ANALYSIS OF CHASSIS FRAME FOR SOLAR VEHICLE

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ABSTRACT

The automotive industry is one of the largest and most widely spread industries. However, due to growing concerns caused by fossil fuel emission the industry is shifting to alternate sources of energy. Of these, solar energy is one form that has seen large growth in usage around the world as well as in the recently growing electric vehicle industry. The development of a fully solar powered electric car has been an ongoing process with various organizations around the world doing research for the most optimal version. However, most of these vehicles require expensive customized parts. This work gives an introduction to the design and analysis of a solar-electric car that is completely fabricated through off the shelf parts which undergo minor modification in order to be fit to the frame.

Keywords— *Solar car, NSVC,*

I. INTRODUCTION

A solar car is a solar vehicle used for land transport. Solar cars are usually run on only power from the sun, although some models will supplement that power using a battery, or use solar panels to recharge batteries or run auxiliary systems for a car that mainly uses battery power. Solar cars combine technology typically used in the aerospace, bicycle, alternative energy and automotive industries. The design of a solar vehicle is severely limited by the amount of energy input into the car. Most solar cars have been built for the purpose of solar car races. Some prototypes have been designed for public use, although no cars primarily powered by the sun are available commercially. Solar cars depend on a solar array that uses photovoltaic cells (PV cells) to convert sunlight into electricity. Unlike solar thermal energy which converts solar energy to heat, PV cells directly convert sunlight into electricity.[1] When sunlight (photons) strike PV cells, they excite electrons and allow them to flow, creating an electric current. PV cells are made of semiconductor materials such as silicon and alloys of indium, gallium and nitrogen. Crystalline silicon is the most common material used and has an efficiency rate of 15-20%.

WHY SOLAR?

- One of the biggest concerns today is the problem of power production causing pollution by the use of fossil fuels
- The solution for using of polluted plug in electric source is Solar energy. When these types of vehicles are charged through solar power it becomes a complete environmental eco-friendly Vehicle.

EVOLUTION

The first solar car invented was a tiny 15-inch vehicle created by William G. Cobb of General Motors. Called the Sunmobile, Cobb showcased the first solar car at the Chicago Powerama convention on August 31, 1955. The solar car was made up 12 selenium photovoltaic cells and a small Pooley electric motor turning a pulley which in turn rotated the rear wheel shaft. The first solar car in history was obviously too small to drive. Now, let's jump to 1962 when the first solar car that a person could drive was demonstrated to the public. The International Rectifier Company converted a vintage model 1912 Baker electric car to run on photovoltaic energy in 1958, but they didn't show it until 4 years later. Around 10,640 individual solar cells were mounted to the rooftop of the Baker to help propel it. In 1977, Alabama University professor Ed Passerini built the Bluebird solar car, which was a prototype full scale vehicle. The Bluebird was supposed to move from power created by the photovoltaic cells only without the use of a battery. The Bluebird was exhibited in the Knoxville, TN 1982 World's Fair. Between 1977 and 1980 (the exact dates are not known for sure), at Tokyo Denki University, professor Masaharu Fujita first created a solar bicycle, then a 4-wheel solar car. The car was actually two solar bicycles put together. At the engineering department at Tel Aviv University in Israel, Arye Braunstein and his colleagues created a solar car in 1980. The solar car had a solar panel on the hood and on the roof of the City car comprised of 432 cells creating 400 watts of peak power. The solar car used 8 batteries of 6 volts each to store the photovoltaic energy. In 1981 Hans Tholstrup and Larry Perkins built a solar powered race car. In 1982, the pair became the first to cross a continent in a solar car, from Perth to Sydney, Australia. Tholstrup is the creator of the World Solar Challenge in Australia.

In 1984, Greg Johanson and Joel Davidson invented the Sunrunner solar race car. The Sunrunner set the official Guinness world record in Bellflower, California of 24.7 mph. In the Mojave Desert of California and final top speed of 41 mph was officially recorded for a "Solely Solar Powered Vehicle" (did not use a battery). The 1986 Guinness Book of World Records publicized these official records. The GM Sunraycer in 1987 completed a 1,866 mile trip with an average speed of 42 mph. Since this time there have been many solar cars invented at universities for competitions such as the Shell Eco Marathon. There is also a commercially available solar car called the Venturi Astrolab. Time will only tell how far the solar car makes it with today's and tomorrow's technology**.**

II. MATERIALS

2.1 Batteries

The battery pack in a typical solar car is sufficient to allow the car to travel about 250 miles (400 km) without any sunlight, and allow the car to maintain and average speed of approximately 60 mph (97 km/h).

