwatch was used for recording endurance time.

Subject were asked to drill holes at pre-marked locations along a straight line for as long as possible, while maintaining a pre-defined feed force. The feed force applied was displayed on the LED board and monitored closely by the experimenter. They were instructed to use both hands for drilling [20] and to hold the drill in a neutral wrist position for better results [17]. They were encouraged to adopt a comfortable standing distance from the drilling point, to have some adjustability [6], [19]. Verbal encouragement was provided by the experimenter to maintain the feed force levels within +/- 15% of the preset values [21]. However, a participant was considered fatigued if the applied force varied more than three times in 30 seconds beyond permissible limits or if he opted to quit the experiment and the task was discontinued [21]. The total time duration of the drilling task and number of holes drilled were noted. Subjects were then asked to rate their discomfort on the scale from 1 to 5 on bishop corlett body chart after each task.

## 3 RESULTS

### 3.1 STATISTICAL ANALYSIS

A Shapiro Wilk's test of normality in SPSS ( $p > 0.05$ ) [22] (Table 1) showed that the results of productivity [skewness of 0.783 (SE= 0.209) and kurtosis of 0.126 (SE= 0.414)] are not normally distributed. Also, since sample size taken was small, a non-parametric ANOVA on rank test (Table 2) and nemenyi post hoc test (Table 3) were performed in R studio to test the hypothesis. Significance level was selected as  $p=0.05$ .

### 3.2 PRODUCTIVITY

Productivity was found to be significantly affected by drilling height ( $p < 0.001$ ) and feed force ( $p < 0.001$ ) but not by drilling speed. A post hoc test revealed that drilling height  $H_1$  was significant different from  $H_2$  and  $H_3$  in terms of its effect on productivity. Error bar chart fig 1, shows that productivity was maximum when the drilling task is performed at drilling height  $H_1$ , and minimum at drilling height  $H_3$ . Further, post hoc test showed that a feed force of 4.5kg was significantly different from 6 kg ( $p= 0.01859$ ) and 7.5 kg ( $p=0.00035$ ) in terms of its effect on productivity. Fig 2 shows that the productivity was minimum at 4.5 kg feed force and maximum at 7.5 kg feed force. All the two-way and three-way interactions had no significant effect on the productivity. Fig 5 shows, the productivity was maximum for drilling height  $H_1$  feed force applied 7.5 kg of the drilling speed and minimum for drilling height  $H_3$ , feed force applied 4.5 kg of the drilling speed.

### 3.3 PERCEIVED DISCOMFORT

Subjects perceived, shoulder, elbow, arm and wrist/hand as the most discomforted part on the basis of the modified bishop carlott scale. Non parametric ANOVA analysis of discomfort score in table 2 showed that shoulder, elbow, arm and wrist/hand discomfort were significantly affected by 3 shoulders height ( $p < 0.05$ ), shoulder discomfort was significantly affected by 3 feed force ( $p=0.02982$ ) and wrist discomfort was



significantly affected by 3 drilling speeds ( $p=0.00176$ ). Post hoc test showed that significant difference exists between drilling at  $H_1$  and  $H_2$  ( $p < 0.001$ ),  $H_1$  and  $H_3$  ( $p < 0.001$ ) on discomfort of shoulder. Error bar chart fig 3, shows that discomfort in shoulder is minimum for  $H_2$ . A nemenyi post hoc test showed a significant difference between drilling speed 2400, 2600 ( $p= 0.011$ ) on discomfort of wrist. Fig 4 shows that discomfort in wrist is minimum for 2400 rpm of drilling speed. Post hoc test showed no significant difference in the effect of 3 feed forces on discomfort of shoulder.

**Table 1 ANOVA on rank test**

P Values	Drilling height	Drilling speed	Feed force	Drilling height: Drilling speed	Drilling height: Feed force	Drilling speed: Feed force	Drilling height: Drilling speed: Feed force
Productivity	1.35E-06	0.8734	1.05E-05	0.14	0.466	0.3568	0.9297
Discomfort score in Shoulder	2.42E-10	0.3916	0.0298				
Elbow	2.00E-16	0.3852	0.5404				
Arm	2.00E-16	0.3852	0.5404				
Wrist	2.20E-16	0.0017	0.3511				

**Table 5 Nemenyi post hoc test**

	Productivity (p values)			Discomfort score in Shoulder (p values)			Discomfort score in Wrist (p values)		
Drilling height	$H_1$	$H_2$	$H_3$	$H_1$	$H_2$	$H_3$			
		0.0047	6.00E-05	3.00E-07	8.10E-07				
Drilling speed		-	0.5237	$H_2$	-	0.98			
							2400	2600	2800
Feed force							0.011	0.07	0.778
	4.5	6	7.5	4.5	6	7.5			
		0.0186	0.00035	0.32	0.17	0.94			
	6	-	0.50694	6	-				

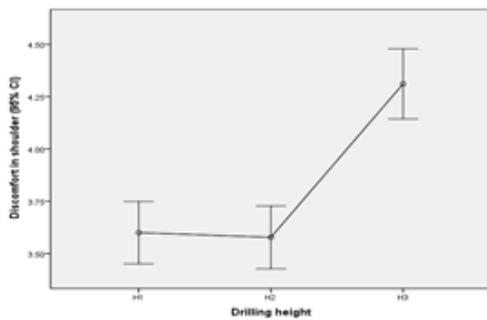


Figure 3 Error bar chart showing the effect of shoulder height on discomfort rating of shoulder

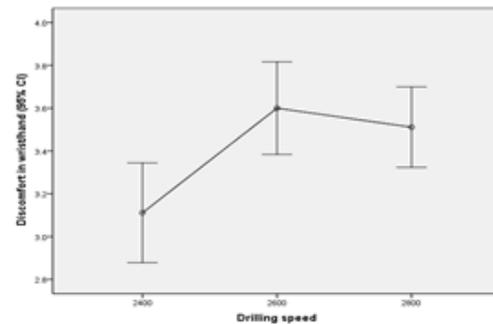


Figure 4 Error bar chart showing the effect of drilling speed on discomfort rating of the wrist

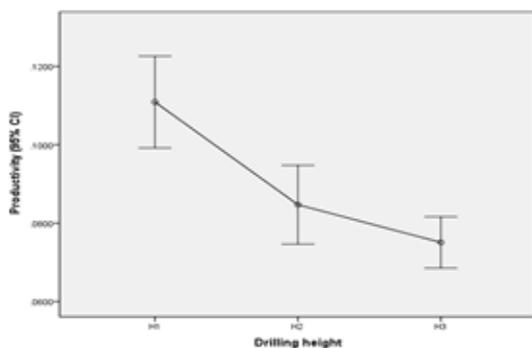


Figure 1 Error bar chart showing the effect of the drilling height on the productivity of a drilling task

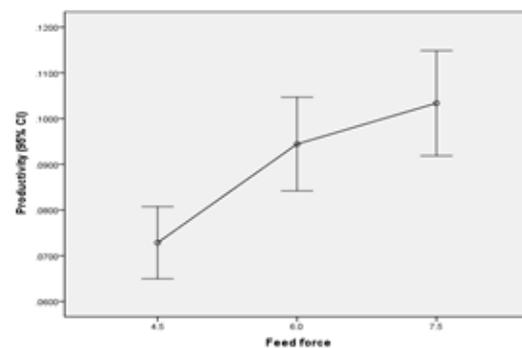


Figure 2 Error bar chart showing the effect of feed force on the productivity of a drilling task

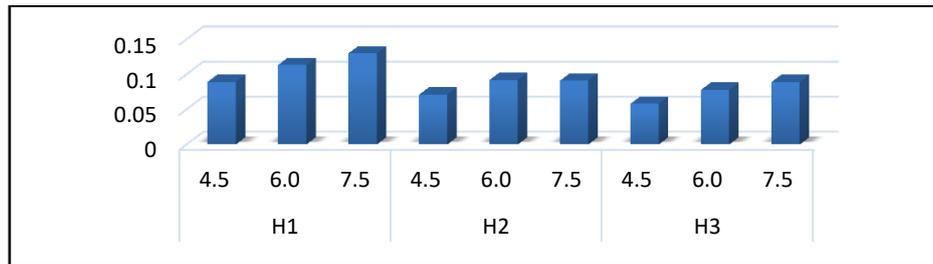


Figure 1 Chart showing the effect of drilling height and feed force on productivity by subjects (average of 5 subjects).

#### 4 DISCUSSION AND CONCLUSION

The study investigates the effect of working posture (in terms of drilling height), human effort level (i.e. feed force applied) and experimental parameter (viz. drilling speed) on productivity and perceived discomfort for a horizontal drilling task. In industrial work, prolonged fatiguing tasks or repetitiveness of such tasks leads to musculoskeletal injury [23]. An understanding of the parameters responsible for worker fatigue and endurance times will facilitate the choice of best combinations of task parameters and work rest schedules so as to optimize productivity and worker health.

Drilling height had an influence on the productivity and perceived discomfort score in the shoulder region. Perceived discomfort ratings showed that discomfort in the shoulder is substantial for all three heights under consideration (H<sub>1</sub>, H<sub>2</sub>, and H<sub>3</sub>), it was maximum at height H<sub>3</sub>, i.e. 15 cm above the shoulder level. Also, productivity was least at drilling height H<sub>3</sub> (15 cm above shoulder level). Similar findings have been reported by Lin et al. [24]. On the basis of subjects' discomfort score, drilling height H<sub>2</sub>, corresponding to a shoulder flexion angle of 90°, was found to be the most comfortable, amongst the three postures under investigation. This might be due to the distribution of shoulder muscle activity to other muscles such as levator scapulae at this working posture, as suggested by Sporrang [25]. This trade off in muscle activity would lead to an increase in glenohumeral stability, thus making the posture most comfortable. Productivity was maximum at H<sub>1</sub> thereafter it decreased with increase in drilling height. Productivity at drilling height H<sub>1</sub> was significantly different than H<sub>2</sub> and H<sub>3</sub>. These physiological findings suggest that submaximal arm exertion task at low shoulder flexion angles leads to less muscle discomfort and more productivity. Hence the use of a ladder or platform with adjustable height are recommended for other cases, as in Phelan and Sullivan [26] and Sood et al [19].

Feed force had an influence on the perceived discomfort score of shoulder and productivity. It was observed that both productivity and discomfort increased with an increase in force applied. These results pointed towards maximum productivity for the most feed force condition of 7.5 kg. However Sullivan and Clancy concluded that productivity decreases with an increase in feed force [27]. The apparent contradiction in findings could be due to the short duration of experiments. Thus, it is possible that increased discomfort due to higher feed force, as evident from the results of the present study, may result in a decrease in productivity over the course of a working day. Similar observations have been made by Kim et al. [5]. Further investigations may be required with the inclusion of work-rest schedule to arrive at the best combination of the two, so as to minimize discomfort without compromising the productivity. Drilling speed had an influence on the perceived discomfort score in wrist only. Discomfort score in wrist decreased as drilling speed increased from 2600 to 2800 rpm. These findings are in line with Masood et al. [9]. However, drilling speed had no significant influence on productivity. This may be because of the relatively short duration of the task and small variation in the three drilling speeds chosen. However Dimov et al. reported higher productivity with increase in drilling speed [8]. The results of the present study also indicate similar trends. These findings suggest that drilling task must be performed at higher drilling speeds for increased productivity and lower discomfort.

Overall productivity was found to be maximum at the drilling height H<sub>1</sub>, and 7.5 kg, feed force. No significant interaction between drilling height, feed force and drilling speed ( $p > 0.05$ ) was found for any dependent measure. In general, the results of the study indicate that working time should be lowered and the use of raised platform or ladder should be promoted, as feed force and shoulder flexion angles are increased, for an arm intensive industrial task.

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**Appendix A-** Table showing readings of the experiment

Subject	Shoulder flexion angle(H)	Drilling speed	Feed force	Number of holes drilled till exhaustion	Productivity (Holes/unit time)	Subject	Shoulder flexion angle(H)	Drilling speed	Feed force	Number of holes drilled till exhaustion	Productivity (Holes/unit time)
1	H <sub>3</sub>	2400	4.5	5	0.043	1	H <sub>2</sub>	2600	7.5	9	0.077
2	H <sub>3</sub>	2400	4.5	5	0.086	2	H <sub>2</sub>	2600	7.5	10	0.154
3	H <sub>3</sub>	2400	4.5	4	0.058	3	H <sub>2</sub>	2600	7.5	5	0.077
4	H <sub>3</sub>	2400	4.5	5	0.051	4	H <sub>2</sub>	2600	7.5	7	0.045
5	H <sub>3</sub>	2400	4.5	5	0.077	5	H <sub>2</sub>	2600	7.5	8	0.1
1	H <sub>3</sub>	2400	6	6	0.065	1	H <sub>2</sub>	2800	4.5	4	0.027
2	H <sub>3</sub>	2400	6	6	0.095	2	H <sub>2</sub>	2800	4.5	11	0.107
3	H <sub>3</sub>	2400	6	5	0.074	3	H <sub>2</sub>	2800	4.5	5	0.053
4	H <sub>3</sub>	2400	6	5	0.075	4	H <sub>2</sub>	2800	4.5	11	0.085
5	H <sub>3</sub>	2400	6	6	0.08	5	H <sub>2</sub>	2800	4.5	7	0.05
1	H <sub>3</sub>	2400	7.5	7	0.1	1	H <sub>2</sub>	2800	6	7	0.054
2	H <sub>3</sub>	2400	7.5	5	0.093	2	H <sub>2</sub>	2800	6	8	0.101
3	H <sub>3</sub>	2400	7.5	6	0.1	3	H <sub>2</sub>	2800	6	5	0.068
4	H <sub>3</sub>	2400	7.5	6	0.086	4	H <sub>2</sub>	2800	6	14	0.154
5	H <sub>3</sub>	2400	7.5	6	0.1	5	H <sub>2</sub>	2800	6	9	0.134
1	H <sub>3</sub>	2600	4.5	5	0.039	1	H <sub>2</sub>	2800	7.5	10	0.07
2	H <sub>3</sub>	2600	4.5	4	0.075	2	H <sub>2</sub>	2800	7.5	9	0.15
3	H <sub>3</sub>	2600	4.5	5	0.063	3	H <sub>2</sub>	2800	7.5	6	0.083
4	H <sub>3</sub>	2600	4.5	5	0.046	4	H <sub>2</sub>	2800	7.5	14	0.169
5	H <sub>3</sub>	2600	4.5	6	0.067	5	H <sub>2</sub>	2800	7.5	7	0.047
1	H <sub>3</sub>	2600	6	7	0.076	1	H <sub>1</sub>	2400	4.5	14	0.124
2	H <sub>3</sub>	2600	6	6	0.118	2	H <sub>1</sub>	2400	4.5	10	0.118
3	H <sub>3</sub>	2600	6	5	0.066	3	H <sub>1</sub>	2400	4.5	6	0.048
4	H <sub>3</sub>	2600	6	6	0.088	4	H <sub>1</sub>	2400	4.5	5	0.043
5	H <sub>3</sub>	2600	6	6	0.071	5	H <sub>1</sub>	2400	4.5	5	0.086
1	H <sub>3</sub>	2600	7.5	7	0.068	1	H <sub>1</sub>	2400	6	13	0.126
2	H <sub>3</sub>	2600	7.5	5	0.119	2	H <sub>1</sub>	2400	6	7	0.117
3	H <sub>3</sub>	2600	7.5	5	0.07	3	H <sub>1</sub>	2400	6	6	0.058
4	H <sub>3</sub>	2600	7.5	6	0.097	4	H <sub>1</sub>	2400	6	6	0.083
5	H <sub>3</sub>	2600	7.5	6	0.06	5	H <sub>1</sub>	2400	6	14	0.169
1	H <sub>3</sub>	2800	4.5	4	0.037	1	H <sub>1</sub>	2400	7.5	15	0.15
2	H <sub>3</sub>	2800	4.5	5	0.074	2	H <sub>1</sub>	2400	7.5	8	0.116
3	H <sub>3</sub>	2800	4.5	4	0.053	3	H <sub>1</sub>	2400	7.5	7	0.096
4	H <sub>3</sub>	2800	4.5	6	0.043	4	H <sub>1</sub>	2400	7.5	5	0.104
5	H <sub>3</sub>	2800	4.5	6	0.06	5	H <sub>1</sub>	2400	7.5	7	0.108
1	H <sub>3</sub>	2800	6	4	0.062	1	H <sub>1</sub>	2600	4.5	12	0.117
2	H <sub>3</sub>	2800	6	5	0.096	2	H <sub>1</sub>	2600	4.5	6	0.069
3	H <sub>3</sub>	2800	6	6	0.092	3	H <sub>1</sub>	2600	4.5	8	0.07
4	H <sub>3</sub>	2800	6	6	0.061	4	H <sub>1</sub>	2600	4.5	13	0.126
5	H <sub>3</sub>	2800	6	6	0.052	5	H <sub>1</sub>	2600	4.5	11	0.107
1	H <sub>3</sub>	2800	7.5	4	0.04	1	H <sub>1</sub>	2600	6	12	0.125
2	H <sub>3</sub>	2800	7.5	5	0.104	2	H <sub>1</sub>	2600	6	9	0.141
3	H <sub>3</sub>	2800	7.5	7	0.108	3	H <sub>1</sub>	2600	6	7	0.068
4	H <sub>3</sub>	2800	7.5	6	0.094	4	H <sub>1</sub>	2600	6	6	0.092
5	H <sub>3</sub>	2800	7.5	7	0.099	5	H <sub>1</sub>	2600	6	6	0.061
1	H <sub>2</sub>	2400	4.5	5	0.048	1	H <sub>1</sub>	2600	7.5	13	0.149
2	H <sub>2</sub>	2400	4.5	8	0.082	2	H <sub>1</sub>	2600	7.5	10	0.164
3	H <sub>2</sub>	2400	4.5	5	0.056	3	H <sub>1</sub>	2600	7.5	8	0.082
4	H <sub>2</sub>	2400	4.5	5	0.104	4	H <sub>1</sub>	2600	7.5	10	0.058
5	H <sub>2</sub>	2400	4.5	7	0.108	5	H <sub>1</sub>	2600	7.5	9	0.15
1	H <sub>2</sub>	2400	6	6	0.075	1	H <sub>1</sub>	2800	4.5	11	0.106
2	H <sub>2</sub>	2400	6	11	0.136	2	H <sub>1</sub>	2800	4.5	12	0.097
3	H <sub>2</sub>	2400	6	6	0.068	3	H <sub>1</sub>	2800	4.5	8	0.063
4	H <sub>2</sub>	2400	6	7	0.1	4	H <sub>1</sub>	2800	4.5	10	0.098
5	H <sub>2</sub>	2400	6	5	0.093	5	H <sub>1</sub>	2800	4.5	6	0.069
1	H <sub>2</sub>	2400	7.5	6	0.08	1	H <sub>1</sub>	2800	6	13	0.178
2	H <sub>2</sub>	2400	7.5	11	0.078	2	H <sub>1</sub>	2800	6	10	0.118
3	H <sub>2</sub>	2400	7.5	8	0.076	3	H <sub>1</sub>	2800	6	8	0.078
4	H <sub>2</sub>	2400	7.5	6	0.065	4	H <sub>1</sub>	2800	6	15	0.161
5	H <sub>2</sub>	2400	7.5	6	0.095	5	H <sub>1</sub>	2800	6	13	0.126
1	H <sub>2</sub>	2600	4.5	7	0.047	1	H <sub>1</sub>	2800	7.5	12	0.167

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2	H <sub>2</sub>	2600	4.5	8	0.1	2	H <sub>1</sub>	2800	7.5	14	0.171
3	H <sub>2</sub>	2600	4.5	7	0.061	3	H <sub>1</sub>	2800	7.5	8	0.086
4	H <sub>2</sub>	2600	4.5	4	0.075	4	H <sub>1</sub>	2800	7.5	15	0.2
5	H <sub>2</sub>	2600	4.5	5	0.063	5	H <sub>1</sub>	2800	7.5	13	0.149
1	H <sub>2</sub>	2600	6	7	0.058						
2	H <sub>2</sub>	2600	6	9	0.134						
3	H <sub>2</sub>	2600	6	5	0.052						
4	H <sub>2</sub>	2600	6	6	0.092						
5	H <sub>2</sub>	2600	6	6	0.061						

## Study on Fluoride Uptake by Modified Polyaniline with Doped Chloride

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### Abstract

This study focuses on the assessment of enhanced fluoride adsorption by amine rich polymer polyaniline doped with chloride and synthesized on the surface of jute fiber (PANI-Cl-jute). Characterization of PANI-Cl-jute surface before and after adsorption was conducted through Fourier-transform infrared spectroscopy (FTIR) and its surface pH is evaluated as 6.6 indicating a positive surface below it. The present study is carried out for various parameters of adsorption like pH, initial F<sup>-</sup> concentration, temperature, a dose of adsorbent, desorption and assessment of groundwater. The maximum F<sup>-</sup> adsorption was observed at acidic pH 1 by the electrostatic attraction between protonated amines (NH<sub>3</sub><sup>+</sup>) at the terminal end of the polymer with anionic F<sup>-</sup>. Doping of chloride throughout the chain of polyaniline enhanced the F<sup>-</sup> adsorption through ion exchange between F<sup>-</sup> and doped chloride.

**Keywords:** Adsorption, Amines, Fluoride, Doping

### 1.Introduction

The health effects of fluoride contamination in groundwater are already a global concern with WHO permits a limit of 1.5 mg/L for drinking water. Its chronic effects include endemic dental or skeletal fluorosis. Fluorides in natural water are generally due to the dissolution of fluorospar, fluorapatite, amphiboles, micas weathered from igneous & sedimentary rocks (Datta P. S et al, 1996) and unstable minerals like sepiolite and palygorskite. There are already several reports during the last two decades for an elevated concentration of F<sup>-</sup> in groundwater all over the world. In India, fluoride affected areas include Andhra Pradesh, Bihar, Gujarat, Madhya Pradesh, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh and West Bengal with millions of peoples affected.

### 2. Research Literature

The Nalgonda technique which is based on co-precipitation is the most widely applied method in India, however, it releases residual aluminum sludge and also increases the sulphate concentration due to using alum as a coagulant (Maniyekkkal et al, 2006). Of all the several available techniques practices, adsorption is one of the most widely used techniques. Several researchers work on activated carbon derived from several kinds of woods and biomaterials based adsorbent such as modified ultrafine tea powder processed using a ball-mill (Huimei Cai et al, 2016), KMnO<sub>4</sub> modified activated carbon derived from steam pyrolysis of rice straw (Yakun et al., 2011), pristine, purified and natural clay, etc. To increase the uptake of F<sup>-</sup>, chitosan-based adsorbents containing amines that are responsible for binding F<sup>-</sup> are reported such as chitosan and its blends with hydroxypropyl cellulose, multifunctional chitosan beads (Natrayasamy et al, 2013), cerium immobilized cross-linked chitosan composite (Zhu et al, 2017) and Al-doping chitosan-Fe(III) hydrogel (Jianqing M. et al, 2014). Generally, these biomaterial-based adsorbents biodegrade with time decrease the stability of adsorbent. Amine-rich polymer polyanilines which are very stable polymers are also used in different ways for adsorbent preparation such co-polymeric resins (Natrayasamy et al, 2013) and also doped polyanilines (Karthikeyan M. et al, 2009) yielding 7.84 and 5.9 mg/g respectively which is synthesized by oxidation of aniline with ammonium peroxydisulfate in an acidic medium. The mechanism of binding fluoride is through ion-exchanged with doped chlorides. We had earlier synthesized short-chain polyaniline known as oligoaniline on the surface of jute fiber (PANI-jute) and employed for adsorption of toxic hexavalent chromium (Kumar P. A. et al, 2008). The

synthesis of polyaniline is different from that reported by (Kathikeyan M. et al, 2009). In our polyaniline, higher chain length increases its molecular weight whereas the lower chain gets soluble in solution. Therefore, we introduced a chain terminating agent, paraphenylenediamine and optimized the chain length of the polymer. As amines at the terminal end of the polyaniline get protonated at acidic pH, anionic compounds get electrostatically attracts to it. The main objectives of this study are the surface characterization of chloride doped polyaniline synthesized on the surface of jute fibre (PANI-Cl-Jute) rich in amines that bind fluoride after adsorption and identify the mechanism.

### 3. Materials and Methods

All the chemicals and reagents employed for the experiments were of analytical grade except for aniline which was distilled with KOH. Characterization of adsorbent before and after fluoride adsorption on PANI-Cl-jute was conducted with the Fourier Transform Infrared (FTIR) (Perkin Elmer Spectrum) and Selective Electron Microscopy (SEM) measured on Zeiss Sigma 300, Germany. The analysis of fluoride is done by ion-selective electrodes (Orion Star A211 Thermo Fisher) using the TISAB solution.

#### 3.1 Synthesis of Adsorbent

The synthesis of polyaniline was carried out with mixing 21.5 mmol aniline ( $C_6H_5NH_2$ ) and 3.05 mmol ammonium peroxydisulfate  $[(NH_4)_2S_2O_8]$  at 0– 5 °C. Various concentration of HCl (0.1, 0.5, 1, 1.5 and 2 M) was added at different sets of polymer preparation for doping chloride followed by addition of 5 g jute as a support medium and chain terminator agent para-phenylenediamine and kept overnight to complete the reaction. An alkali treatment (1 M  $NH_4OH$ ) was given to ensure complete deprotonation and the obtained adsorbent is dried and used as an adsorbent (PANI-Cl-jute).

#### 3.2 Adsorption Experiment

For a comprehensive study of fluoride adsorption on PANI-Cl-jute, batch experiments were conducted using 500 mL of the desired  $F^-$  concentration in 1000 mL beaker mixed with a pre-evaluated dose of PANI-Cl-jute using rotatory shaker at approximately 300 rpm. The amount of  $F^-$  adsorption per unit weight of adsorbent at time t,  $q_t$  (mg  $F^-$ /g), was calculated using the following equation:

$$q_t = \frac{(C_0 - C_t)V}{M} \quad (1)$$

where  $C_0$  is the initial fluoride concentration (mg/L);  $C_t$  is the concentration of fluoride at time t (mg/L); V is the volume of the solution (L) and M is the mass of adsorbent (g). At equilibrium time,  $q_t$  thus becomes  $q_e$  and  $C_t$  becomes  $C_e$ .

### 4. Results and Discussion

#### 4.1 Optimization of chloride for doping on polyaniline

To optimize the amount of chloride doping, an initial  $F^-$  concentration of 10 mg/L was contacted with 10 g/L of the obtained various chloride doped PANI-Cl-jute at pH 2 and pH 5. As can be seen in Fig. 1, PANI-Cl-jute synthesized with 0.1 M HCl yields  $F^-$  adsorption of 49% and 28% at pH 2 and pH 5 respectively. The corresponding adsorption further increased to 89% and 69% at 1.5 M HCl doped PANI-jute. The doping of chloride in PANI-Cl-jute enhanced the fluoride adsorption ability through ion-exchange between chloride ions and fluoride ions. Thereafter the  $F^-$  adsorption (%) remains the same even with an increase in HCl concentration to 2 M. This is due to the limited chain length of polyaniline polymer which restricts the limited doping of chloride. Thus HCl strength of 1.5 M strength is obtained as the optimum for doping and thereafter polyaniline doped with this strength is considered for further studies.

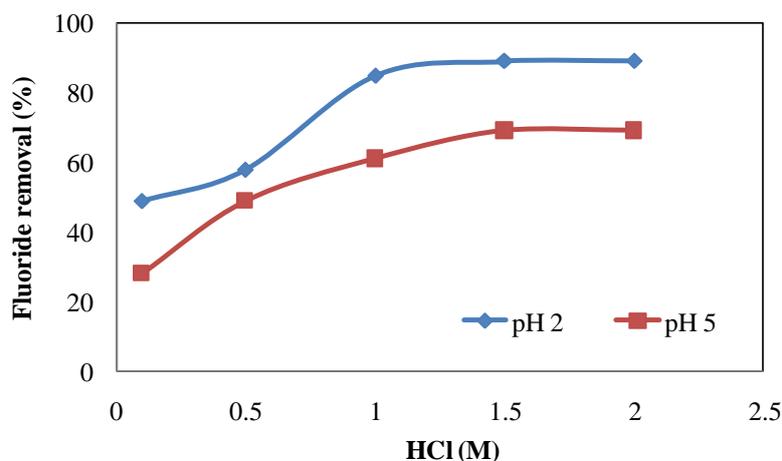


Fig. 1 F removal of PANI-Cl-jute at various HCl concentrations

#### 4.2 Surface charge of PANI-jute-pHZPC

For any chemical-based adsorption process, the surface charge of the adsorbent plays a major role in selective ion adsorption. Thus it is very vital to evaluate the pH of the zero point charge ( $pH_{ZPC}$ ) which is defined as the pH of the adsorbent where the surface charge is zero. The  $pH_{ZPC}$  of PANI-Cl-jute was determined by the fast alkalimetric titration method. The  $pH_{ZPC}$  for PANI-Cl-jute is observed as 6.6 as shown in Fig. 2. Therefore, at pH below 6.6, the surface of PANI-Cl-jute will be positive due to hydrogen ions or protonation and will favour adsorption of anions by electrostatic attraction. Above  $pH_{ZPC}$  6.6, the PANI-Cl-jute surface will become negative and favoured for adsorbing cations.

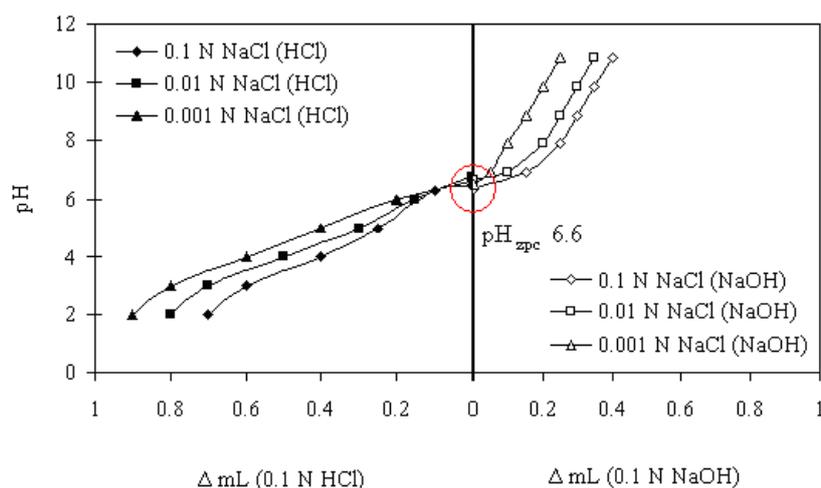


Fig. 2 Estimation of  $pH_{ZPC}$  of PANI-Cl-jute

#### 4.3 Effect of pH & mechanism

The fluoride adsorption on polymer-based adsorbent PANI-Cl-jute being chemisorption nature, the pH is an important parameter to be analyzed as the effect of pH can reveal the main mechanism of adsorption towards the acidic and basic environment. For the study, two different initial  $F^-$  concentrations of 5 and 10 mg/L in a sample

volume of 500 mL were contacted with a PANI-Cl-jute dose of 2 g at various pH of 1-10. To cross-check any loss of F<sup>-</sup> ions on reactor vessels or adsorption on support materials (jute fiber), 2 g of jute fiber without any polyaniline were contacted with F<sup>-</sup> solution of 5 and 10 mg/L as control experiments. The findings are shown in Fig. 3 (inset) and can be seen that the initial F<sup>-</sup> concentration remains the same after 3 hours of contact time at all the pH. This suggests that the decrease in the concentration of F<sup>-</sup> ions after experimentation with PANI-Cl-jute is solely due to adsorption on PANI-Cl-jute. During adsorption with PANI-Cl-jute, removal (%) of F<sup>-</sup> for initial 5 mg/L and 10 mg/L were 35% and 54% respectively at pH 1 and decreased to almost insignificant removal at pH 7. The main mechanism of binding F<sup>-</sup> at acidic pH can be identified as (i) the electrostatic attraction between protonated amines (NH<sub>3</sub><sup>+</sup>) at the terminal end of the polymer with anionic F<sup>-</sup> (Fig. 4) and (ii) by ion exchange of F<sup>-</sup> with doped chloride throughout the chain length of PANI-Cl-Jute (Kumar P.A et al., 2008). Also, pHzpc of PANI-Cl-jute being 6.6 (Fig. 2), electrostatically attract anionic F<sup>-</sup> on its positive surface. Similar findings of fluoride binding with amine-based adsorbents at acidic pH are also reported like amine-functionalized co-polymeric resins, chitosan beads and crossed link chitosan (Chensi S et al., 2016)

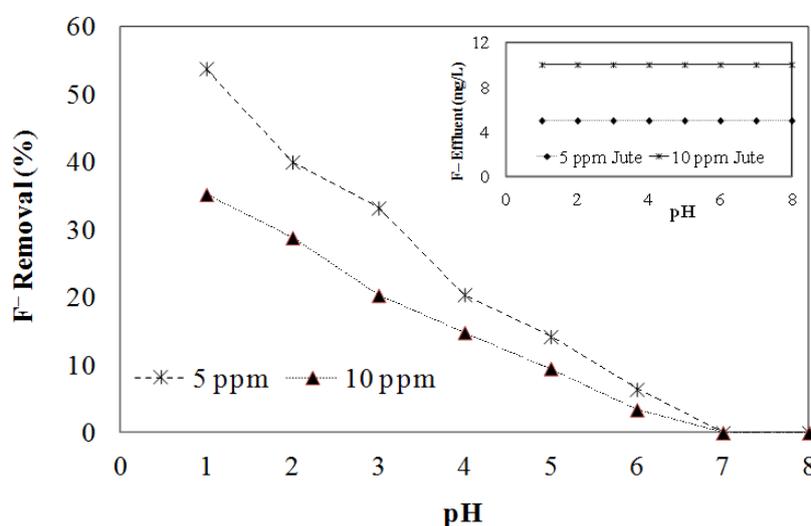


Fig. 3 Effect of pH on adsorption of F<sup>-</sup> to PANI-Cl-jute

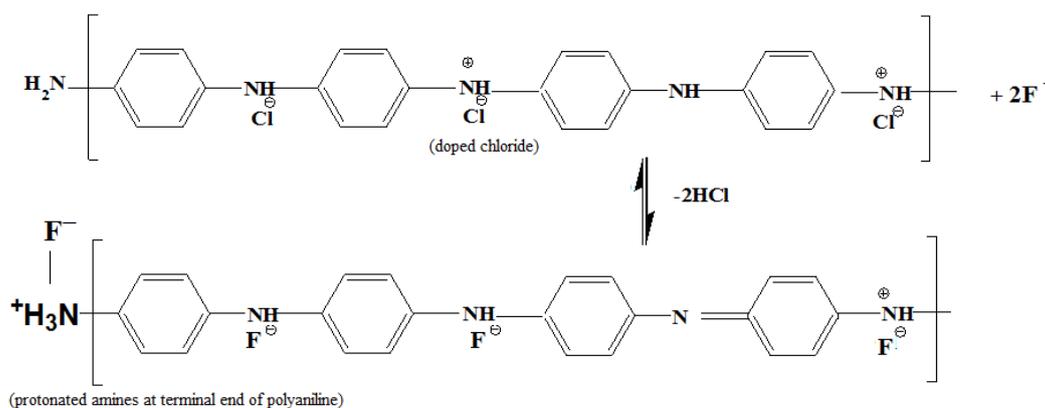


Fig. 4 Proposed mechanisms (i) electrostatic attraction of F<sup>-</sup> with protonated amines at the terminal end of polyaniline and (ii) ion exchange between F<sup>-</sup> and doped Cl<sup>-</sup> on Polyaniline.

#### 4.4 Characterization of adsorbent

The SEM images of PANI-Cl-jute before and after F<sup>-</sup> adsorption are shown in Figure 5(a&b). The SEM of PANI-Cl-jute before adsorption is smooth and even where the surface evenness disappears after F<sup>-</sup> adsorption. The Fourier transmission infrared (FTIR) analysis of PANI-Cl-jute was carried out on adsorbent before and after fluoride adsorption and the respective spectra are shown in Fig. 6(a) and 6(b). The Infrared band assignments of PANI-Cl-jute before and after adsorption of F<sup>-</sup> peak values are tabulated in Table 1. The bands at 3700 cm<sup>-1</sup> to 3500 cm<sup>-1</sup> is associated with water molecule present in PANI-Cl-jute fiber. The peak around 3300 cm<sup>-1</sup> corresponds to the characteristic N-H stretching and peak at 1589 cm<sup>-1</sup> for N-H bending. The sharp peak at 1035 cm<sup>-1</sup> assigned the stretching of the fluoro compound (Fig. 6b) which shows the adsorption of F<sup>-</sup> onto the PANI-Cl-jute fiber.

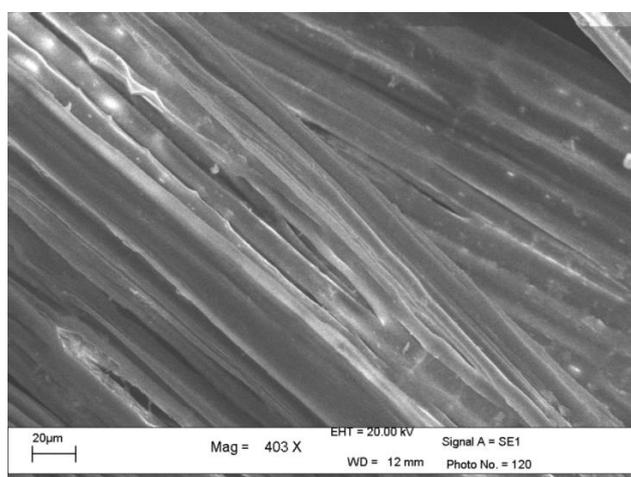


Fig. 5(a) SEM images of PANI-Cl-jute before adsorption

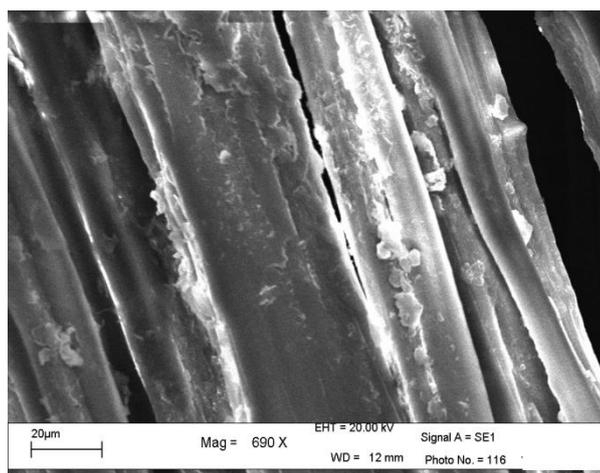


Fig. 5(b) SEM images of PANI-Cl-jute after F<sup>-</sup> adsorption

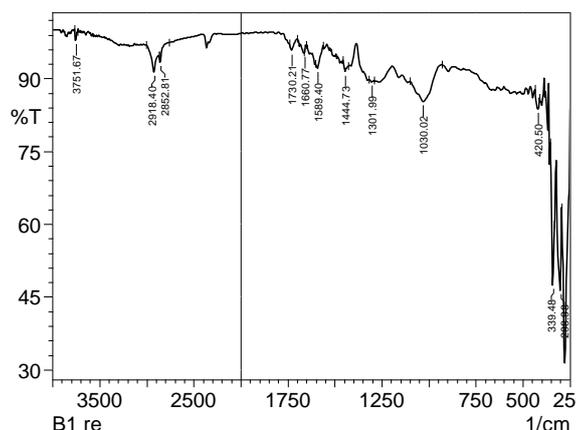


Fig. 6(a) FTIR spectrum of PANI-Cl-jute before F<sup>-</sup> adsorption

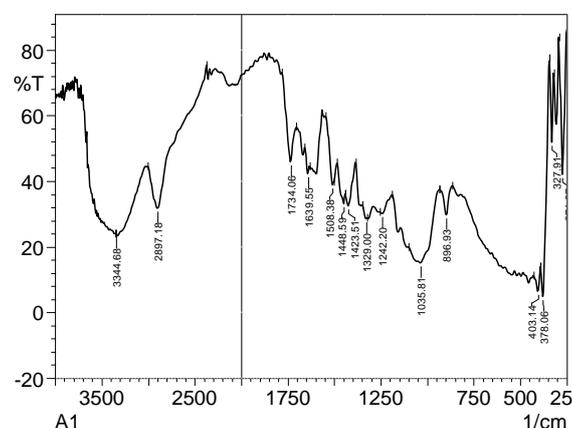


Fig. 6(b) FTIR spectrum of PANI-Cl-jute after F<sup>-</sup> adsorption

Table 1 Infrared band assignment of PANI-Cl-jute before and after adsorption of F<sup>-</sup>

Wavenumber (cm <sup>-1</sup> )	Band Assignment	Wavenumber (cm <sup>-1</sup> )	Band Assignment
PANI-Cl-Jute Fibre Before		PANI-Cl-Jute Fibre after	
3751.67 (m)	O-H Stretching	3344.68 (m)	N-H Stretching
2918.40 (m)	C-H Stretching	2897.18 (m)	C-H Stretching
2852.81 (m)	C-H Stretching	1734.06 (s)	C=O Stretching
1730.21 (s)	C-O Stretching	1639.55 (m)	C=C Stretching
1660.77 (m)	C-N Stretching	1508.38 (s)	N-O Stretching
1589.40 (m)	N-H Bending	1448.95 (m)	O-H Bending
1444.73 (m)	O-H Bending	1423.51 (m)	O-H Bending
1301.99 (s)	C-N Stretching Aromatic amine	1035.81 (s)	C-F Stretching Fluoro Compound
1030.02 (s)	S=O Stretching	896.93 (s)	C=C Bending

\*s = Strong; m = medium and w = weak.

