6th International Conference on Research Developments in Applied Science, Engineering & Management
Mahratta Chamber of Commerce, Industries and Agriculture, Pune (India)
Conference World
23rd March 2019 www.conferenceworld.in ISBN : 978-93-87793-78-1

Review Paper On Cryogenic Machining

Sachin S Umadi[1] , Prof. M. L. Deshpande [2]

[1] PG Student,Department of Mechanical Engineering,Rajarambapu Institute Technology, Rajaramnagar, Sakhrale, Maharshtra, India.

[2] Prof,,Department of Mechanical Engineering,Rajarambapu Institute TechnologyRajaramnagar, Sakhrale, Maharshtra, India.

Abstract

Because of conventional cutting fluid large amount of environmental and health problems are developed to overcome thisproblem now a days cryogenic machining is used .In a cryogenic machining micro nozzle jetting is placed near the cutting zone, in this machining type liquid nitrogen is sprayed in cutting zone. It decreases tool wear rate & increase tool life five times more than regular conventional machining, so by using cryogenics machining high speed cutting is done because of that productivity is increased & production cost is reduced. In addition to this surface quality of product is increased. This paper gives information about new cryogenic machining approach. cryogenic machining is economical compared to conventional machining.

Keywords- *Coolent, Cryogenic Machining Principle*

I.Introduction

Machining is a major manufacturing process in the industry. Inthe machining process, heat is generated during the formation of chipsprocess, which raises the temperature of the cutting tool andaccelerates the wear of the tool. Classically, the cutting fluid is used to cooland lubricate the cutting process, thus reducing tool wear andextend the life of the tool. However, conventional emulsion coolinghas inherent health and environmental problems. Conventionalcutting fluid is a contaminant of the environment and the governmenthas strict regulations limiting the dumping of cutting waste. Although the cutting fluid can be recycled, recycling services inthe United States charges twice the purchase price for disposaland the cost is four times higher in Europe. Conventional coolantalso constitutes a threat to the worker's health. Long-term exposure tothe cutting fluid can cause dermatitis, a generic medical term that describes skin disorders ranging from ugly to malignant eruptioncancer [1].

In Ohio, line operators at a large car factoryreported that 30% of their machining operators have developeddermatitis to varying degrees due to prolonged contact withcutting liquid; both required hospitalizations. The prevalence of dermatitisresulting from exposure to cutting fluid has constantlybeen underreported.In addition to environmental and health concerns, machiningIndustry continues to explore ways to reach a longer toollife, superior cutting speed, better work surface quality, lessaccumulation, easier fragmentation of chips and reduction of production costs.Although dry machining eliminates the use of cutting fluid,negatively affects the life of the tool.However, in most cases, a solution without lubricant [2]. Identify waysto simultaneously improve machining technology and respond to environmental problemsand health risks require technological innovation.

Cryogenic machining, which uses nitrogen as the coolant, is aecological alternative to conventional machining. Cryogenicmachining has been explored since the 1950s.reports revealed the benefits of cryogenic machining, such asimprove tool life, improve machined surface finish and reducecutting forces [3]. After the 1980s, new trends such ashigh-speed cutting, concern for the environment and employeeshealth awareness has renewed interest in cryogenic machining. However, cryogenic machininghas never been claimed as an economic process.The machining process is designed to produce products that generateprofits for a company. Before cryogenic machining can becomea common process, it must be practical and economicaluse[4].

Cryogenic machining is a machining process in which the traditional cooling lubricating fluid (oil-in-water emulsion) is replaced by a jet of liquid nitrogen (LN2) or precompressed carbon dioxide (CO2). It is helpful to preserve the integrity and quality of machined surfaces in finishing operations. The researchers have been testing cryogenic machining for several decades, but the actual commercial applications are still limited to very few companies. Cryogenic machining by turning and milling is possible.The cryogenic machining setup shown in the figure 1.1.where the liquid nitrogen is compressed in the compressor & sprayed in cutting zone .the liquid nitrogen is carried up to cutting zone using stainless steel pipes. Then sprayed in cutting zone using micro nozzle[1].