2.2 Motors

There are no restrictions on the type of motor used in a solar car. They are generally rated between 2 and 5 hp. The most common type of motor used in solar cars is the dual-winding DC brushless. A DC brushless motor is fairly lightweight and can reach efficiencies of 98% at their rated rpm, however they are quite a bit more expensive than a typical brush type DC motor.

2.3 Telemetry

To keep the car running smoothly, the driver must monitor multiple gauges to spot possible problems. Cars without gauges almost always feature wireless telemetry, which allows the driver's team to monitor the car's energy consumption, solar energy capture and other parameters and thereby freeing the driver to concentrate on driving.

2.4 Solar cells arrangement

The solar array consists of hundreds of solar cells converting sunlight into electricity. In order to construct an array, PV cells are placed together to form modules which are placed together to form an array. The larger arrays in use can produce over 2 kilowatts (2.6 hp).

The solar array can be mounted in six ways:

- horizontal. This most common arrangement gives most overall power during most of the day in low latitudes or higher latitude summers and offers little interaction with the wind. Horizontal arrays can be integrated or be in the form of a free canopy.
- vertical. This arrangement is sometimes found in free standing or integrated sails to harness wind energy. Useful solar power is limited to mornings, evenings, or winters and when the vehicle is pointing in the right direction.
- adjustable. Free solar arrays can often be tilted around the axis of travel in order to increase power when the sun is low and well to the side. An alternative is to tilt the whole vehicle when parked. Two-axis adjustment is only found on marine vehicles, where the aerodynamic resistance is of less importance than with road vehicles.
- integrated. Some vehicles cover every available surface with solar cells. Some of the cells will be at an optimal angle whereas others will be shaded.

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- trailer. Solar trailers are especially useful for retrofitting existing vehicles with little stability, e.g. bicycles. Some trailers also include the batteries and others also the drive motor.
- remote. By mounting the solar array at a stationary location instead of the vehicle, power can be maximized and resistance minimized. The virtual grid-connection however involves more electrical losses than with true solar vehicles and the battery must be larger.

The choice of solar array geometry involves an optimization between power output, aerodynamic resistance and vehicle mass, as well as practical considerations. For example, a free horizontal canopy gives 2-3 times the surface area of a vehicle with integrated cells but offers better cooling of the cells and shading of the riders. There are also thin flexible solar arrays in development. Solar arrays on solar cars are mounted and encapsulated very differently from stationary solar arrays. Solar arrays on solar cars are usually mounted using industrial grade double-sided adhesive tape right onto the car's body. The arrays are encapsulated using thin layers of Tedlar. Some solar cars use gallium arsenide solar cells, with efficiencies around thirty percent. Other solar cars use silicon solar cells, with efficiencies around twenty percentage.

III DESIGN GOALS AND SPECIFICATIONS

3.1 Frame

- Structure should be light in weight
- Should bear weight up to 250kgs (kerb weight)
- It should hold suspension as per requirement
- No sharp edges and corners
- Safety when frontal impact
- Easy design for escape of driver
- Material :- hard steel , Iron tubes , aluminum Sheets
- Wheelbase of 40 to 70 inches i.e.., 1.7 meters
- Driver to components clearance
- Good ground clearance

3.2 Vehicle weight

- Vehicle weight including battery, panels, motor, seats, suspension, steering system, wiring should be 250KG including driver 340 kg
- Even 1 Kg is more than the given limits, it will lead to disqualification.
- So each part which is chosen for manufacturing should be calculated.

3.3 Suspension

- Suspension should bear all the weight of the vehicle and good shock absorbing capacity with light weight.

- It should protect the solar panels from the jerks & jolts.
- It should withstand any terrain.
- Front suspension should be individual & rear dependent if four wheeler.

3.4 Steering system

- It should compulsory control two wheels of front side.
- Steering full turn lock is compulsory both RH, LH side.
- It should adjust with suspension.

3.5 Brakes and axles

- Brakes should work efficiently as test to stop at 40KM speed within 20 feet of application.
- It should be fitted to two wheels for sure i.e front or rear based on our construction.
- Electronic switch to be installed for emergency brake failure (magnetic switch).