## 5. Conclusion

An extensive study was carried out to enhance the adsorption of  $F^-$  through doping of Chloride on polyaniline polymer synthesized on the surface of the jute fibre. The doping of chloride with 0.1 M and 1.5 M yield increase in  $F^-$  uptake from 30-84% and 49-89% at pH 2 and 5 respectively. The optimum pH for adsorption was observed as 1 and the mechanism of binding  $F^-$  are identified as an electrostatic attraction with protonated amines of the adsorbent, surface attachment of  $F^-$  on the positive surface of PANI-jute below  $pH_{zpc}$  of 6.6 and the ion exchange with doped chloride.

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## STUDY OF BIOMASS TORREFACTION FUNDAMENTALS AND PROPERTIES

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### Abstract

The heating value of coal is necessary for its usage in power generating. This is tested experimentally, although theoretical models have been used to forecast the heating value; either greater heating value (HHV) or lower heating value (LHV). The same approach has been used to biomass, which is being promoted as a alternative for coal or as a co-fired fuel. Biofuel production was seen as a significant countermeasure for lowering anthropogenic CO<sub>2</sub> emissions, removing the worsening greenhouse effect in the atmosphere, and slowing global warming. Thermochemical conversion is thought to be the most effective method of generating biofuels from biomass, with the least potential for global warming. The toorefied biomass is used for making biomass material into an useful energy and it also enhance the property of that material by torrified it..

**Keywords-** Co-Fired, HHV, LHV, Biofuels

### 1. INTRODUCTION

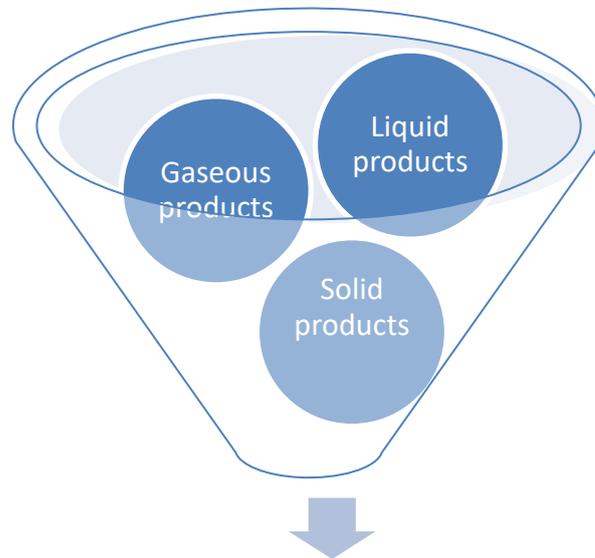
Torrefaction of biomass has gained widespread attention. For example, in steel production, it can be used to replace coal or work alongside coal by co-firing it with biomass in a specific ratio to reduce emissions. A lot of articles have been written on biomass torrefaction, but this study tries to look at it from another angle, showing various elements of torrefaction and how it ties into other technologies, as well as showing the chemistry underlying torrefaction's processes and products [1]. I think it's safe to say that a lot has changed with the technologies utilised in the process. There is a change in attention to raw biomass and how it is analysed, along with the different analyses conducted to derive useful information about the biomass characteristics. Different types of reactors are in use, but there is no favoured one because they all have pros and cons. There are no substantial variations between them, thus it's the procedure that's the focus, rather than the reactor itself [5]. As the process's principal result, torrefied biomass defines its efficiency and how it may be used to other technologies. Current biomass torrefaction methods include co-firing with coal, as well as pre-treatment for pyrolysis and gasification. The technique has not yet achieved its full potential because to the varied forms of biomass in different nations, but it is believed that it will with the growing need for renewable energy sources.

#### 1.1. Biomass

Plants and animals that are alive or have been dead for a brief length of time might be considered biomass. By converting atmospheric carbon dioxide into carbohydrates, plants produce biomass. In the process of eating these botanical or other biological species, biota will multiply and contribute to the biomass chain to convert carbon dioxide into glucose and release oxygen as a waste product, green plants break down water in the presence of visible light, particularly in the blue (425–450 nm) or red (600–700 nm) wavelength ranges. This process is called photosynthesis.

## 1.2. Conversion of Biomass

The biomass basically divides into three types of products as show in in figure 1



**Fig. 1.**Conversions of biomass

### 1.3. Gaseous products

To convert biomass into gaseous products, gasification, a thermo chemical process in which the biomass is exposed to high temperatures with low oxygen levels, can be used.

As a first step, the biomass char (C) is burnt in order to create CO<sub>2</sub>, CO gases, and HO. As a result, gasification reactions take place in line with the reactions that have taken place.

### 1.4. Liquid products

There are several methods that may be used to turn biomass into liquid products like biodiesel or bio-oil. In the processes described below, pyrolysis generates charcoal, bio-oil, methanol, and gases from wood or coal. A common mixture of gases generated by pyrolysis is a mixture of CO<sub>2</sub>, H<sub>2</sub>O, CO<sub>2</sub>, and CH<sub>4</sub>. Water, tar, and moisture combine to form bio-oil (tar is a mixture of complex hydrocarbons). This process happens between 300 and 7000 degrees Celsius, although it may also occur between 200 and 1000 degrees Celsius.

### 1.5. Solid products

Fuels like coal may be made from biomass through carbonization and torrefaction, and then burnt directly to create heat and electricity. As well as liquid products, there are also gaseous products, which may be classified into permanent and condensable. Permanent gases include CO<sub>2</sub>, CO, and so on, while condensable gases include H<sub>2</sub>O, acetic acid, and so on. Thermal decomposition takes place at temperatures ranging from 200°C to 3000°C.

### 1.6. What is torrefaction?

Torrefaction was invented to enhance its characteristics so that they would equal coal's. When combined with coal, this technology allows power plants to use torrefied biomass as a source of energy, which reduces the need for

huge amounts of coal. It takes a lot of water to prepare coal for use in power production, and this valuable resource is becoming increasingly rare [9-15]. Nonrenewable coal has been replaced by renewable resources to continue our industrial advantages. Coal is a nonrenewable resource.. More and more countries are pushing for renewable energy sources, and many are shifting to electric vehicles, resulting in increased demand for electricity. The use of solar electricity, wind power and biogas for illumination is becoming more popular amongst some individuals. In energy generation and metallurgical uses, coal must be substituted. Alternatively, you may use a torrefied biomass in this situation. Coal on the other hand releases harmful gases when burnt.

### 1.7. Torrefaction analysis

Torrefaction typically requires raw biomass that has been dried and nitrogen gas to create an inert environment [9]. However, it has been shown that biomass torrefaction in inert circumstances delivers the greatest results. In order to compare biomass to coal, it can be characterised. There will be a discussion of the various analyses presently as shown in figure 2

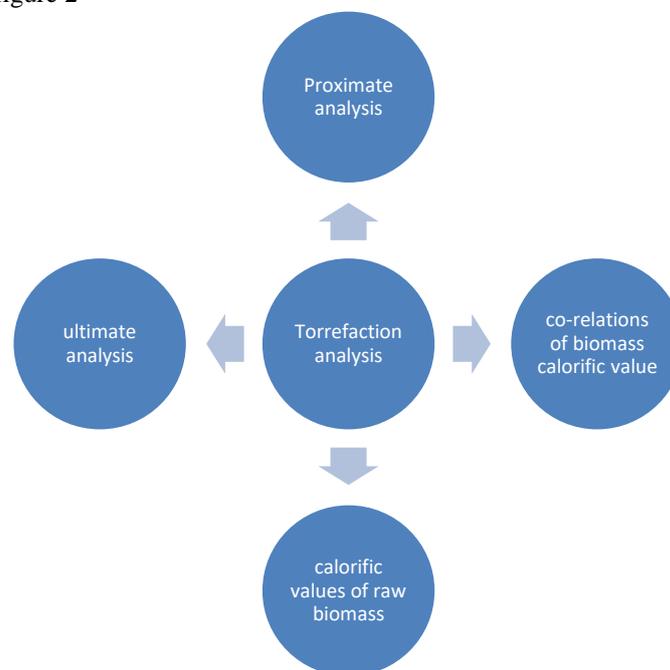


Fig.2. Analysis of torrefication

### 1.8. Proximity analysis

Wetness (MC), Ash, Volatile Matter, and Fixed Carbon are all measured using the standard test on a sample of biomass that has been dried and ground. It has been a long time since these experiments have been conducted on coal, and they give an excellent basis for comparing how biomass, whether raw or torrefied, compares to coal in terms of energy output.

This material was calculated using a variety of formulas, including

$$\% \text{ MC} = (\text{initial mass of sample} - \text{final mass of sample}) / \text{Initial mass of sample} \times 100$$

$$\% \text{ ASH} = \text{mass of residue} / \text{initial mass of sample} \times 100$$

$$\% \text{ VM} = \text{mass loss due to VM} / \text{initial dry mass of sample} \times 100$$

$$\% \text{ FC} = (\% \text{ MC} + \% \text{ ASH} + \% \text{ VM})$$

### 1.9. Ultimate analysis

While biomass and coal contain mineral stuff as well, the major chemical components found in biomass and coal include carbon and hydrogen (O). Chemometric analysis is essential for estimating biomass material balance and calorific value. ASTM E870-82 (2013) is used for the final examination of wood fuel (ASTM,

2019d). Methods for calculating CHNS are described in this standard. There are several tests that may be performed in order to find out what the elemental condition of biomass.

### 1.10. Calorific value of raw biomass

For example, a fuel's calorific value is the quantity of heat generated when a fuel (such as coal or biomass) is entirely burnt at the condition of combustion products. Typically, it is reported at two distinct temperatures, which are 25°C and 1000°C, respectively.

### 1.11. Co relations of biomass calorific value

It is possible to adapt the conventional coal testing procedures to biomass if analytical equipment is not readily available. Temperature values for biomasses can also be calculated using correlations built over time. A few assumptions found in the literature may be utilised to estimate the calorific value of coal using Dulong's equations.

### 1.12. Technologies of torrefaction

There are various types of technologies such as rotating drum reactor, Affecting bed reactor, Screw conveyor reactor, oscillating bed reactor, tarbed reactor, turbo dryer and micro reactor as shown in Figure 3.

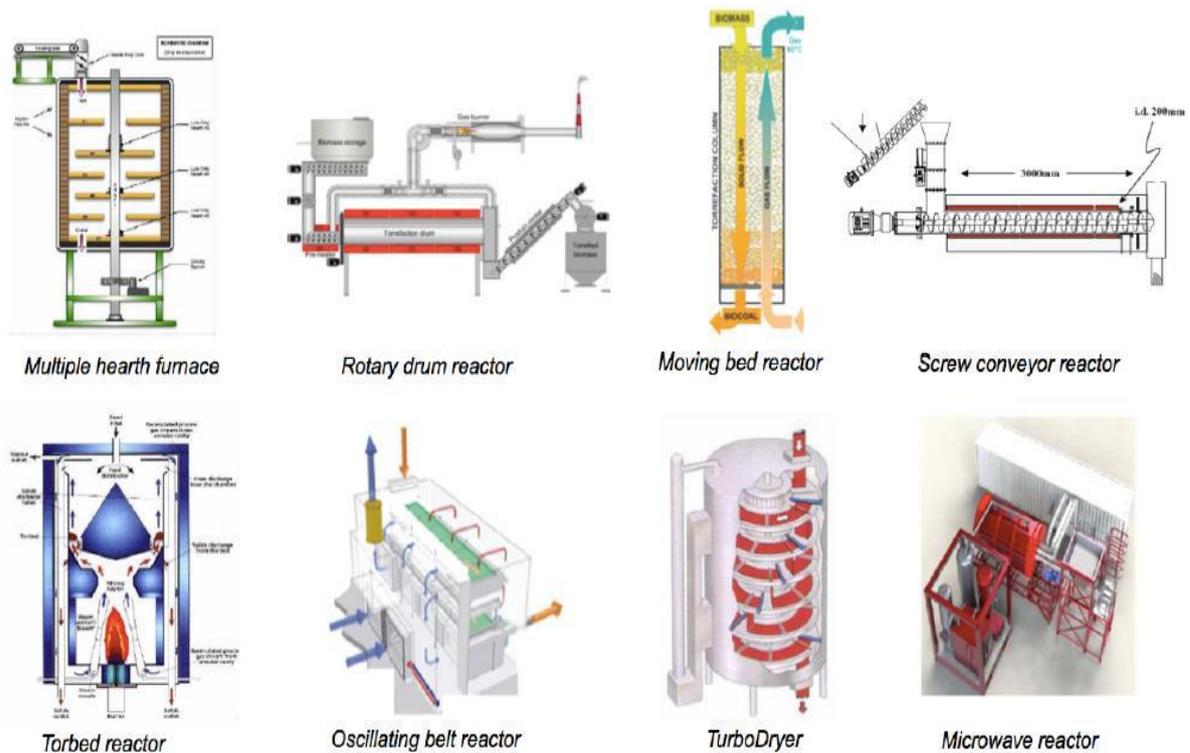
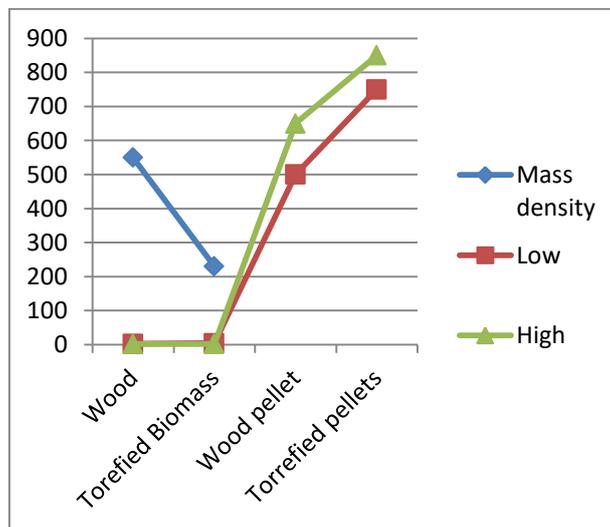
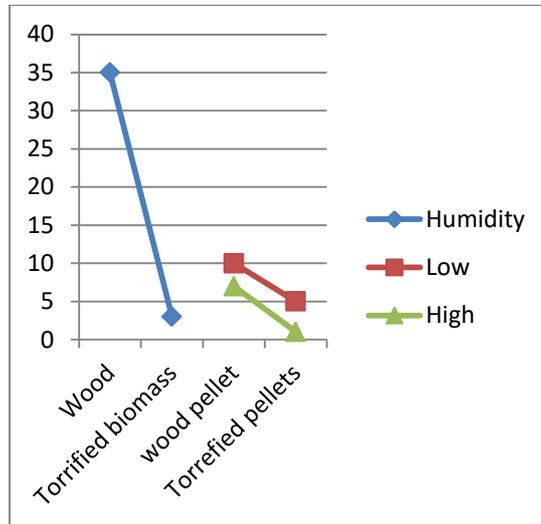


Fig. 3. Different technologies of torrefaction

Heat and power generation from renewable biomass resources is a growing business sector, which has resulted in a significant increase in global biomass trade, particularly biomass pellets. In comparison to conventional fuels, lingo cellulosic biomass has a low bulk and energy density, as well as a low degree of homogeneity. Torrefaction and other thermal pre-treatment technologies are used to improve the fuel properties of biomass, i.e. less water and oxygen in the fuel, better milling and storage properties. Torrefaction is the process of roasting biomass at temperatures ranging from 240 to 320 °C in an oxygen-depleted environment. Torrefaction removes moisture and low molecular weight volatiles from biomass, resulting in a product with low O/C and H/C atomic ratios. The mechanical properties of the fibres are altered during thermal treatment due to the thermal degradation of the biomass polymers, namely lignin, hemicellulose, and cellulose, resulting in the fibres becoming brittle and partially hydrophobic. Torrefaction is typically combined with pelletization or briquetting operations to improve the handling properties of torrefied biomass. The goal is to create a long-lasting, water-resistant energy carrier that can be used in existing conveying and storage facilities designed for hard coal,

making them an excellent replacement for coal in existing heat and power plants. Torrefied biomass pellets have a higher energy density per volume than established bio fuels like wood chips or pellets, resulting in lower transportation and storage costs. Depending on the species and processing conditions, the bulk density of torrefied wood can range from 200-400 kg/m<sup>3</sup> for torrefied wood chips to 600-850 kg/m<sup>3</sup> for torrefied pellets. Figure 4 provides an overview of the fuel properties as well as a comparison to other solid bio fuels.



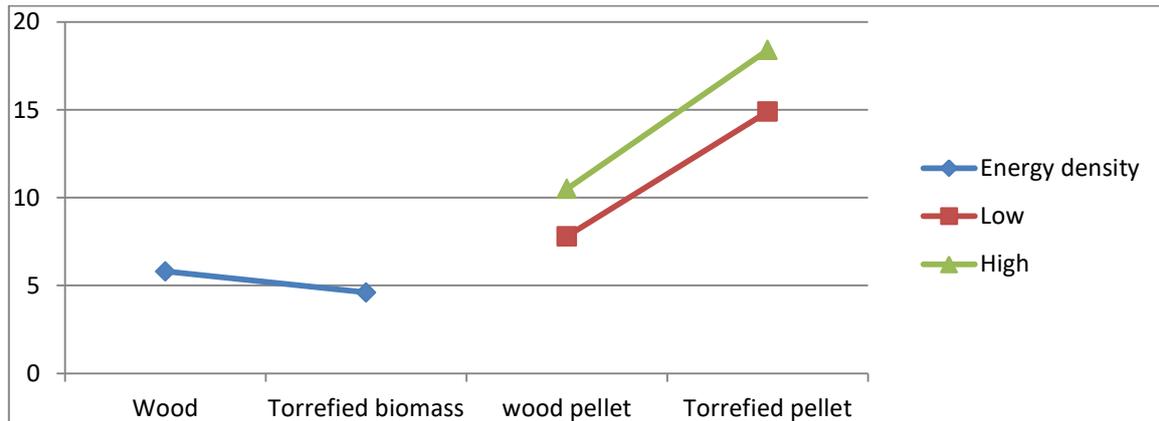


Figure 4: Overview of the fuel properties

Figure 5 describes the process by which raw materials are transformed into torrefied materials at varying temperatures. After a while, the pellets grew darker and rougher as torrefaction temperature climbed, especially for pellets torrefied at 270°C. They found that changes in the acid-insoluble lignin component, rather than the carbohydrate portion, were responsible for the colour shift.



Figure.5. Transformation of raw materials into torrefied materials

### 1.13. Conclusion

For this reason, torrefied biomass is gaining in popularity as a greener option than coal. Torrefier designs are patented by a variety of firms, each of whom claims supremacy over the others. Selection of a torrefaction technology has become extremely challenging due to the lack of a standard method for comparing different types of reactors. With this study, an essential knowledge gap in torrefaction technology is attempted to be filled by reviewing reactor types, comparing their torrefaction performance on an equal footing, and examining its economic consequences.

From the last few years' ammonia emissions in urea fertilizer industries, and the reduction of these emissions, have become an increasingly challenging issue. The continuous ammonia emissions cause burning of skin, eyes, mouth, and lungs of human beings and therefore, accidental emissions resulting from sudden failure of plant operation comes into spotlight. The sudden failure of a plant operation due to inefficient maintenance policy not only affects the profitability of the considered industry but also has significant impact on human health.

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## DESIGN AND MODELLING OF PERFORATION MACHINE FOR SDC CHILLIES

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### Abstract

The Production rate of sun-dried curd chillies (SDCC) is increasing seasonally. By survey, One Ton of SDC chillies were punched manually and progressed. Workers are not coming forward to work because of fewer wages given (ie.2/kg) and for the mass production, it takes much time to punch a hole. In the process of making SDC chillies, punching hole (Perforation) on the chilli is one of the mandatory steps. Set up of machine will compensate for the shortage of manpower and increases the production rate in prescribed time. The perforation machine (CAD Model) is designed using a Slider crank mechanism to reciprocate the punching tool and Geneva mechanism for conveyer movement. This perforation machine is highly recommended for food processing industries.

**Keywords: Sun-dried curd chillies, Perforation machine, Slider crank mechanism, Geneva mechanism.**

### 1. Introduction

Perforation machine works on mainly two mechanisms they are Geneva mechanism for belt movement and crank-slider mechanism for punching.

Geneva mechanism, also called Geneva Stop, one of the most commonly used devices for producing intermittent rotary motion, characterized by alternate periods of motion and rest with no reversal in direction. It is also used for indexing (rotating a shaft through a prescribed angle).

Geneva mechanism is commonly used in indexing mechanism where an intermittent motion is required [1]. The inverse Geneva mechanism which is variation of the Geneva

mechanism is used where the wheels to rotate in the same direction as crank. It required less radial space and the locking device can be a circular segment which is attached to the crank that locks by wiping against a built-up rim on the periphery of the wheel.

The design and fabricating of a conventional Geneva mechanism is generally simple and inexpensive as there is no specially curved profile on any of the component except straight line and circular arcs. Tool holder is designed in the similar shape of 3D needle punching tool. Geneva wheel is designed by using design procedure followed in design data handbook [2]. The rig operates on the intermittent rotary motion from a three-slot external geneva mechanism, it requires manual loading and unloading of bottles [3]. The bottles are loaded on subsequent indexing part of the rotating table and are washed one after another.

In slider-crank mechanism, arrangement of mechanical parts are designed to convert straight-line motion to rotary motion as like in a reciprocating piston engine, or to convert rotary motion to straight-line motion as like in a reciprocating piston pump. This paper designed a slider-crank mechanism with crank radius of 35mm and connecting rod length of 129mm. Tools are attached to the slider.

## **2. Research background**

A study has provided a brief review of usage of Geneva mechanism with different applications such as, the rig operates on the intermittent rotary motion from a three-slot external Geneva Mechanism [3]. It requires manual loading and unloading of bottles. The bottles are loaded on subsequent indexing part of the rotating table and are washed one after another. A study said that it can be used for a lever mechanism in combination with the geneva mechanism, this resulted in a reduction in mark-up time, human fatigue. and application is Automatic paper cutting machine [1]

## **3. Design Procedure**

### **Geneva Mechanism**

Geneva mechanism for the perforation machine is designed by using the following design procedure:

$$\begin{aligned} & \text{Distance to be moved by conveyer for one complete revolution of crank} \\ & = \text{Circumference of Geneva wheel } (2\pi r) \\ & \div \text{no. of stations } (Z) \end{aligned}$$

Where,

Distance to be moved by conveyer for one complete revolution of crank (L) = 300mm

No of stations (Z) = 3

$$2\pi r/3 = 300$$

$$r = 143 \text{ mm.}$$

- Available inputs

No. of stations (Z) = 3

Radius of Geneva crank wheel (r) = 248 mm

1. Distance between Geneva & Crank wheel(e)

$$e = [r/(\sin\alpha)] = [R/(\cos\alpha)]$$

$$e = 143/(\sin(180/3))$$

$$e = 286 \text{ mm}$$

2. Radius of Geneva crank wheel(r)

$$r = e * \sin\alpha$$

$$r = 286 * \sin(180/3)$$

$$r = 143 \text{ mm}$$

3. Length of slot (h)

$$h = R + r - e$$

$$h = 143 + 248 - 286$$

$$h = 105 \text{ mm}$$

4. Diameter of crank shaft (dc)

$$dc < 2(e-R) \quad 2(e-R) = 158 \text{ mm}$$

$$dc < 158 \text{ mm}$$

$$\text{assume } dc = 30 \text{ mm}$$

5. Diameter of Geneva wheel shaft (d<sub>w</sub>)

$$d_w < 2(e-r) \quad 2(e-r) = 158 \text{ mm}$$

$$d_w = 76 \text{ mm}$$

6. Width of slot (or) diameter of crank pin (d<sub>p</sub>)

$$d_p = dc/5$$

$$d_p = 6 \text{ mm}$$

7. Radius of circular segment ( $r_{cs}$ )

$$r_{cs} > (e-R) \text{ and } < (e-w)$$

$$r_{cs} > 143 \text{ and } < 248 \text{ mm}$$

$$r_{cs} = 145 \text{ mm}$$

#### 4. CAD Models

4.1 CAD models for different machine parts are designed by using Catia V5. They are,

a. Box: modelled by using Sheetmetal module and thickness of sheet is 2mm. Box is used to catch chillies and carry them into the working area. Box is modelled with tapered surfaces which are used to direct the chilli into the canter as shown in Fig.1. a.

b. Tool holder: It is the component designed to hold the tools and it is provided with the sliders on every corner of the part as shown in Fig.1. b.

c. Perforation tool: It is the tool used to perforate hole into the chilli shown in Fig.1. c. It is assembled to the tool holder as shown in Fig. 4.

d. Geneva crank wheel: Geneva crank wheel is designed and modelled in Catia V5 part design module. Crank pin is also added to crank wheel as shown in fig.1. d.

e. Geneva wheel: 3 slotted Geneva wheels is designed and modelled by using Part module. Design procedure is considered from design data handbook by S. Md. Jalaludeen.

f. Chain: chain is modelled by using part module and assembled by using product module shown in Fig.1.f. Specifications of chain is taken from the European series, they are Pitch- 9.5mm, width between inner plates- 5.72mm, Roller diameter (D) -6.35mm, Bearing pin diameter – 3.72mm, Plate height – 8.20mm, Width over bearing – 13.50mm, width over joint fasteners – 18.8D, Projected bearing area – 0.28mm, Avg. weight per meter 0.40kg, Tensile strength – 820Kgf.

g. Slider crank: This is the crank wheel which is designed to hold the connecting rod. Several holes are provided on the crank wheel shown in Fig.2.g which are used to adjust the sliding length and to increase or decrease the perforation depth.

h. slider-crank mechanism: it is the basic mechanism of slider crank shown in Fig. 2.h. where crank diameter will be 35mm and the rod length will be 129mm.

i. Slider frame: this is the frame which has 4 pillars and the tool slider will slide by using these pillars and the part is shown in the Fig.2. i.

j. Shaft: diameter of the shaft is 25mm and length is 55mm. it is modelled in part module. Shown in Fig.2. j.

k. Chain roller plate: it is also called chain inner roller link as shown in Fig. 2. k. The dimensions are given in the chain assembly.

l. Chain Pin plate: it is also called chain outer link, it is shown in Fig. 2. l.

m. Sprocket: the chain sprocket is modelled by using 18 teeth as shown in Fig.3. m. The pitch of the sprocket is same as the chain designed.

n. Special chain attachment: it is the attachment used to hold the box to the chain. The attachment is attached to the chain by using the curve present at the bottom side of the strip and will be pressed to the chain tightly as shown in Fig. 3.n.

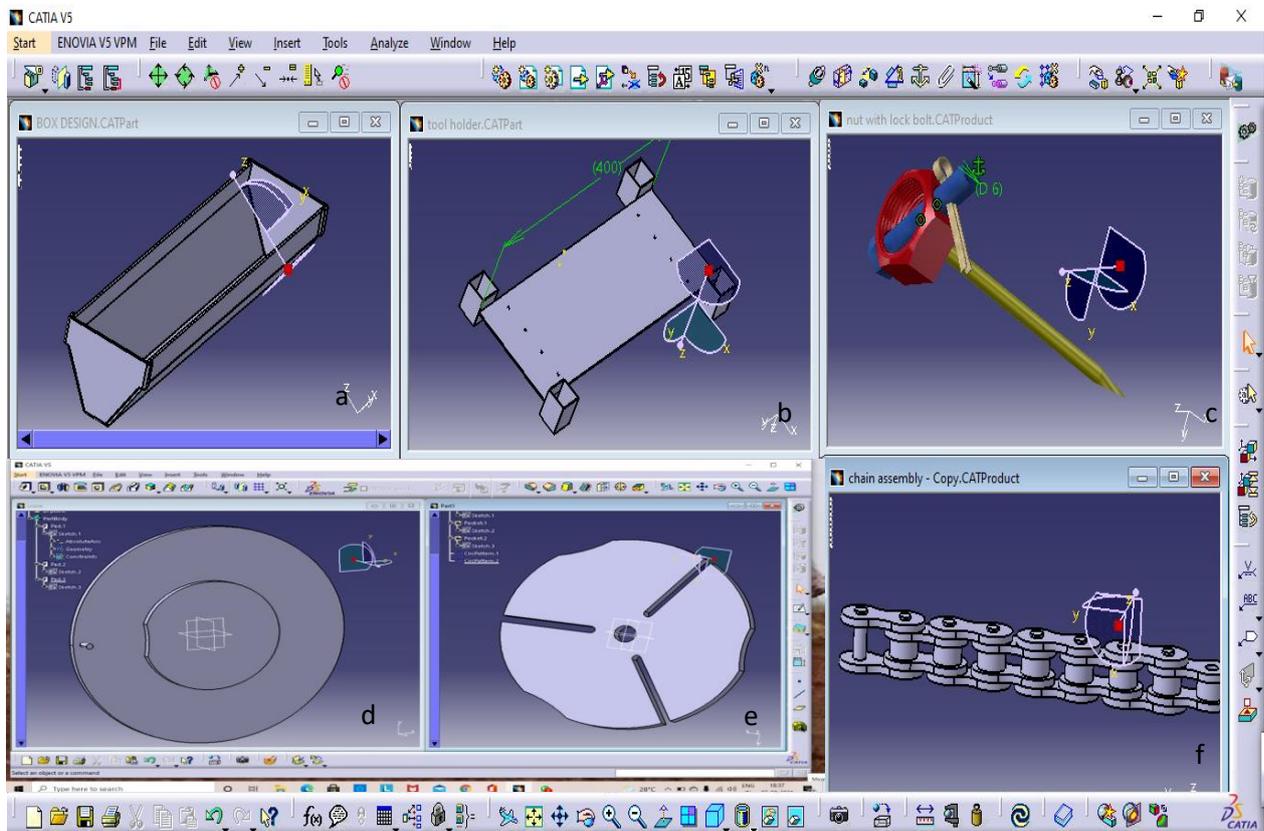


Fig. 1: CAD models of parts a. Box, b. Tool holder, c. Perforation tool, d. Geneva crank wheel, e. Geneva wheel, f. Chain.

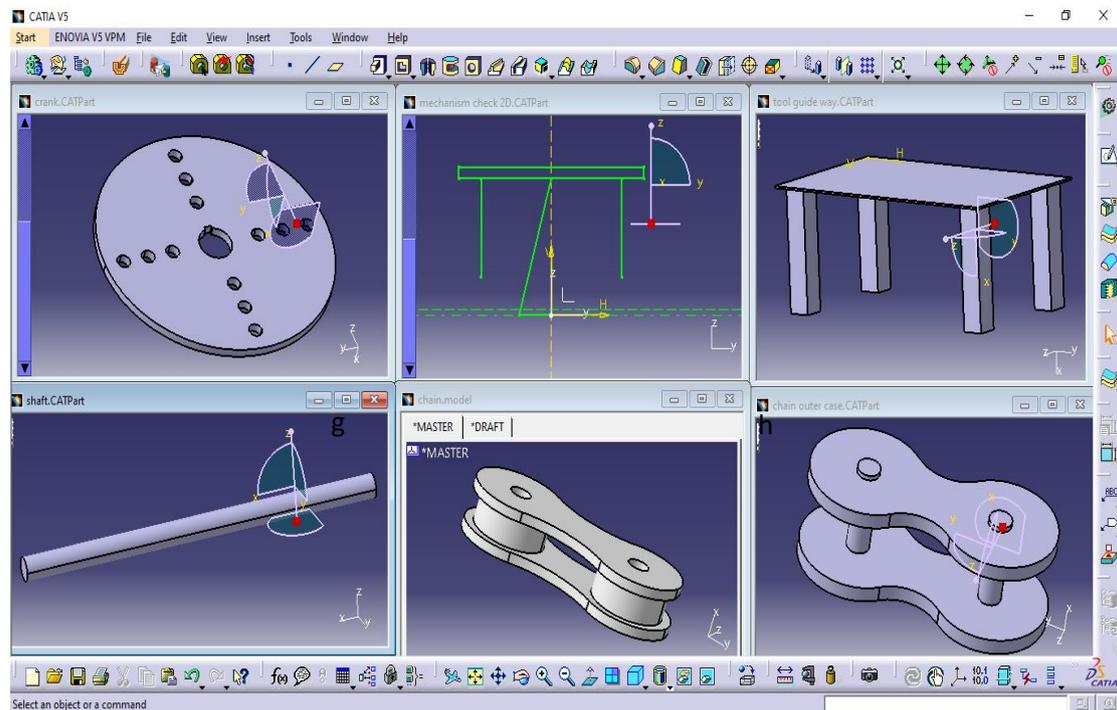


Fig. 2: CAD models of parts g. Slider crank, h. slider-crank mechanism, i. Slider frame, j. Shaft, k. Chain roller plate, l. Chain Pin plate.

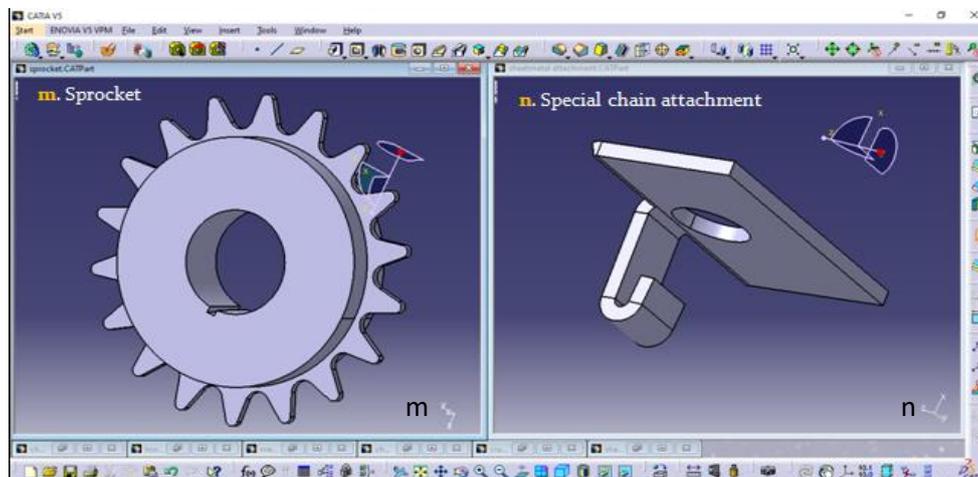


Fig. 3: CAD models of parts m. Chain sprocket, n. Special chain attachment.

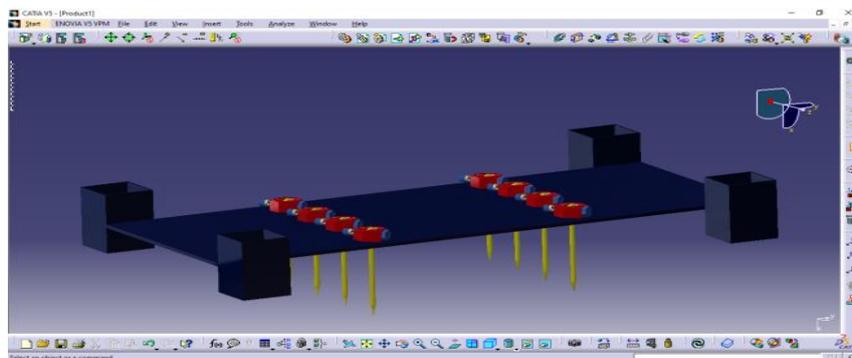


Fig. 4: Tool holder with tools assembled.

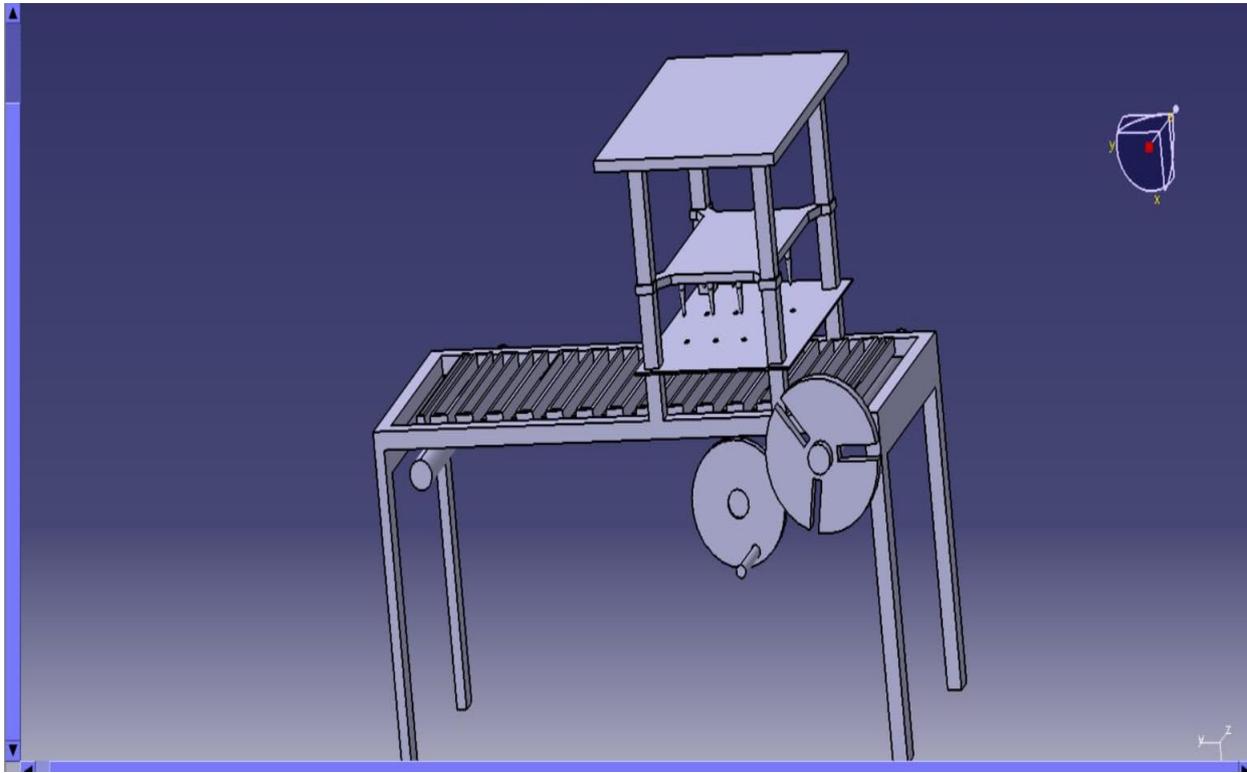


Fig. 5: Machine tool assembly (CAD model)

## 5. WORKING

- In this perforation machine, the worker has to give electric current input to the machine.
- Chillies will be placed in the boxes manually.
- The CAD parts are assembled in the Catia V5, product module as shown in the Fig. 5.
- Dumping of chillies will be done on baffle plates provided on the machine.
- Vibrations created on the baffle plates will move the chillies into the boxes placed at the end of baffle plates.
- Boxes which will carry chillies are attached to the chain by using chain special attachments.
- Chain is engaged to the chain sprocket, which are assembled on the shafts.
- Shafts are arranged at both the ends of the machine.

- Geneva wheel is assembled on one of the shafts, with the centre distance another shaft is attached to the frame of the machine.
- On the respective shaft, chain drive from motor will be engaged. Therefore, power will be transmitted from driver motor – crank wheel shaft – geneva wheel shaft – chain sprockets – chain.
- Perforation tool is used to punch a hole on chilli by sliding on the side pillars provided.
- Motor is directly connected to the crank rod in the slider crank mechanism
- Hole is produced on the chilli when the conveyer belt gets stopped. And when the conveyer is moving the sliding tool will go up after punching.
- After punching hole, the chillies present in the box will fall into the drum placed at the end of the conveyer belt.
- And after removing the chillies the upside-down boxes will return to the top side and perform the same operation until the machine is stopped.
- At one successive stroke of the slider 20 punched chillies will come out of the machine.