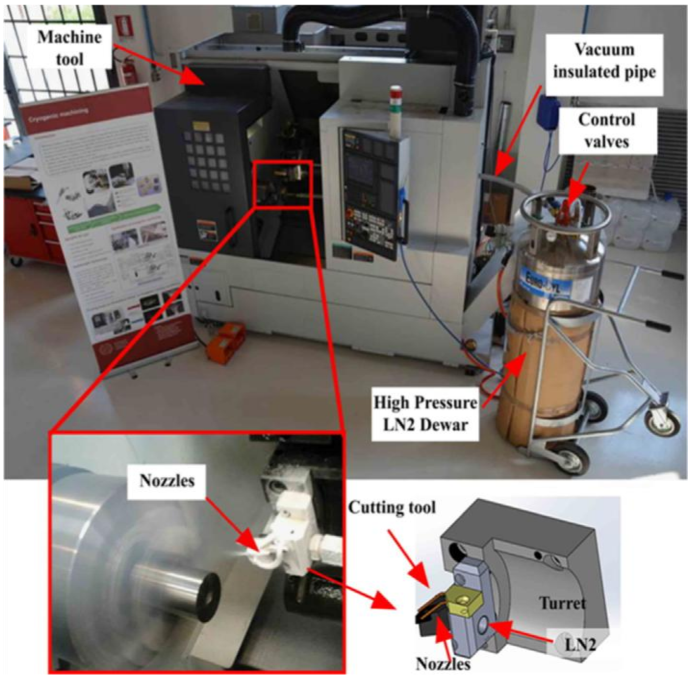

Figure 1.1-Cryogenic machining setup for the turning

II.LITERATURE SURVEY

One of the main goals of now days industries is the reduction of the production costs through the productivity increase. In the attempt to reach this goals, many researchers have been used the cryogenic machining method.It increases material removal rate through high cutting speed which is four times more relation to the conventional machining . high surface finish & tool wear rate[1].

Shane Y. Hong studied economical and environmentally friendly cryogenic machining in 2016. In order to eliminate the health and environmental problems caused by the use of conventional cutting fluids in the machining industry, a new approach has been developed. . By using micro-nozzles locally to reach the cutting point, this approach minimizes fluid consumption to a level where nitrogen costs less than conventional cutting fluid. It reduces tool wear and extends tool life by up to five times, enabling high-speed cutting, improving productivity and reducing production costs. In addition, this approach reduces frictional force, improves chip breakage, eliminates the construction edge, and improves the quality of the surface. This paper describes the new approach to cryogenic machining and assesses the economics of process versus advanced conventional emulsion cooling [2].

A. Bordinn studied the tool wear analysis during cryogenic machining in 2015 of a Ti6Al4V alloy manufactured by additive. The investigation revealed that glue wear was the main tool wear mechanism observed in dry and cryogenic turning. The high cooling capacity of the supplied liquid nitrogen in the cutting zone inhibited the adhesion of the workpiece material to both the cutting edge and the cutting face, as evidenced by the reduction in the tool-contact contact length. chip and reducing the thickness of the layer glued on the cut facing the increase in cutting time compared to dry machining. The adoption of cryogenic cooling has prevented the formation of crater wear even for the most severe cutting parameters. Abrasive wear on the cutting edge and the face of the face is limited by the layer of material of the bonded part in all the cutting conditions tested. the tool life criterion was not met for any of the cut conditions tested. Cryogenic cooling improved the surface integrity of machined specimens compared to dry turning when most cutting parameters were met. have been adopted, showing n reduction in surface roughness and microstructure parameters. modifications [4].