3.6 Front body

- Team name (Fight Fossil 2K18) and logo(under design) should resemble in front portion

3.7 Power transmission

- Arma class is chosen we can use with 2 KW capacity and upto 60 V DC with maximum 70 AH batteries. Transmission can be used of our choice., It should be fixed and visible when inspection time., Also safety of driver is must., Reverse gear is mandatory.

3.8 Electrical system

- It must include at least two power sources:

1). Battery pack: Motor, controller, Brake light and all other equipment should use this power system

2). Solar power: To charge batteries and supply power for vehicle to run directly on solar. (big challenge)

- The brake light, and any reverse light and alarm, must be powered whenever the vehicle is in motion

Based on all the above goals we went on to design a frame in SOLIDWORKS 2019 and performed analysis of the frame in ANSYS 14.5.

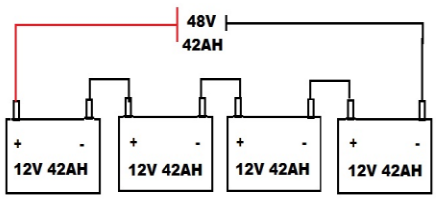

Fig.1 Series connection between the batteries

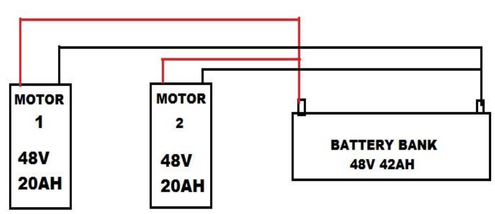

Fig.2 Connection between motor and battery

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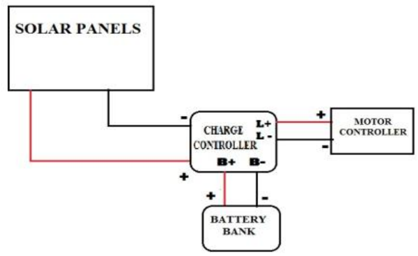

Fig. 3 Complete schematic of the vehicle

4. ANALYSIS RESULTS AND DISCUSSION

4.1 Monocoque unit body frame

From the limited space available in the body and aerodynamic design of the solar car it would prove difficult to use the ladder and space frame concepts. The ladder frame uses too much material with the majority of materials not performing any significant structural work in providing torsional stiffness. The space frame could provide the necessary torsional stiffness, but will prove difficult to assemble in the limited space inside the body of the solar car.

Thus it can be concluded that using the integrated body and frame (Monocoque) concept for its superior weight saving and structural properties is the right direction to move it

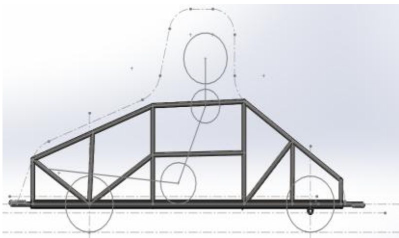

Fig.4 Side view of frame

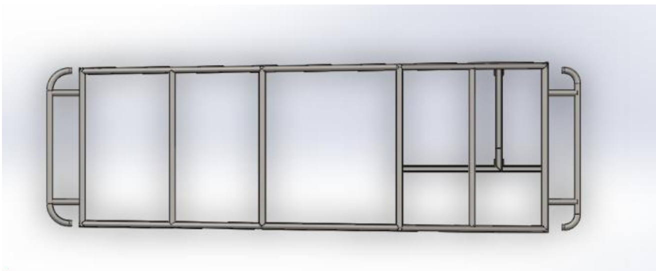

Fig.5 Top of Frame

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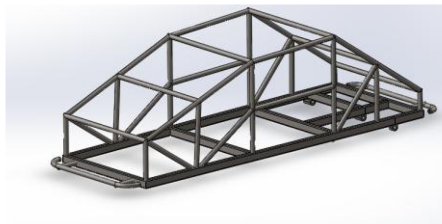

Fig.6 Isometric View of Frame

After the concept selection was done, based on the literature study and the preferences of the team, the next step is the design and analysis of the structure. To do this, an understanding of the operating loads it will be subjected to, will be discussed in this chapter. The loads are used to analyse the structure in order to define the composite material layup. The shape of the frame to be integrated into the body will be defined in this section, with motivation for its use.

4.2 Load cases

The first step to designing a vehicle frame, or any structure, is to understand the different loads acting on the structure .The loads imposed on the vehicle are formulated by considering the normal running conditions of the car by defining the loads in the list given below. The load cases can be formulated for the analysis of the frame.