## **6. FABRICATION**

- Geneva wheel can be fabricated by mild steel (M S) plate of thickness 5mm. The mild steel is a combination of a low amount of chromium, and molybdenum with low carbon as well. Because of the low carbon alloy, it is more weldable, ductile rather than the carbon steel. These plates offer high strength, tensile, yield, mechanical strength, ductility, hardness, toughness [4] [5].
- Cut-off wheels are made of abrasive grain bonded with an organic bond system and used for cutting, notching and grinding. They are used with both portable and stationary tools on numerous materials including aluminium, plastic, sheet metal, stainless steel and more. Slots of the Geneva wheel is be cut by using cutting wheel technique.
- Crank wheel with the crank pin will be fabricated by MS plate and fastened together by using arc welding technique.
- The chain material is of Medium-carbon steels. Medium-carbon steels are similar to low-carbon steels except they contain carbon from 0.30% to 0.60% and manganese

from 0.60% to 1.65%. These steels are mainly used for making shafts, axles, gears, crankshafts, couplings, and forgings.

- This roller chain has special links spaced every 4th pitch, which is a 2" spacing between attachments. The special attachment link has 90 degree bent tabs with one hole per tab. This special attachment is made by Galvanized Iron sheet (GI) of 24 gauge.
- GI sheets are basically steel sheets which have been coated with zinc. It reacts with the atmosphere to provide the base steel a protection. Boxes will be fabricated by G I sheets of 20 gauge.
- Punching tool will be stainless steel needle of diameter 4 mm.

## **7. RESULT AND DISCUSSION**

Designing and modelling of Geneva wheel and crank wheel with specified dimensions are manufactured by using MS plate of thickness 5mm. Attachment of boxes to the chain is performed by using special attachments can made from GI sheets. Chillies will be placed in the boxes correctly [6]. Removal of punched chillies from the boxes will be carried correctly without any jamming between punched chilli and box inner surface when the box comes downwards for the conveyer [7]. Enough clearance is provided for the boxes and other parts where the chain will operate smoothly without touching any other machine surface [8]. Slider and crank mechanism are working as per the theoretical calculations which is animated in Catia V5 [9]. Punching one hole on one chilli will be performed correctly by using slider-crank mechanism [10].

## **CONCLUSION**

Design and modelling of different parts have been performed by using Catia V5 software. These models are designed by considering the basics standards. This CAD model can be brought into working model and can be implemented in the Sun-Dried Curd Chillies manufacturing unit and some food processing units. To increase the production rate of the machine, length of the tool holder can be increased and it can hold more than 8 tools therefore more than 8 punched chillies will be produced for one complete successful stroke of the slider. The stroke length of the slider can be increased or decreased by changing the

holding point of rod on the crank wheel. Therefore, by varying the stroke length we can vary the perforation depth into the chilli.

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## A review of performance and emission characteristics of single cylinder diesel engine fuelled with different alcohols.

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### Abstract

The use of fossil fuel in industrial and transportation sector have reached its peak and thus resulted in depletion of the reserves. This stimulating problem has raised the opportunity for the researchers to search for renewable resources such as alternative fuels. To meet the current energy demand and to reduce the burden on oil reserves, it is necessary to search for alternate fuels. Alcohols, being an alternate fuel, has been used in automotive since decades. The conventional diesel and gasoline engines emit harmful emissions of CO, nitrous oxides, unburnt hydrocarbons which affect the environment adversely. Utilization of alcohol tends to reduce harmful emission by promoting better combustion owing to presence of oxygen in it. Also it has been reported that the use of higher alcohols in diesel engines is better than utilization of lower alcohols. As the lower alcohols have low cetane rating, lower calorific value and phase separation takes place on mixing with diesel. In this context the present research paper summarizes a review on the use of alcohol derivatives like 1-octanol, hexanol and butanol with the diesel fuel to make blends and compare its physical and chemical properties, production method and performance and emission characteristics.

**Keywords-** Higher Alcohols, Combustion, performance, emission characteristics, energy

### 1. INTRODUCTION

The requirement of energy resources such as mineral oil and gas fuels has hiked tremendously over the past several years and the replenishment rate of these natural resources is not able to meet the increasing energy consumption demand. The increasing carbon emissions and global warming has been a serious concern which motivated the researchers around the world to look for alternative fuels. The alternative fuels besides providing the energy security also creates the employment opportunities for the people. Alcohols being a renewable fuel may provide energy security to the world. Recently the NITI-AYOG in INDIA has decided to invest Rs. 50 billion INR towards methanol economy insisting on the development of methanol and di-methyl ether as an alternate fuel for diesel engine. The estimated global biofuel consumption is 1777 mtoe by end of 2019. The largest share was held by US (49%). India spent nearly 120 trillion INR in importing crude oil in fiscal year 2019-2020. The globally estimated oil reserve was proven to be 244.6 million tonnes by the end of year 2019. The largest share of oil reserves was in Saudi Arabia (17%). The total reserves of natural gas by the end of year 2019 was 3989.3 billion cubic meters. US has the largest share of the reserve (23%).

The World primary energy consumption is estimated to be 583.9 billion tonnes of oil equivalent. The primary energy consumption of India is 34.06 billion tonnes of oil equivalent. The country shares 5% world world's primary energy consumption. India has 10 % share of the global coal reserves with reserve to production ratio of 140 years. Despite huge reserves the country still depends heavily on oil imports for meeting the primary energy demand. Owing to the large population, India has higher primary energy consumption. The rising crude oil prices pose a huge concern to look for alternatives that could lower the spent on importing the fossil oil to meet the energy demands. The transport sector degrades the environment owing to the harmful effluents released from the engine. The consumption of diesel fuel in India is nearly four times the consumption of gasoline. Hence, substituting the mineral diesel by alternate fuel pose greater economic advantage as compared to alternative fuel for gasoline engine.

Diesel engine utilization in India is increasing day by day owing to high efficiency and also the subsidy of government on diesel fuel. Agriculture equipment, transport and industrial sector rely heavily on diesel fuel for their operation. The IEA also suggests that the use of alternative could reduce the emissions upto 50 percent by 2035. In accordance of protecting the global environment and to eliminate the problem of rapid fuel depletion , it has become very necessary to explore renewable fuels which are not only better for the environment but will also not hamper performance of the engine and its durability. [1,2]

However the use of alcohol-diesel blends has gained importance as alcohols can substitute the mineral diesel partially without any modifications in the engine. Higher alcohols are also easily miscible with diesel without any appreciable reduction in performance characteristics. Some of the well-known alternate fuels include bio-diesel, bio-alcohol, vegetable oil, etc. The present paper focusses on the blends of alcohols like 1-octanol, hexanol and butanol with diesel blends of different proportions stating their physical and chemical properties, blend production method and performance and effluents characteristics observed when diesel engine is fueled with these alternatives.

### 2. BLEND PRODUCTION METHOD

1-Octanol can be produced by oligomerization of ethylene. It can be also be obtained from the esterified products of methyl caprylate and coconut oil, subsequent reduction by sodium and alcohol. It may also be prepared by the reaction of acetaldehyde and crotonaldehyde followed by hydrogenation. Many researches reported that 1-octanol can be readily blended with diesel in various proportions. Some researchers blended the diesel with maximum 20% by volume of mineral diesel while some investigators substituted 40% by volume of mineral diesel with 1-octanol. These blends were found homogenous. However on testing these blends for physico chemical properties, it was observed by Amar et al. that as the 1- Octanol content increased in the mixture, it raised the density and viscidness of the blends but simultaneously it lowered heating value with the increase in concentration of 1-Octanol content in the mixture. [3,4]

Hexanol  $\text{CH}_3(\text{CH}_2)_5\text{OH}$  exhibits six carbon chain and is an organic alcohol. It is produced by oligomerization of ethyl alcohol which can be obtained from agricultural products nad wastes. Aloko et al. observed that if 5% of hexanol is mixed with mineral diesel by volume proportion(v/v), it exhibits the required diesel properties and an increment in performance and effluents characteristics is observed. Sundar et al. substituted the mineral diesel by blends of diesel and 1-hexanol and replaced the 50% by volume mineral diesel with 1-hexanol. It was noted that as the hexanol content was increased in the blend the heating value lowered.

Butanol ( $\text{C}_4\text{H}_{10}\text{O}$ ) is a four carbon alcohol which may be mixed with mineral diesel in any proportion without observing any phase separation. It can also be mixed in higher ratios with mineral diesel as compared to ethanol. Shukla et al. prepared blends of 5% and 10% butanol by volume for the investigation and designated them as Bu5 and Bu10 respectively. Blends were kept under inspection for two-three weeks but no visible separation occurred in it. Then after this both the mixtures were centrifuged but no separation occurred even at high speed of 1200rpm for 20-30 minutes and the sample was also stable at sub zero temperatures when observed for 48 hours.

### 3. PHYSICAL AND CHEMICAL PROPERTIES

Various researchers emphasized on the physio-chemical properties with regard to the diesel fuel and alcohols which were used to make the blend of specified proportion.

With the increase in number of carbons the properties of alcohols tend to come closer to mineral diesel, 1-Octanol exhibit the same with regard to the physico-chemical properties. The physio-chemical properties of diesel and 1-octanol are stated in Table1[3]

Table1. Properties of diesel, 1 octanol

Properties	Diesel	1-Octanol
Density ( $\text{kg/m}^3$ , at 15°C)	810	826
Boiling Temperature (°C)	215	196
Flash Point (°C)	65	82
Cetane Number	46	39

Viscosity (cSt at 40°C)	3.2	6.02
Calorific Value (KJ/Kg)	45180	39150
CFPP (°C)	7	-13

The chemical properties of diesel and hexanol are stated in Table2 [4] Table2. Fuel Properties of diesel and hexanol

Fuel Properties	Diesel	Hexanol
Density at 20°C(.10 <sup>3</sup> Kg/m <sup>3</sup> )	.830	.8218
Latent heat of evaporation(KJ/Kg)	250	486
Boiling point (°C)	215	180
Flash point(°C)	70	65
Viscosity(mPa.s)	3.2	5.32
Heat value(KJ/Kg)	45000	38100
Cetane number	46	42

It has been found that the density of n-butanol is very close to density of diesel, thus it does not affect the density adversely while being blended to diesel in lower volumes. The important physio-chemical properties of test fuel (diesel and butanol) are stated in Table3 [5]

Table3. Properties of diesel and butanol

Property	Diesel	Butanol
Density	820Kg/m <sup>3</sup>	805Kg/m <sup>3</sup>
Boiling Point	266°C	117.6°C
Flash point	85°C	37°C
Volatility	Volatile	Volatile
Kinematic viscosity (Cst at 40°C)	3.2 cSt	2.20 cSt
Auto-ignition temperature	316°C	343°C
Heating value	45000 KJ/Kg	36800 KJ/Kg
Latent heat of vaporization	250 KJ/Kg	550 KJ/Kg
Cetane number	46	17

#### 4. PERFORMANCE AND EMISSION CHARACTERISTICS

1-Octanol-Diesel fuel blend- Amar et al. investigated the suitability of 1 –octanol on a single cylinder 780 cc 5 kw diesel engine and observed the performance and effluent characteristics. There was a marginal decrease in the Brake thermal efficiency with increase in percentage of 1-octanol alcohol content in the blend simultaneously. For the 10 % 1-octanol blend BTE reduced by 7.42 %. Subsequently 10.24 % reduction in BTE was observed for the 20% blend and 15.55% reduction in BTE was observed for the 40% 1-octanol blend [3]. Also there was rise in Brake Specific Fuel Consumption wa with the rise in percentage by volume proportion of 1-Octanol in the blends. The rise in brake specific fuel consumption was attributed to lower net heating value of octanol compared to mineral diesel.

The effluent characteristics were enhanced as well. NOx emissions were lowered considerably with the increase in concentration of 1-Octanol in the blend. Thermal NOx emissions decreased by maximum 26.68% for the 40% 1-octanol blend. However, the 10 % octanol blend showed only 13.34% reduction. Reduction in carbon monoxide was observed for all the test fuels. Maximum reduction was obtained with the 40% blend. The reduction was observed due increased availability of oxygen present in 1- octanol. Considerable rise in Unburnt hydrocarbon content have been observed with the increase in concentration of 1-Octanol fuel blends, The increase in 1-octanol content lead to further rise in unburnt hydrocarbon emission. Reduction in smoke opacity was observed for 1-octanol diesel blends and reduction increased with the increased concentration of 1-octanol blends. The reduction in smoke opacity was attributed to higher oxygen content of the 1-octanol diesel fuel blends [11]

Hexanol-Diesel fuel blend- Sundar et al. investigated the suitability of hexanol in 5.2 KW single cylinder naturally aspirated diesel engine. They substituted the 20% by volume diesel fuel with 1-hexanol. The net



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heating value, density and viscidness decreased with the addition of 1-hexanol to mineral diesel. The lower net heating value of 1-hexanol increased the brake specific fuel consumption. And the increase in BSFC was proportionate to increased concentration of 1-hexanol in the blend. Enhancement in brake thermal efficiency was observed owing to enhanced combustion due to higher oxygen content of 1-hexanol diesel fuel blends. The maximum brake thermal efficiency was reported for 10% 1-hexanol diesel blends. However, on further addition of 1-hexanol in the diesel fuel reduced the BTE owing to the lower heating value of 1-hexanol which increased the consumption of fuel to generate the same output. Reduction in soot emissions were observed for all the blends of 1-hexanol and diesel, the maximum reduction being observed for the 20% 1-hexanol diesel fuel blends and minimum reduction has observed for 5% 1-hexanol blend. The exhaust gas temperature increased for all the tested blends thereby increasing the NOx emissions for the different blends. The NOx emission was lowered by 60% by employing a exhaust gas recirculation technique in the experimental set-up. [4,10]

Butanol-Diesel fuel blend- Dimitrios et. al investigated the suitability of n-butanol in Direct injection high speed diesel engine. It was observed that Brake thermal efficiency enhanced with increase in concentration of n-butanol for all blends. The maximum BTE was reported for the blend with maximum butanol content. This can be attributed to the higher oxygen content of butanol diesel blends. Reduction in Smoke opacity was observed with butanol-diesel blend compared to mineral diesel. Rise in Hydro carbon effluents was observed for all the test fuels when compared to the baseline diesel data, this can be attributed to the quenching effect occurred due to lower cetane rating of the blends. At low loads, Rise in CO emissions were observed. This can be attributed to high latent heat of evaporation of blends compared to mineral diesel. At low loads greater smoke opacity was also observed owing to the short combustion cycle at high speed. Smoke opacity is higher with butanol blends at lower loads than with mineral diesel. At low loads the thermal NOx effluents were found to be comparable to mineral diesel. This phenomenon can be attributed to lower net heating value and high latent heat of vaporization of butanol leading to lower combustion temperatures inside the engine cylinder. [5,6,7]

### 5. CONCLUSION

The current paper summarizes a review of the viability of 1-octanol, hexanol and butanol as a substitute for mineral diesel. This review gives a comparison of alcohols with diesel blends and discusses about their various aspects while emphasizing on its performance and emission characteristics. The results can be concluded as follows- Alcohols are easily miscible with diesel fuel and blends of 1-octanol, hexanol and butanol were made with diesel fuel in different proportions and were found to be homogeneous and quite stable at different temperatures.

Brake thermal efficiency is observed to be increased at part loads because the alcohols act as oxygenated fuels and makes the combustion to occur properly, but simultaneously Brake thermal efficiency is reduced at full load condition owing to low heating value of alcohol fuel blends as compared to mineral diesel.

The addition of alcohol to diesel fuel increases the specific fuel consumption of the engine as to generate the same amount of output more fuel was consumed due to lower heating value. The exhaust temperature reduced with utilization of alcohols there by lowered the NOx emissions However effluents of CO reduced owing to higher oxygen content in blends due to alcohols, while the quantity of unburnt hydrocarbon got increased simultaneously. These all research studies are done for short term duration and this shows promising improvement in emission characteristics with the satisfactory performance of engine. Long term assessment of usage of alcohols in diesel engine needs to be carried out.

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## A Comprehensive Study of Lean Manufacturing Approaches and Applications in Industries JIT, Lean and Agile Manufacturing Nittin<sup>1</sup>, Mahesh Chand<sup>2</sup>

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### Abstract

Lean Manufacturing is becoming a popular method to allow the industries to interactively business supply to gain a competitive benefit and maximize customer value in the marketplace. Various techniques such as lean practice, internet of things, MICMAC analysis, I4.0 Technology approaches have been used by researchers in the field of lean manufacturing. Various researchers have focused in the literature to retrieve an efficient and effective technique using lean manufacturing is primarily intended to reduce the number of operational issues to enhance industries benefits. Lean manufacturing acts as a computational study of various set of principles and processes which helps companies to control and organize production as it is widely disseminated and used among various industry sectors. By devising an accurate method for I4.0T and lean manufacturing by means of considering critical issues strictly is a task of great importance. Lean considers processes (i.e., implementation, and context processes) that directly impacts employees' environment of working and well-being etc. From the previous discussion of various researchers, it is required a forementioned bodies on lean practice knowledge is diverse and disperse constructing it hard for practitioners and researchers to achieve a clamp of LM which makes lean manufacturing a compact questionable field both in business and academic. To support lean theories evolution, new practitioners should consider to address the previous research excuses and should determine a more communicate and completely essence and applications of lean practices. This research study on lean manufacturing successfully addresses the significant challenges of lean manufacturing and by identifying the scopes of future works in that direction.

**Keywords-** Lean Manufacturing, I4.0, 5S, Supply Chain Management, KANBAN.

### 1. INTRODUCTION

Lean Manufacturing (LM) represents various principles and processes to favour companies to control and organize production as it is widely disseminated and used among various industry sectors. LM works in the direction of improving quality, reducing waste in the value stream, maximizing productivity in accordance of customer's expectation due to LM wide acceptance accuracy and ease in application for industries. Industry 4.0(I4.0) corresponds to similar goals as it seeks continuous improvements in quality, focus of elimination of waste, increasing productivity [24]. LM also acts as an approach which encloses a number of manufacturing practices with the intent of reducing process variations, eliminating and identifying waste onward to the value stream. It is evident from various researches that Lean Manufacturing is a social - technical approach which acknowledges human acts as a crucial aspect for regular improvement, affecting individual human being and the aspects of the performed work [35], [39]. LM considers 5 basic fundamental aspects for iterative improving value and waste reduction: value definition from customer's viewpoint; flow value definition; constructing the flow value; manufacturing as per customer's requirement; and inquiry of perfection. LM various examples are: VSM, visual management, 5S, kanban, and so on [1], [23], [36].

As per digitalization era, I4.0 has developed various important demands in new jobs and production systems [3]. LM considers systematic way of waste reduction for improving productivity within manufacturing industries. This waste corresponds to labour, complexity, space, defects, overproduction, defects, materials, transport and time. Waste does not require value of product but uses resources [27]. Waste elicitation is the important objective of lean manufacturing. Toyota identified mainly 3 varieties of waste corresponds to lean manufacturing; muri, muda and mura. Firstly, muri, considers all unreasonable strains which are applied on employees and machines. Mura considers all wastes of un-leveled employees and machines work load [28]. Lastly, muda represents waste which considers in-process waste but acts as a medium for increasing productivity. In various studies, Toyota Production System (TPS) classified 3<sup>rd</sup> variety in mainly 7 wastes, i.e., transportation, waiting, overproduction, motion, inventory, defects and over-processing. Unreliable evidence identifies those various organizational parameters constraint or enable lean practices implementations [2], [32], [33].

An I4.0 manufacturing environment assures all availabilities of information flows and various physical measures to stay connected with real-time partners. I4.0 and LMP are primarily focused for improving qualities of SOP and sustainable development operational excellence goals through I4.0 by considering the fact that I4.0T and LMP integration accelerates the advancement of lean manufacturing systems in organizations however also eliminates risk correlated with the huge costs of I4.0 T implementation. In spite of knowledge of 3 pillars of sustainability, since it is very hard to appoint the correct selection criteria to evaluate and characterize the sustainability degree for individual organization. The conclusions suggests that lean or six sigma enabled companies will clamp the perception of sustainability [5], [6].

### 1.1 Lean Manufacturing Applications in Industries

Lean manufacturing and technology collectively primarily objective is to highlighting the prominent tools combination for capturing the perceived level to operational performance and manufacturing practice to enhance operational performance [37]. Various industry applications were used to support lean attributes such as standardized work, Kanban, for continuous improvement (KAIZEN), and total productive maintenance (TPM), and are as follows:

#### 1.1.1 KAIZEN

Kaizen acts as the underlying organisational philosophy of LM, with the main objective is to enhance the added-value work amount and waste reduction through efficient continuous improvement which is represented by long - term and key for continuous improvement is represented by small changes. Important kaizen application affects waste elimination, lower costs, quality, productivity, efficient improvement, and workplace safety etc [22], [29], [31].

#### 1.1.2 5S

5S comprises of 5 keywords, i.e., sort, set in order, shine, standardize, and sustain. Researcher identified that it is widely used as the first step of lean manufacturing implementation as per systematic literature studied [3]. The key to 5S was not only used for improving efficiency, but also for operational and safety learning, i.e., associated with the origins of lean [4].

#### 1.1.3 Kanban

It represents as an important tool for continuous material flow promotion with the help of reduced waste processes and implementing customer pull production by maintaining inventory at pre-defined level with the aim of uninterrupted material supply. On the basis of a particular customer demand, various visual cards may be effectively created to triggering the replenishment of required inventory, dies, and raw materials as well as for signalling the required manufacturing processes.

#### 1.1.4 Poka Yoke

It represents the methods of LM to support operators to reduce mistakes in their work caused by selecting the leaving out a part, wrong part, and backward part installation e.g., proofing error represents distinct product design that uses shapes of physical nature; it is evidently described by researchers that installation of these kind of parts in the suitable orientation is very difficult task.

#### 1.1.5 Value Stream Mapping (VSM)

It is an application of LM with the aim of successive systematic identification of waste improvement potential and consecutive production processes respectively.

#### 1.1.6 Standardized Work

It is represented as work procedure set to build the most efficient sequence and method for individual worker and individual worker with the aim of maximizing performance and minimizing waste for ensuring the lined production effectively in accordance of customer orders enable operators to change their positions in accordance of process. This work, once displayed and established, is the effective improvement process through kaizen with the primary advantages such as variability reduction, injuries and strain reduction, current process documentation for individual shifts, and a baseline for improvement activities [18].

#### 1.1.7 Total Productive Maintenance (TPM)

It acts as a path of LM for maintenance that eliminates breakdowns, effectiveness of equipment's, and promotion of autonomous maintenance process by operators through daily basis by considering whole

workforce by compromising structural approach to making a visible change in the work culture of an organization by changing employee's mindset [18]. Researchers concluded that some important lean tools/ concepts and their implementation frequencies as shown in Table 1 as follow:

Table 1: Lean concepts/tools and tools implementation frequencies [18]

Tool/ Concept	Frequency
KAIZEN	97%
5S	80%
Visual Management (KANBAN)	70%
PDCA	59%
VSM	56%
Standardized Work	53%
TPM	50%

### 1.2 Challenges in Lean Manufacturing

Based on literature studied in this research work, the various challenges in lean manufacturing are as follows;

#### 1.2.1 Lean Production is fragile

In modern business environment, whereas LM is employed, extra inventory is always required due to mass production buffers required for successful LM, more workers and more space in order to work. Problems arise usually when unavailability of parts, workers due to their health problem, and their disability in detection of problem before mass production. However, to build effective LM system which can works better effective approaches such as elicitation slack, work at all, and capitalizing each worker best ability.

#### 1.2.2 Degree of engagement

For developing a work environment in lean manufacturing where everybody is intended for finding ways in improving work processes. To achieve this task, lean manufacturing requires fully engaging the creativity, energy and imagination of everybody for improving work processes in an efficient manner.

#### 1.2.3 More Failure Rate

Unlocking the full potential of a workforce results in difference between success and failure in today's global marketplace using lean manufacturing. There is approximately 75% failure rates in lean manufacturing production since lean transformations extensively depends on work processes, supervision, beliefs and leaderships.

#### 1.2.4 Human Related/ Organizational Issues

In lean manufacturing, there are a large number of organizational/ human related issues; out of which, some main change cultural issues factor always exists i.e., reduced transparency and self-criticism, high personnel turnover, reduced participative management teamwork, minimum cooperation, alignment of leadership and effort (i.e. in the form of commercial vs. construction team), hard-lined organizational structures or rigid organizational processes, bad leadership, inefficient housekeeping, too much trust on consultants, leadership conflict, more focused trusts on trainer, exclusively manufacturing idea, pseudo-lean implementations for secondary reasons, "Lean department" exclusive business, overuse of Lean jargon, and fear of unfamiliar practices. Thereby, it is advised by various researchers that by using a process and project governance or by using a process business and project business strategy focused approach should apply while incorporating Lean construction [3].

#### 1.2.5 Technical Issues

Some issues in lean manufacturing are considered as technical issues as they possesses a straightforward effect on lean construction approaches, such as, lack of constructible designs, incomplete designs, not process based

design (poor performance measurement strategies), client’s value generation poor understanding, not a perfect clearance in agreed LM methodology, reduced pre-fabrication and reduced standardization for the effective adoption of LM, not giving proper attention to non-quantifiable/ quantifiable gains, inability to define the business for effective LM, supply chain uncertainty, reduced lean thinking are the primary technical issues of LM and the industry fragmented kind treats these barriers as a collaborative partnering and teamwork issues for successful implementation of LM practices in organization.

### 1.2.6 Management Issues

There are various issues already described in literature and introduction of this research study, but out of which, the most critical issues of lean manufacturing were considered as management issues that comprises decision making delays, reduced supplier involvement and support of top management, lack of client involvement, less management commitment, delays in material deliveries, minimized customer focus and contractual uncertainties, poor project definition, lack of equipment, conventional contractual mechanisms possesses adversarial relations, material scarcities, less time for innovation generation due to cost and schedule pressure, unsuitable for LM organizational structure, rushing, weak administration, minimization of supply chain integration SCM alliances, inefficient communication, lack steady work involvement, use of substandard components, inadequate pre-planning, long implementation periods, poor procurement selection strategies, inadequate resources, were considered as the prime managerial pitfalls for Lean manufacturing adoption in organizations [4].

## 2. OBJECTIVES

1. To explore and study various lean manufacturing processes.
2. Construction of a systematic literature review based on recent literature studied and work done by researchers in the field of lean manufacturing.

## 3. LITERATURE REVIEW

For building of systematic literature review, research papers related to lean manufacturing frameworks were searched from Web of Science and Scopus by using the various key words in Lean Manufacturing area from 2016 to 2021. Various literature studied with respect to this research work is as follows:

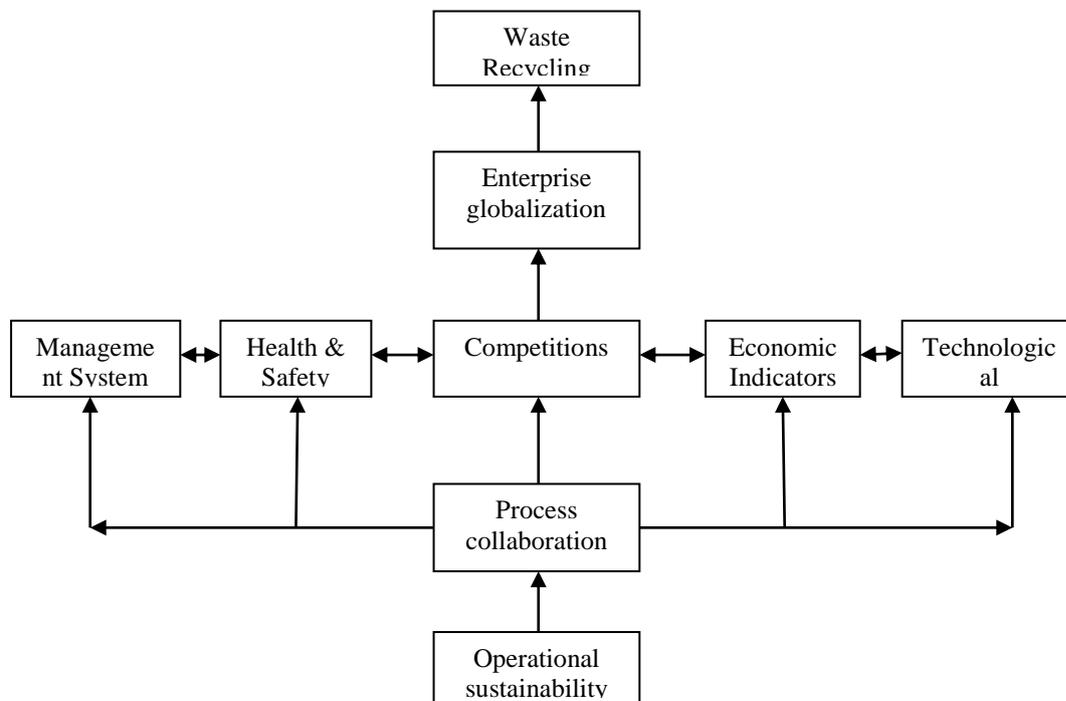


Figure 1: ISM Based model for operational issues in SSCM [2]

Mahesh Chand [2] identified ISM approach of factor analysis to analyse the LM practices which acts as an interactive learning process and it can be used to identifying and summarizing the relationship between the specific variables that defines the issues and problems. ISM approach incorporates a set of many indirectly and directly related elements which can be structured to accomplish a comprehensive systematic model. MICMAC is also referred as 'cross - impact matrix multiplication applied to classification'. This research work also used ISM Based model for operational issues in sustainable supply chain management (SSCM) as shown in Figure 1. ISM methodology used by researcher followed various steps which are following:

- Variables/ elements identification in context of research problem.
- To Establishment a contextual relationship between variables/elements in accordance of element pairs.
- By building a structural self-interaction matrix (SSIM) of variables/elements for pair-wise relationship across variables/elements and then computation of validating of matrix for achieving transitivity.
- Next phase is to build a reachability matrix (RM) with the help of SSIM.
- Sequentially, next phase is to partitioning of RM into various levels.
- Conversion of RM into conical form.
- Lastly, hierarchy of variables is formed.

A total seven numbers of step in ISM methodology are following:

- Step 1: Identification of different operational issues in sustainable SCM relevant to the research problem.
- Step 2: Identification of a contextual relationship among operational issues with respect to examination of pair of variables. Sequentially, construction of a SSIM for sustainable operation issues pair-wise comparison.
- Step 3: Creation of binary matrix (initial RM) obtained from SSIM transformation.
- Step 4: Transitivity checking by conversion of the RM into the final RM.
- Step 5: Conversion of the final RM into the canonical matrix format according to their levels by arranging elements.
- Step 6: Designing a directed graph from canonical matrix and elimination of transitive links in accordance with the relationships obtained from the reachability matrix. Sequentially, conversion of resultant digraph into an ISM model.
- Step 7: Finally, conceptual inconsistency checking in the ISM model and if required, necessary modifications are incorporated for operational issues in SSCM. Research results expressed highly beneficial results towards industries implementation of LM.

In this research work, lean practices (LPs) are distributed into 4 clusters, namely as autonomous cluster, dependent, linkage and driven cluster which are described as follows;

- 1<sup>st</sup> Cluster: Autonomous variables – This kind of variables defines weak dependence and weak drive power by consisting of 3 factors i.e., JIT, kanban and reduction of lot size.
- 2<sup>nd</sup> Cluster: Dependence variables – these variables define weak drive power but strong dependence power by consisting of 6 factors i.e., removal of bottleneck, continuous improvement process, PCM Process, reduction in cycle time, TQM and re-engineered production process.
- 3<sup>rd</sup> Cluster: Linkage variables – these variables define strong dependence and strong drive power. No factors were existed in this cluster.
- 4<sup>th</sup> Cluster: Driving variables – these variables define strong drive power but weak dependence power by consisting 4 factors i.e., Benchmarking, cross-functioning workforce, PSS and maintenance optimization.

Pagliosa M. [1] – Researcher focused on a methodology of systematic system flow for its better reliability and consistency. For this work, method consisted of various phases namely as search and database query, management of document, document standardization and selection of bibliographic portfolio. Synthesis phase were intended for the information retrieved from the previous phase and for presentation by the use of tables, reports and graphs from 3 conceptual directions: first is employment of I4.0 value stream technologies were employed; secondly comparisons of I4.0 technologies and LPs synergy level; and lastly disagreement of the LPs with the I4.0 methodologies by building MS-excel knowledge matrix. This research work also obtained 126

pair-wise relationships, out of which, 24 pair-wise were high synergy defining the positive interaction between I4.0 technologies and LPs to build a higher efficient performance. As a result, future work can be done in the direction of validating synergies between lean practices and I4.0 technologies, to differentiate relationship effects for all flow levels and for operational performance.

Evangelos Psomas [3] focused on SLR due to more replicable, transparent and scientific process for analysis, it also provides more informative guidance to cooperate researchers to conduct SLR and for analysis the literature review, it minimizes bias and reducing errors to build efficient procedures and conclusions, making able for extensive literature review and finally advancement in academic research with respect to literature studies in LM field. Researcher used three stages for this study. First stage is planning the review is intended for the preparation and the development of review protocol. The team firstly identify research problem and research questions formulation with consideration of objectives to evaluate inclusion/exclusion criteria along with quality assessment. Second stage of this study was intended with the aim of identification of research, quality assessment, and selection of studies data monitoring progress, data extraction, and data synthesis, e.g., search string in the form of: LM or LPs and manufacturing companies. Input for bibliographic databases was taken by search strings. The disciplined screening process used in this research study resulted 403 articles published in 62 reputed journals relevant to each other. Sample articles general information was created by using excel spreadsheet including title of journal, publication year, kind of paper, research geographical area, sub-sectors of industries, and count of companies. Last stage was intended for reporting and dissemination where the primarily focus was on presenting the report along with the recommendations. Lastly, LM practical implications and future research scopes are presented in this research study.

Gunjan Yadav [4] focused on valuable contributions towards LM domain for researchers and company leaders in various ways as follows: Researcher utilized this study by using AHP-DEMATEL methodology for creating LM framework for manufacturing industries corresponding to emerging economies. In this research work, not only driver weights were computed but also discussed the effects of several driver's despite to others to obtain a driver-base dataset, comprehensive, which can be utilized for creating Lean Manufacturing framework for their organizations by assessing the inter-relationships of LM drivers. Research design of this study was tested and formulated by using AHP-DEMATEL approach in a distinct organization for testing and effectively check the increased and strengthened the performance to check applicability of the LM framework. The fuzzy analytical hierarchical process which helps in evaluating LM driver weights for taken as inputs for DEMATEL approach. Then this approach was used to estimate relationships across the several drivers by following relationship diagrams. It was evidently revealed from this research work that the shop floor manufacturing and the quality management manufacturing strategies served as formal drivers whereas, supplier management, customer management, the manufacturing processes, and workforce management were the effective drivers of one year duration. This research study results resulted in a overall percentage increase of overall equipment maintenance, planned maintenance, and overall net operating profits.

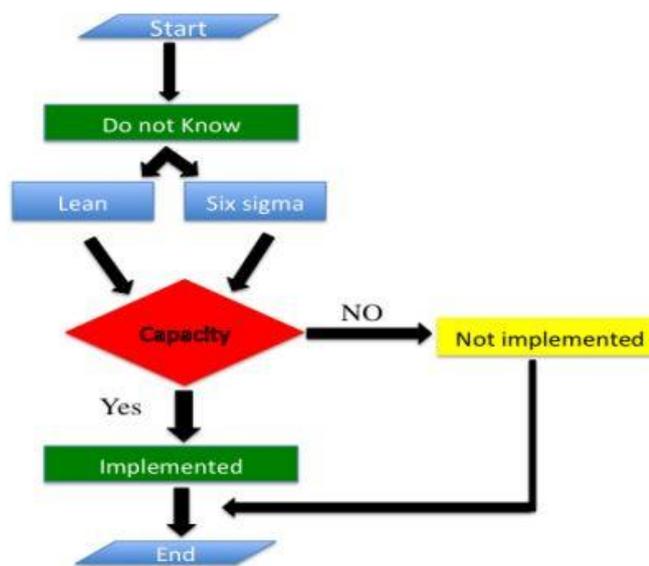


Figure 2: six sigma capacity and lean manufacturing capacity

Alhuraish [7] focused on lean manufacturing analysis of the available literature and it was evident that green practices deployment can be easily achieved by adoption of lean implementation. Various researchers' results were similar to this research work results except further applicability to estimate whether lean and six sigma approach should be effectively implemented sequentially or simultaneously. In addition to above, it was evidently stated that when these two approaches united with sustainability, yield to better results rather than with lean, six sigma, or sustainability implementation practices alone. It is evidently expected that the research results of this study can surely help organizations to evaluate a method to fit resources and capabilities critical success factors as shown in Figure 2 above. This study results can be used successfully for companies pursuing to achieve six sigma, lean manufacturing, and for building an integrated version of both. This study described and identified manufacturing strategies for organizations that were planning to apply both approaches either collectively or single. It was observed from this research study critical success factors can be achieved by interpretation and implementation of cultural influences. Therefore, researcher can work in the direction of successful LM implementation by considering various national cultural dimensions interaction with specific success factors.

Arkar Htun [10] focused on study of "Lean Manufacturing, Kanban system, Just in Time (JIT), and TPS". In modern business environment, it was evidently stated from previous researches that various manufacturing industries should follow the all-innovative tools and technology for effectively representative of their organization as a great competitor across the globe. LM is represented as efficiency-based system for reduction in wastage, flow optimization, and by adoption of advance methodologies to improve manufacturing system by changing or modifying previous ideas to sustain market conditions for better product efficiency and accuracy with lower cost whereas speed acts as key competitive factor to eliminate offering good prices, high quality and good service. Researcher utilized shorter lead time taken by manufacturing for supplying its products is directly proportional to higher probability. Since High velocity manufacturing is a most precise objective for each and every manufacturing business in which Machine, fund, people, materials is constantly moving at a regular pace. Researcher concluded that stocked inventories can be sustained for a very short duration of time, therefore, inventories will lead to remaining stocked locations, and for high velocity manufacturing such as for level linearity, line balancing, flow manufacturing, and level schedule respectively.

Sajan M.P. [12] focused on lean manufacturing practices in context of India small medium enterprises (SMEs) and their direct impact on sustainability performance. Researcher identifies that by adoption of sustainable development, SMEs have successfully implemented various acting strategies of large-scale enterprises such as green and lean practices. This research paper was primarily intended to investigate the linkage between sustainability performances in SMEs and lean manufacturing practices (LMPs) in SMEs. Further, this study also explored the relationships between sustainability 3 levels (i.e., social, environment, and economic) sustainability performances. The study primarily data collected from 252 manufacturing SMEs in India and a large questionnaire survey were established to accomplish the aim of this research work. The hypothesized relationships are then analysed in accordance of Structural equation modelling (SEM) model respectively. Analysis results of this work expressed that lean manufacturing practices are positively linked with different sustainability performances parameters which are categorized primarily as social, economic, and environmental performances. Further, it was evident from this research work that environmental sustainability was correlated to social and economic sustainability performances for the managers to convince their different stakeholders for LM implementation practices in SMEs. Lastly, researcher concluded that this research study was primarily summarized the positive effect of lean manufacturing practices towards the positive effect of environmental sustainability to social and economic sustainability performances and sustainability performances effectively.

Bai, C., [13] focused on research study that was primarily intended to investigate lean manufacturing practices in accordance of operational and environmental perspective. In this research study, mainly six kinds of bundles were utilized which comprised of four internal lean manufacturing practices and two external lean manufacturing practices. This research paper approach consisted 6 different manufacturing organizations for implementing lean manufacturing practices at various stages of supply chain management and their manufacturing processes respectively. Two organizations were in aerospace domain out of six organizations, two organizations were of automotive domain, one organization was from pharmaceutical domain, and one in textiles industry. All six organisations were primarily recognised best in their sectors in accordance of lean manufacturing practices implementation. It is evident from this research work, that operational LPs were root cause analysis, continuous improvement for problem solving, concurrent engineering, parts modularization, and design respectively. Researcher described that continuous improvement was the mostly suited important factor for achieving best operational performance. Sequentially, researcher described in the context of Environmental LPs are concurrent engineering, customer involvement, manufacturability design for improving the

organizations environmental performance. It was also been clear from the observations that the lean manufacturing practices that contribute to operational performance LPs different from environmental performance LPs. This study also described the common six LMPs are concurrent engineering, problem solving root cause analysis, team leadership and team work, manufacturability design, continuous improvement, and parts modularization part standardization respectively be the most successful factor for adoption of lean and green. Internal lean manufacturing practices included product design and human resources, equipment and process, planning and control, and manufacturing respectively. Two external lean manufacturing practices that were include in this research study were customer relationships and supplier relationships respectively. Excellent lean manufacturing practices represented the best rankings in environmental and operational implementation performance by considering the top 10 ranking lean manufacturing practices across the performance attributes. Based on this assumption, only one practice i.e., team leadership and work ranked in top 10 for each and every classification effectively in creation of green and lean organization. Researcher concluded in the context of poor lean manufacturing practices that these LMPs result in lesser environmental and operational performance improvements. Only 2 LMPs i.e., one-piece-flow multi-functionality and cross-training ranked in the bottom 10 for each and every distribution that provided the lack of environmental and operational mental performance improvement potential as well as hard to implement the both practices; conclusively, organizations might consider dropping these two practices from their implementation list respectively.

Vinod [14] research study focused on analysing LMPs in various organizations as well as to the critical factor identification factors for LMPs implementation. For this research study, for LMPs, data collected by empirical methodology by managing several manufacturing industries Tamil Nadu. A Structural Equation Modelling approach was efficiently utilized to develop the structural models and measurement models. Researcher described that LM suitably described global manufacturing with the integration of: (1) Fully committed management (2) eminently motivated employees working of team, eminently empowered employees working of a team, and highly trained employees (3) Operations internal integration with customers (4) Innovative culture promotion (5) Waste elimination streamlining and streamlining of processes. It is evident from this research work that lean manufacturing practices may provide significant and positive influence of the environment practices were tested effectively. Manufacturing Strategy, manufacturing management, and leanness manufacturing responsibility have been incorporated as the most prime drivers for LMPs by following a SLR approach for LM analysis in an integrated manner which the help of real time environment.

Möldner, A. K., [15] research work focused on exploring the LMPs that have direct impact on innovation performance. In this study, an efficient framework consisting of 22 scales of measurement and mainly 3 kinds of hypothesis were utilized on the basis of an SLR for large scaled questionnaire prepared by a number of selected industrial experts. For this research work, total of 340 responses of usable kind collected by factor analysis, correlations, statistics of descriptive nature, and several linear regression models respectively including various steps in a large-scaled questionnaire. Initially, the questionnaire approach ensured a partition of research subject and reduction of interviewer biases of researcher subject for result distortion. Sequentially, generation of large-scale samples obtained from quantifiable data were built. Sequentially, data were statistically analysed for estimation of interdependencies in between research framework and framework dimensions for generating reliable inferential conclusions. Lastly, researcher described that decentralisation may not reduce industry flexibility for innovation process adoption as hypothesised since standardisations can improve only internal distributions. On the basis of research results, it is evident that the results i.e., Human Lean practices and indirect i.e., technical LPs for improve process innovation. As a result, this research work suggested that the standardisations direct effect on innovation which could never be generalised. Negative LM impacts on work environment and health of employee's due to increased stress levels and deteriorating working conditions. Researcher concluded that both human LPs and technical LPs have a moderate to strong positive affect on the occurrence of radical, incremental process, and inputs of these processes' innovation in organizations as well as an output to justify the improvement of process innovation operational performance.

Sahoo, S., [16] study explored the technical aspects and social aspects of LMPs relationships as well as LMPs effects on business performance by using structural equation modelling (SEM) technique. This research paper main purpose was to examine the impact of TPM practices, human-related support practices, and TQM practices on their inter-relationship, and manufacturing performance parameters for providing useful insights to practicing managers. Social (or support) practice acted as the primary technical operational practices enablers for building continuous improvement system. Researcher suggested that by path following through which employee and leadership involvement positive outcomes can be influenced effectively, this study is beneficial to theoretical contribution that support and complements socio-technical system theory as well as for contributing this research study. Interrelationship results of the study explains between technical and social practices which can

be efficiently used by practicing researchers of social and technical practices aspects clearly towards the organizational objectives of sustainability. Researcher also explained the relationship between behavioural and technical practices aspects which can be used by practicing researchers for developing better gathering of technical and support practices towards organizational objectives such as growth and sustainability. SEM incorporated both “hard” and “soft” LPs which are related to performance parameters of business. Researcher concluded that by using “hard” lean practices it was easy to utilize fully business performance parameters than the relationship between “soft” LPs performance parameters.

Khalfallah, M., [17] explored LMPs in the context of just-in-time (JIT) production, JIT purchasing, TQM, and TPM, financial performance, operational performance, and agile manufacturing etc. For this research work, 205 Tunisian manufacturing firms’ data were collected through survey, and the results of surveys were analysed in accordance of an approach i.e., structural equation modelling (SEM). The results of this research work indicated that, for the successful implementation of LMPs for supporting agile manufacturing, but unable to increase performance. Research results of this study expressed that agile manufacturing higher level may improve performance efficiently as compared to prior one as well as it also provides empirical evidences to support the relationships between operational performance and lean manufacturing. Accordingly, it is evidently said on the behalf of research results that, it would be suited to recommend an effective JIT implementation, TPM, and TQM. This paper also described the importance of LMPs to adoption of agile manufacturing effectively as well as agile manufacturing role for ensuring performance effectively as this research work incorporated simultaneously study of the 3 dimensions of LM i.e., environmental, social, and economy along with their relationship for organizational performance and agile manufacturing. This research study results indicated main conclusions such as (1) LMPs provides a linear positive relationship in accordance of agile manufacturing excluding JIT production, (2) positive impact on performance is easily achieved by using agile manufacturing and (3) to achieve fully operational performance, lean manufacturing practices may not contribute efficiently, but the same relationship can be achieved efficiently through the use of agile manufacturing.

#### 4. CONCLUSION

Lean manufacturing for business industries as well as for sustainable supply chain development is a task of great importance to reducing the operational issues by using suitable analysis techniques for organization. LM has main application in several domains like corporate procurements, library, and government sector and for the real-time analytical systems. Some authors proposed a predictive model for operations issues by using lean manufacturing, sustainable environment and I4.0T, while some authors focused on MICMAC analysis and the 5S, KANBAN to reduce operational issues. Various researchers specified value in accordance to end customer policy such as by identifying necessary value stream all steps for individual product family, reducing or minimizing the redundant steps. It is evidently stated by various researchers that effective value streams should possess tight sequence to follow smooth product delivery to customers. A considerable survey is being followed in this research work of lean manufacturing in industrial applications. Some research study has been studied in literature focused primarily on lean manufacturing applications in industries. In this study, lean manufacturing practical implications and future scopes are presented. It is evident from literature that several researchers focused only on I4.0T, LMP, and SOP empirical relationship. Conclusively, this study findings reveals that I4.0T has positive influence on lean manufacturing practices.

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#### 6. FUTURE SCOPES

- The further work in the direction of lean management is the creation of customer value through eliminating and minimizing wasteful steps in a process; it must process ideally across a whole supply chain and must exceed a single function to obtain maximum benefit.
- Hardest challenges in a lean manufacturing will be to face the degree to which individual lean practices uncovers the greater problems and new challenges effectively.



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- Lean manufacturing possesses efficient elimination of waste by using proven track record for process improvement.
- Lean philosophies are influencing approximately every aspect of industrial business, as companies' transitions are shifting from industrial economy to digital one.

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## An Algorithm for Minimum Zone Sphericity Evaluation from Coordinate Data

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### Abstract

Deviations in the specified sizes and shapes of the manufactured parts is inevitable. Such deviations affect the functionality of those parts. The shape deviations are specified using geometric tolerances. Spherical parts find wide engineering applications, e.g., ball bearings, and they are controlled for sphericity tolerance. In this paper, a volume hunting algorithm has been proposed for the minimum zone sphericity evaluation. The proposed algorithm has been compared with several existing minimum zone algorithms using the coordinate data taken from literature. The proposed algorithm has performed at par or better than the existing algorithms considered.

**Keywords-** Minimum zone sphericity, coordinate data, volume hunting algorithm.

### 1. INTRODUCTION

It is extremely difficult to achieve perfect sizes and shapes on the features of manufactured parts due to several reasons, including the approximations in computer numerical control (CNC) machining. Suitable dimensional and geometric tolerances are specified to account for such variations and hence the manufactured parts must be checked for their conformance to design specifications. Geometric tolerances (form, profile, orientation, location, and runout) are specified with or without the use of datums [1-2]. The form tolerances are specified without datums, while other geometric tolerances are specified using one or more datums. Their specification covers the entire controlled feature unless specified.

Form tolerances may be verified based on a GO-NO GO decision or measured using suitable instruments. Form measurements involve data acquisition and fitting. The data can be acquired using some dedicated form measuring instrument or a general-purpose coordinate measuring machine (CMM). Spherical form evaluation based on coordinate measurement data is considered in this work. Sphericity tolerance specifies a tolerance zone bound by two concentric spheres within which each element of the measured spherical feature must lie.

### 2. LITERATURE REVIEW

Sphericity deviation can be evaluated using one of the following criteria, viz. minimum zone sphere (MZS), least-squares sphere (LSS), maximum inscribed sphere (MIS) or minimum circumscribed sphere (MCS). The standards recommend the minimum zone evaluation. Most of the modern measurement software facilitate the user-selection of any of these criteria. The following paragraphs provide a review of research on the sphericity evaluation algorithms using the coordinate data.

Grinde and Ventura proposed a mathematical programming formulation to find the centre and radius of a sphere such that the largest distance from a set of sample points to the boundary of sphere is minimized [3]. Yau and Menq proposed a unified least squares (LS) method that inversely transforms the measurement coordinates to best-fit a nominal geometry, rather than the substitute best-fit feature [4]. Gass et al. attempted to enclose the data points between two concentric spheres with minimum radial separation (MRS) using algebraic Chebyshev formulation and solved it by linear programming [5]. Fan and Lee transformed the MZS into a problem of finding the minimum elastic potential energy of a corresponding mechanical system and solved by a direct search scheme [6]. Huang proposed two theorems based on 3D Voronoi diagrams to find the sphericity using minimax criterion [7]. Chen and Liu proposed three mathematical models to evaluate the MCS, MIS and MZS by solving the simultaneous linear algebraic equations directly [8]. Kim et al. proposed a procedure for finding a pair of concentric spheres with MRS enclosing all the points by constructing discrete farthest and nearest Voronoi diagrams, using a voxel map generated in a small volume near LSS centre [9]. Samuel and Shunmugam proposed the concept of 3D equidistant lines using which they constructed the 3D farthest and nearest

equidistant diagrams to establish the MZS, MCS and MIS [10]. Wang et al. studied the characteristics of spherical functions in the neighbourhood of a local optimum using infinitesimal analysis to derive the necessary and sufficient conditions and proposed an algorithm based on MRS criterion [11].

Chen proposed two genetic algorithms (GA) based algorithms for MIS, MCS and MZS [12]. First algorithm explores the optimality of sphericity evaluation while the second one checks for sphericity feasibility. Samuel and Shunmugam used 3D equiangular lines for constructing 3D farthest and nearest equiangular diagrams to establish MCS, MIS and MZS [13]. Wen and Song proposed an improved GA for simultaneous sphericity estimates based on MZS, MCS and MIS [14], and an immune evolutionary algorithm that takes the objective function and constraints as antigens for developing an antibody that best fits the antigen [15]. Gosavi and Phatakwal proposed a methodology for form evaluation, based on the theory of finite-differences derivative descent [16]. Zhang proposed an approach based on ant colony optimization algorithm and compared it with other optimum evaluation methods [17]. Balakrishna et al. discussed the applicability of SVR to establish the tolerance zones of nonlinear surfaces [18]. They used the  $\gamma$ -SVR to assess the quality inspection of spherical parts. Kovvur et al. used a particle swarm optimization (PSO) algorithm for MZ form evaluation using their unconstrained formulation [19]. Meifa et al. proposed a mathematical model for MZS using Lp-norm and solved it by an improved PSO algorithm [20]. Wen et al. proposed and implemented a PSO-based approach for simultaneous sphericity evaluation using MZS, MCS and MIS [21]. Soman et al. proposed a selective zone search using the geometric constructs to identify five extreme points for fitting the inner and outer MZSs [22].

Meng et al. formulated the sphericity evaluation problem as a non-differentiable unconstrained optimization problem [23]. They solved the MIS and MCS by iterative comparisons and MZS using their relationship with MZS. Patel and Gandhi proposed a maximum distance point strategy to find the radius or diameter of spherical features for MZS [24]. Zhang et al. presented a unified method to evaluate the forms of spheres, cylinders and cones [25]. They used a primal-dual interior point solution method and an arc search to recursively update the solution. Aguirre-Cruz and Raman proposed a freeform orientation approach to model the form deviations and to cancel out axis misalignments using a flatness model and used them to verify the MZ forms of curved surfaces [26]. Zhang et al. proposed a mathematical model for MZS and solved it using GA [27]. Lei et al. proposed a geometry optimization searching algorithm that collocates a regular hexahedron centred on an initial reference point [28]. The initial error and maximum difference in radius, calculated by taking each of the hexahedron vertices as centre, are compared to change the length of hexahedron or reference point for next iteration. Liu et al. proposed an intersecting chords method (a simplification used for concentric spheres) to construct the models of MZSs [29]. Calvo proposed an algorithm that reduces the algebraic LSS fitting into a fifth-degree polynomial equation [30]. The dataset was projected into polar planes by transforming the MZS problem into MZ flatness of those planes and then solved iteratively. Mei et al. proposed an asymptotic search algorithm that searches for five control points dominating the homocentric spheres to obtain the MZS [31].

The foregoing review reveals the availability of several MZS evaluation algorithms based on coordinate data. These algorithms have just shown moderate improvement in the results over the published values which means that even the most recent algorithms may not have yielded the lowest MZS. The present work is based on this opportunity to develop an improved MZS algorithm. A volume hunting algorithm is proposed in this paper. The algorithm is compared with several existing MZS algorithms using the coordinate data obtained from the literature. Remainder of the paper is organized as follows. Section 3 presents the details of proposed algorithm, Section 4 presents the results and discussion, and Section 5 presents the conclusions based on this work.

### 3. THE PROPOSED ALGORITHM

The geometric approximation searching algorithm [28] uses a regular hexahedron, the corners of which serve as the centres of reference spheres for computing the sphericity deviation. This algorithm may potentially fall into a local minimum depending on the length of side of the hexahedron. The proposed algorithm uses a 3×3×3 subdivision of a regular hexahedron (or a cubic search volume) of side  $a$  so that more grid points are available and hence can avoid the local minima. A spherical search volume of diameter  $d$  has also been proposed. It is subdivided into segments using the longitude ( $\theta$ ) and colatitude ( $\phi$ ) angles. The centre of initial search volume is computed as follows:

$$x_0 = \frac{x_{max} + x_{min}}{2}; y_0 = \frac{y_{max} + y_{min}}{2}; z_0 = \frac{z_{max} + z_{min}}{2} \quad (1)$$

where,  $x_{max}$  and  $x_{min}$  are the maximum and minimum values of  $x$ -coordinates respectively,  $y_{max}$  and  $y_{min}$  are that of  $y$ -coordinates and  $z_{max}$  and  $z_{min}$  are that of  $z$ -coordinates.

### 3.1 Problem Formulation

A substitute or reference sphere must be established from the measurement data for sphericity evaluation. Let the equation of reference sphere be  $(x - x_0)^2 + (y - y_0)^2 + (z - z_0)^2 = R^2$ , where  $R$  is the radius of sphere and  $(x_0, y_0, z_0)$  is its centre. The sphericity deviation can be extended from that of circularity into three-dimensions as follows:

$$e_i = \sqrt{(x_i - x_0)^2 + (y_i - y_0)^2 + (z_i - z_0)^2} - R \quad (2)$$

where,  $x_0, y_0, z_0$  and  $R$  are the defining parameters of the reference sphere and  $(x_i, y_i, z_i)$  are the measured data points. According to the minimum zone criterion, the sphericity deviation ( $s$ ) is evaluated as follows:

$$s = \max(e_i) - \min(e_i) \quad (3)$$

### 3.2 The Volume Hunting Mechanism

Volume hunting refers to an iterative search procedure carried out around an initial centre point, which may be LSS centre, for example. It can be seen as an extension of area hunting [32] to three-dimensional features. Though the convergence of volume hunting will not be affected by the initial centre, a poorly selected centre may not lead to the minimum zone deviation.

**Regular Hexahedron or Cubic Search Volume:** The side ( $a$ ) of the regular cubic search volume is divided into  $N \times N \times N$  units. The  $N$  value of 3 leads to 64 ( $4 \times 4 \times 4$ ) intersection points  $(x_j, y_k, z_l)$ , which are considered as auxiliary centres (Fig. 1). These auxiliary centres are calculated as follows:

$$x_j = x_0 - \frac{a}{2} + j \left( \frac{a}{N} \right); y_k = y_0 - \frac{a}{2} + k \left( \frac{a}{N} \right); z_l = z_0 - \frac{a}{2} + l \left( \frac{a}{N} \right) \quad (4)$$

In Eq. (4), the values of  $j, k$  and  $l$  vary from 0 to  $N$  in steps of 1. The sphericity deviations evaluated using the initial centre and 64 auxiliary centres are used to decide the new centre and search volume for the subsequent iterations as detailed in the proposed algorithm (Fig. 3).

**Spherical Search Volume:** The spherical search volume of diameter  $d$  is divided using Eq. (5), based on the longitude ( $\theta$ ) and colatitude ( $\phi$ ) angles. The longitude ( $\theta$ ) and colatitude ( $\phi$ ) angles vary from  $0^\circ$  to  $360^\circ$  ( $\theta$  in  $45^\circ$  steps and  $\phi$  in  $30^\circ$  steps). This division leads to 42 auxiliary centres  $(x_j, y_j, z_j)$  as shown in Fig. 2. Single indexing is used for programming convenience.

$$x_j = x_0 + \frac{d}{2} \sin\theta \cos\phi; y_j = y_0 + \frac{d}{2} \cos\theta \cos\phi; z_j = z_0 + \frac{d}{2} \sin\theta \quad (5)$$

The new centre and diameter of search sphere for subsequent iterations are established based on the sphericity deviations evaluated using the initial and 42 auxiliary centres as detailed in the proposed algorithm (Fig. 3).

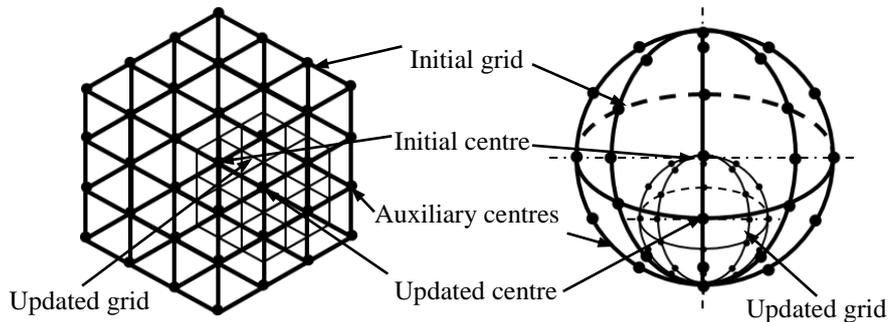


Fig. 1. Cubic search volume

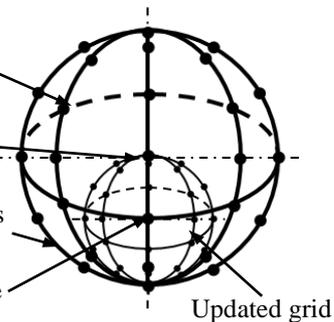


Fig. 2. Spherical search volume

### 3.3 The Algorithm

Fig. 3 shows the flowchart of the proposed volume hunting algorithm. The processing steps are same for both cubic and spherical search volumes. The initial centre  $(x_0, y_0, z_0)$  is computed using Eq. (1) and corresponding sphericity ( $s_{cur}$ ) using Eq. (2) and Eq. (3). The search volume is then subdivided as described in Section 3.2 to obtain the auxiliary centres. The sphericity deviations are evaluated using each auxiliary centre as the centre of the reference sphere. The lowest sphericity deviation ( $s_{new}$ ) is obtained and its location ( $j, k, l$ ) (for cube) or  $j$  (for

sphere) is saved. If the value of  $a$  (or  $d$ ) is less than the specified accuracy, further iterations will be stopped and  $s_{new}$  will be the minimum sphericity. Otherwise, the  $s_{new}$  and  $s_{cur}$  values are compared. If  $s_{new}$  is less than  $s_{cur}$ , iteration will be repeated by taking the coordinates of position  $(j, k, l)$  (for cube) or  $j$  (for sphere) as new centre and halving the search volume size  $a$  (or  $d$ ).

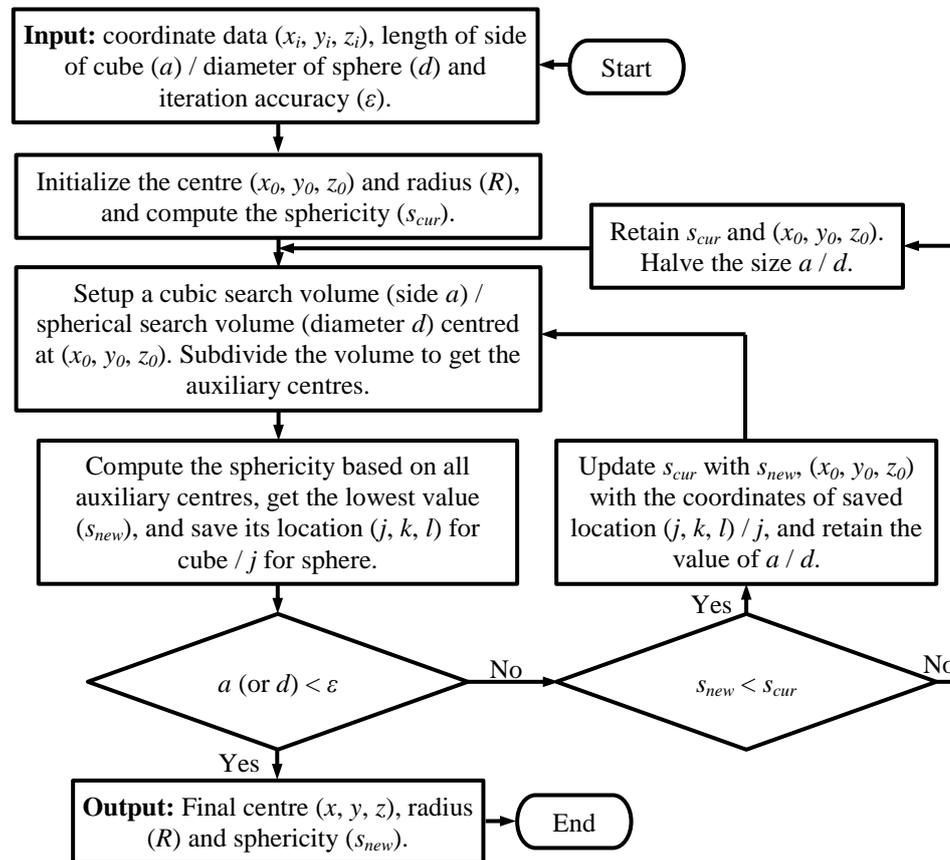


Fig. 3. Flowchart showing the proposed algorithm

#### 4. Results and Discussion

The proposed MZS algorithm (Fig. 3) has been programmed using C++ language under Visual Studio 2019® Community Edition. Through trials, the search volume parameters  $a$  and  $d$  were both set to 0.40 mm and the iteration accuracy to 0.000001. Several coordinate datasets and their results have been taken from the literature for testing and validation. The results obtained using 5 datasets are shown in Table 1, wherein PH stands for the hexahedron (cubic) search volume and PS stands for the spherical search volume. The proposed algorithm is expected to yield smaller sphericity deviations or at least match with the already reported values.

The proposed algorithm has yielded smaller sphericity deviations for dataset 1 (0.0008243 against 0.000885 [30]) and dataset 3 (0.0001403 against 0.0008214 [24]). With rest of the datasets, sphericity deviations yielded by the proposed algorithm are either the same or remarkably close to the literature results. Thus, the proposed algorithm meets the stated objectives. While the reported algorithms have been evaluated on limited number of measurement points (small or large datasets), the proposed algorithm has been evaluated and found to work very well over a range of small to large datasets. The comparison between cubic and spherical search volumes reveal that the deviations yielded by both search volume types are either the same or close to each other.

Table 1 also reveals that the spherical volume requires a smaller number of iterations with almost every dataset considered in this work. The cubic search volume has 64 auxiliary centres, while the spherical search volume has 42 auxiliary centres. Thus, the cubic search volume will require  $65 \times n$  (1 initial and 64 auxiliary centres) calculations in first iteration and  $64 \times n$  (64 auxiliary centres) calculations in subsequent iterations, where  $n$  is the

number of measured points. On the other hand, spherical search volume will require only  $43 \times n$  (1 initial and 42 auxiliary centres) and  $42 \times n$  (42 auxiliary centres) calculations respectively for the first and subsequent iterations. The ratio between the number of iterations required for cubic and spherical search volumes is about 1.5:1. It is thus clear that the spherical volume is better in terms of computational efficiency. Spherical search volume has also been found to yield the sphericity values remarkably close to that yielded by the cubic search volume.

Table 1. The results obtained from different datasets from literature

Dataset	Points	Method	Centre of Sphere	Radius	Sphericity	Iterations
1	50	[30]	(0.0000403, 0.0000952, 0.0004246)	25.380058	0.0008850	----
		PH	(0.0000044, -0.0002619, 0.0003950)	25.3801703	0.0008243	36
		PS	(-0.0000033, -0.0002564, 0.0004289)	25.3801505	0.0008243	40
2	50	[12]	(0.0025, -0.0001, 0.0005)	1.00543	0.0076602	----
		[21]	(0.002506, -0.000097, 0.000481)	1.005	0.007660	----
		[26]	(0.0025050, -0.0000962, 0.0004817)	1.0053741	0.0076600	----
		[29, 31]	(0.002504, -0.000096, 0.000482)	----	0.007660	----
		[30]	(0.0025042, -0.0000961, 0.0004815)	1.00537	0.0076602	----
		PH / PS	(0.0025044, -0.0000961, 0.0004815)	1.0053709	0.0076602	47 / 40
3	92	[24]	(181.150541, 449.935688, -489.279092)	12.488976	0.0008214	----
		PH	(181.1505497, 449.6356956, -489.2791230)	12.4889812	0.0001403	69
		PS	(181.1505494, 449.6356957, -489.2791226)	12.4889812	0.0001403	55
4	100	[12]	(0.0000, 0.0000, 0.0000)	----	1.0000	----
		[19]	----	----	1.0114	----
		PH	(-0.0000002, -0.0000001, 0.0000001)	9.5000000	1.0000001	45
		PS	(-0.0000004, 0.0000001, -0.0000003)	9.5000002	1.0000001	42
5	384	[29]	(0.000179, -0.000332, 0.011747)	----	0.015385	----
		[30]	(-0.0011426, 0.0000027, 0.0107779)	47.9842083	0.0154077	----
		PH	(-0.0005361, -0.0001555, 0.0112121)	47.9837792	0.0153975	154
		PS	(0.0000886, -0.0003185, 0.0116591)	47.9833374	0.0153870	97

## 5. Conclusion

In this paper, a volume hunting algorithm has been proposed for sphericity evaluation from coordinate data using MZS criterion. Two search volumes, viz. hexahedron (or cubic) and spherical, have been proposed and implemented. The length of side of cubic and diameter of spherical search volumes have been fixed as 0.40 mm through trials. The iteration accuracy has been taken as 0.000001. Coordinate datasets from the literature have been used for validating the proposed algorithm. These datasets range from small to large numbers of measurement points. Both the cubic and spherical search volumes have been found to yield comparable results that are better or at par with the literature results. The spherical search volume has been found to take fewer iterations than the cubic search volume, while giving nearly similar sphericity values. The proposed algorithm with spherical search volume may therefore be used for practical purposes.

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## Current voltage relationships in electrochemical wastewater treatment

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### Abstract

The present work analyses the current voltage relationships during electro-oxidation and the combined electro-oxidation and electro-coagulation of an anti-diabetic drug metformin hydrochloride (MET-HCL) over the time. Anodes used were Ti/DSA (Ta<sub>2</sub>O<sub>5</sub>-Ir<sub>2</sub>O<sub>5</sub>) and stainless steel (SS). Effect of applied current density was evaluated at 50 ppm of sodium sulphate (Na<sub>2</sub>SO<sub>4</sub>) as supporting electrolyte, and the influence of supporting electrolyte concentration was also evaluated at current density of 0.93 mA/cm<sup>2</sup> in 50 ppm MET-HCL solution. As a result of electro-oxidation experiments on MET-HCL, carried out on Ti/DSA anode, maximum potential of 10.16 V was observed at corresponding current density of 0.93 mA/cm<sup>2</sup> and 50 ppm Na<sub>2</sub>SO<sub>4</sub> concentration. At the other hand minimum potential of 6.02 V was observed at a corresponding current density of 0.93 mA/cm<sup>2</sup> and 100 ppm Na<sub>2</sub>SO<sub>4</sub> concentration. Further, as a result of combined electro-oxidation and electro-coagulation experiments under identical conditions on SS anode, maximum potential of 7.16 V was observed at corresponding current density of 1.16 mA/cm<sup>2</sup> and 50 ppm Na<sub>2</sub>SO<sub>4</sub> concentration. At the other hand minimum potential of 5.52 V was observed at a corresponding current density of 0.93 mA/cm<sup>2</sup> and 100 ppm Na<sub>2</sub>SO<sub>4</sub> concentration.

**Keywords-** Potential, electro-oxidation, electro-coagulation, Sodium sulphate, applied current density

## 1. INTRODUCTION

In the best of our knowledge and based on the literature, there is no previous report on the current voltage relationships by electro-oxidation on Ti/DSA (Ta<sub>2</sub>O<sub>5</sub>-Ir<sub>2</sub>O<sub>5</sub>) anode and combined electro-oxidation and electro-coagulation of MET on SS anode. Ti/DSA electrodes were reported in electrochemical oxidation, and they were having high efficiency and stability in wastewater treatment of refractory molecules (Jeong and Lee, 2012). Stainless steel is chosen as electrode material for combined process due to its reported more effectiveness in drug remediation compared to the anode of platinum and slightly less effectiveness compared to the BDD anode (Ghatak, 2014). Electro oxidation, though demanding in terms of electrical energy, is attractive treatment method as no oxidant is to be added from outside. Further, utilization of cathodic hydrogen through process integration can reduce the overall energy consumption (Ghatak, 2020).

This study reports the current voltage relationships of MET-HCL using the process of electrooxidation on Ti/DSA (Ta<sub>2</sub>O<sub>5</sub>-Ir<sub>2</sub>O<sub>5</sub>) and combined electro-oxidation and electro-coagulation on SS anode. The effect of different process parameters is studied. The two processes are compared for their cell voltage requirements.

## 2. MATERIAL AND METHODS

### 2.1 Chemicals and reagents

MET-HCL (C<sub>4</sub>H<sub>11</sub>N<sub>5</sub>.HCl) of pharmaceutical grade was used as the target organic pollutant, in the study. It was kindly donated by M/s IOLCP, Barnala, India. Ti/DSA (Ta<sub>2</sub>O<sub>5</sub>-Ir<sub>2</sub>O<sub>5</sub>) plates (50mm×45mm×1mm thick with Hook 60mm×8mm×1mm thick) were purchased from Ti Anode Fabricator Pvt. Ltd., Chennai, India. SS 304 (50mm×45mm×1mm thick with Hook 60mm×8mm×1mm thick) were purchased from local metal shop Sangrur, India. Sodium sulphate (anhydrous) of SQ grade was procured from Thermo Fisher Scientific India Pvt. Ltd, Mumbai, India. All the solutions were prepared with ultrapure deionised water obtained with a millipore water purification system (Merck prograd<sup>®</sup> TS2).

### 2.2 Electrochemical experiments

All the electrochemical experiments of the MET-HCL were performed in a glass reactor of 250 mL in conjunction with a computer controlled potentiostat/galvanostat model SP-150 with EC Lab V10.33 software.

Ti/DSA as the anode and SS-304 as cathode was used for the electro-oxidation experiments, whilst SS-304 electrode was used as anode plus cathode for the combined electro-oxidation and electro-coagulation experiments. Both electrodes were rectangle shaped with each having working area of 90 cm<sup>2</sup> and a 5 mm inter-electrode gap was used.

All experiments were carried out using 200 ml synthetic wastewater carrying 50 ppm of MET-HCl at 3 different supporting electrolyte concentrations of 50, 75 and 100 ppm of Na<sub>2</sub>SO<sub>4</sub> at three current densities of 0.67, 0.93 and 1.16 mA/cm<sup>2</sup>. All experiments were performed in duplicate and the average results were reported.

### 3. RESULT AND DISCUSSION

#### 3.1 Electro-oxidation of MET-HCl

To assess the effect of current density  $j_{app}$  (0.67, 0.93 and 1.16 mA/cm<sup>2</sup>) we carried out electro-oxidation experiments on 50 ppm MET-HCl solution supported with 50 ppm Na<sub>2</sub>SO<sub>4</sub> as electrolyte.

Fig 1 shows the effect of the current density on the cell voltage as a function of time (seconds) for the Ti/DSA anode. The value of cell voltage during process depended on the current density, and it was observed increasing from 5.44 V to 10.16 V as current density increased from 0.67 mA/cm<sup>2</sup> to 0.93 mA/cm<sup>2</sup> after 5 hours run of electro-oxidation experiment. With increasing current density, oxidant radicals will form rapidly. At the same time, the electro-oxidation will be carried out at increased potentials as shown in Fig 1. But value of cell voltage during process was observed decreasing from 10.16 V to 8.68 V as current density increased from 0.93 mA/cm<sup>2</sup> to 1.16 mA/cm<sup>2</sup> after 5 hours run of electro-oxidation experiment.

It is important to record that when the current density exceeds a certain value – in this case from 0.93 mA/cm<sup>2</sup> to 1.16 mA/cm<sup>2</sup> – the cell voltage drops from 10.16 V to 8.68 V. This is because the occurrence of reaction of oxygen evolution is favoured (You et al., 2016; Martinez et al., 2015).



Production of greater amount of gas at the surface of the electrode also masks the anode's active sites (Samet et al., 2010, further suppressing the generation of hydroxyl radicals.

To assess the effect of Na<sub>2</sub>SO<sub>4</sub> Concentration (50, 0.75 and 100 ppm mA/cm<sup>2</sup>) we carried out electro-oxidation experiments on 50 ppm MET-HCl solution at current density of 0.93 mA/cm<sup>2</sup>.

Fig 2 shows the effect of the Na<sub>2</sub>SO<sub>4</sub> Concentration on the voltage as a function of time (seconds) for the Ti/DSA anode. The value of Cell voltage during process depended on the effect of Na<sub>2</sub>SO<sub>4</sub> Concentration, and it was observed continuous decrease in cell voltage from 10.16 V to 6.24 V and then to 6.02 V when Na<sub>2</sub>SO<sub>4</sub> Concentration increased from 50 to 75 and then to 100 ppm respectively after 5 hours run of electro-oxidation experiment. Higher the Na<sub>2</sub>SO<sub>4</sub> concentration, lower the cell voltage required to maintain a given current density.

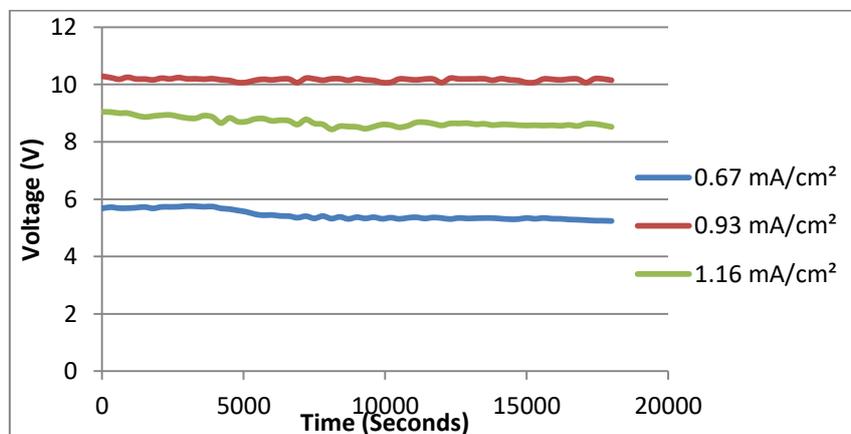


Fig 1: Effect of the current density over time on the voltage for the electro-oxidation of MET-HCl on Ti/DSA anode

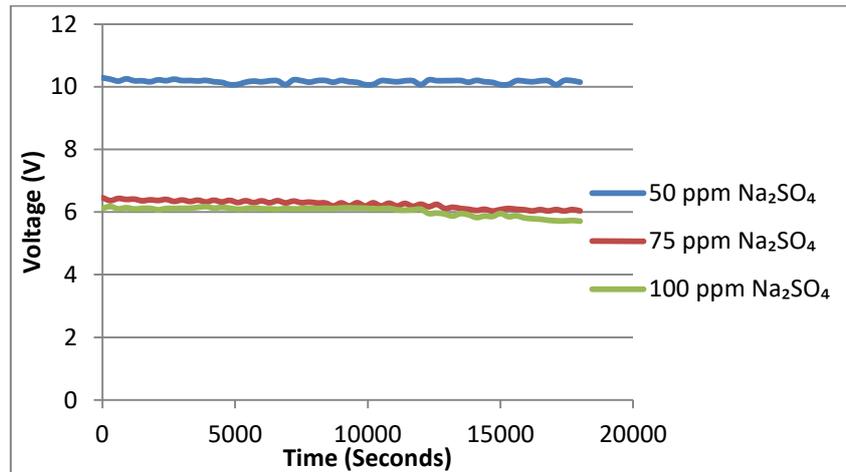


Fig 2: Effect of the Na<sub>2</sub>SO<sub>4</sub> over time on the voltage for the electro-oxidation of MET-HCl on Ti/DSA anode

### 3.2 Combined Electro-oxidation & Electro-coagulation of MET-HCl

To assess the effect of current density  $j_{app}$  (0.67, 0.93 and 1.16 mA/cm<sup>2</sup>) we carried out combined electro-oxidation and electro-coagulation experiments on 50 ppm MET-HCl solution supported with 50 ppm Na<sub>2</sub>SO<sub>4</sub> as electrolyte.

Fig 3 shows the effect of the current density on the cell voltage as a function of time (seconds) for the SS anode. The value of cell voltage during process depended on the current density, and it was observed continuous increase in cell voltage from 5.56 V to 6.12 V and then to 7.16 V when current density increased from 0.67 mA/cm<sup>2</sup> to 0.93 mA/cm<sup>2</sup> and then to 1.16 mA/cm<sup>2</sup> respectively after 5 hours run of combined electro-oxidation and electro-coagulation experiments. As higher potentials associated with higher current densities, a larger proportion of specific charge is consumed in oxygen evolution compared to the generation of hydroxyl radicals (Hamza et al., 2009).

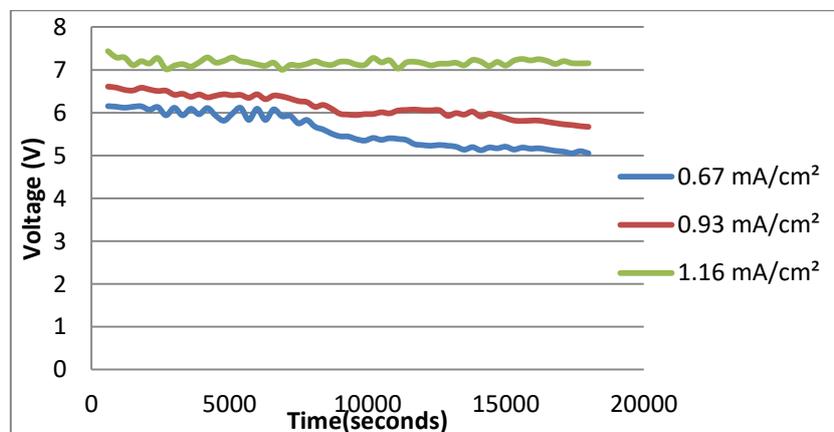


Fig 3: Effect of the current density over time on the voltage for the combined electro-oxidation and electro-coagulation of MET-HCl on SS anode

Fig 4 shows the effect of the Na<sub>2</sub>SO<sub>4</sub> Concentration on the cell voltage as a function of time (seconds) for the SS anode. The value of Cell voltage during process depended on the effect of Na<sub>2</sub>SO<sub>4</sub> Concentration, and it was observed continuous decrease in cell voltage from 6.12 V to 5.96 V and then to 5.52 V when Na<sub>2</sub>SO<sub>4</sub> Concentration increased from 50 to 75 and then to 100 ppm respectively after 5 hours run of combined electro-oxidation and electro-coagulation experiments.