The following list can be used to define the load cases for the analysis of the solar car frame:

- **Vertical bending**: The vertical bending acting on the frame is due to the weight of components and the driver in the interior of the car body. This force is always present even if the vehicle is not in operation making it the least critical of the loads acting on the frame.
- **Torsional loads**: Torsional loads on the frame are due to any road imperfections encountered during the normal operation of the solar car. These imperfections can include potholes and road bumps that cause one wheel of the car to lift higher than the other wheels or to leave the surface of the road inducing a torsional load on the chassis.
- **Vertical load**s: The vertical loads are caused by road imperfections at the suspension mounting locations. Imperfections such as bumps in the road surface, also known as bump loads.
- **Lateral loads**: The lateral loads on the vehicle are caused by the car turning around a corner or by sliding across the road surface.
- **Longitudinal loads:** These loads are induced by the vehicle during acceleration and breaking. The loads act on the mounting locations of the suspension in a forward or aft direction.

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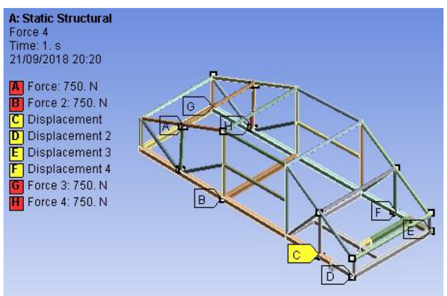
- **Impact loads:** Impact loads are mainly considerations for the event of an accident, where the car may experience impacts from the front, rear, or sides of the vehicle. These are provided by the race organisation as multiples of the car weight.

By calculating the weight distribution of the vehicle, the load cases mentioned can be expressed as multiples of the weight on the individual wheels or application points of the frame and these values comply with SAE (Society of Automotive Engineers) standards .These values are given in the table below along with the loads supplied by the race regulations to insure the safety of the roll bar:

Loads and dynamic load multipliers

Bump load vertical 4, Bump load longitudinal 3, Cornering load 1, Braking and acceleration 1, Front impact 5, Rear impact 5, Side impact 5, Roll bar vertical [N] 16300, Roll bar horizontal (Fore and aft) [N] 12300, Roll bar lateral [N] 3300.

4.3 Bump impact



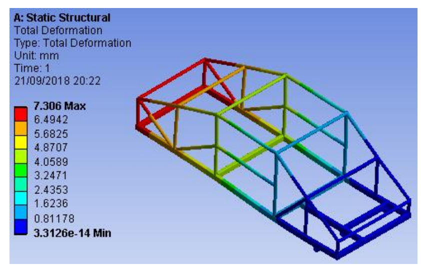


Fig.8 Total deformation of the members of the frame

Fig.7 Force and displacements on the frame members

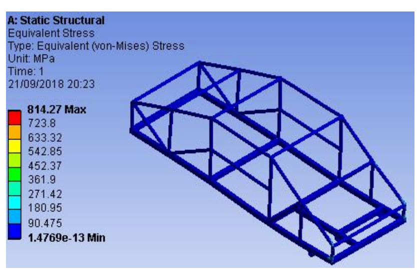


Fig.9 Equivalent Von-mises stresses in different members

4.4 Front impact

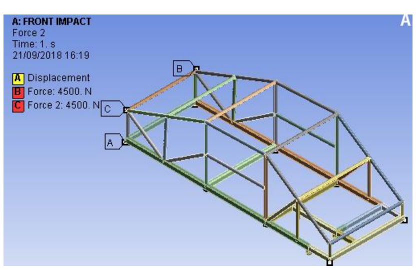


Fig.10 Force and displacement of the members (Front members)