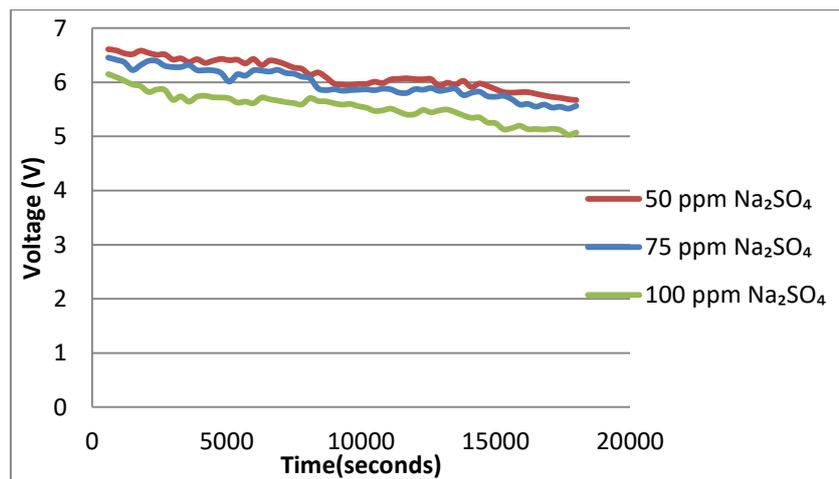


Fig 4: Effect of the Na<sub>2</sub>SO<sub>4</sub> over time on the voltage for the combined electro-oxidation and electro-coagulation of MET-HCL on SS anode

#### 4. Conclusions

In the present experimental investigation the current voltage relationships during electro-oxidation and the combined electro-oxidation and electro-coagulation of an anti-diabetic drug metformin hydrochloride (MET-HCL) over the time was analysed on Ti/DSA (Ta<sub>2</sub>O<sub>5</sub>-Ir<sub>2</sub>O<sub>5</sub>) and stainless steel (SS) anode respectively. The current voltage relationships during electro-oxidation and the combined electro-oxidation and electro-coagulation of an anti-diabetic drug metformin hydrochloride (MET-HCL) over the time depended on the anode type.

In electro-oxidation operation on MET-HCL, carried out on Ti/DSA anode, maximum cell potential of 10.16V was achieved whereas in combined electro-oxidation and electro-coagulation on MET-HCL, carried out on SS anode, maximum cell potential of 7.16V was achieved. Combined electro-oxidation and electrocoagulation on SS anode required less cell voltage than electro-oxidation on Ti/DSA reflected in the current voltage relationships, in the two processes.

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## Dimensions for the optimized siting location of EVs charging station: The Indian scenario

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### Abstract

India has made remarkable growth in the automobile sector which leads to rising atmospheric adulteration and pressure of traditional fuel sources. To mitigate these effects, Electric vehicles (EVs) are the most promising solution. The inadequate charging foundation extraordinarily hinders the advancement of the electric vehicle (EV) industry. Instructions to proficiently convey charging stations in a city have turned into an earnest issue for the local government. Charging stations have become a significant source of power for electric vehicles, and their location is important to the vehicle's mobility in a city. They must be strategically positioned because an electric vehicle may visit a replenishing station within its driving range and then continue driving around the city once recharged. This research paper examines the possible necessity of electric vehicles (EV's) and charging station (CS) infrastructure, as well as the associated problems with it. We have utilized delicate investigations to look for the explicit elements unequivocally affecting the localization of power stations. Hence, this research presents 10 dimensions to be considered before the selection of an optimized deployment site for the EVs charging stations.

### 1. Introduction

India is becoming one of the top ten leading automobile markets worldwide, with a rapidly growing middle-class population with purchasing power and sustained economic growth ([Murthy et al., 2021](#)). However, in the previous several years, the price of gasoline has risen by more than 50% ([Kumar et al., 2013a](#)). In the present situation, electric vehicles (EV's) proliferation on a large scale has enhanced the potential to increase India's resources. Here comes the prospective need for alternate car technologies such as electric vehicles, which ultimately leads to the establishment of one crucial component that is the electric vehicle charging stations throughout India. The central government as well as private firms have begun implementing the required steps for the installation of EV charging infrastructure ([Kumar et al., 2013a](#)). Thus, the location of charging stations is of utmost importance.

We have primarily concentrated on few key portions in this paper. Beginning from the introduction (section 1) which is followed by a study of the literature (section 2). This paper aims to assess the factors encountered during the location and installation of charging stations through analyzing scholarly works on locating EV charging stations and infrastructure and named them as dimensional variables ( section 3). Section 4 presents the result. Then there is the conclusion and future work in section 5.

### 2. Literature Review

There is currently a transition of paradigm from conventional cars to electric vehicles in towns ([Jordán et al., 2021](#)). So, the necessity to distribute the charging infrastructure accordingly is unavoidable. The placement of charging stations is a complex challenge of location optimization which requires considering many-dimensional variables ([Liu et al., 2019](#)). The allocation of refilling stations may be accomplished with the standard techniques in accordance with the location facilities ([Micari et al., 2017](#)). Unfortunately, Some electric vehicle charging stations (EVCS's) are owned by individuals whose sole purpose is to maximize their earnings ([Tan and Wang, 2015](#)).



According to the author of (Rigas et al., 2018), there are two types of charging based on charging time: rapid charging and slow charging and the rate for each form of charge can be specified. According to (Shen et al., 2021) study showing that most EVs travel only short distances and rely mostly on home, charges was conducted in 2017. While numerous EVs use the communications system, for example, the 3G/4G system, to select and inform their desired recharge station as suggested in (Vardakas, 2014). According to the paper published by (Jia et al., 2019) they presented, among other authors, an optimization model that takes into account the advantages of both the Power Company and Electric Car customers. The results show the effect of the traffic flow on the charging stations' placement and service area. According to (Shen et al., 2021) the integration with EV charging station (CS) of solar photovoltaic (PV) as PV based CS allows cleaner energy to be accommodated and the load peak reduction to be reduced. The notion of proposing a recharge station location model for EVs in Taiwan, utilizing a vehicle-based mixed-integer programming approach, was described in (Karaşan et al., 2020a).

Thus, the placement of EV charging stations is often a standard mathematical problem of location and size(Shahraki et al., 2015). Mathematical programming (MP) has therefore been frequently used in order to address the charging station problem in consideration of many consequences including economic, environmental, and traffic implications (Jia et al., 2019).

In this altered interaction, electric vehicles (EVs) have a main position because of their low-harm impact on the climate. Choosing the most manageable area for charging stations for EVs assumes a significant part in their life cycle(Karaşan et al., 2020b). This cycle needs to think about some clashing standards and has a mind-boggling choice issue that can be demonstrated as a multi-rules dynamic issue(Kumar et al., 2013b). The incorporation of such rules into an area's determination requires the fuzzy sets to be utilized in the decision-making methodology.(Liu et al., 2018b).

From the above literature, it is evident a lot of research work had been done in this sector but there is a demand for robust study on the dimensional variables affecting the selection of the most fitting site for EVs charging stations in the Indian context. This study fills this research gap by discussing the above variables.

### 3. Factors Table

After a thorough analysis of the related literature, this paper presents ten dimensions affecting the optimal search of the prime location of the charging stations. In this section, a table is framed consisting of the different columns which incorporate the dimensions, their related work and their impact on EVs charging stations in the Indian circumstance.

**Table 1: Dimensions affecting the siting of the EVs charging station**

S.NO	Dimensions	RELATED LITERATURE	IMPACT ON EV CHARGING STATION
F1	Construction / leasing cost	(Ye et al., 2015) (Ji et al., 2020)	The rising cost of charging stations mandates a prudent organizational strategy that prioritizes development costs. The development cost of charging stations is primarily comprised of two components: charging gear cost and charging station building cost, which are determined by the charging station's limit and the charging station's area. The foundation acquired, which may be leased or owned, should meet the basic requirements for the support of electric cars.
F2	Prerequisite of charging station	(Huang et al., 2020) (Elma, 2020)	Many economic decisions are made to service needs effectively while reducing system costs. Their purpose is to ensure the best possible service. Different charging



			station specifications rely on the basic electric vehicle requirements. A minimum of three rapid injectors are needed for each charging station. The first two of these will have to run on 50kW/20-1000V, but they will have to work on 22kW/380-480V.
F3	Popularity index of the site	( <a href="#">Liu et al., 2018a</a> ) ( <a href="#">Davidov and Pantoš, 2017</a> )	To guarantee far-reaching EVs use and limitless EV portability, urban areas should put resources into the legitimate extension and support of the electrical force matrix just as the foundation of the charging station framework. This depends completely on the city's popularity. The aspect of the location, in conjunction with the place's attractiveness, is essential.
F4	EV's threshold drive range	( <a href="#">He et al., 2019</a> ) ( <a href="#">Davidov and Pantoš, 2017</a> )	Using a distance criterion, the charging station optimization model assures charging reachability by locating at minimum one charging station within EV drivers' vicinity. To address the EVs' limited driving range, charging efficiency is utilized in tandem. This network of finding stations should be configured in such a way that the vehicle can navigate the range between two charging stations.
F5	Reliability and safety of refuelling stations	( <a href="#">Pratt and Carroll, 2019</a> ) ( <a href="#">Aswani et al., 2018</a> )	The infrastructure-including charging systems, energy management and building automation systems as well as electricity grid systems can have a detrimental influence, adversely affecting safety, reliability and efficiency. We propose Vehicle Charging Security Infrastructure (VCIS) concepts that solve major holes in the current security paradigm while maintaining stakeholder confidentiality and autonomy.
F6	Traffic and EV's density	( <a href="#">Deb et al., 2019</a> ) ( <a href="#">Liu et al., 2019</a> )	The ever-growing population of India is accompanied by a tremendous increase in on-road vehicles, thus increasing the demand for refueling stations. The charging request of EVs isn't focused on hubs, but instead on streams in the rush hour gridlock organization. In this manner, the traffic stream can be utilized to reproduce the charging requests of EVs.
F7	Proximity to the power supply	( <a href="#">Liu et al., 2019</a> ) ( <a href="#">Khan et al., 2018</a> )	Implementation of an electric power supply control technique for the best allocation of charging stations, taking into consideration the limitations of power supply and the requirements of EV owners. DC systems need specific cables and equipment and can be installed at charging stations for electric vehicles. Since the output is DC, the voltage must be modified to fit the battery packs in various cars. Sites like factories, office buildings and industrial zones are the ideal spots where solar EV charge may be installed on photovoltaic panels in the area below the rooftops and car parking of the building.
F8	Supply source and network for charging zones	( <a href="#">Elma, 2020</a> ) ( <a href="#">Ji et al., 2020</a> )	In accordance with the supply source connections, charging stations are categorized into three categories. They are the electric hybrid PHEV plug-in, the electric HEV plug-in and the electric BEV battery. PHEV and HEV models comprise a hybrid motor using internal and

			electric combustion motors. On the other hand, BEV includes electric cars which solely use electric power, which has lately become increasingly popular.
F9	Transportation connectivity to customers	( <a href="#">Yang et al., 2017</a> ) ( <a href="#">Deb et al., 2019</a> )	In recent years, electric cars (ETs) have been an attractive alternative transport option across the world, in light of the environmental and economic issues connected to fossil fuels. More and more customers are beginning to view EVs as a feasible alternative. Potential consumers are still concerned about EVs in terms of battery costs, charging time and connectivity. Road connectivity to the EVCS must be there so that customers would reach EVCS easily and in the least time.
F10	Legal policies of the government	( <a href="#">Ghatikar et al., 2016</a> ) ( <a href="#">Dhingra et al., 2021</a> )	The government of India has announced the National Mission for Electric Mobility (NMEM) to promote hybrids and electric vehicles in a progressive attempt to improve its people's energy security and quality of life. Therefore, certain guidelines have been mentioned for the deployment of the charging stations. The engineers must consider these rules before choosing the site for EVCS.

#### 4. Results

This study robustly researched the previous literature and found out the importance of the framework of the electric vehicle in the Indian context along with its crucial component, the charging stations. This study primarily lists out ten dimensions on which the location of a charging station depends. The policymakers and the R and D department of electric vehicles could look into this to get insight regarding the dimensions affecting the deployment of EVCS.

#### 5. Conclusion and Closing Remarks

In the previous decade, a dramatic development in the market for electric vehicles has been noticed. To moderate this impact, there is a prerequisite for the execution of alternate fuel-based cars, while electric vehicle systems have arisen as one of the promising areas that prompt the flow of exploration. Our commitments in this paper incorporate the importance of electric vehicles and charging stations followed by recognizing the ten-dimensional variables affecting the search for the optimized location site for EVs charging stations. Logical scientists can go through this paper for their review purposes since there's a ton of future extent of this paper. Moreover, an MCDM Methodology named FUZZY ISM MICMAC analysis can be applied to an in-depth understanding of the ten factors discussed above. This methodology gives an algorithm to organize the dimensions in the different hierarchy levels of inter-relationship along with categorising the variables in four different clusters named autonomous, independent, linkage, dependent, all these are the future scope of the study.

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## All-Terrain Vehicle Rollcage Design and Analysis

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### Abstract

The aim of this paper is to design and analyse a Rollcage for an All-Terrain Vehicle. The design is made suitable to participate in competitions such as BAJA SAE. Rollcage is an essential part of the vehicle as it houses the driver and connects other sub-systems to make one unit. The CAD modelling of the Rollcage was done on SolidWorks and its Ergonomic analysis on CATIA. Furthermore, the material selection and force calculations are also explained in detail. The Finite Element analysis (FEA) for critical impact conditions was simulated on Ansys.

**Keywords-** CAD Modelling, Ergonomics, Material Selection, Force Calculations, FEA

### 1. INTRODUCTION

Rollcage is the basic skeleton of an ATV which incorporates the components of all other departments such as suspension, steering, engine and transmission as well as brakes. It gives structural base to all components along with ensuring driver safety. Rollcage is designed primarily according to the rules of BAJA SAEINDIA. The main objective is to design a structure that ensures safety and comfort along with being light weight, compact, durable, easy manufacturing, high strength and rigidity.

Special focus was laid towards ergonomics to ensure optimum driver comfort and reduced chances of driver fatigue during the event. The components were kept well in reach of the driver to ensure their easy accessibility and a comfortable posture for the driver. It was also ensured that driver vision was not compromised in any aspect.

### 2. DESIGN

An initial CAD model as shown in fig.1 was designed on SolidWorks software according to the rules of BAJA SAE INDIA and the design was iterated based upon the specifications of the other departments. The design comprises of rigid structures introduced by truss formations. The members which are critical to collisions and impacts, tubular pipes with slightly greater OD and thickness are considered than the other members. Bends are introduced to lower the stresses along with the use of continuous members wherever possible.



Fig 1. CAD Model of Rollcage

### 3. ERGONOMICS

The major design consideration while designing the rollcage was driver ergonomics. Ergonomics is the study of how one should structure and build a driver control system in order to improve efficiency and comfort while driving. ATV cockpit was designed in such a way that it carries a Human which falls in the range of 5 percentile females and 95 percentile males. Some of the major factors that were taken into account were the seat location and inclination, location of steering wheel, design of the foot box area so the driver will be able to properly operate the vehicle in all the driving scenarios. To enable the proper movement of driver's feet to control the acceleration and brake pedal, the foot box was designed as small as possible assisting the driver to operate the

control safely. Lumbar support was added to the seat to suit the driver comfortability increasing the overall performance.[4]

### 3.1 Rula Analysis

Insert a mannequin with appropriate percentile in the CATIA software then a position the origin of the mannequin. We can also change any dimension as required. After that we set the mannequin position by changing the angles. It takes time to set each angles as per the requirements and also helps us to verify where changes in the design are needed. As we know that the RULA Analysis is the Rapid Upper Limb analysis so, the RULA score majorly depend on the upper body posture. It allows you to calculate the risk of musculoskeletal loading within the upper limbs and neck. It's the relative score of risk.

Action level 1. Score of 1-2 = Acceptable

Action level 2. Score of 3-4 = Investigate further

Action level 3. Score of 5-6 = Investigate further and change soon

Action level 4. Score of 7 = Investigate further and change immediately

## 4. MATERIAL SELECTION

High yield strength, toughness, weldability, machinability, and corrosion resistance are all mechanical properties that must be present in the rollcage material. To optimise an ATV's kerb weight material used must have a high strength to weight ratio. The required materials are AISI 4130 and AISI 1018, both of which are available in the market. The following are the properties of both materials in table 1 and table 2.

Table 1. Material properties AISI 4130

Density	7.85 g/cm <sup>3</sup>
Young's modulus	205 GPa
Poisson ratio	0.3
Yield strength	560 MPa
Ultimate strength	690 MPa

Table 2. Material properties AISI 1018

Density	7.85 g/cm <sup>3</sup>
Young's modulus	205 GPa
Poisson ratio	0.3
Yield strength	370 MPa
Ultimate strength	440 MPa

AISI 4130 was chosen based on comparisons because of its high strength, which is required by our design and dimensions are provided in table 3..

Table 3. Dimensions of the tubular rollcage material

Members	Outer Diameter (mm)	Thickness (mm)
Primary Members	31.75	1.6
Secondary Members	25.4	1.2

## 5. IMPACT FORCE CALCULATION

Impact forces [3] under different loading conditions are calculated using work energy principal. Time of impact for rigid bodies like a wall is assumed as 0.13s whereas time of impact for deformable bodies like an ATV is assumed as 0.3s.

From work energy principle,

Work done (W) = Change in kinetic energy

$$\begin{aligned}
 W &= (0.5 \times M \times v_{\text{final}}^2 - 0.5 \times M \times v_{\text{initial}}^2) \\
 &= (0.5 \times 230 \times 15^2) \\
 &= 25875
 \end{aligned}$$

Also, Work done = force  $\times$  displacement

$$s = \text{impact time} \times v_{\text{maximum}}$$

$$= 0.13 \times 15$$

$$= 1.95$$

(assuming a rigid body under this scenario)

Therefore,  $F = W/s$

$$= 25875/1.95$$

$$= 14269.23 \text{ N or } 6G$$

## 6. FINITE ELEMENT ANALYSIS

Static structural analysis and modal analysis of rollcage were performed on Ansys 16 to analyse the frame under various impact loading conditions that may occur at the event site and to check the strength and rigidity of the structure. Impact forces are calculated and applied under different scenarios and suitable constraints are applied. [3]

### 6.1 Meshing

The type of mesh generated for analysis is 2D meshing as thickness of the pipe is considerably less in comparison to the other two dimensions, i.e., length and outer diameter. Moreover, it helps in reducing the solver time to a great extent. The mesh size was calculated by checking the mesh independency. Mesh size of 8mm was selected since, there were negligible changes in accuracy of results on further reduction in mesh size and reduced the solver time, resulting in fast iterations. A fine meshing was performed with a positive relevance. Shell elements were used for carrying out the 2D meshing of the rollcage. The mesh consists of both quad and tria shape elements having total nodes and elements as 68905 and 69332 respectively.

The criteria for finalizing the parameters of elements were:

Warpage < 1

Aspect ratio < 5

Jacobian > 0.6

Skewness < 0.5

### 6.2 Front Impact Analysis

The front impact analysis [1] is performed to analyse the frame under a condition where the front portion of the ATV collides with another ATV or collides with a rigid object.

Since, the time of impact for rigid bodies is lesser than that of deformable bodies, the time of impact for rigid bodies is considered during impact force calculations for front impact to accommodate worst case scenario.

#### 6.2.1 Boundary Conditions

A force of 6G was applied on the front most members of the rollcage since it will be the first member to be impacted in case of front impact analysis.

#### 6.2.2 Constraints

The rear suspension points were constrained and nodal displacement and nodal rotation was ramped in all three directions as shown in fig2.

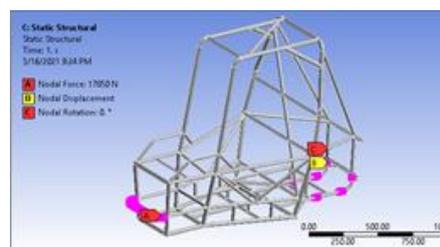


Fig 2. Loading Condition Front Impact

### 6.3 Rear impact analysis

The rear impact analysis [2] is performed to analyze the frame under a condition where the rear portion of the ATV collides with another ATV. Since the ATV is a deformable body the time of impact considered during impact force calculation will be for deformable body.

#### 6.3.1 Boundary conditions

A force of 4G was applied on the rear portion of the rollcage since it will be the first member to be impacted in case of rear impact analysis.

### 6.3.2 Constraints

The front suspension points were constrained and nodal displacement and nodal rotation was ramped in all three directions as shown in fig3.

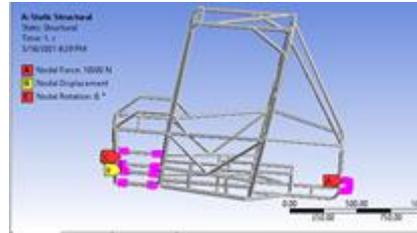


Fig 3. Loading Condition Rear Impact

### 6.4 Side impact analysis

The side impact analysis [2] is performed to analyse the frame under a condition where an ATV hits another ATV on side members.

#### 6.4.1 Boundary conditions

A force of 4G was applied on members of one particular side of the rollcage considering it will be the first member to be impacted in case of side impact analysis.

#### 6.4.2 Constraints

The front and rear suspension points of opposite side were constrained and nodal displacement and nodal rotation was ramped in all three directions as shown in fig 4.

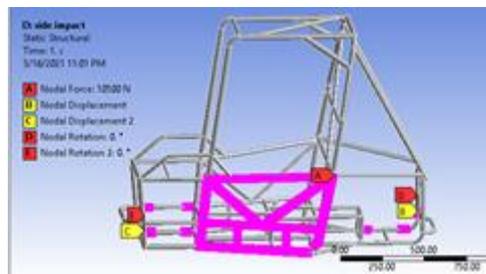


Fig 4. Loading Condition Side Impact

### 6.5 Rollover analysis

The rollover analysis [1] is performed to analyse the frame under a condition where the ATV undergoes a rollover and collides with the ground.

Calculations for rollover analysis:

Assuming rollover height to be 10 feet (3.04 meters)

$$m \times g \times h = 0.5 \times m \times v^2$$

$$v = \sqrt{2 \times g \times h}$$

$$= \sqrt{2 \times 9.81 \times 3.04}$$

$$= 7.72 \text{ m/s}$$

Now, from work energy principal

Work done = change in kinetic energy

$$|W| = | -0.5 \times m \times v^2 |$$

$$= | -0.5 \times 230 \times (7.72)^2 |$$

$$= 6856.48$$

$$\text{Work done} = F \times s$$

$$s = \text{impact time} \times v$$

$$= 0.13 \times 7.72$$

$$= 1.006$$

$$\text{Therefore, Force} = 6856.48 / 1.006$$

= 6831.88 N or 3G

### 6.5.1 Boundary Condition

A force of 3G was applied on the topmost members of the rollcage since they would be the most impacted members during a rollover.

### 6.5.2 Constraints

The front and rear suspension points were constrained and nodal displacement and nodal rotation was ramped in all three directions as shown in fig 5.

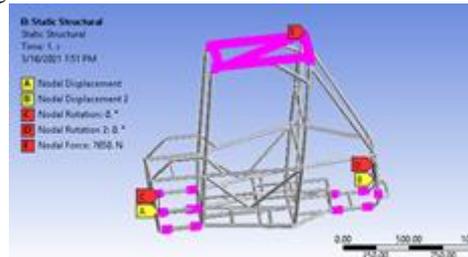


Fig 5. Loading Condition Rollover

### 6.6 Torsional Analysis

Torsional Analysis [5] is carried out in order to determine the torsional stiffness of the frame during a scenario of cross bump at the front and rear which occurs at event site. The main purpose of torsional analysis is to find greater rollcage stiffness to withstand dynamic suspension loads and ensure required stability.

Torsional analysis is used to determine the frame's torsional stiffness in case of cross bump at the front and rear which occurs at event site. The primary objective of torsional analysis is to determine a higher rollcage stiffness that can bear dynamic suspension loads while maintaining needed stability.

#### 6.6.1 Boundary Condition

An upward and equally opposite downward force of 3G was applied on the front suspension points in case of front torsional analysis. For rear torsional analysis, force was applied on the rear suspension points.

#### 6.6.2 Constraints

The rear suspension points were constrained, nodal displacement and nodal rotation was ramped in all three directions, for front torsional analysis. Similarly, the front suspension points were constrained for rear analysis as shown in fig 6.

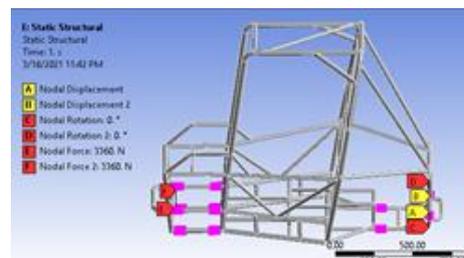


Fig 6. Loading Condition Torsional

### 6.7 Modal Analysis

Modal analysis [4] of frame is performed to find the natural frequency of the frame to avoid the phenomena of resonance. When the natural frequency of vibration of frame equals to the frequency of forced vibrations it leads to resonance which can cause a large deflection of the structure. The major cause of forced vibration in an ATV is the engine. The range of vibrating frequency of an engine is 20Hz-25Hz. Therefore, we have to analyse our rollcage such that its natural frequency at various mode shape is well above this range.

### 6.7.1 Boundary Conditions

The frame was fixed at the front and rear suspension points and nodal displacement and nodal rotation was ramped in all three directions as shown in fig 7.

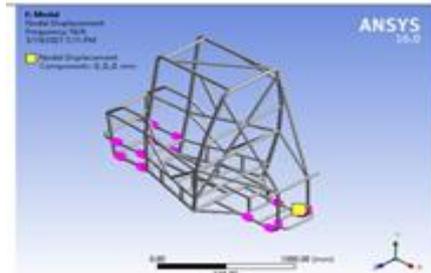


Fig 7. Loading Condition

## 7. RESULTS

The following table shows the values of deformation, stress and factor of safety produced of the above performed analysis. A number of iterations have been performed to ensure minimum stress and deformation and to obtain an optimum factor of safety. Von mises stress theory has been used to obtain the stress values since the theory is most suitable and accurate for ductile materials.

Table 4. Analysis Results

Impact Type	Deformation (mm)	Stress (MPa)	Safety Factor
Front impact	1.77	395.35	1.41
Rear impact	1.14	291.26	1.92
Side impact	7.01	454.63	1.23
Rollover impact	3.99	249.4	2.24
Front Torsional	8.35	280.75	1.99
Rear torsional	6.17	237.55	2.35

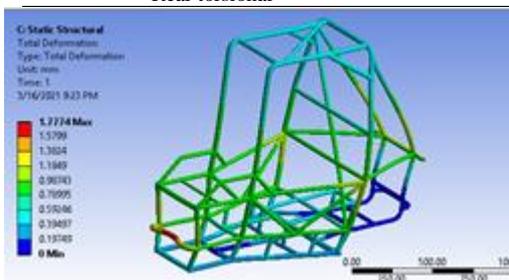


Fig 8. Total Deformation Front Impact

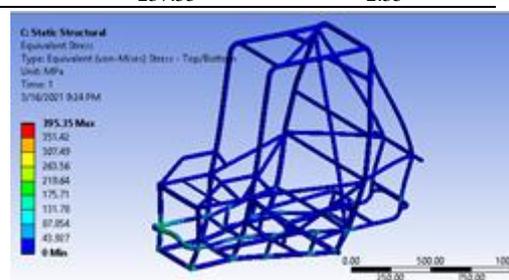


Fig 9. Equivalent Stress Front Impact

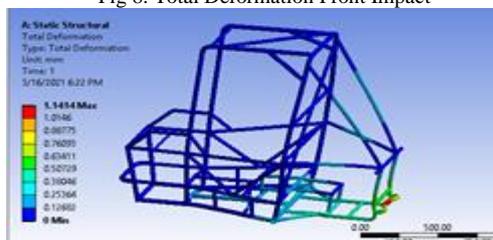


Fig 10. Total Deformation Rear Impact

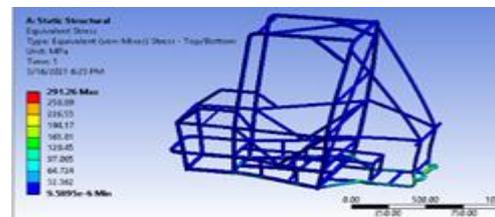


Fig 11. Equivalent Stress Rear Impact

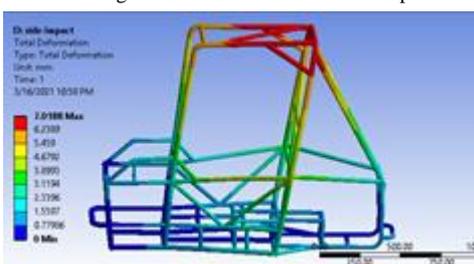


Fig 12. Total Deformation Side Impact

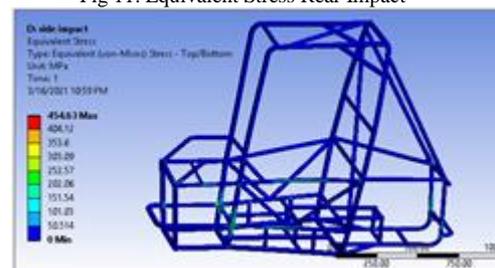


Fig 13. Equivalent Stress Side Impact

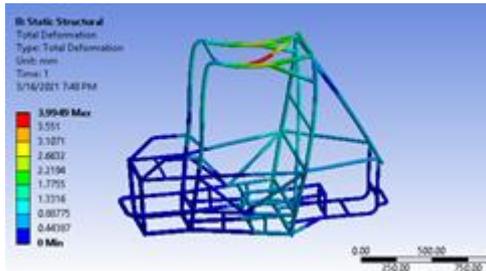


Fig 14. Total Deformation Roll Over

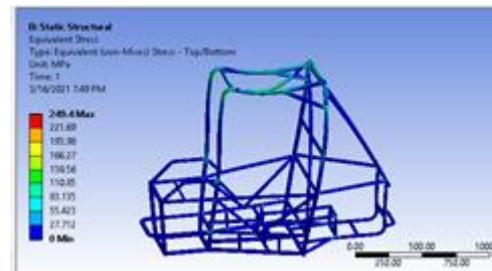


Fig 15. Equivalent Stress Roll Over

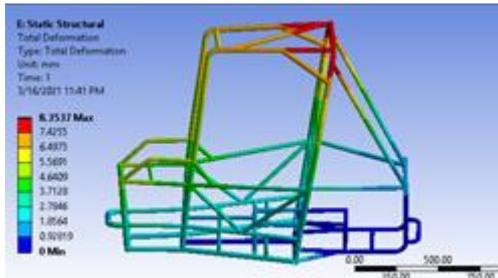


Fig 16. Total Deformation Torsional

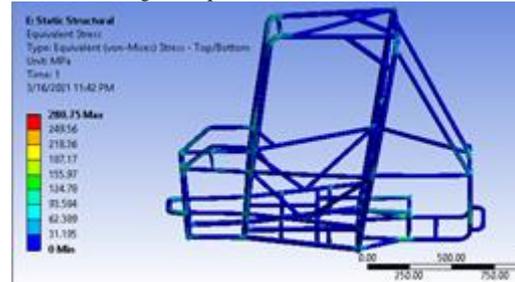


Fig 17. Equivalent Stress Torsional

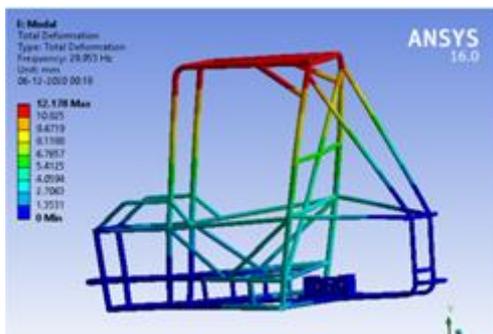


Fig 18. Total Deformation at Min Frequency

Table 5. Modal Analysis

Mode shape	Frequency (Hz)	Deformation(mm)
Mode shape 1	29.95	12.17
Mode shape 2	57.861	14.77
Mode shape 3	70.383	9.43
Mode shape 4	94.134	22.89
Mode shape 5	98.532	17.28
Mode shape 6	101.94	23.11

Since the induced stresses are within limits and the natural frequency at various mode shape is well above the desired range, hence the design is safe.

## 8. CONCLUSION

The paper contains the entire methodology and parameters involved in the design and analysis of rollage for an All-Terrain Vehicle. Several iterations were performed to ensure a safe, compact and light weight structure without compromising on its strength. Optimum values of safety factor ensures that the rollage will be safe under different loading condition that may occur at the event site.

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## Elemental analysis of Ayurvedic medicines using X-ray tube based portable energy dispersive XRF setup

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### Abstract

Elemental analysis of fourteen Ayurvedic medicines procured from three manufactures has been done using the portable energy dispersive X-ray fluorescence (EDXRF) technique. The experimental measurements were performed with a portable EDXRF setup equipped with a mini-X-ray tube and a small silicon drift (SDD) detector. The XRF analysis confirmed the presence of sixteen essential and toxic elements viz, <sup>15</sup>P, <sup>16</sup>S, <sup>17</sup>Cl, <sup>19</sup>K, <sup>20</sup>Ca, <sup>25</sup>Mn, <sup>26</sup>Fe, <sup>29</sup>Cu, <sup>30</sup>Zn, <sup>33</sup>As, <sup>38</sup>Sr, <sup>47</sup>Ag, <sup>50</sup>Sn, <sup>77</sup>Ir, <sup>80</sup>Hg and <sup>82</sup>Pb in these medicines. All the analyzed samples showed the presence of <sup>16</sup>S, <sup>20</sup>Ca, <sup>26</sup>Fe, <sup>29</sup>Cu, and <sup>80</sup>Hg in excess amount. Other elements <sup>17</sup>Cl, <sup>19</sup>K, <sup>25</sup>Mn, <sup>30</sup>Zn, <sup>33</sup>As, <sup>47</sup>Ag, <sup>50</sup>Sn and <sup>82</sup>Pb are present in some samples of different manufacture with varying concentrations. <sup>38</sup>Sr and <sup>77</sup>Ir elements are present in the one medicine manufactured by Baidyanath. The elemental analysis of Ayurvedic medicines is of interest from the point of view of their remedial and toxic nature of some elements. The importance of the analyzed essential elements in human physiology is also discussed.

**Keywords:** Ayurvedic medicine, Elemental analysis, Energy dispersive X-ray fluorescence (EDXRF).

### INTRODUCTION

Ayurvedic medicines are generally used for the treatment of various diseases since ancient times. The presences of different elements/ingredients in these medicines play a major role in the functioning of the human body. The efficient functioning of the human body requires a variety of minerals in different amounts. The deficiency of minerals in the human body may result in metabolic disorders, nervous system failure and muscle abnormalities [1, 2]. On the other hand, some toxic elements are harmful even at low concentrations. The Ayurvedic medicines are prepared from various organometallic compounds and herbs obtained from plants. The trace elements present in Ayurvedic medicines play crucial preventive and curative roles in combating diseases. The elemental analysis of Ayurvedic medicines made by diverse manufacturers is critical for determining their medicinal value as well as the hazardous character of particular elements.

In literature the concentration of various elements in Ayurvedic medicine has been determined using total reflection X-ray fluorescence (TXRF) [3], inductively coupled plasma mass spectrometry (ICP-MS) [3, 4], neutron activation analysis (INAA) [5], atomic absorption spectrometry (AAS), energy depressive X-ray fluorescence (EDXRF) techniques [3, 6] and proton-induced X-ray emission (PIXE) [7]. Each technique has their own advantages and limitation. The EDXRF spectrometry is multi-elemental, rapid, non-destructive, environmentally friendly and highly accurate relative to other techniques. The better detection limits and more accurate results in the EDXRF method can be obtained by target excitation with X-ray tubes. Queralt et al. [3] used TXRF, EDXRF and ICP-MS techniques for the elemental analysis in some medicinal herbs. Milani et al. [4] determined the trace element concentration in herbal beverages using the ICP-MS technique. The elemental analysis of several herb plants commonly used in Indian Ayurvedic medicines was done using INAA by Singh and Garg [5]. Obiajunwa et al. [6] have been used energy depressive X-ray fluorescence (EDXRF) techniques for the elemental analysis of twenty Nigerian medicinal plants. The proton-induced X-ray emission (PIXE) technique was used by Mohanta et. al [7] to correlate the elemental profiles of some medicinal plants in North Eastern India, with therapeutic and curative use in Ayurveda.

The present work deals with elemental analyses of various herbo-metallic Ayurvedic medicines used for the treatment of chronic diseases related to digestive, cardiac, respiratory, nervous, female reproductive and skeletal systems. The measurements were performed using portable EDXRF using thin targets. The elemental analysis of various elements in these medications is interesting because of their therapeutic effectiveness as well as the toxicity of certain elements. The elemental analysis of fourteen different drugs was performed using the energy dispersive X-ray fluorescence (EDXRF) technology.

### EXPERIMENTAL DETAILS

**Sample collection and target preparation:** Using a systematic plan seven Ayurvedic medicines *i.e.* Arshkuthar, Bolbaddha, Kafketu, Pradarantak, Nityanand, Pushpadanwa and Somnath manufactured by Baidhyanath, Dabur and Unjha for selected for their elemental analysis using EDXRF technique. All the medicines were procured from local vendors of Mohali (Punjab) and Chandigarh of India. All the purchased medicines met the inclusion criteria that they are prepared from Ayurvedic herbal remedies and intended for oral use. The name, manufacturer's location, lot number, indications, recommended dosages, formulation, and cost per package were recorded for all purchased products. All the medicines are crushed in very fine powder using mortar and pestle and dried in an oven at temperature ~ 45 °C to remove the moisture. The powdered materials were then uniformly distributed on cello tape to make thin targets.

**Elemental analysis using EDXRF technique:** Elemental analysis of the Ayurvedic samples was carried out using a portable EDXRF spectrometer available at the Department of Physics, Panjab University, Chandigarh. The EDXRF spectrometer consists of an Ag anode mini-X-ray tube and a small silicon drift (SDD) detector [80 mm<sup>2</sup> X 5 mm, 25-µm Be window and full width at half maximum (FWHM) = 125 eV at 5.895 keV, Amptek, US]. Bremstrahlung's radiations obtained from the X-ray tube operated at 40 kV and 20 µA current were fall on the targets placed at 45° to beam direction. The detector was kept at 90° to the target position and 45° to the X-ray beam direction. The photo of the experimental portable EDXRF setup used in the present measurements is shown in Fig. 1. The portable XRF system is fully controlled by PC using ADMCA and mini-X controller software. Typical EDXRF spectra of one of the medicines manufactured by Baidhyanath company is shown in Fig. 2. The spectra clearly showed presence of <sup>17</sup>Cl, <sup>19</sup>K, <sup>20</sup>Ca, <sup>26</sup>Fe, <sup>29</sup>Cu, <sup>33</sup>As and <sup>80</sup>Hg elements in the medicine.



Fig. 1 Picture of portable EDXRF spectrometer used in present measurement

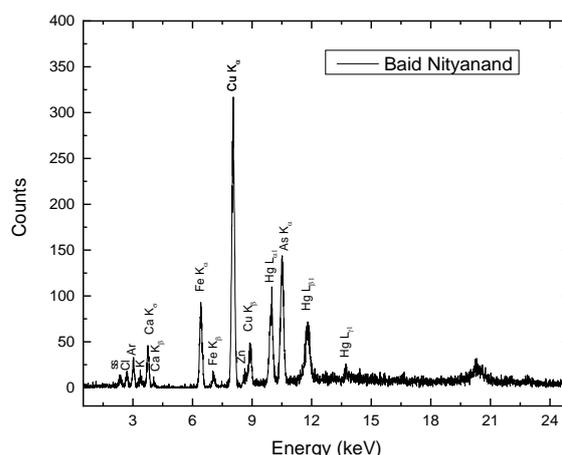


Fig. 2 EDXRF spectra of Nityanand medicine manufactured by Baidhyanath.

The mass thickness ( $\mu\text{g}/\text{cm}^2$ ) of the various elements present in Ayurvedic samples has been evaluated using the relation

$$m_{\text{unknown}} = m_{\text{known}} \times \frac{N_{\text{unknown}}}{N_{\text{known}}}$$

where  $m_{\text{unknown}}$ , and  $m_{\text{known}}$  are the mass thickness of Ayurvedic sample and standard thin target, respectively.  $N_{\text{known}}$  and  $N_{\text{unknown}}$  are the count rate of element present in sample and standard thin foil, respectively.

## RESULTS AND DISCUSSIONS

The present work reports elemental analysis of 14 Ayurvedic medicines manufactured by three reputed Indian manufacturers; Baidyanath, Dabur and Unjha. These Ayurvedic medicines are prescribed by practitioners to cure various diseases. The mass concentration of biocompatible and toxic elements in  $\mu\text{g}/\text{cm}^2$  are listed in Table 1. The overall errors in the measured concentration values for various elements have been estimated to be ~2-6 % for major elements and ~7-11 % for trace elements. The EDXRF analysis of all the medicines showed the presence <sup>15</sup>P, <sup>16</sup>S, <sup>17</sup>Cl, <sup>19</sup>K, <sup>20</sup>Ca, <sup>25</sup>Mn, <sup>26</sup>Fe, <sup>29</sup>Cu, <sup>30</sup>Zn, <sup>33</sup>As, <sup>38</sup>Sr, <sup>47</sup>Ag, <sup>50</sup>Sn, <sup>77</sup>Ir, <sup>80</sup>Hg and <sup>82</sup>Pb elements. All the analyzed samples showed the presence of <sup>16</sup>S, <sup>20</sup>Ca, <sup>26</sup>Fe, <sup>29</sup>Cu, and <sup>80</sup>Hg in excess amount. Other elements <sup>17</sup>Cl, <sup>19</sup>K, <sup>25</sup>Mn, <sup>30</sup>Zn, <sup>33</sup>As, <sup>47</sup>Ag, <sup>50</sup>Sn and <sup>82</sup>Pb are present in some samples of different manufacture with

varying concentrations. Two elements <sup>38</sup>Sr and <sup>77</sup>Ir elements are present only in one of the medicines manufactured by Baidyanath. <sup>15</sup>P is present only in one of the medicines manufactured by Dabur. Also, some medicines prepared by different manufacturers show the presence of <sup>33</sup>As, <sup>80</sup>Hg and <sup>82</sup>Pb toxic in excess and trace amounts. Many of these elements are essential for the growth of living organisms and of cardinal importance in human metabolism.

The presence of <sup>16</sup>S elements in the human body is important for wound healing and the cure of skin rashes. The deficiency of <sup>16</sup>S leads to various dermatological disorders. The ions of <sup>19</sup>K element in the human body acts as an electrolyte to balance the cell integrity and maintain a heartbeat. <sup>20</sup>Ca is one of the essential elements which plays a vital role in blood clotting, hormonal actions and cellular mortality. Several enzymatic processes in the human body are controlled by <sup>25</sup>Mn element, it helps to reduce nervous irritability and eliminate fatigue. <sup>26</sup>Fe element mostly present in human blood in form of haemoglobin which plays a crucial role in oxygen transportation from lungs to tissue cells. The deficiency of <sup>26</sup>Fe in the human body causes anaemia disease. <sup>29</sup>Cu responsible for many metabolic reactions and requirements for maintaining a healthy heart and nervous system. The <sup>30</sup>Zn element is present in more than 250 enzymes present in the human body and its deficiency leads to multisystem failure. The <sup>33</sup>As, <sup>80</sup>Hg and <sup>82</sup>Pb daily doses are based on a measurement of their concentration in the Ayurvedic product. The American National Standards Institute (ANSI) recommends that people consume no more than 20 g/d of mercury, 10 g/d of aluminium, and 20 g/d of lead [8]. The influence of heavy metals on human health and the usage of polluted herbal medicines are both hotly debated. In general, the contents of heavy metals are present in noticeable amounts in some medicines three Ayurvedic brands. There is a clear indication that the non-existence of proper quality controls checks is due to huge variation in elemental concentration in Ayurvedic medicines procured by different manufacturers. The manufacturers need to be looked into this variation of concentration and should be controlled.

## CONCLUSION

In the present work, elemental analysis of 14 Ayurvedic medicines procured by three reputed manufactures was done using a portable EDXRF spectrometer. The experimental results show the presence of 16 essential and toxic elements. The experimental results report unacceptably high concentrations of <sup>33</sup>As, <sup>80</sup>Hg and <sup>82</sup>Pb toxic elements, which are in general 2 to 3 orders above the permissible limit given by the various Government agencies, which is a matter of safety concern. The experimental data will be of immense importance in the synthesis of Ayurvedic formulations. Existing large variations in ingredient concentrations from different manufacturers indicate the lack of proper quality control mechanisms. These observations necessitate the standardization and quality control in the manufacturing and development of Ayurvedic medicines. Highly intensive research encompassing Physico-chemical and biological aspects need to be carried out to understand the applicability, bioavailability and toxicity of such preparations of Ayurvedic medicines.

**Table 1:** Elemental concentrations ( $\mu\text{g}/\text{cm}^2$ ) in 14 Ayurvedic medicines of prepared by different manufacturers.

Elements	Baidhyanath							Dabur			Unjha			
	B <sub>1</sub>	B <sub>2</sub>	B <sub>3</sub>	B <sub>4</sub>	B <sub>5</sub>	B <sub>6</sub>	B <sub>7</sub>	D <sub>1</sub>	D <sub>2</sub>	D <sub>3</sub>	U <sub>1</sub>	U <sub>2</sub>	U <sub>3</sub>	U <sub>4</sub>
<sup>15</sup> P		–	–	–	–	–	–	–	–	383	–	–	–	–
<sup>16</sup> S	37.2	114	–	19.7	54	178	35.7	36.5	276	41.8	61	16.0	65	63
<sup>17</sup> Cl	201	–	–	67	–	–	–	134	–	–	201	74	–	–
<sup>19</sup> K	142	–	128	83	–	22.5	70	365	–	70	110	40.5	–	97
<sup>20</sup> Ca	46.2	14.1	360	54	242	127	42.3	221	37.2	496	81	104	214	75
<sup>25</sup> Mn	–	–	–	–	1.47	–	0.65	–	–	–	–	–	1.96	–
<sup>26</sup> Fe	65	8.97	3.96	14.7	599	97	79	50	3.76	1.01	28.8	16.4	324	73
<sup>29</sup> Cu	38.3	0.28	–	15.9	1.18	0.36	0.31	28.7	–	0.27	0.28	17.5	4.33	0.45

<sup>30</sup> Zn	-	-	-	2.89	813	-	-	-	-	-	-	-	743	-
<sup>33</sup> As	-	-	-	15.1	19.6	-	-	-	-	-	-	-	-	-
<sup>38</sup> Sr	-	-	1.20	-	-	-	-	-	-	-	-	-	-	-
<sup>47</sup> Ag	-	-	-	-	72	-	-	-	13.9	-	-	-	38.4	-
<sup>50</sup> Sn	-	-	-	-	90	25.4	-	-	-	-	-	14.0	135	-
<sup>77</sup> Ir	-	-	-	-	-	8.00	-	-	-	-	-	-	-	-
<sup>80</sup> Hg	1.04	3.75	-	0.41	1.78	2.82	1.36	1.09	12.2	-	0.72	0.39	1.58	1.75
<sup>82</sup> Pb	-	-	-	-	-	185	3.33	-	-	-	-	40.8	4.11	-

B<sub>1</sub>-Arshkuthar, B<sub>2</sub>-Bolbaddha, B<sub>3</sub>-Kafketu, B<sub>4</sub>-Nityanand, B<sub>5</sub>-Pradharantak, B<sub>6</sub>-Pushpdhnwa, B<sub>7</sub>-Somnath medicines manufactured by Baidyanath, D<sub>1</sub>- Arshkuthar, D<sub>2</sub>-Bolbaddha, D<sub>3</sub>-Kafketu medicines manufactured by Dabur and U<sub>1</sub>-Arshkuthar, U<sub>2</sub>-Nityanand, U<sub>3</sub>-Pradharantak, U<sub>4</sub>-Somnath medicines manufactured by Unjha.

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## Hardware-in-loop simulation of Grid Connected PV system for optimizing maximum output power

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### Abstract

The demand for energy is increasing day by day due to surge in population and rapid development of industries. With limited reserves of conventional energy sources like oil, petrol, diesel, coal etc. the immediate concern is harnessing renewable energy sources. Thus, it is imperative that we rectify and improve the drawbacks of renewable energy sources. The paper introduces a real time-based autonomous simulation model which drives values of variables (Illumination and Temperature) from designed macro timer code which makes the analysis simpler and more realistic. The model has caliber to operate on multiple MPPT techniques and for current designing INC algorithm has been used. Real time simulation results have been obtained by performing the synchronization of grid-load systems with a PV module of 300W capacity, which on the P-V curve simulates real time tracking of power for specific locales. The analysis of the simulation results has been done on the (Hardware-In-Loop) HIL SCADA panel and it has been observed that the performance of the proposed model is robust and efficient.

**Keywords-** GCPV, SCADA, INC, MPPT, Typhoon HIL, Real time Simulation.

### 1. INTRODUCTION

As the world progresses towards new technology and era, the need for advancement is crucial in every field. As the conventional grid connected technology weighs on the passing generation, its demerits become visible to the researchers all over. The solution for the impending technology was to incorporate the renewable sources to the present grid connection, either wind, solar, tidal, etcetera. But the most tangible and easy to access renewable energy source is solar energy. The addition of this renewable technology will ease the burden on depleting sources such as coal, oil, etcetera. The most commonly used renewable energy is Solar energy. As solar energy has got a great potential to produce energy and is in abundance, research in the past decade has been focused in this area. But there are drawbacks with solar as its efficiency and output power changes with the changes in temperature and irradiation. So, the problem can be minimized by applying a DC-DC converter whose switching is controlled by MPPT between the PV and the load. Algorithms is used to control DC-DC converter and maximum power point tracking (MPPT) functions. MPPT is mainly used to utilize the optimum amount of power. Conductance is the facility offered by a material to the flow of current. As the conductance increases, resistance decreases. Out of all the algorithm, INC is the most simple, convenient and easy to control. As of now, PV systems do not provide efficient output for the purpose of use and also have high initial cost. So, in order to make it more efficient, various MPPT techniques came into existence. For this research, such MPPT technique (INC) is used [12][13]. For better understanding of this grid connected model the advantages of grid connected photovoltaic (GCPV) system are summed up as follows:

- It is pollution and noise free
- It is renewable and reduces the burden on grid
- It is harmless and free from the reservation of resource distribution area [9][11]

In this paper an attempt has been made to design a GCPV model which runs on the real time data of a specific locale with the data such as irradiation and temperature. And in order to achieve the MPP, the Incremental conductance technique is used. The software that is used for the real time analysis is Typhoon HIL. The proposed model is firstly designed in Schematic editor with appropriate parameters and then compiled, which will take the designed model for the real time simulation in HIL SCADA, where with help of appropriate widgets, the MPPT is done as it will be discussed in further sections in detail.

**2. PV SYSTEM MODEL**

As discussed in the introduction, the main objective of this research was to incorporate the renewable source of energy and to uplift the conventional system of grid power supply to the consumer. For such purpose the chosen source was PV and the parameters that will control the outcome of this real time model would be irradiation and temperature under the appropriate control algorithm for attaining MPP. Fig 1. Shows the mathematical approach for the PV system.

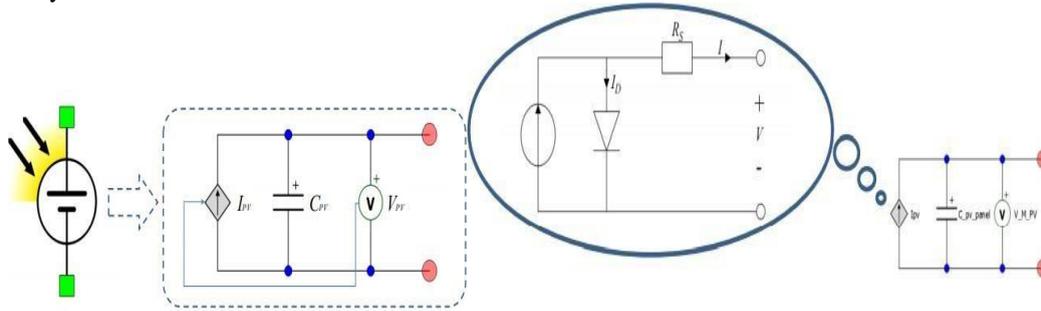


Fig 1: Standard PV model [2]

Fig 2: Expansion of PV cell [2]

$$I = I_{ph} - I_D = I_{ph} - I_0 \exp\left(\frac{e(V + iR_s)}{m k T_c} - 1\right) \dots \dots \dots (1)$$

Whereas,  
 m = ideality factor  
 K = Boltzmann constant = electron charge  
 T<sub>c</sub> = junction temperature

The above equation in accordance with Fig 2., gives the mathematical understanding for standardization of PV modules [2].

**3. MPPT TECHNIQUE**

The power generated by photovoltaic panels is not constant under variable illumination and temperature conditions, we can observe a non-linear relation of PV curve with the varying illumination and temperature, this may lead to inefficient output power from PV panel. To overcome this Maximum Power Point Tracking is designed, in which a calculative technique is designed to derive maximum and stable power out of PV in any possible conditions. Several techniques for this purpose are designed having their own advantages or losses. The technique constantly tracks maxima on P-V curve to harvest most efficient power.

**3.1 Incremental conductance Technique (INC)**

The incremental conductance technique is one of the conventional techniques among the hill climbing techniques, this works on the calculation of slope of PV curve which determines the maximum power condition. The value of slope for maxima is zero where the conductance  $G = I/V$  is equal to the incremental value of conductance, as the instantaneous position of the operating point is calculated to control the duty cycle. In case the negative of conductance is less than the incremental conductance the operating point is to the left of MPP so duty cycle is decreased, and when the incremental conductance is less than -G, the operating point lies to the right of MPP so the duty cycle is increased [3]. When a load is connected to the PV module, the operating point only corresponds to the MPP in very specific cases; the system is not operated at full power for all other conditions. Therefore, MPPT circuits must ensure that PV modules operate at their maximum output most of the time, regardless of temperature and irradiation conditions [6]. The incremental conductance has an observed advantage over P&O as it is more stable at MPP and faster too as compared to its counterpart under variable irradiance conditions due to its lesser deviations [4]

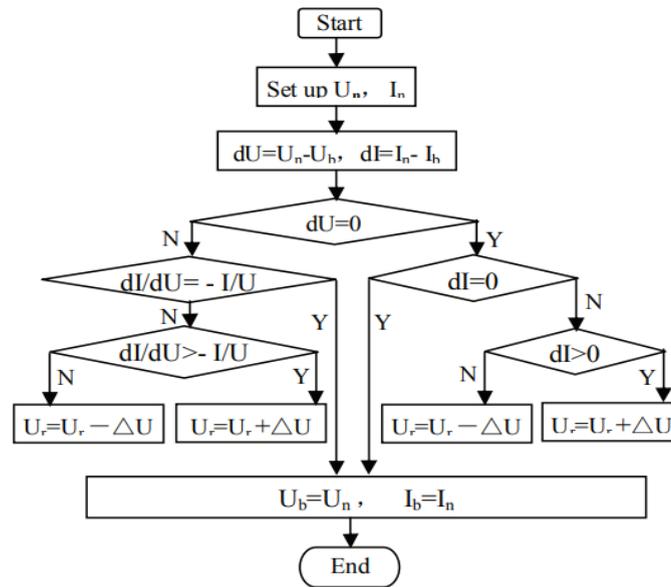


Fig 3: Detailed flowchart of INC algorithm [7]

#### 4. PHASE INVERTER & CONTROLLER

In the designed model of the GCPV system, the main purpose of the inverter is to convert the dc voltage fed by the PV to the grid side into the ac current [1]. Here the inverter switching is controlled by the internal modulator setting and the  $E_n$  is given in order to enable and disable the Pulse width modulator (PWM) and the reference signal inputs [2]. The power converter is used to convert renewable energy (Solar) into useful electrical energy as per requirement of the grid. In the proposed system the Inner loop is controlled by the Proportional regulator (PR) & Outer loop is controlled by the PI regulator. Outer loop is the dc bus voltage in the link capacitor and voltage reference command is compared by the outer loop. Inner loop is the synchronization of 3-phase inverter line current with the 3-phase utility grid voltage is done by the inner loop which has 2 controllers to govern dq or the  $\alpha\beta$  component of the line current. To understand through Parks Transformation, the dq component of the inverter current is governed by a PI regulator.  $\alpha\beta$  component of the inverter is governed by a PR regulator [1].

#### 5. BOOST CONVERTER

The boost converter is used to boost the voltage level and obtain continuous output. The components in designing it include a diode, inductor, capacitor and load resistor, which are connected to step up the output voltage given by the formula.

$$V_{out} = V_{in} / (1-D) \text{-----} (2)$$

Where  $V_{out}$  is the output voltage and  $V_{in}$  is the input voltage and  $D$  is the duty cycle or the ratio of  $T_{on}$  and  $T_{off}$  of the boost converter switch, which is controlled by the switching impulse generated by the MPP algorithm. The current value keeps on decreasing till the switch turns ON again, meanwhile the polarity of the inductor is reversed which makes the  $V_{out}$ , greater than the  $V_{in}$  hence stepping up the voltage. The ideal values of inductor and capacitor can be calculated through the following equations [5].

$$L = V_{in} / f_s \Delta I_{scr} \text{-----} (3)$$

#### 6. SIMULATION MODEL OF GCPV

The proposed model was designed in the Schematic editor of Typhoon HIL Software. The proposed model for the GCPV system is shown in Fig. 1. This system consists of the installed PV pane which supplies the generated power by inserting the real time illumination and temperature data of locales, the preinstalled Jinko\_JKM300M-72.ipvx file provides the required variables for designing of an ideal PV module. The generated power is fed to a DC-DC boost converter prior to feeding it to the inverter to boost up the voltage as desired. The boost converter

switching is controlled by Incremental Conductance (INC) MPPT controller to supply power at maximum value. The INC block receives panel voltage and current values as well as their delayed values to track the slope of P-V curve to determine the operating point through coded mathematical equations so as to modulate the duty cycle to obtain MPP through perturbations in the duty cycle. The output is then fed to the 3-phase inverter via a coupling capacitor which smoothen the output of the booster. Inverter performs AC -DC transformation to feed the power to the grid, the controlling of which is done through Phase Locked Loop synchronization technique consisting of a Proportional integral based current controller placed in a closed loop to generate a switching pulse for the inverter. The PLL block takes 3 phase voltage values from the grid transmission and to transform it from 3 phase to dq axis, which further calculates  $V_d$  and  $V_q$  values along with phase angle to feed it to the current controller. The reference P and Q values are also taken to calculate the reference  $I_d$  and  $I_q$  values, which are compared with the instantaneous values. The generated signals are then transformed from dq to abc phase and then given to the Bus joint to provide inverter switching. Finally, the converted AC power is transmitted to the load after passing it through LC filter to reduce harmonics in power transmission as shown in Fig 4.

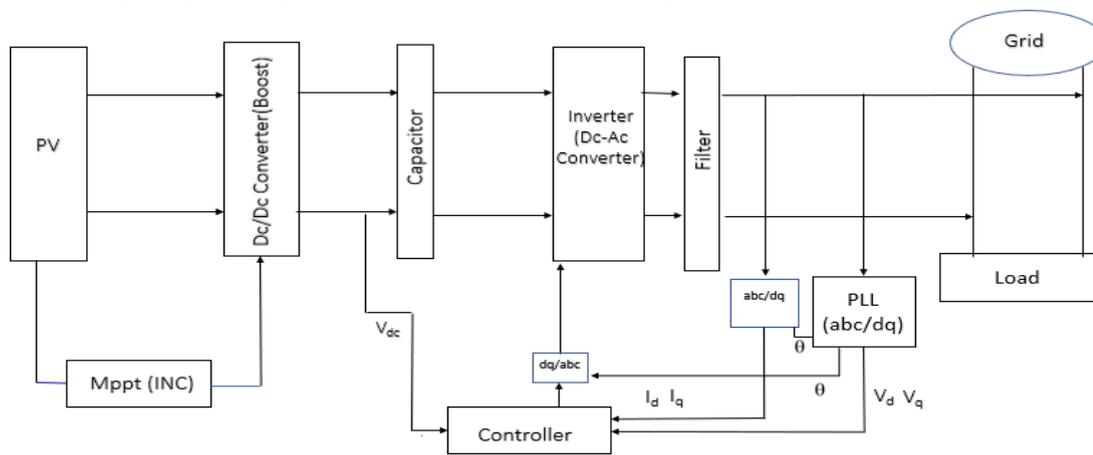


Fig .4: Schematic Model of GCPV

The Model parameters are taken as per the simulated model as shown in Fig. 5 The elements that have been used during the designing of the Model are R1 - the resistance used on the PV side to provide stability L is the inductor of the boost converter. C3 is used to smoothen the output of PV.  $L_a$ ,  $L_b$ ,  $L_c$ ,  $C_{fa}$ ,  $C_{fb}$  and  $C_{fc}$  are the elements of the filter used to eliminate harmonics.  $T_s$  is the execution rate taken for the simulation.

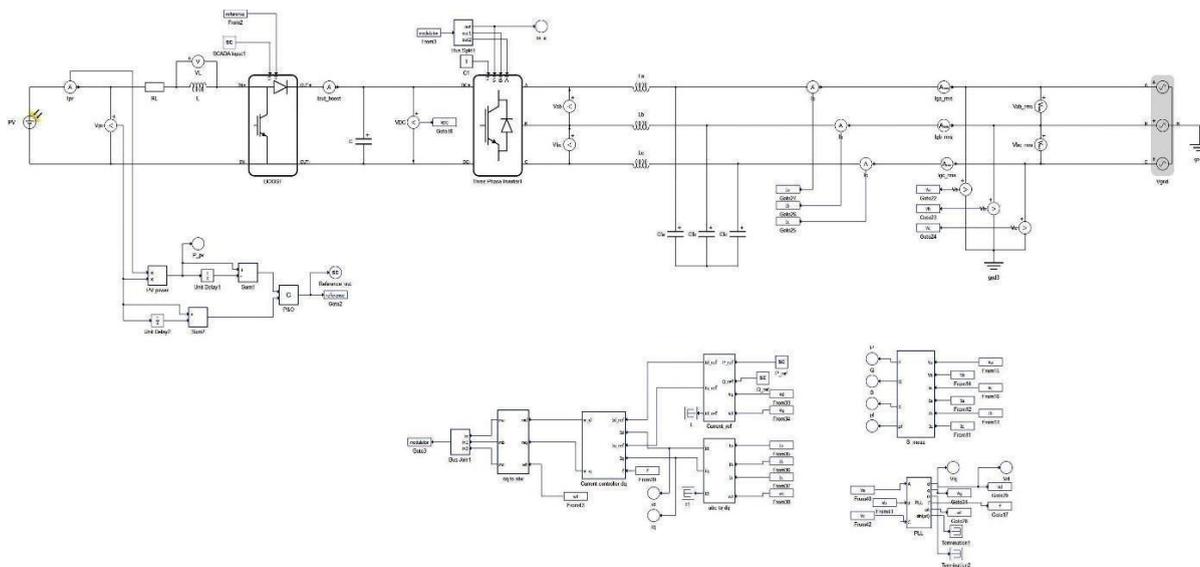


Fig .5: Schematic Model of GCPV

The data which has been used over twelve months has been selected for a particular area. The average data (irradiance and temperature) of twelve months is represented in the form of a line graph plotted shown in Fig. 6 for a chosen locale (Noida, Uttar Pradesh, India).



Fig.6: Irradiation and Temperature data of Noida (India)

## 7. Results and discussion

The Schematic model is now run in HIL SCADA panel, after compilation, where a timer generated code is designed to automate the real time execution of the model. The timer injects the data of irradiance and temperature collected for the mentioned locale into the PV module for the respective power generation. The designed model can even be used in real time application with actual varying irradiance and temperature conditions in a day to analyze the performance of any GCPV model with a high run time efficiency.

The PV monitor in Fig. 7 and 8 shows the MPP tracking for the month of May and October. As the timer code injects the irradiance and temperature of different months automatically at an execution rate of 1000 microseconds, the MPP tracking starts. As the simulation demonstrates the real time execution of the data, it achieves the maximum efficiency and the output power at a steady pace. Where the green dots shown in the mentioned figures of PV monitor goes back and forth and eventually achieves the MPPT.

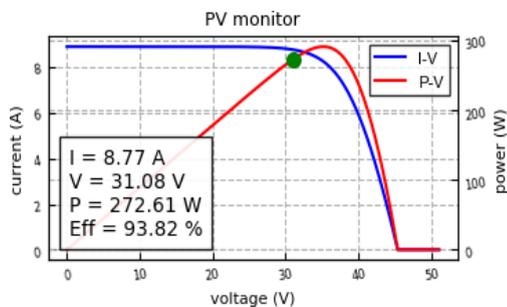


Fig. 7: PV graph for May

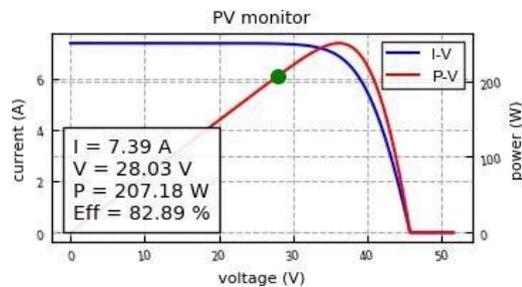


Fig. 8: P-V graph for October

The power outputs for different months vary according to the changing irradiance and temperature and are observed and represented as bar graphs as seen in Fig. 9. The output of power in every month is dependent on parameters like temperature and irradiance. With the help of the PV monitor, the output power was drawn. As mentioned before, how the real time simulation worked in achieving maximum power output of a specific month and hence shown. The comparison can be seen quite clearly with the help of the bar graph, side by side.

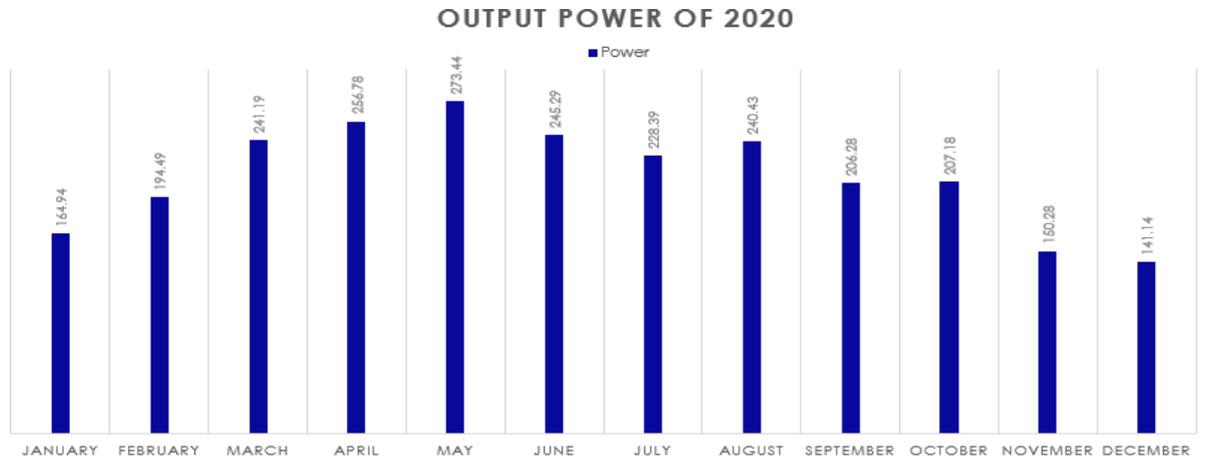


Fig. 9: Power output for 12 months

## 8. CONCLUSION

The real time analysis of the work attempted has been showcased successfully. The motive was to design a simulation model which can show output on the real time basis, so as to eliminate the cost in manufacturing the experimental systems for cross-verification of theoretical research and to save a lot of time for a fair judgement of proposed system if it comes into an existence in future. The model has been designed to use the INC algorithm to ascertain the power output for different months in a year for a particular location. The advantages are the ability to draw a comparison between different output powers of different months of 2020 for the location of Noida, Uttar Pradesh, India or for any locale all over the world in future. It is observed that for low irradiance and temperature, the output power is less and if the irradiance and temperature increases, the output power increases, hence shows the effect of irradiance and temperature on output power. Using the INC algorithm for attaining MPP on the PV curve, made the response of the system quick and easy to implement. This model is robust and has the capability of comparing and testing more advanced algorithms to ascertain the output power of different locations all over the world in future.

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## Artificial intelligence and Cyber security as key challenges of Industry 4.0

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### Abstract

Today, industries are looking to digitalize their organizations for the betterment and effectiveness of their services. Although industries are not aware of industry 4.0 as such, they are familiar with digitalization. On the surface, both are the same. So, to adopt industry 4.0, industries have to meet the demands for adoption. Data security is vital for winning the trust of consumers, investors. Data privacy is a big concern against digitalization. Having a secure network will help communicate data over a broader area and can be controlled from even a remote site. Cybersecurity is a challenge and driver at the same time for industry 4.0. However, we only discuss the challenging part of cybersecurity. We also discuss artificial intelligence. Artificial intelligence helps in decision-making by identifying, collecting, and analyzing data. AI implementation faces few challenges, and these challenges are discussed.

This paper mainly focuses on artificial intelligence and cybersecurity as key challenges against fourth industrial revolution implementation in industry.

**Keywords-** Artificial intelligence, Cyber security, Industry 4.0

### 1. INTRODUCTION

Before discussing Industry 4.0, the earlier industrial revolutions need to be considered first to understand the development during those revolutions. The First industrial revolution (I1.0) occurs in the late 18th century with the transition from handmade production to mechanical production with the help of the steam engine and water power. During this industrial, industrialization first came into the picture. Also, the first industrial revolution (I1.0) is also known as the Mechanical revolution. In the late 19th century or earlier 20th century, the production of electrical energy increased. This allows the production engineers to design new production lines to utilize these electrical energies. This integration of electrical energy into the industry brings the 2nd industrial revolution (I2.0). In 2<sup>nd</sup> industrial revolution, the concept of mass production comes into picture. Also, during this revolution, the productivity and profitability of organizations increased significantly. After the second world war, in the 1960s, the first z1 computer was developed, which uses binary floating-point and Booleans logic. This computer laid the foundation for developing many advanced computers that we see today. Integrating computers and electronic devices into the industry brings the 3rd industrial revolution (I3.0). Industry 4.0 integrates conventional manufacturing processes with intelligent communication, information, and intelligent technologies. These industrial revolutions are shown in figure1.

Industry 4.0 development relies on the various vital technologies which apply from physical floor levels to the virtual intelligence levels. Artificial intelligence helps in improving the process capabilities and effectiveness by collecting, processing, and optimizing the data and take necessary actions to meet the goals. There are few challenges for the adaptation of artificial intelligence in the organization. The organization has to identify these challenges and rectify them to get the full advantages of applying artificial intelligence. In Industry 4.0 environments, security of companies depends upon the cyber security. Cisco's 2018 Annual Cybersecurity Reports concluded that 32% of businesses have suffered attacks on operative Technology and 37% anticipate assaults to spread beyond operative Technology to OT. A paper was being compiled by Cyber Security of European Organization (ESCO) in relation with cyber security standards. Cyber security challenges can be addressed through this paper (Lezzi et al., 2018).

Furthermore, the International Electro technical Task (IET) has produced a handbook on data privacy and security, which includes recommendation to be included in publications of IET as well as instructions on how to apply them. Intelligent systems lead to convenience as well as risk. In Industry 4.0 networks, connectivity can

be wireless or wired. Manufacturers who embrace Industry 4.0 must be aware of different cyber hazards and establish cyber-security measures to mitigate these threats. In defending cyber-attack risks the implementation during the installation phase is more helpful rather than the implementation of defence strategies to an existing system (Sharma and Dhote, 2018).

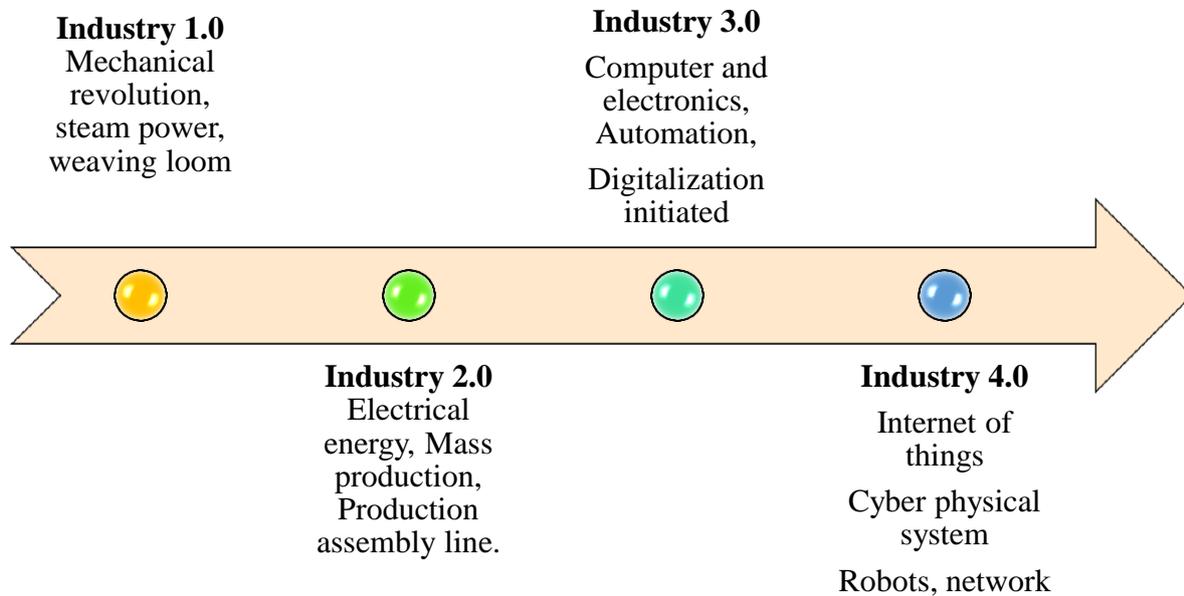


Figure 1: Industrial Revolutions

The scientific and normative literature was used to investigate cybersecurity ideas and solutions in the context of Industry 4.0. Due to the multiple new technologies involved, we demonstrated the complexity created by cybersecurity procedures to keep systems safe. Then, to demonstrate that every level of an organisation has a role to play, we presented a categorization of cybersecurity that included both technical and management features. (Mullet et al., 2021).

This paper mainly focal point on the artificial intelligence and cybersecurity challenges for industry 4.0 implementation in the industry. Although other challenges affect the implementation of industry 4.0, artificial intelligence and cybersecurity are vital for assuring the investors and stakeholders to invest in the organization's transformation to industry 4.0 standards.

## 2. Artificial intelligence

In 1923, the word "robot" was used in Capek's play named 'Rossum's Universal Robots.' As robots are integral parts of artificial intelligence for controlling operations. In 1956 the term 'Artificial intelligence' was termed by John McCarthy. Artificial intelligence is the similar intelligence display by the machines as by the human and animals. AI systems monitor their environment and take necessary actions to meet their goals. These systems train themselves by analyzing the data and continuously updating the database, and acting like the cognitive ability to think by human minds.

Industrial AI is a structured paradigm that focuses on solving industrial problems using artificial intelligence for sustainable working. AI consists of fields like natural language processing, and robotics. The fusion of these fields strengthens the systems by solving the problem with the given disposal of resources by autonomous actions. Industrial AI is further classified into five different aspects, namely, Infrastructure, Data, Algorithms, Decision-making, and objectives. Infrastructure is concerned about the hardware and software and tries to create an environment where the data can be communicated in real-time. It also focuses on providing high dependability with high-safety requirements and interrelationships as per industrial standards. In the case of data, industrial AI requires large quantities with high velocity and variety. So, the organization can train its models over such diverse data and give more accurate results. Data collection must be done from different resources like various products, processes, units, etc. The algorithm integrates the physical, cognitive, and digital knowledge and develops the algorithm for the diverse nature of data. In the algorithm, high complexity is observed due to model deployment, governance, and handling. Decision-making is one of the essential parts of



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an industrial AI. This will help make the right decision under uncertain conditions and keep the model within the tolerance limit. In the case of optimization of large-scale problems, efficiency are vital parameters. In the objective part, the AI is most concerned with the concrete added value with the help of factors like scale reduction, augmented performance of the operation, accelerated ramp-up time, or improved quality (Peres et al., 2020).

Artificial intelligence monitors, optimize, and controls operations or processes to increase efficiency and performance (Bécue et al., 2021). We can disintegrate industrial AI into AI for monitoring, controlling, and optimization. In AI, we need to monitor the efficiencies of processes and systems to help us forecast the failure of the machine part or similar undesirable results (Ji and Wang, 2017). AI planning goes ahead from AI monitoring to allow the user to plan and get the desirable states of the system to optimize the target. Optimization's advantages can be used in machine learning (ML) or AI, which include planning the process in such a way that the processes which cause lots of money, time, labor, or material should be assigned with more priority than the other processes (Xue et al. 2001). Controlling systems are the most integrated part of the modern operations, with the help of which the organization can benefit fully from the digitalization they are doing in the organization (Bécue et al., 2021). Reducing the failure by predicting or identifying, monitoring data is essential to control the undesirable results. After predicting and identifying the loss. AI provides the pathway to resolve the issue and optimize the process to meet the targets. In the optimization stage, the strategies are built, and to put these strategies into action, a controlling system is required. The controlling system includes robotics, autonomous vehicles, factory automation, and HVAC automation.

Machine learning is essential for achieving artificial intelligence (Alpaydin, 2020). It uses a machine modelling technique to trail the model, Machine modelling means estimating the uncertain dependency of the machine between the inputs given to the machine and the output from the given data. When the machine's dependency is found, we can predict the output for the given data. Algorithmic machine learning techniques may incorporate inductive logical programming, Bayesian networks, decision tree, clustering, and reinforcement learning (Copeland, 2016). An artificial neural network (ANN) consists of artificial neurons. These neurons try to mimic the behaviour of biological neurons that are connected via direct graphical connection (Nielsen, 2015). The artificial neural network is difficult to adapt due to the complexity, i.e., it can alter its internal structure by varying the weight of the inputs. Deep learning neural network is more advanced than the traditional neural network due to more no. of hidden layers (Bakon et al., 2018). Deep learning uses complex structures to identify the different structures with the help of back propagation algorithms. The essence of deep learning is that humans do not develop it, but they are identified from the dataset with the help of standard learning procedures (LeCun et al., 2015).

The knowledge graph is a well-known and propitious technique for managing the joining data in AI. Its organized semantic networks help in defining the concepts and their connection. The knowledge graph can give logics based upon regulation or deep learning techniques. These abilities permit the relationship between entities within the pre-set classes. From process safety point of view the knowledge graph can be classified into three parts: process security details extraction, knowledge processing, and knowledge fusion. In the case of process security details extraction, the development of a graph initiates with collecting information about process security, reactions, controlling systems, process-related details, and risk-related knowledge. The data collected should have a degree of diversification. It should not only consider the data in a structured format but also can be in the form of text, graphs, tables, or written in natural language (NL). In the case of process security knowledge processing, the series of primary expression that gives tangible results can be expressed. From the safety point of view, safety-related factors hold greater importance. To prevent the failure, automatic identification of harmful parameters has to be identified, and the deviation of this parameter should be monitored. If there is some deviation more than acceptable limits, then the trigger events downstream of the process should be diagnosed as per the predefined rules. The application of knowledge graphs can be seen in social networking, social security systems, and many more areas (Mao et al., 2019).

Today, advanced technologies are changing the lives of humans. This can be seen from how we travel, take education, use medical facilities, and transport. Most industries and production plants are using some digitalization in their organization partially or entirely, like using autonomous robots or devices embedded with selecting mechanism of AI. Computer-aided design (CAD) helps prepare the complex contour or shapes to implement specialized orders, which are helped by controlling devices that can identify the complexity of individual items. These quality controlling algorithms are based on machine learning algorithms that gain experience over time. They are also looking for the faults in the product classes to prevent those failures from occurring. AI is also being used in complex optimization problems worrying material management and

planning. Implementing AI in other sectors than the tech sector is still in the experimentation stages as organizations are still working their ways to understand and trying to bring the technology within the organization by looking for its implementation in the organization (Niewiadomski et al., 2019).