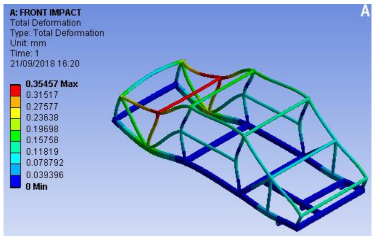


Fig.11 Total deformation of members

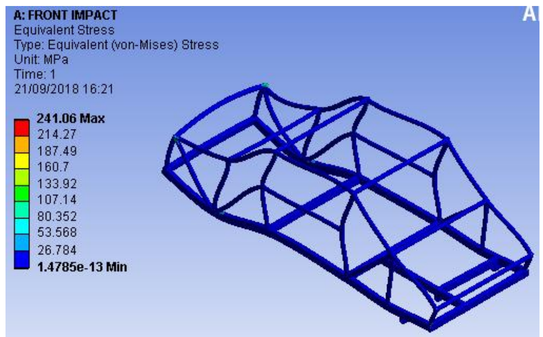


Fig.12 Equivalent Von-mises stresses

4.5 Side impact

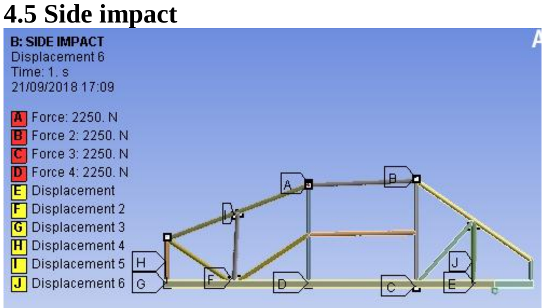


Fig.13 Force and displacement of the members (Side members)

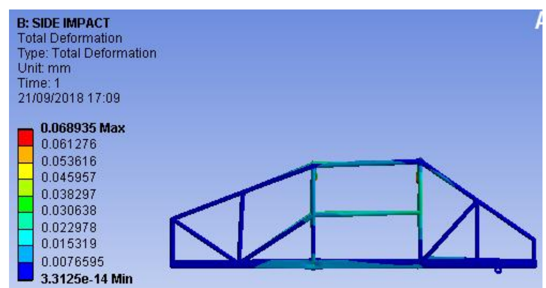


Fig.14 Total deformation of members

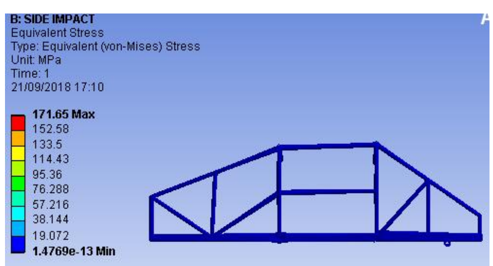


Fig.15 Equivalent Von-mises stresses

4.6 Torsion impact

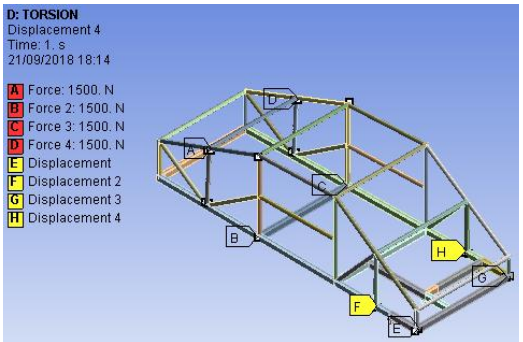


Fig.16 Force and displacement of the members

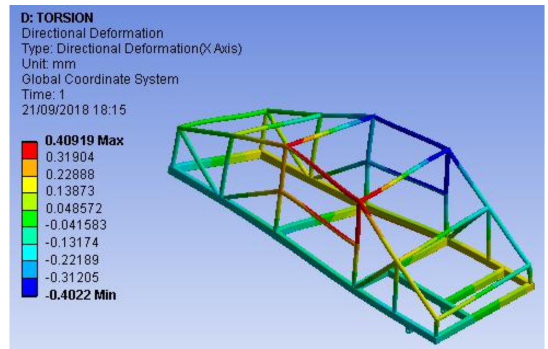


Fig.17 Directional deformation (Y-direction)

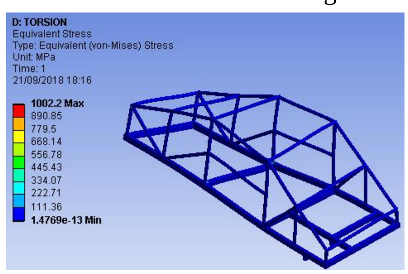


Fig.18 Equivalent Von-mises stresses

V CONCLUSIONS

The completed frame and body had a measured weight of 65kg; This resulted in the fully assembled car having a weight of 260kg without the driver. This compares well with the leading teams in the world having vehicle weights of 200kg to 250kg. Therefore it can be concluded that the objective of weight reduction in this design has been met.

The car did not sustain any structural damage to the frame or the body during either of the competitions. The suspension and shock absorber mountings withstood all the loads imposed on them during the testing and the race without any damage or failure. Therefore the reliability of the frame was confirmed in practice and it can be concluded that the analysis method used on the frame was applied correctly for each of the load cases.

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