Vyshnevskiy et al. studied the impact of industry 4.0 and AI on economic growth. They analyze that industry 4.0 and AI are not giving many economic advantages as they have not yet become economic growth drivers. Although, economic development means that the implementation of technologies that are associated with industry 4.0 and AI increases. They also concluded that the implementation or adaptation of industry 4.0 and AI helps the organization grow, but individual growth does not determine universal growth. Although, the question for increasing the economic growth will be there irrespective of technologies as there will be the opportunity of improving the efficiencies of these technologies and processes (Vyshnevskiy et al., 2019).

Industry 4.0 requires the transitional shift from classical manufacturing practices to modern manufacturing practices, enabling organizations to achieve mass production. Organizations need to use cyber-physical systems and artificial intelligence to manufacturing shop floor levels to achieve that. Semantic web serviced-based AI is a well-known and established service that can provide reasonable manufacturing capabilities to bring AI to the organization. For that, we need to develop semantic web services that provide interoperability and connectivity, connect to the existing representational knowledge, enable real-time capabilities, enrich web services with semantic description, model relation between web, resolve mutual exclusion, and composite web services. Malburg et al. modeled the web semantic based upon standard Web Ontology Language for Web Services (OWL-S) and Web Service Modelling Ontology (WSMO). These models are tested with significant inputs, outputs, preconditioning, or postconditioning. The results from their analysis are that the developed semantic web services are compatible with workflow to build cyber-physical production workflows (Malburg et al., 2020).

Edge AI is also used in industry 4.0. The edge AI has three different edge techniques that can be used in industry 4.0. These techniques are transfer learning, federated learning, and active learning (Tziouvaras and Foukalas, 2020). Transfer learning can be used in the organization to provide lightweight, innovative manufacturing applications by using the pre-trained models that have already been tested and verified (Pan et al., 2009). Transfer learning is similar to meta-learning, which grows the model to achieve automation, integration, and commoditization. Although, the questions will be raised overusing the predefined model, which uses the existing framework. However, most of the time, these models can train itself and develop more efficient models that have not been developed yet (Shao et al., 2014). Federated learning is the technique that will find its application in intelligent factories soon due to its decentralization. This will allow the industrial internet of things (IIoT) to not send the data to the cloud-first during critical time conditions. Fog computing (FC) will be placed between federated learning (FL), which is also a decentralization technique of machine learning. In this case, the local nodes will share the data only within the neighbourhood and update the model with the cloud (Hao et al., 2019). Active learning is an excellent approach to machine learning that can give accurate results in lesser training labels if it is empowered to use the data from which the model has trained. Extracting the results from the unlabelled data can sometimes be very difficult. Active learning tries to prevail over the labelling restriction by asking queries in the form of unlabelled to be labelled by the operator. Active learning also assists in updating the time automatically, which helps improve production capacity (Qian et al., 2019).

AI helps solve industry problems, but organizations face few challenges while implementing AI in the industry. These challenges should be discussed before an organization thinks about adopting AI. Also, where the organization stands for the adoption and how much work is still required to implement AI effectively. In the next section, we find few challenges against AI implementation and discussed them in detail. The literatures used in this research paper are shown in table 1.

### 3. Challenges for Artificial intelligence

Artificial intelligence has enormous potential in the manufacturing industry, from quality control to maintenance, ergonomics, and helping people in physical tasks. Data available to training and validating the model is still not sufficient. Technologies like deep learning and machine learning require massive data for training the model to give unfiltered results (Peres et al., 2020). In manufacturing, the data is acquired from different sources or environments may be false data that misguide the models from achieving their target. So, the data should check whether it is false or accurate data. Training models over false data is unfeasible from both financial and operational points of view.



Having the accessibility to the data that was in an orderly manner for the artificial intelligence model not only helps in making error-free decisions but also helps predict the requirement of the intelligent industries (Jagatheesaperumal et al., 2021). The availability of such data is difficult to collect as the data is collected from different sources, and accessing the data without any restrictions is not simple. Few attempts have been made to develop an easy exchange mechanism for the safe and straightforward data access (Gaba et al., 2020).

In case of data analytics, the process of data auditing plays a vital role. Analysis of data in data auditing is done based on the application like; during the process, the data acquired for forecasting analysis is analyzed as to if the data is compatible with the operation. Risks associated with data are systematically defined (Ahmad et al., 2020). In industries, the data is acquired from different sources, which are unstructured in huge volumes. To fully exploit data capability in various applications within the industry, data auditing is vital to analyze and measure the quality of the data to use for the training of machine learning or artificial intelligence models. Few works are already being done in this area as a decentralized auditing program were proposed like Dreads for data auditing acquired for the industrial conditions. This auditing method promises three different auditing kinds: public, dynamic, and batch auditing (Fan et al., 2020). Wu et al. identified the crucial infrastructure while auditing the industrial data. He also provides the analysis of the combination of Blockchain and edge computing techniques for scalability and safe data management frameworks (Wu et al., 2020).

Checking data quality is essential before training the models over it. Data quality includes completeness, timeliness, accuracy, consistency, dependency on task context, interpretability, accessibility (Peres et al., 2020). The data is acquired by the sensors from the physical environment, which tends to have noise in the data, making it challenging to train models over such data (Bécue et al., 2021). Also, for training the models, labelled data are beneficial. However, in the industry case scenario, as the data come from different sources, labelling that data is difficult (Pinker, 2018).

Transferring the data is also an essential factor to keep in mind. There are no global or universal standards for transferring and communicating the data. The interoperability between two different devices and resources data decreases. However, we can transfer the data to subsystems through the existing infrastructures such as fiber, Ethernet, or some wireless ways for the users to interpret the transferred data and collect helpful information. In this field, research has been done which presented safe, fast, and efficient ways to transmit data intelligent sensors to the cloud servers. It also helps in de-clustering the waste data that was collected from waste management in a profound way (Cotet et al., 2020). Silvestri et al. overview the data transfer strategy for remote maintenance. This strategy helps in the self-maintenance of intelligent factories and reduces the operator's risk management (Silvestri et al., 2020).

Explain ability is defined as the ability of an artificial intelligence (AI) model to justify its decision convincingly to humans, whereas interpretability is defined by the ability of the artificial intelligence (AI) model to link the cause behind the decision. Both explain ability and interpretability are essential for an AI model to justify its decisions to its operators (Ahmad et al., 2020). In the case of lower threat tasks, the need for interpretability is not that much as the loss associated with it is minimal. However, on the contrary, in the case of high threat tasks, interpretability is highly required. In these cases, interpretability and explain ability help gain the users' trust by providing them with the cause and justification behind the reason. We have to compromise between accuracy and interpretability, which is challenging as we need both for our models (Guidotti et al., 2018).

Before implementing artificial intelligence in the industries, the organizations have to understand the potential risk they can face, like model-thieving data manipulation. Various attacking methods can impact the organization's performance, like poison, evasion, Trojan, and model extraction. In case of a poison attack, the manipulated data is transferred to the artificial intelligence model so that the model re-trains itself and reduces the model's performance (Dunn et al., 2020). In an evasion attack, the attackers aim to continuously query the model so that they can detail inputs to pass the model. This kind of attack can lead to power consumption and system availability (Ahmad et al., 2020). Trojan attacks try to alter the model's weights without changing the structure. This attack works smoothly under normal conditions, and they can also predict the inputs that can trigger those trojan-generated weights (Liu et al., 2020). In extraction model attacks, the model is once again constructed to compromise the properties of the input data. This attack does not require the knowledge of model or training data. It can access by simply submitting the query's response (Yang et al., 2020).

The model's biasness and fairness impact the performance of the modelled algorithm. As there is no standard for biasness, it becomes hard to make the model bias-free. The biasness can be incorporated from different sources

like data pipelines, operators handling the process, pre-processing, etc. thresholding can be done with the help of additional data and adaptive processing. This biasness can be done with the help of data auditing. For this, the open-source library is developed, which helps policymakers and participants audit their fairness model. This helps deploy and develop the forecasted solutions (Peres et al., 2020).

The cost of failure is tremendous; similar is the case with changing the product or parts. A skilled workforce is required for the smooth operation of artificial intelligence in the industry. Data scientists and engineers are splines of the AI team for the effective implementation of artificial intelligence in the system (Mao et al. 2019). Compliance requirements such as public/employees health and safety, workplace safety is depending upon the markets and industries.

For assuring investors/stakeholders to invest in the solution with enormous potential, the explanation of the solution is essential, which means that having the proper knowledge of AI and how it can be used to better the process/operations in industry 4.0. Proper training of employees is also an essential step that an organization has to perform to understand the pros and cons of technologies.

#### 4. Cyber security

This paper adds to the body of knowledge on Investing in cybersecurity in the supply chains of Industry 4.0 in three ways. An exponential function of breach probability has been used to convert a nonlinear combinatorial optimization issue into a linear one. The compromise cybersecurity investment tries to balance vulnerability across the whole supply chain, regardless of the likelihood of cyber attacks or possible costs from security breaches (Sawik, 2020).

Global industrial operations now need more demanding standards than ever before, including privacy and transaction security, among other things. This study provides an integrated modelling environment for SDN-based manufacturing applications (that is, software-defined networks-based) where Cybersecurity and resilience methods are used to overcome the problem of manufacturing system assurance. The suggested integrated cybersecurity-resilience ontology is presented in this research and will be utilised in the production network design phases to capture needs (Babiceanu et al., 2016).

The area is growing more importance as people rely more on Internet, computer systems and wireless protocols such as Wi-Fi and blue tooth as well as the proliferation of "smart" gadgets such as cell phones and the numerous devices that comprise the "IOT." Due to its complexity, both politically and technically, cyber security is considered to be as one of the prominent challenges that is faced by world in today's scenario. Willis Ware's April 1967 meeting at the Joint Spring Computer Conference and the publication of the "Ware Report" were pivotal considerations. In 1977 NIST publication, the "CIA triad" that includes availability, integrity, confidentiality was introduced as a simple way to define security objectives.

However, there were no serious computer threats in the 1970s and 1980s and threats related to security were easy to detect. The most common threats come from harmful insiders who gained access without permission to confidential documents and files. Although preachment existed in the early years was not used for gain. IT companies like IBM began offering accessible control systems and IT security products (Lezi et al., 2018).

In today's fast-paced scenario, cyber security is expected to be an important component of the strategy and operation of organizations that calculates the 4.0 concept structure.

Products must grow smarter and more networked as part of the Industrial Internet of Things (IIoT), but they also become more exposed to cyber attacks. Some firms may already have the capacity to execute corporate process modifications in order to establish a more secure cyber strategy, but this may not be possible for others. UL can assist any producer or system integrator of industrial control systems in gaining customer trust in the cyber vigilance of both their organisational and product security procedures (Chaturvedi, 2017).

Various protection tactics that enterprises and end-users must employ in the face of cyber threats in Industry 4.0 are explored and described in this paper. The company faces issues such as the security of its IoT devices, employee training, and inefficient use of the network and its assets. The execution of the study's findings will need a lengthy procedure (Sharma and dhote, 2020).

Cyber-attacks on vital industrial equipment can put a company's business model in jeopardy. Having knowledge and analysing the most vital assets to be secured from prospective cyber-attacks, as well as the business repercussions that may ensue, is a competitive advantage. This research suggests a systematic classification of

key industrial assets as part of Industry 4.0, as well as the possible negative effects of cybersecurity breaches on corporate performance (Lezi et al., 2020).

The threat of cyber attacks on the Direct Digital Manufacturing (DDM) community will be examined, as well as possible attack scenarios and reasons. A security evaluation of an AM system utilised in the defence sector for quick prototyping and sophisticated part manufacturing will be provided. Security best practises will be reviewed along with protocols and recommendations for adopting them during system installation and subsequent operation (Glavach et al., 2017).

In older times, cybersecurity techniques were mainly to protect computers from attacks and intrusions but attacks are massive, continuously developing, incredibly quick, persistent, and highly sophisticated as defined in the present Internet security scene. For this, the cyber-attack detection technique is using neural networks, outputs of which are fed in an oracle that is neural network and evolved from neuro, depending upon ensemble intelligence. This generates optimal categorization result which is fed into active attack response systems as feedback (Thames and Schaefer, 2017).

Industry 4.0 is a long-term transition that brings new computing and economic models to the industry. Some technologies are well-established in other industries, such as finance and information technology, yet there is a large amount of adaption required. Cybersecurity is at the top of the list of threats. This chapter explains why Manufacturing and the Industrial sector as a whole face unprecedented problem (Jesus and Josephs, 2018).

Industry 4.0 is a manufacturing revolution that integrates disruptive technologies into factory's heart. Despite extensive literature, many businesses are only now realising the importance of cybersecurity. This paper takes you step by step through the concepts and practical aspects of cybersecurity. We present our guidelines, as well as those of some international organisations working on cybersecurity harmonisation and standardisation (Mullet et al., 2021).

As a result of the IoT, the number of access points for malevolent actors is rapidly expanding. Businesses are exposed to risks that cannot be controlled directly due to the complicated digital value chains. Cyber-attacks are potential enough in causing serious damage as regards disrupting operations of businesses and stealing confidential information. Due to the complexity of issues and concerns, C-suite executives and entrepreneurs are perplexed (Podrecca et al., 2019).

The Industrial Internet of Things and Industry 4.0 are concepts that are propelling the present industrial revolution by linking the management tools, products and industrial machinery to the Internet so that they may be controlled and data is collected. Many devices of IIoT/IoT have been linked with the internet beyond sufficient security measures in place, resulting in a slew of misconfigured or poorly secured gadgets. In order to secure such systems, it involves a set of abilities that aren't frequently taught in engineering colleges. This paper describes how students with no prior knowledge in industrial cybersecurity may undertake audits using a framework that allows them to learn cybersecurity through actual use cases (Carames and Lamas, 2020).

Industry 4.0, a new revolution in which industrial systems are interfaced and integrated into smart factories using Internet communication technologies, is rising and trending. Cybersecurity is a typical necessity in every Internet technology; therefore users of I4.0 face a significant problem. This chapter gives a quick rundown of some of the most important cybersecurity components, principles, and paradigms. With high-profile assault instances, it also covers industry-relevant cybersecurity vulnerabilities, risks, threats, and responses. (Khalid et al., 2020).

### **Cyber security characterization**

There are some elements of cyber security concept and the questions to be answered are: -

1. What is to be protected against?
2. How should you protect yourself?

### **Aim of cyber attacks**

1. Unauthorized access to data
2. Destruction
3. Service blocking

Cyber-security refers to protect the privacy and gage against especial dangers and vulnerabilities posed due to cyber-attacks. Service disruption, illegal data access etc. Are all goals of cyber-attacks? Cyber-attacks are classified as: • Test for Vulnerability and Penetration, • Phishing, • Sniffing, • Spam e-mail, • malicious software that include: Viruses, Trojans, spyware and many more (Lezi et al., 2020).

### 5. Challenges for Cyber security

Industry 4.0 is facing a number of difficulties as a result of cyber-attacks:

- Reduction in output, device misunderstanding, loss of data, and service disruption.
- Due to use of Internet of Things (IoT) appliance coordination and communication between devices is harmed badly making the entire system vulnerable.
- It includes Cyber-physical systems CBS, which is not risk-free and may result in sudden system failures.

Because of this, numerous defence methods for cyber-security have been alleged for reducing the bad effects of it.

#### Systems vulnerability

Jansen and Jeschke describe vulnerabilities as flaws in the automation or IT systems as exploited by hackers to undermine the CPS. In a broader sense, vulnerability is a flaw in an IT system, internal controls, or application that could be activate by a threatening source, according to National Institute of Standards and Technology. Vulnerabilities can be classed as remote access, software, or LAN and they can be linked to both virtual machines and IT systems.

#### Cyber Threats

Threat can be defined as a situation or event that has the ability to effect organization internally. Three dimensions can be used to describe attacks on linked physical systems 1 The type of system attacker 2 The attacker's goals and objectives 3 The assault style.

#### Managerial Challenges

Cybersecurity must now be viewed as a strategically, organizational and technical subject of study - Senior ICT Manager. Today, no one can describe cybersecurity; many people feel it is still about information security, but it is much more. - Director of Cybersecurity.

It is presently not tied in with overseeing digital dangers, however about dealing with trust issues. Network protection ought to amplify its concentration to what exactly is pertinent to the clients - Cybersecurity Director, Retail; - Cybersecurity should be founded on an essential vision. Change the executives is the best approach to make an interpretation of this vision into the real world - Head of Digital (Lezi et al., 2020).

In latest literature, the concepts of cybersecurity in Industry 4.0 have shown to be a developing and significant issue. This research intends to examine, using a systematic technique to review literature, how the current state of the art addresses cybersecurity challenges in such situations. The examination of the primary factors related with the cybersecurity issue will be the emphasis in particular (i.e., system vulnerabilities, asset involved into cyber-attacks, risks, countermeasures as well as cyber threats).

Because data is the primary fuel for Industry 4.0, it is more vulnerable to cyber-attacks. Control system protocols, the omission of frequent penetration testing, exposed connections, and inexperienced people have all been identified as cyber-security vulnerabilities. These vulnerabilities are identified in this paper, as well as cyber protection solutions. The many vulnerabilities found, as well as their mitigation, will guarantee that the damage caused by these vulnerabilities is kept to a bare minimum (Sharma and dhote, 2020).

For optimising investing in cybersecurity in supply chains of Industry 4.0, a mixed - integer programming approach is presented in this study. The complicated nonlinear stochastic combinatorial problem has a linear equivalent model for optimization with a breach chances is created using a conventional exponential formula via a recursive linearization approach. The compromise cybersecurity investment tries to balance vulnerability across the whole supply chain, regardless of the likelihood of cyber-attacks or possible costs from security breaches (Sawik, 2020)

Because of the industries competitive salary offers, a difficult time is faced by universities in finding university professors who are well-trained and ready to work in academics. Data science, cybersecurity and artificial



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intelligence are all in high demand, and there is no sign of this trend slowing down in the coming years. It is studied how businesses might avoid some of the risks involved with integrating new technology and training their staff (Dawson, 2021).

Global development industries are progressing toward satisfying current and future demands that are always changing. In Industries 4.0 and 5.0, it's critical to address the reality and premises of cyber security. Various organisations' techniques to mitigate risks are critical for reducing hazards. Cyber security is critical for the growth of digital industrial transformation because of the gaps and risks created by interconnectivity. (Clim, 2019).

Large organisations require a security strategy and risk management system that are suitable for their specific security demands. The purpose of this article is to discuss the various challenges that businesses should deal with in order to protect themselves against cyber-attacks. Production has been more digitalized, paving the door for approaches such as the IoT, Augmented Reality, and many more to emerge (Efe and Isik, 2020).

The series of publications from the European Union Agency for Network and Information Security in the field of Industrial IoT security have been examined in this article. This IIoT Security Framework was then created based on the semantic contents of the ENISA publications analysed. IIoT taxonomy and assault scenarios are given special consideration. (Sklyar and Kharchenko, 2019).

The Industrial Control Systems (ICS) which are used these days were planned in order to function for years, also many of these were established beyond any significant care for security in IT. New hazards have emerged in the realm of industrial automation as a result of these new technologies. InCyS4.0 (Industrial Cyber Security) is a project for two years named KA2 that has been financed and supported by the European Union's Erasmus program that aims to train industrial production technicians to deal with cyber-security vulnerabilities. The research took the design of an unidentified questionnaire aimed at local industry IT professionals. The study's goal was to look at the security flaws of the companies who took part, as well as to create a profile of industrial IT engineers (Karampidis et al., 2019).

As we go into the Industry 4.0 age, the present workforce is becoming increasingly vulnerable in the workplace - for example, it is currently estimated that by 2030, up to 800 million worldwide workers will be replaced by robots and AI. To keep people employed, only a rethink of how we train and give education is required, but should colleges be concerned? (Rabah, 2018).

All the components of Industry 4.0 face many problems. They include cloud computing, big data and cyber physical systems. The design of these technologies and cybersecurity requirements analyses of these technologies were covered in this paper. The need of taking precautions against cyber-attacks and hazards in developing technology, as well as the deployment of security systems, were also emphasised (Ilhan and Karakose, 2019).

Industry 4.0-related IT technologies make it easier to put the foundation for sustainable production in place. This, in turn, creates security worries among executives in the industrial industry. The lack of a recognised methodology to help the decision-making process for selecting the appropriate cybersecurity techniques and means is, in fact, a substantial impediment to the growth of sustainability. The adoption of Industry 4.0 technology and the implementation of a sustainable manufacturing framework in businesses are slowing dramatically. (Torbacki, 2021).

The cyber physical systems (CPS) security has become increasingly important in later years. Industrial control systems (ICS) are the most frequent type of CPS, and they are found in practically all essential infrastructure. A thorough and in-depth overview of CPS is presented in this study along with a detailed overview of the present state of ICS security in the United States and Europe and comparison with other developed countries like China. ICS security has risen to the top of the security priority list (Lu et al., 2014).

Information and communication technology has been deployed to numerous essential infrastructures, such as power plants, smart factories, and financial networks, in the era of Industry 4.0. Legacy systems that formerly functioned as stand-alone systems now have connections to external networks. Power control systems have absorbed security vulnerabilities from legacy ICT in this trend. To deal with cyber vulnerabilities and dangers, several security technologies are being investigated and developed. However, using innovative security methods to a power control system that has not been certified as safe is dangerous (Lee et al. 2018).

By incorporating the big data analytics, the Industrial Internet of Things, sophisticated robotics and cloud computing in the production processes, manufacturing promises digitally to develop highly adaptable products with improved quality and cheaper prices. While advances in artificial intelligence, wireless technology and sensing enable a change in production, a serious danger to the industry is there in cyber-attacks. This study examines the cybersecurity in the manufacturing systems that work digitally, including threat and vulnerability

identification, system characterisation, risk assessment, along with obstacles for future research (Wu et al., 2018).

Cybersecurity is one of the most significant concerns facing businesses as they transition to the Industry 4.0 paradigm. In order to provide a unified picture of the cybersecurity controls required in the industry, European and international standard bodies have created standards and advice publications. According to the literature review, there are a large variety of ways for dealing with cybersecurity challenges. None of them focuses on security concerns by connecting the essential assets to be safeguarded from cyber-attacks and the associated business repercussions, as well as giving a measure of those impacts (Lezi et al., 2020)

This study looked at cybersecurity challenges in the context of Industry 4.0, utilising a systematic approach to the literature review and a qualitative examination of the contents of the articles that were chosen. Each area's primary aspects were outlined in a reference framework. It gives a shortcut to a comprehensive picture of cybersecurity in I-4.0 that can be used as a reference resource for training in IT departments as well as a basis for supporting decision-making on cybersecurity concerns. Future research can use this study as a platform for addressing industry investigations and expanding the existing state of the art (Lezi et al., 2018). The literatures used in this research paper are shown in table 1.

Table 1. List of reviewed papers

S.No	Author	Journal	Year	Publisher
1	(Lezzi et al., 2018)	Computers in Industry	2018	Elsevier
2	(Corallo et al., 2020)	Computers in Industry	2020	Elsevier
3	(Shapo, 2018)	Journal of scientific perspectives	2018	Rating Academy
4	(Sharma and dhote, 2020)	International Journal of Modern Agriculture	2020	IJMA
5	(Sawik, 2020)	International Journal of Production Research	2020	Taylor and Francis
6	(Mullet et al., 2021)	IEEE Access	2021	IEEE
7	(Podrecca et al., 2019)	IEEE Engineering Management Review	2019	IEEE
8	(Carames and Lamas, 2020)	Applied sciences	2020	MDPI
9	(Clim, 2019)	Informatica Economica	2019	INFOREC
10	(Efe and Isik, 2020)	International Journal of Intelligent Systems and Applications in Engineering	2020	IJISAE
11	(Sklyar and Kharchenko, 2019)	10th IEEE International Conference on Intelligent Data Acquisition and Advanced Computing Systems	2019	IEEE
12	(Karampidis et al., 2019)	24th International Workshop on Computer Aided Modeling and Design of Communication Links and Networks	2019	IEEE
13	(Ilhan and Karakose, 2019)	International Artificial Intelligence and Data Processing Symposium	2019	IEEE
14	(Torbacki, 2021)	Sustainability	2021	MDPI
15	(Jhanjhi et al., 2021)	Turkish Journal of Computer and Mathematics Education	2021	Karadeniz Technical
16	(Lu et al., 2014)	International Journal of Distributed Sensor Networks	2014	Springer
17	(Lee et al. 2018)	The Journal of Supercomputing	2018	Springer
18	(Chaturvedi, 2017)	56th Annual Conference of the Society of Instrument and Control Engineers of Japan	2017	IEEE
19	(Wu et al., 2018)	Journal of manufacturing systems	2018	Elsevier
20	(Babiceanu et al., 2016)	International Workshop on Service	2016	Springer

		Orientation in Holonic and Multi-Agent Manufacturing		
21	(Wang et al., 2019)	Engineering	2019	Elsevier
22	(Stachowiak et al., 2019)	25th International Conference on Production Research Manufacturing Innovation:	2019	Elsevier
23	(Bécue et al., 2021)	Artificial Intelligence Review	2021	Springer
24	(Bogoviz et al., 2019)	On the Horizon	2019	Emerald
25	(Patalas-Maliszewska et al., 2020)	International conference on fuzzy systems	2020	IEEE
26	(Peres et al., 2020 )	IEEE Access	2020	IEEE

### 6. Conclusion

Industry 4.0 implementation is heavily dependent on the capabilities of the organizations to bring the advanced technologies within the system. The technologies associated with I4.0 are very new to most users. Before bringing them within the organization, we need to understand the technologies first and the challenges we will face. We also need to look for the technologies adopted by significant no. of organization. So, we can have their implementation already existing in the industry. Artificial intelligence and cybersecurity are technologies that have found their application in the industry; their implementation is in an initial stage. As artificial intelligence expands its tentacles, there is an expansion in cyber safety-related issues, but it can act as a boon. People need to understand that it can resolve various problems by using AI in malware attributes. For unlocking its benefits, we need to understand that it has numerous benefits. In this paper, we try to understand the technologies and find out the challenges that organizations are facing while implementing these technologies in the industry. This work will help in planning the strategies to bring the technology within the organization.

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## Efficiency Enhancement of Iterative Filtering Algorithm by Simulative Analysis

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### Abstract

Wireless Sensor Networks are deployed in adverse and unprotected areas, so they are prone to assaults by foreign entities resulting in manipulated nodes and thus injection of bogus and distorted data. So, immune techniques for data aggregation are vital. Iterative filtering (IF) algorithms are an optimal choice to administer secure data aggregation by accrediting suitable weight factors to the nodes according to their reliability. For iterative filtering, the choice of an appropriate discriminant function to calculate weights is of paramount importance. Different discriminant functions offer different converging rates to the iterative filtering algorithm resulting in different efficacies. In this paper, we have analyzed and contrasted the rates of convergence of iterative filtering algorithm by implementing it with the help of novel proposed discriminant function as well as the pre-existent ones.

**Keywords-** Wireless Sensor Networks; Unprotected environments; False data injection; Secure data Aggregation; Converging rates; Iterative Filtering; Discriminant Function

### 1. INTRODUCTION

Wireless sensor networks (WSNs) are spatially dispersed sensors that monitor geographical and phenomenal parameters, like temperature, noise, stress, strain, power, etc. and then conjointly transmit the collected data through the network towards the destination. The WSN is built of various nodes and these nodes are linked to the sensors [1, 6]. Thus data aggregation algorithms focus on accumulating data in effective and methodical way to enhance lifespan of the network.

#### 1.1 Data Aggregation and its necessity

A wireless sensor network comprises of a central station and an assembly of wireless sensor nodes. The base station is has a tremendous amount of energy, thus it is unassailable from energy deficiencies, however the sensor nodes are associated with a limited energy and thus are assailable [6]. The sensor nodes collect info regarding several physical and phenomenal values and characteristics from a geological area. Then the amassed information is communicated to the Base Station through step by step transmissions [3]. Data aggregation is frequently utilized in case of wireless sensor networks [1, 3]. Data aggregation is a mechanism of aggregating the data reported by sensor nodes by data amalgamation techniques. Data aggregation compiles crucial data sensed by the sensors and broadcasts it to the base station in an economical and efficient way [6]. Data originated from various sensor nodes is collected and communicated to the amalgamating node. This helps in limiting the traffic and hence congestion in network, so there is a need of energy-efficient data aggregation algorithms for augmenting network lifetime [7]. However, the existing aggregation procedures such as averaging are vulnerable and susceptible to attacks and new security procedures are thus required [3].

#### 1.2 Collusion Attacks

Insertion of malicious data in WSN by the attackers through various malevolent nodes is referred to as collusion attack. When the assailants have a high awareness about aggregation approach and its aspects, then this sophisticated attack is feasible and dangerous. So the assaulters have an eye on the the accumulation manners of the networks involving wireless sensor nodes.

### 1.3 Drawbacks of existing data aggregation techniques and need for secure ones

Collecting info from multiple sensor nodes is usually implemented through conventional manners like averaging, and wireless sensor networks being set up in unsafe and adverse areas are highly procumbent to the intrusion caused due to the destructive nodes. Thus, it becomes very crucial to ensure that only reliable and accurate information is being transferred through the network. But the existing aggregation procedures such as averaging are vulnerable and susceptible to attacks. So immune data aggregation techniques are mandatory for constraining inoculation of false data through malevolent traducers [4, 5] and new secure techniques are thus required [3].

### 1.4 Iterative filtering (IF) algorithm

Iterative filtering (IF) algorithms are a favorable preference for WSNs as these cater to data aggregation as well as reliability estimation by employing the repetitive procedure [8, 10]. Iterative filtering algorithms designate integrity factors to the nodes which are called weights. The deflection of the reported values of a sensor node from the anticipated values fetched in the prior rounds by using suitable amalgamation technique provides the allegiance and reliability measure of a sensor node. The sensors whose readings have a large difference from such prediction have a lower reliability and hence are accredited a smaller weight, so their contribution to the final amalgamated value reduces, thus maintaining authenticity and fidelity in the eventually recorded reading. Iterative filtering algorithm is executed by employing discriminant function.

## 2. RESEARCH BACKGROUND

In this part, the authors have given a concise analysis of applicable literature associated with data aggregation techniques and Iterative Filtering. To name a few, E Cayirci (2003) introduced DADMA (Data Aggregation and Dilution by Modulus Addressing) procedure for data aggregation in WSN. S Yoon and C Shahabi (2005) focused on Employing Dimensional Interrelation for an Energy adequate Clustered Aggregation Technique (CAG) which reduced communication overhead. P Laureti et al. (2006) proposed Iterative Distillation for info processing in which simple reciprocal discriminant function has been used to compute the weights. E Ayday et al (2009) expounded an Iterative Algorithm for Credibility and Reliability administration. S Ozdemir and H Cam (2010) suggested Alliance of noise estimation with Data amalgamation along with reliable transference of info in wireless sensor networks where data aggregation is done by supervising nodes of every data accumulator. M Rezvani et al. (2015) introduced Protected Data Agglomeration Technique for Wireless Sensor Networks in the environment of Collusion Attacks in which trust assessment of the nodes is provided as the respective weight values. M Raja and R Datta (2018) introduced Potent accumulation method for assuring data confidentiality in wireless sensor networks in which actual sensed data is broken down into fragments at the nodes and then amalgamated at the Cluster Heads.

## 3. RESEARCH METHODS

### 3.1 Iterative filtering algorithm for data cumulation

Wireless sensor networks are set up in hostile and unprotected environments, so the traditional data amalgamation methods like averaging, are prone to these kinds of assaults, and thus one cannot depend on them. To protect WSN in such unprotected environments, secure data aggregation technique involving iterative filtering algorithm proposed by Mohsen Rezvani et al. in 2015 has been used effectively. The iterative filtering algorithm has been described in brief as follows:

**Definition 1:** Iterative filtering is a technique used for data aggregation in WSN. Iterative filtering algorithm employs repetitive procedure to achieve both data aggregation and reliability determination. Iterative filtering algorithm achieves the aim by assigning weight values to the nodes according to their integrity and fidelity. Lower reliability and thus a low value of weight is assigned to the sensor nodes whose reportings are greatly different from the aggregate estimate obtained from previous round of iteration and correspondingly, their role in the estimation of the final aggregate value is minimized, thus endowing trustworthiness and fidelity in the value reported finally. Iterative filtering algorithm is executed by employing discriminant function.

### 3.2 Discriminant function

In case of iterative filtering (IF) algorithms, the discriminant function is an expression which is used to calculate weights and hence has a great implication. Thus, the careful selection of an apt discriminant function is imperative to uplift the rate of convergence, thus offering an increased efficacy for iterative filtering algorithm. There are various existing discriminant functions. In this paper, a new discriminant function has been recommended for executing the iterative filtering (IF) algorithm with which the rate of convergence and hence

the efficacy of iterative filtering algorithm is further amplified as compared to the pre-existing discriminant functions. The number of repetitive cycles needed to settle and fix the reputation vector  $r$  gives a measure of the convergence rate. The settlement of reputation vector  $r$  to a particular value implies that the evaluated values of weights are the ultimate finalized weights. Various existing and available discriminant functions are mentioned as follows-Reciprocal:  $g(d)=d^{-1}$ , Laureti:  $g(d)=d^{-0.5}$ , Exponential:  $g(d) = e^{-d}$ , Square Reciprocal:  $g(d)=d^{-2}$ , Cubic Reciprocal= $d^{-3}$  etc. Different convergence rates are offered to the iterative filtering algorithm by these different discriminant functions and this paper proposes a new discriminant function i.e. Quadratic Reciprocal : $g(d)=d^{-4}$  to enhance the rate of convergence of IF algorithm.

#### 4. Case study

To illustrate the employment of novel recommended discriminant function, temperature values reported by ten sensor nodes in an unprotected environment have been considered in the present study. Three nodes have been attacked by the malicious attacker and thus those three nodes state temperature values which are very much different from the values stated by other nodes. Iterative filtering algorithm using different discriminant functions is applied on these set of readings of sensor nodes and it is observed that different convergence rates for IF algorithm are obtained by using different discriminant functions. The following table (Table 1) exhibits the values of temperature sensed through ten sensor nodes [12].

**Table 1:** Values of temperature sensed by ten sensor nodes

Time	Sensor Readings										Reputation Value
	x1	x2	x3	x4	x5	x6	x7	x8	x9	x10	r
t=1	19.7336	19.6160	19.7728	20.2040	20.4196	19.4494	13.4516	19.0084	13.2001	13.5609	17.8416

#### 4.1 Application of research methods

The iterative filtering algorithm is executed on MATLAB on the above set of sensor readings, with pre- existent and new proposed discriminant functions. On the basis of extensive computer simulations, it has been observed that different convergence rates have been offered to the IF algorithm by different discriminant functions. The following table (Table 2) displays and compares the convergence rates of IF algorithm with existing and the new proposed discriminant functions with respect to the number of repetitive cycles executed to stabilize the reputation value  $r$ .

**Table 2:** Rate of convergence of different discriminant functions

Discriminant function	Expression	Convergence rate (Number of iterations)
Exponential	$e^{-d}$	10
Laureti	$d^{-0.5}$	8
Reciprocal	$d^{-1}$	8
Square Reciprocal	$d^{-2}$	6
Cubic Reciprocal	$d^{-3}$	5
Quadratic Reciprocal	$d^{-4}$	4
Polynomial Reciprocal	$d^{-n} : n>4$	4

### 5. Result discussion

From the result table i.e. Table 2, it is ascertained that with the new suggested Quadratic Discriminant Function  $g(d)=d^{-4}$ , the iterative filtering algorithm converges in just 4 rounds which is higher than the convergence rates yielded by other discriminant functions. Thus, an accelerated and expeditious rate of convergence and an elevated efficacy is yielded with the Quadratic Discriminant Function  $g(d)=d^{-4}$ . In addition to this, it has been noticed that for Polynomial Reciprocal Discriminant Function  $g(d)=d^{-n}$  (where  $n>4$ ), the rate of convergence of IF algorithm does not increase further and stabilizes to the value of 4 rounds. Thus -4 is the optimum value to which the divergence factor (d) must be raised and as such Quadratic Reciprocal Discriminant Function is the optimum reciprocal discriminate function with respect to rate of convergence of IF algorithm as beyond the value of -4, the rate of convergence stabilizes and remains constant.

### 6. Conclusion

Ensuring secure data aggregation coupled with increased efficiency has been a great challenge in scenarios where wireless sensor networks are installed in unprotected and unsafe regions. In the current study, the authors have utilized iterative filtering algorithm for data aggregation which is both secure and efficient. Different discriminant functions have been used to implement the IF algorithm and finally by simulative analysis, it has been concluded that the Quadratic Discriminant Function  $g(d)=d^{-4}$  provides the fastest convergence rate to the IF algorithm. It has also been concluded that -4 is the optimum value to which the divergence factor (d) must be raised to get fastest convergence rate as beyond -4, the convergence rate remains constant and equal to 4 i.e. the convergence rate stabilizes to the value of 4 rounds.

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## Fabrication of nano-Al<sub>2</sub>O<sub>3</sub> dispersed W-Zr alloy by mechanical alloying and conventional sintering

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### Abstract

The present investigation aims to fabricate 1.0 wt. % nano-Al<sub>2</sub>O<sub>3</sub> dispersed W<sub>98.5</sub>Zr<sub>0.5</sub> (wt. %) alloy through high energy planetary ball milling for 20 h followed by sintering at 1400 °C for 2 h in an inert argon atmosphere. The mechanically milled powders and the sintered alloy was evaluated using X-ray diffraction (XRD), Particle size analyzer and Scanning electron microscopy (SEM). The minimum particle size of 511.62 nm was observed after 20 h of mechanically milling, compared to 650.52 nm at 0 h. The maximum hardness of 4.01 GPa was observed in the sintered alloy due to grain refinement. The minimum mean wear depth of 24.42 μm was observed in the sintered alloy at 20 N load.

**Keywords-** Tungsten alloy, Mechanical milling, Hardness, Wear

### 1 INTRODUCTION

Tungsten (W) is an excellent choice in the field of electronics, aviation, nuclear power plant and space vehicle equipment attribute to its high melting point, highest density and high thermal conductivity (Smith, 1993; Patra et al., 2016). However, low performance and elevated ductile-brittle transition temperature (BDTT) (200–500 °C) of W is a significant problem in its application. In recent years, to improve the properties and applications, many efforts had been made to develop W based alloys. The work primarily focuses on goals such as improving productivity, especially at high temperatures and reducing the BDTT of W based alloys. Thereby, amorphous and nanocrystalline W alloys have gained much attention in recent years due to increased demand for better mechanical properties. The nanocrystalline materials possess high yield strength and hardness. Mechanical alloying is a good alternative for rapid-solid state synthesis of alloys to improve the mechanical properties of W based alloys through microstructural refinement (Suryanarayana, 1998; Kolia et al., 2014). High-energy ball milling is an appropriate alloying method based on economical, mass production and enhanced efficiency (Suryanarayana, 2001).

The consolidation of nanocrystalline W powder is difficult (Trazaska, 1996). Gurwell (1994) and Uray (2002) reported that the fabrication of W alloys requires a temperature above 2700 °C. A few studies reveal that pure W can be sintered at a lower temperature (~1800 °C) compared to 2700 °C by fabricating nanostructured W powder before sintering (Malewar et al., 2007). At high temperatures, volatile oxide forms at the tungsten grain boundary limit its application. It is therefore necessary, to form a protective film on the W surface at high temperature. The addition of alloying elements to the pure W enhanced the possibility of elevated temperature applications (Norajitra et al., 2004).

Ultra-fine and uniform Cr<sub>2</sub>O<sub>3</sub> and Y<sub>2</sub>O<sub>3</sub> dispersion into the W matrix inhibit grain refinement, reduction in sintering temperature and recrystallization temperature (Das, 2020; Patra et al., 2017; Aguirre et al., 2011). The oxide dispersion into the W matrix improves the creep resistance and high-temperature strength as it restricts the dislocation and grain boundary sliding. There is thermodynamical stability and least reaction to base metal owns to uniform oxide dispersion. Present works aim at the fabrication of Al<sub>2</sub>O<sub>3</sub> dispersed W-Zr alloys through mechanical alloying. The consolidated W based alloys are subjected to physical and mechanical characteristics.

### 2 EXPERIMENTAL PROCEDURE

Mechanical alloying of W powders (particle size (0.6–1 μm), Sigma Aldrich), Zirconium (Zr) powder (-325 mesh) and aluminum oxide (Al<sub>2</sub>O<sub>3</sub>) powder (particle size (<50 nm), Sigma Aldrich) was milled using a high energy planetary ball mill (Fritsch, Pulverisette 5). The detailed parameters used during milling are according to our recent report (Das, 2020). The milled powders of 0 h, 1 h, 5 h, 10 h, 15 h and 20 h was collected from the container for further study purposes.

The phase study of the powders was carried out through by X-ray diffractometer (Rigaku SmartLab) using Cu-K<sub>α1</sub> radiation ( $\lambda=1.54056 \text{ \AA}$ ), 20°–100° diffraction angle ( $2\theta$ ), scan rate 20°/min and 0.05° step size. The records were verified with the JCPDS data. The microstructure evolution at various milling hours has been carried out using a scanning electron microscope (SEM) (JEOL, JSM-6084LV). The energy dispersive spectroscopy (EDS) was used for the elemental analysis of the powders at different milled times. A nano zeta sizer (Model: Nano ZS, Malvern) was used to measure the particle size in the nanometer range of ultrafine particles in the nanofluid. A small amount (0.005g) of ultrafine powder particles has been dispersed in deionized water and ultrasonicated for 30 minutes each. The sample is then stored in the sample holder with the aid of a syringe and analyzed.

The 20 h mechanically milled powders were compacted into a cylindrical pellet of ~10 mm diameter using a hydraulic press with 5-ton pressure and 5 min of holding time without using any binders or lubricants to minimize impurities. The green pellets have been sintered conventionally for 1400 °C for 2 h. The sintered samples were taken out after the furnace cooling for further study.

The consolidated alloy was polished in emery paper followed by diamond polishing to eliminate the scratches before the SEM study. The hardness of the sintered alloys was evaluated using Vickers microhardness tester (Omni Tech) with 200 gf load and dwell time of 20 s on W matrix from edge to centre. The wear test of the sintered alloy was carried out using pin on disc (Ducom, TR-201) for 15 minutes at 360 rpm with 20 N and 30 N load. The worn-out surface morphology was observed through Field emission scanning electron microscopy (FESEM) (Model: SIGMA 300; Make: ZEISS).

### 3 RESULT AND DISCUSSION

#### 3.1. XRD of milled powder

Fig. 1 show the phase evaluation of 20 h mechanically milled powder as determined through XRD analysis. The XRD patterns revealed the presence of body-centered cubic (BCC) lattice W as major peaks due to major weight contains corresponding to  $2\theta$  values of 40.15°, 58.15°, 73.1°, and 86.85°. The peak intensity of Zr and Al<sub>2</sub>O<sub>3</sub> is very small due to their low content in the composition. The XRD analysis evident the formation of solid solution (W-Zr-Al<sub>2</sub>O<sub>3</sub>) at 20 h mechanically milled powder due to mechanical milling. The plot reveals a tungsten carbide peak which might be from the surface erosion of the ball during milling.

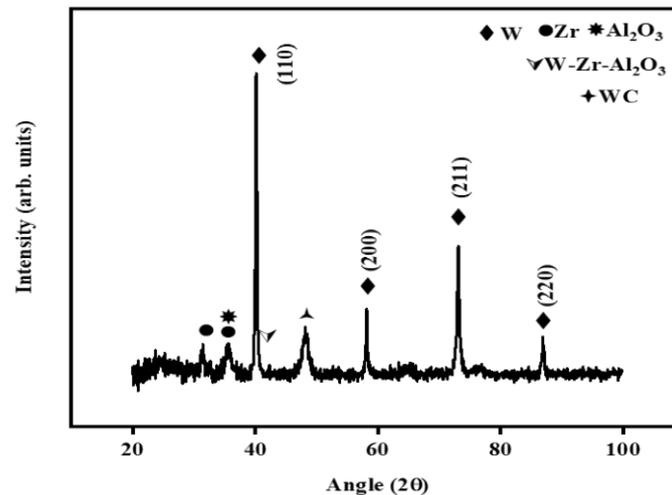
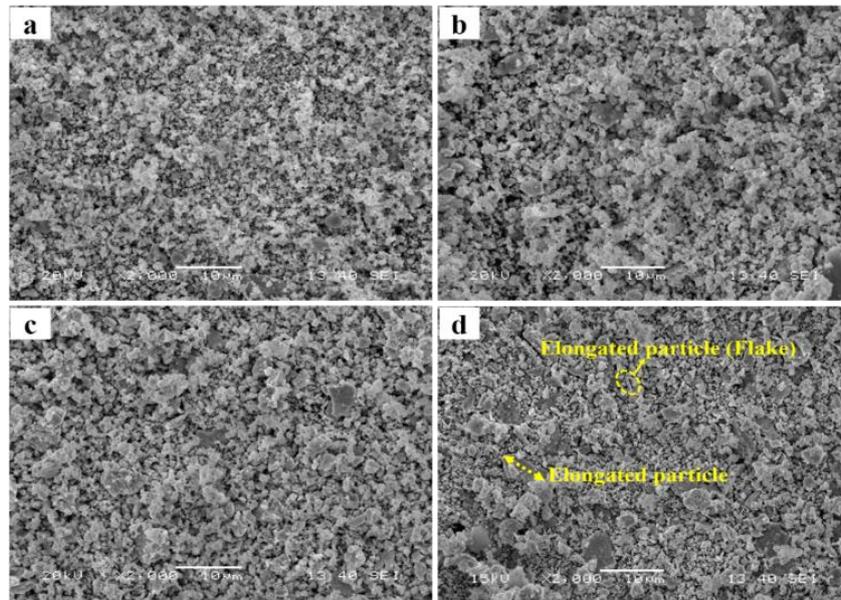


Fig 1: XRD patterns of 20 h mechanically milled powder

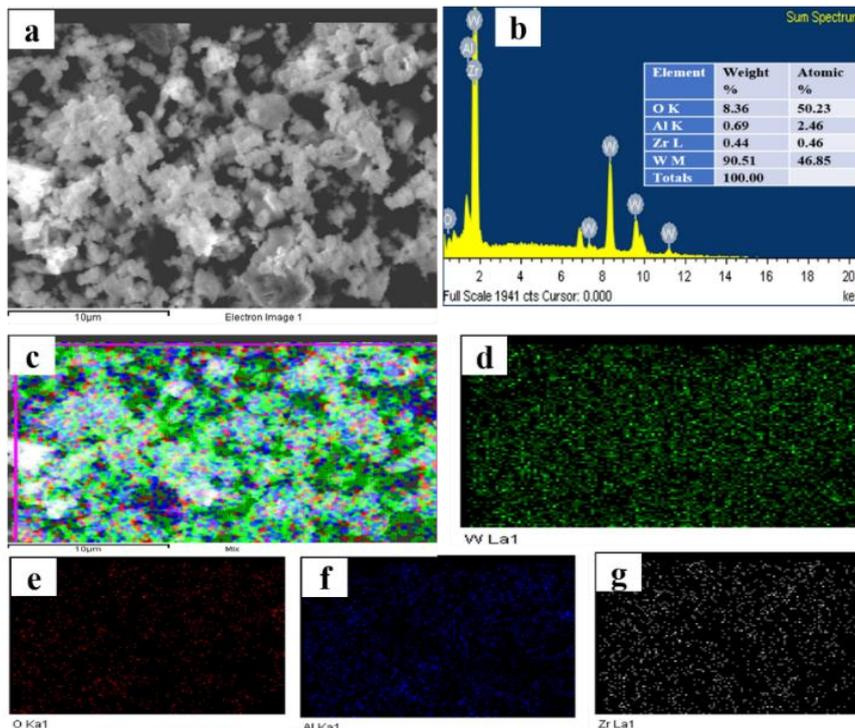
#### 3.2. Microstructure of milled powder

Fig. 2 shows the variation of particle size morphology of different milled hours. The particle morphology evident the presence of uneven shape and size before milling (Fig. 2(a)). The powder particles during mechanical milling undergo severe strain hardening, rupturing and fracturing due to fatigue failure. The development of new surfaces during fracture leads to agglomeration (cold welding), which is evident in 5–10 h of mechanical milling and form a new particle (Fig. 2(b–c)). So in the early stage of milling, because of the higher tendency of a particle to agglomerate, an extensive amount of new particles is formed. After 10 h of

milling due to lack of strong agglomeration force, milled fragments form without significant cold welding. The addition of toluene also reduces cold welding by hindering the surface of the particles. The diffusion of solute (Zr and Al<sub>2</sub>O<sub>3</sub>) into W lattice is higher as the mill time increase attributes to lowered diffusional distance for the formation of an alloy. The equilibrium between the fragmentation, alloying and cold welding of milled powders is attained at longer milling hours. The uneven and courser particles of 0 h is converted to elongated and flake shape morphology with regular size distribution at 20 h of milling (Fig. 2(c-d)). Figs. 3(a-f) shows the EDS analysis, which evident the elemental presence and heterogeneous distribution in the alloy.



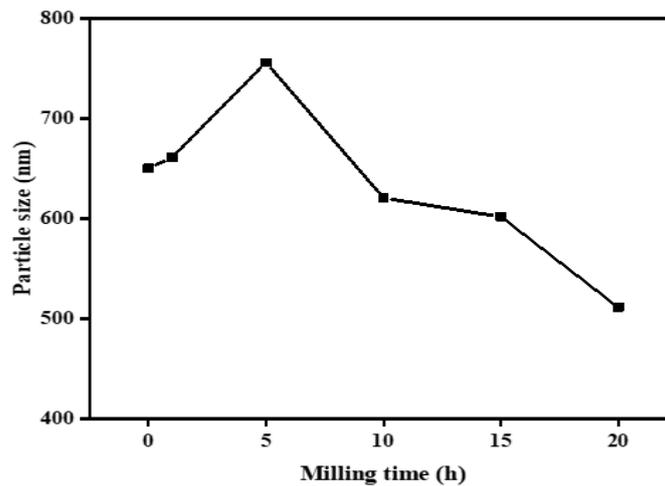
**Fig 2:** The powder morphology of different milled hours, (a) 0 h, (b) 5 h, (c) 10 h and (d) 20 h



**Fig 3:** (a) SEM morphology, (b) EDS and elemental distribution, (c) elemental mapping and corresponding maps of (d) W, (e) O, (f) Al and (g) Zr of 20 h milled powder

### 3.3. Particle size analysis

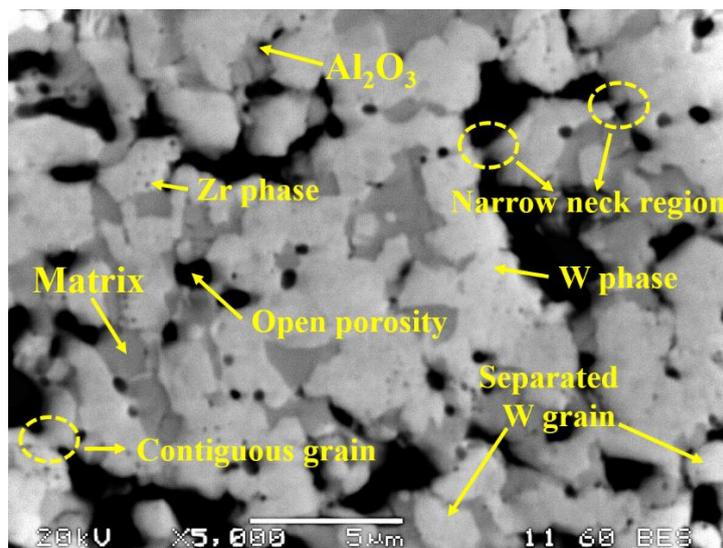
Fig .4 show the variation of powder particles size from 0–20 h. The mechanically milled powder morphology changes continuously throughout the milling process. During the initial hour of milling the particles size increases followed by the continuous reduction in size due to intense fracturing of powders. The increment in the particles size during the initial hour evident cold welding of powder. The minimum particles size of 511.62 nm was observed in 20 h milled powder compared to 650.52 nm at the initial hour before milling.



**Fig 4:** The particle size of different milling hours

### 3.4. Microstructure analysis of sintered alloy

Fig. 5 shows the SEM microstructure of W-Zr sintered alloy. It reveals the presence of different phases like W (white phase), Zr (grey phase) and Al<sub>2</sub>O<sub>3</sub> (dark phase). The open porosity was observed in the micrograph which is in lesser quantity. The pores can initially be irregular or spherical. The spherical pores are evenly filled with liquid, irregular pores, on the other hand, are preferably filled with an area with a small radius (Park et al., 1986). Both spherical, contiguous W grains and a few separated grains are also observed in the micrograph. In addition, the neck area between the grains is very wide and narrow due to the disparity in liquid phase formation. The fine and coarser grains distribution evident in the morphology is due to grain boundary pinning by dispersing Al<sub>2</sub>O<sub>3</sub> oxides at the W matrix boundary.

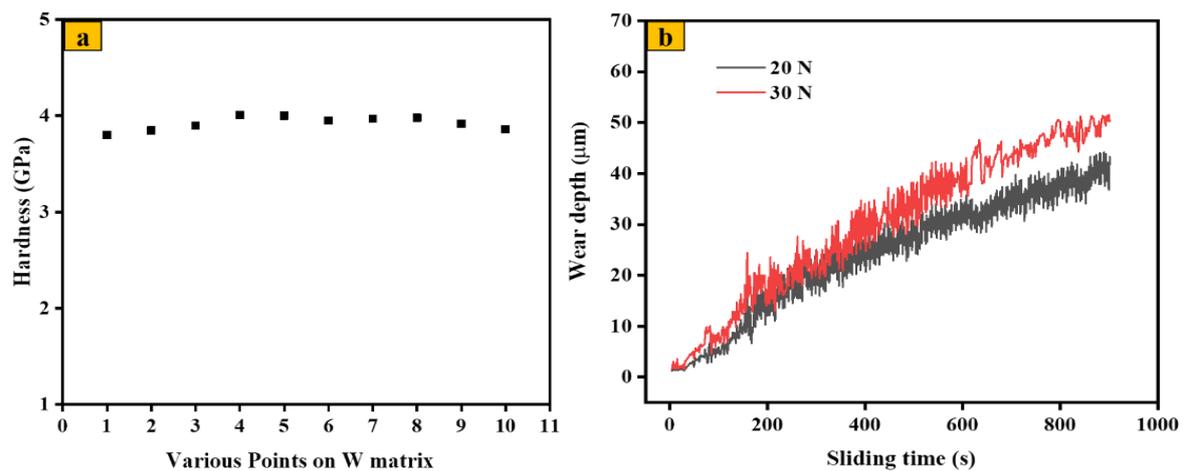


**Fig 5:** SEM microstructure of the sintered alloy

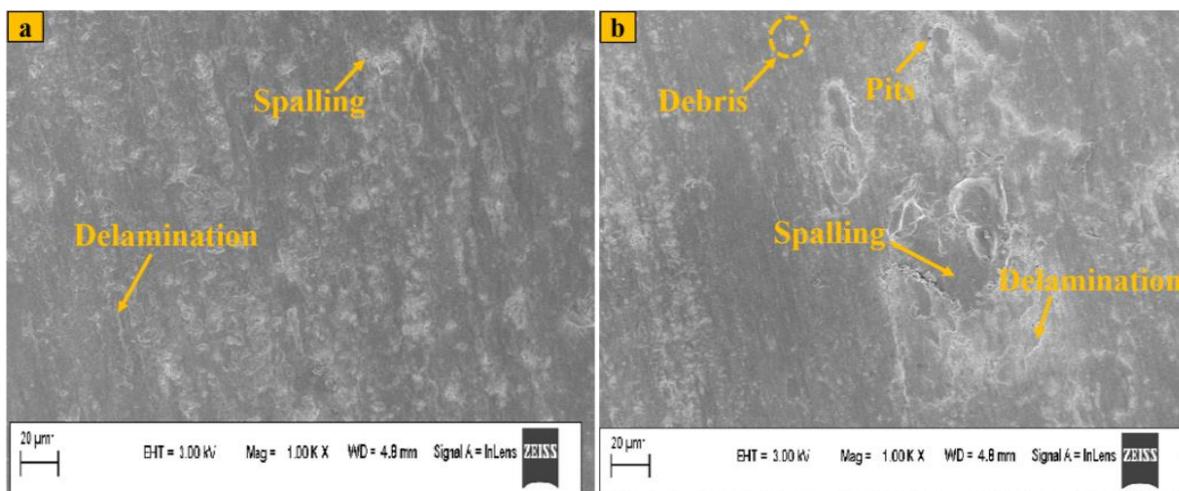
### 3.5. Evaluation of mechanical properties

Fig. 6(a) show the microhardness variation with 10 different indents along the cross-section of the sintered alloy. The microhardness is calculated basically on the W matrix from the edge to the centre. However, the hardness value is still varying, which is due to the heterogeneity in composition throughout the cross-section. The indentation was selected on the surface of the W matrix to minimize the effects of intermetallics on the hardness value. The maximum microhardness was measured to be 4.01 GPa. The achieved hardness is higher than the hardness observed in a few reports for W base alloy (Lin et al., 2002). The improvement in the microhardness can be attributed to the effects of dispersion strengthening due to Al<sub>2</sub>O<sub>3</sub> nanoparticles. The bimodal grain distribution and grain refinement due to the effects of mechanical milling also surplus the enhancement of hardness value in the sintered alloy.

Fig. 6(b) show the variation of wear depth versus sliding time at 20 N and 30 N loads. The wear depth increases with increasing test load. Fig. 7 display the FESEM micrograph of the worn surface of the sintered alloy. Abrasive wear properties such as spallation, pits and delamination are evident on the micrograph of the worn surface. During the abrasion wear phenomenon, the hard phases and Al<sub>2</sub>O<sub>3</sub> nanoparticles are removed from the matrix. A few reports suggested that substantial removal of hard particles could improve the wear through the three-body motion processes (Nuthalapati et al., 2015). The minimum mean wear depth of 24.42 μm was observed in the case of 20 N applied load compared to 30 N it was 30.35 μm. The rise in wear depth at a load of 30 N compared to 20 N is attributed to the presence of hard particles that are removed in the worn path, which leads to an increase in abrasion and wear loss.



**Fig 6:** The variation of (a) hardness, (b) variation of wear depth with the sliding time of the sintered alloy



**Fig 7:** The worn surface morphology of the sintered alloy, (a) 20 N applied load and (b) 30 N applied load



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### 4 Conclusion

Nanostructured novel W-Zr-Al<sub>2</sub>O<sub>3</sub> alloy was fabricated effectively through mechanical alloying followed by conventional sintering. The uneven powder particles of 0 h were converted to regular and uniform shape distribution after 20 h of milling. The minimum particles size of 511.62 nm was observed in 20 h milled powder compared to 650.52 nm at the initial hour before milling. The hardness of 4.01 GPa with significant wear resistance is achieved through dispersion strengthening effects of nano Al<sub>2</sub>O<sub>3</sub>.

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## Photovoltaic panel integration using phase-change material (PCM): Review

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### Abstract

Solar PV panels convert some solar radiation into electricity, while residual radiation raises the panel's surface temperature. This high operating temperature induces a loss of energy output and causes structural damage, which in turn reduces the average lifespan of PV modules. According to a study of various research, TES (thermal energy storage) is an effective way to collect and discharge waste heat from many thermal applications. PCMs are isothermal, so PCM have high energy storage capacity and operate over a wide temperature range. PCM requires enhancement in both the aspects of technical as well as economical. I examine the literature on PV-PCM systems and focus on material selection and technology improvement in this article. By the study of several types of research, we got that Organic PCM container with fins can primarily be used in the development of PV-PCM technology.

**Keywords-** Phase change material, Photovoltaic Panel, Solar Efficiency, Heat transfer.

### 1. INTRODUCTION

Renewable resources reduce fuel demand, ultimately lowers system maintenance costs, and reduces energy wastage. The photovoltaic panel absorbs approximately 27.6% of the radiation and the panel reflects the remaining radiation. The reflected radiation generates heat and raises the temperature of the panel. Various factors, such as tilt angle, wind speed, and dust build-up, will affect the panel surface temperature. Increasing the temperature of the photovoltaic surface will reduce the voltage drop in the photovoltaic panel, which will also affect the structural integrity. Due to the higher surface temperature, the conversion rate of photovoltaic panels is reduced by approximately 0.5%/°C above the nominal operating temperature of the panel which is 25°C defined by the industry standard.[1] Summertime temperatures vary between 40-70 degrees Celsius, causing the conversion rate to fall from 7.5% to 22.5%. Therefore, some techniques have been practiced on photovoltaic panels to control their temperature as minimal as possible. By increasing the heat transfer rate, the most widely used cooling technology in thermal engineering is adopted.

Storing renewable energy is the best way to utilize it. Energy storage is very economical because it can reduce costs and energy consumption.[2] Even after storing energy, we are not able to fully utilize sources due to losses. Temperature-controlled heat storage systems are categorized as SHS, LHS, and TCHS. When compared to SHS & LHS systems, LHS has a higher capacity for storing heat at the same temperature rise. And on comparing LHS and thermochemical heat storage (TCHS), TCHS gives high heat storage capacity but it is not controllable and takes too much time for the reverse process.[3] So LHS gives the best result for the thermal storage system, that's why LHS is mostly used in thermal management in many applications. PCM is the best example of an LHS system. During its phase transition, PCM stored a significant amount of heat. In this paper, we studied pcm based photovoltaic panels (PVPCM system).

### 2. RESEARCH BACKGROUND

Solar application efficiency decreases mainly due to high surface temperature. For better performance temperature should be low by the cooling of the panel. Air-based, water-based, heat pipe and PCM are the main techniques for the cooling process.[4] Researchers are using PCM for solar system cooling to get better performance. The first experimental test by Huang et al in which a building-integrated solar panel with PCM mounted system is presented, this experiment represents a comprehensive evaluation of the PV-PCM module. In this experiment RT25 as PCM was stored in an aluminous container and fins to maximize thermal capacity. After the experiment, they got that the 30mm PCM layer decreases the front surface heat from 45°C to below 35°C, and the 20mm layer thickness maintains below 36.4°C. [5] Many researchers used this as a reference, as the reference many types of research done with different parameters like with many other PCM's, in different climates/weather, and by changing some technology in it for better enhancement.



Nada experimented on building an integrated photovoltaic panel with PCM RT55 and 2% Al<sub>2</sub>O<sub>3</sub> nanoparticles to improve the thermal conductivity of PCM. Panel front surface temperature rises from 50°C to 75°C after installing the free stand, PCM box front surface temperature rises from 50°C to 59°C. After the experiment overall, daily average efficiency improved by 7.1%. [6] Nasrin Abdollahi used a zigzag vessel to increase the heat transfer area. The vessel consists of composed oil and Boehmite. Nasrin concludes that oil with nano capsulated PCM is more effective than composed oil only. [7] N Soares compare horizontal, vertical, and normal aligned thermal energy storage. Movable TES with PCM RT22HC experimented, he got that energy produced by the reference panel is greater than the horizontal and vertical. [8] K Senthil Kumar used nano PCM's of Cu, SiC, and Calcium Carbonate in PV-PCM technology. Experiment shows that temperature drops of 4-5°C occur and 4.3% performance enhancement. [9] Rajvikram did experimental work for two days with organic PCM OM29; he used the aluminum sheet to increase thermal conductivity. He got that average conversion efficiency increased up to 24.4% and an average temperature drop of 10.35°C. [10] Nikolaos compared two experimental setups in the Mediterranean climate; he used a copper plate for thermal conductivity enhancement and a copper tube as external fins. In comparing PV with RT27 PCM and PV with RT31 PCM, he got that energy generation of RT27 & RT31 PCM panel increases by 4.19% & 4.24%, respectively, and conversion efficiency increased from 2.86% to 4.19%. [11] Jasim M. Mahdi used multiple PCM for thermal conductivity enhancement. His experiment used three setups; in the first PV-PCM setup, he used RT35, second with RT26 and RT42 layer, and third with RT26, RT35, and RT42. All layered PCM arranged in heat flow direction according to their melting temperature ascendingly; that is why melting time of PCM increased up to 18% and thermal management duration up to 33%. [12] Shastry used a metal matrix in a honeycomb structure and aluminum tube to enhance the heat transfer rate. He also compared three standard PV panels, PCM with PVT and PVT with PCM and aluminum metal matrix. PVT with PCM increases thermal efficiency from 6.4% to 42%, and metal matrix PVT with PCM shows a 7.1%-48.5% increase. [13] S. Adibpour used a sun-tracking solar panel with PC29 PCM. He got that the sun-tracking panel gives a better result than the fixed panel researched in his previous experiment. Sun tracking experiment gives 4.6% average efficiency enhancement and a maximum 6.8% enhancement. Furthermore, an average temperature drops of 9.1°C was found. [14] P. Sudhakar used OM35 PCM at the back of the panel and used a water channel to enhance the heat transfer rate. He experimented with three types of water supply in the PV-PCM system, top to bottom continuous flow, bottom to continuous top flow, and periodic water flow. In the end, he got that top to continuous bottom flow to give better results than others; the average temperature drops up to 5.4°C and electrical efficiency improved up to 12.4%. [15] Mauricio used a hybrid solar module with PCM RT35. This experimental setup uses a copper coil in direct contact with PCM and the water supply channel to enhance the heat transfer. He got that temperature drop of 10-17°C and 7.43% electrical efficiency enhancement per day. The result shows that 20.45% more energy is extracted from solar radiation by the hybrid panel than the traditional panel. [16] Sachin V. Chavan compared two panels with standard PV panels. One was PV with PCM (Petroleum jelly) stored in a triangular fins container, and another one was a PVPCM system with water supply in copper pipes to enhance heat transfer rate. Results show that 8.10% heat reduction in PVT-PCM system compared to standard panel and 4.06% higher electrical power in water-based PVT-PCM system compared to the standard one. [17] Rishabh Sharma experimented in two climatic conditions; he compared water-cooling-based PV panel and PCM-mounted PV panel with the standard panel. He got that the PVPCM system gives better results than another one. In January at Jaipur, electrical efficiency increased up to 7.95%, and at Dwarahat Uttarakhand, electrical efficiency increased up to 10.2%. [18] Manoj Kumar used paraffin wax with 0.5% TiO<sub>2</sub> nano-PCM for thermal conductivity enhancement. The result shows that PV with nano PCM enhances panel efficiency up to 2.1% and gives a temperature drop of 13°C. [19] Preeti Singh experimented with a CaCl<sub>2</sub>.6H<sub>2</sub>O (Calcium Hexahydrate) PCM-filled container attached at the back of the PV module. She got that temperature drop from 64.4°C to 46.4°C at January and from 77.1°C to 53.8°C at June. Electrical generation increased by 6.2% daily in January and 8.3% daily in June. [20] Abdulmunem analyzed the effect of tilt angle (0° to 90°) on Paraffin PCM mounted PV panel. He got that on tilting panel (90° to 0°) melting time of PCM increased, showing the temperature drop from 0.4% to 12%. [21]. All these researches are summarised in Table (1).

Table 1 Summary table of above research on PV-PCM technology

S.n	PCM CONSIDERED	MELTING TEMPERATURE (°C)	LATENT HEAT (KJ/KG)	MODE OF RESEARCH	METHODOLOGY	RESULT	REFERENCE
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1.	Paraffin wax + 0.5% TiO <sub>2</sub>	52	140	Experiment	Nano PCM container attached PV panel used	Temperature drops of 13°C and daily efficiency increased up to 2.1%	[19]
2.	RT20	20	155	Experiment	PV attached PCM in tin container and PV system with water-based cooling technique used	Electrical efficiency increased in January at Jaipur up to 7.95% and at Dwarahat Uttarakhand up to 10.2%	[18]
3.	Paraffin	46.9°C-59°C	154.4	Numerical + Experimental analysis	Analysis based on PV-PCM system with different tilt angle 0°C to 90°C	Temperature drops from 0.4% to 12% and tilt of system increased melting time of PCM	[21]
4.	White petroleum jelly	36°C-60°C	-	Experiment	PCM in aluminium container with triangular fins attached with PV panel and PV-PCM with copper pipe for water supply	Electrical efficiency increased up to 4.24% and temperature reduction 8.10%	[17]
5.	RT35	35	160	Experiment	PCM with direct contact with copper coil attached at PV panel and water supply through aluminium channel	Electrical efficiency increased up to 7.43%/day and temperature drop from 10°C to 17°C	[16]
6.	OM35	35	197	Experiment	PV-PCM with water supply through aluminium chamber	Electrical efficiency increased 12.4% and avg. temperature drop of 5.4°C	[15]
7.	PC29	29	188	Experiment	Sun tracking Panel with PCM	Avg. efficiency increased 4.6%, and avg. temperature drop of 9.1°C	[14]
8.	RT26, RT35, RT42	26,35,42	180,160,165	Numerical Simulation	Multiple PCM used with three different PV setup	PCM melting time increased 18%, Thermal management duration increased 33%	[12]
9.	CaCl <sub>2</sub> .6H <sub>2</sub> O	30	191	Experimental	PCM filled aluminium containers attached at back of PV panel	Temperature drops from 64.4°C to 46.4°C in January and 77.1°C to 53.8°C in June. Electrical efficiency increased from 9.5% to 10.5%	[20]
10.	OM47	48	196	Experiment	Honeycomb structure metal matrix used at PVTPCM container and Aluminium tube with PVTPCM used	Thermal efficiency by PVTPCM setup increased from 6.5% to 42% and PVTPCM with matrix increased from 7.1% to 48.5%	[13]

11.	RT27, RT31	25-28,27-31	179,165	Experiment	PV attached PCM filled copper plate container and copper tube used as fins	Conversion efficiency increased up to 2.86% to 4.19%	[11]
12.	Composed Oil (Coconut oil, Sunflower oil), Boehmite nano powder	25-26	308	Experiment	Zig-Zag geometry PCM container attached with PV panel	Only oil efficiency enhancement 21.19%,26.88%,29.24 % and by adding Boehmite nano powder efficiency increased to 44.74%,46.63%,48.23 %	[7]
13.	RT22HC	22	190	Experiment	Movable thermal energy storage system used with PV panel	Reference PV panel give more energy output than vertical & horizontal.	[8]
14.	Nano PCM's of CU, SIC and Calcium Carbonate	36-60	-	Experiment	PV system integrated with PCM at the backside of panel	Surface temperature DROP FROM 48.6 to 45 and average efficiency of panel increased up to 4.3%.	[9]
15.	OM29	29°C	229	Experiment	PV with PCM in aluminium sheet container	Avg. panel temperature drop 10.35°C, Avg. conversion efficiency increased to 24%	[10]

### 3. Research Methods

PCM is used for LHS systems. Telks and Raymond laid the foundation of the study of phase change material.[22] PCM is a material that, depending on its temperature, undergoes a reversible phase transition. During the process, it tends to absorb or releasing heat.[23] When the temperature rises, the chemical bond between molecules breaks, resulting in a transition from one phase to another. During the phase change process, it absorbs heat from the contact surface. Fig (1) shows the thermal cycle of PCM.

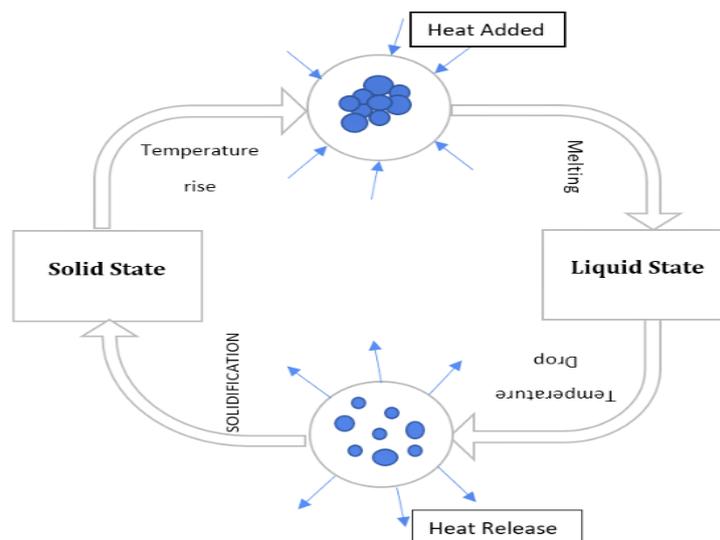


Figure 1 Thermal Cycle of PCM

### 3.1 Classification of PCM

PCM changes its state after attaining heat and vice versa. Figure (2) shows the classification of PCM based on the transition of phase. This is the one way of classification, PCM can be classified in different ways such as according to phase transition temperature it can be divide into three types i) Low-temperature range: where PCM's phase transition temperature below 15°C, ii) Mid temperature range: where phase transition temperature

lies between 15-90°C, iii) High-temperature range: where phase transition temperature above 90°C.[24] On the market, there are many distinct types of PCM available with various heat capacities, melting temperatures, and freezing temperatures. Organic, inorganic, and eutectic are the three types of PCM available.[25]

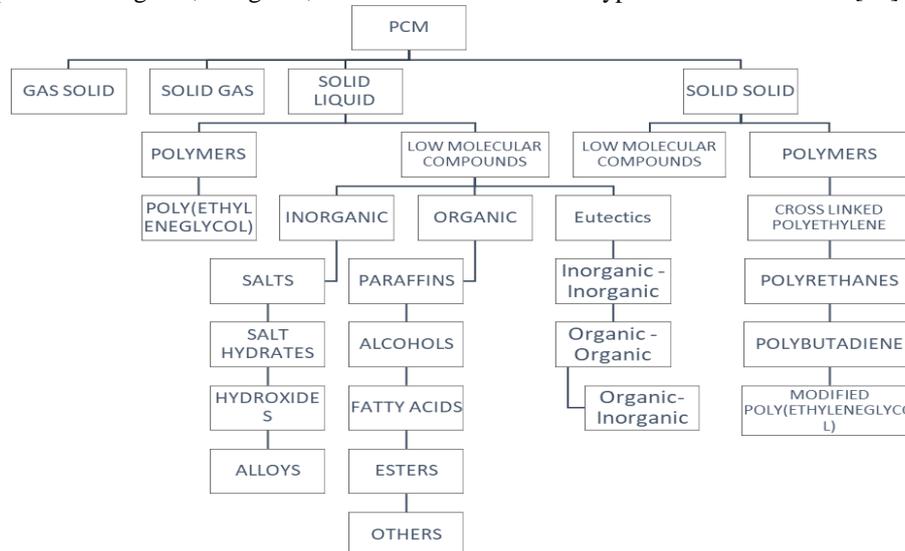


Figure 2 Classification of PCM

### 3.1.1 Organic PCM

Organic PCMs were associated with a broad variety of components includes paraffin, fatty acids, and their eutectic mixes, esters, and other organic substances. Due to its high heat of fusion, fluctuating stage change temperature, zero supercooling properties, lower vapor pressure, chemical inertness, and continuous conductivity, among other important properties, paraffin has been used for energy storage.[26] In commercial organic heat storage, paraffin wax is the most prevalent kind of paraffin. [27] They're recognized for being chemically inert and stable below 500 degrees Celsius. In addition to paraffin, the organic PCM subgroup also includes a fatty acid. They are produced by hydrolysis of plant and animal waste, that's why fatty acids are also known as renewable PCM. In comparison to other phase transition materials that have been considered and researched, fatty acids have good chemical and thermal characteristics, negligible toxicity, melting compatibility, have proven appropriate for melting temperature range for a few heat storage applications, and biodegradability.[28] They can undergo melting and freezing cycles that acquire a variety of materials if they are not subjected to thermal deterioration. They were chosen for their superior thermal and physical characteristics, as well as their ease of inclusion into complex structures.

### 3.1.2 Inorganic PCM

Inorganic PCMs have a higher heat conductivity and storage capacity (about double that of organic PCMs). Salt hydrates and metals are two standard classifications. The phase transition in salt hydrates, which includes the disappearance of a significant amount of water, is essentially comparable to the thermal process of melting in other substances. Nucleating chemicals were blended with salt hydrates to overcome the limited nucleating capacity problem, which results in substantial supercooling.[29] Despite these disadvantages, salt hydrates were often recognized as ideal materials for TES applications due to their high latent heat of fusion, an appropriate phase transition temperature, and substantial cost-effectiveness and profitability.[30] Metals are also seen in inorganic PCMs. Metal alloys with melting points in the 400–1000°C range have been used in extremely high-temperature systems.[31] They can be used in integrated pv module in the form of high-temperature PCMs.

### 3.1.3 Eutectic PCM

It is a combination of two PCM's, Organic-inorganic, organic-organic, inorganic-inorganic. The characteristics of eutectics are remarkable. Eutectic mixtures' melting and freezing temperatures are often lower than their components' melting and freezing temperatures. During the phase transformation process, it does not break down into its components. The most frequent kind is inorganic-inorganic eutectics. Recent studies have focused on organic-inorganic and organic-organic variants.

### 3.2 Selection of PCM

The PCM, a crucial component in forming the LHSU, has a significant impact on the LHSU's proper operation. The usefulness of a particular PCM to LHSU depends on the PCM's thermophysical, kinetic, and chemical properties. Since no one substance has all the desired properties for the best heat storage medium, it is essential to make the best use of available materials, and at the same time, do everything possible to effectively compensate for the physical characteristics existing in the system design. That's why the selection of suitable PCM is the most significant barrier for researchers. PCM selection is based on the need depends upon various parameters[29], [30], [32], [33]:

- i. **Thermal Properties:** These are primary properties, so high energy storage density, high thermal conductivity, desired melting, and freezing temperature should be considered.
- ii. **Physical Properties:** PCMs are dependent on the PV systems collectively. High-density PCM should be selected for low container volume. But density variation of material should be low to reduce the change in physical structure.
- iii. **Chemical Properties:** Properties of PCMs should not degrade early on the freezing/melting cycle. It should not possess corrosive effects with containers and PCMs should be chemically stable. It should not be poisonous and free of fire risk.
- iv. **Kinetic Properties:** High nucleation rates and crystal growth rates. i.e., at the thermodynamic freezing point, the melt should crystallize. And heat transfer rate especially in isothermal conditions should be effective.
- v. **Economical:** Material must be cost-effective and easily available in abundant quantity.

For thermal management, PCM is used in many applications like PCM walls to maintain building temperature, smart textiles, solar energy storage, food industry, space application, electronics, automotive industry, etc.[34] According to study in decades many types of research done on PV panel surface cooling with the help of different types of PCM but still didn't get the perfect result.

### 4. Result and Discussion

By the study of several types of research, we got that PV module efficiency can be enhanced by attaching heat storage to increase the system's thermal capacity and by lowering the temperature of the rear surface for PV modules.

- i. To increase the thermal capacity of the system PCM filled containers or heat pipes are used. We have to concentrate on making greater use of the attached PCM. We have to use PCM with a significant heat storage property, chemically stable, non-corrosive, and give good performance in a repeated number of cycles. The thermal conductivity of PCM can be increased by adding some additives into it such as low-cost metal powders and nano-pcm PV-PCM setup should be simple structured and keeping in mind that this hybridization should not increase total costs.
- ii. Surface overheating can be reduced by using water flow through the rear surface. Surface cooling of the panel through naturally flow of air but it's not sufficient, to lower the more solar heat's access temperature, continuous water circulation is created at the backside of the PV using metal pipes (mostly copper tubes) that serve as a heat exchanger. And also, to increase heat transfer rate metallic fins in the container are used which is more effective.

The efficiency of the panel depends on panel surface temperature; more surface temperature drops can create a more effective PV-PCM system with great output. The findings of the research mentioned above indicate that PCM is effective for efficiency enhancement. Such systems are financially feasible in medium temperature and sun irradiation environments, as well as with the lowest PCM combination and pollution-free operation with minimal space requirements.

Most of the current research has concentrated on the use of organic PCM. Organic PCM gave better results than other PCM due to its property but it has also disadvantaged, such as low thermal conductivity they are slightly costlier than inorganic. So, the problem of low thermal conductivity can be overcome by adding some additives to it. Whereas inorganic PCM has good thermal conductivity and is cheaper than organic PCM but they are not stable for a repeated number of cycles. That's why organic PCM is the better option with some improvement in that.

### 5. Conclusion

This article offers a literature analysis of various methods for efficiency enhancement of PV panels, with the assistance of various kinds of PCM. All of the various current technologies and PCMs were discussed in-depth above. Because there are certain limits to utilizing other PCM, such as supercooling, phase segregation, lack of

thermal stability, corrosion effect with some metals, and they are a little poisonous. But PCM can store a large amount of excess heat on panel surface which will help to improve panel efficiency.

- Organic PCM can overcome the disadvantages stated above as compared to the other PCM-based method. We can use organic PCM primarily in the development of PV-PCM technology.
- The heat transmission rate is also increased when fins are installed in PCM containers. To make a cost-effective setup, aluminium containers with aluminium fins are mostly used.
- External cooling sources, such as forced flow water supply through tubes, provide greater cooling results.

As a result, we can conclude that we can work on PCM selection for improved performance with new methods since PV-PCM technology may be the main source of energy production that is both cost-effective and long-term.

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