Y. Kaynaka investigated the surface integrity characteristics of NiTi shape memory alloys resulting from dry and cryogenic machining in 2014. In this study, surface integrity parameters induced by cryopreservation and dry (quality surface, topography, surface roughness, microstructure and phase transformation temperature) were studied during the machining of the NiTi alloy. The cryogenic machining process has further improved the surface quality of machined components than dry machining. Although no clear machining-induced layer was observed on dry specimens and machined cryogenically by optical microscopy, further investigation is needed to determine the exact depth of the affected layer. The martensite to austenite transformation temperatures are higher and the transformation peak is wider in a cryogenically machined sample than the dry machined sample, indicating that cryogenic machining has more severe effects on the characteristics of surface integrity of NiTi alloys by introducing dislocation density and high residual stresses and subsurface [5].

ISBN : 978-93-87793-78-1

Shane Y. Hong studied friction and cutting forces in cryogenic Ti - 6Al - 4V machining in 2014. Liquid nitrogen is an effective lubricant in cryogenic machining if used correctly. This lubrication effect is evidenced by the reductions in the feed force, the effective coefficient of friction between the chip and the tool face and the thickness of the secondary deformation layer in the microstructure of the chip. . Cryogenic machining tends to increase the cutting force because the working material becomes harder and more resistant at low temperatures. However, the lower temperature makes the material less tacky, thus reducing the frictional force inherent in the cutting process. An intelligent approach to cryogenic lubrication would be to reduce LN2 sputtering on the part while improving cooling at the tool-die interface. LN2 is very efficient when transmitted to the chip-tool interface via the main nozzle. This efficiency can be In addition, the chipbreaker / nozzle is positioned to lift the chip, allowing LN2 to reach the area and eventually form a fluid cushion [9].

Shane Y. Hong has studied the improvement of chip breaking in low carbon steel machining by cryogenic pre-cooling of the workpiece in 2018. Ductile materials such as low AISI1008 steel Carbon content generally exhibit poor fragmentation in conventional machining practices. This paper presents an ecologically sound cryogenic machining process that improves the breaking capacity of the AISI1008 chips by lowering the temperature of the chip to its embrittlement temperature. In this study, it was determined experimentally that the brittle-ductile transition temperature of ASII 1008 was between -60 ° C and -120 ° C. The discussion focused on whether the chip can reach the embrittlement temperature. before hitting an obstacle. Finite element simulation predicted chip temperature under various cutting conditions. Liquid nitrogen (LN2) was used to pre-cool the room by cryogenics. Cutting test results indicate a significant improvement in chip breakability for different feed rates and velocities using this cooling technique. However, the effectiveness of cryogenic pre-cooling of the workpiece strongly depends on the cutting speed [10].

III.TYPES OF COOLANTS USED IN CRYOGENICS MACHINING

There are two coolants used in the cryogenics machining first is liquid nitrogen & liquid carbon dioxide. Nitrogen and carbon dioxides are available in liquid form, and are abundant, making it two of the least expensive liquid gases. At room temperature, CO2 is heavier than the air, which poses the potential problem of accumulation on the workshop. This puts workers at risk for lack of oxygen. In addition, environmentalists believe that CO2 adds to the greenhouse effect on global warming. When pulverized, CO2 tends to accumulate as dry ice, a solid form of CO2 that is less manageable.Conversely N2, lighter than air, tends to evaporate and disperse in the upper space. Nitrogen is the most abundant gas. The boiling point of LN2, 2196 ° C, is much lower than liquid CO2~ 244 ° C. Therefore, liquid nitrogen is the preferred coolant.

ISBN : 978-93-87793-78-1

IV.PRINCIPLES OF CRYOGENIC MACHINING

The ideal cryogenic cooling approach, according to the author, should understand the following concepts:

1. The cryogenic fluid is applied directly and only to the very tip of the cutting tool, where the material is cut and the heat is to be enerated. Cooling power is not uselessareas.

2. Using the concept of energy balance, the flow of cryogenics the fluid is proportional to the heat generated during the cutting process. The room will maintain a constant temperature and not subject to dimensional inaccuracy and geometric distortion.

3. The micro nozzle is formed between the face of the tool and the chip breaker as a new commercial cut tool set, a design that is economical and convenient for users.

V.CRYOGENICS COOLING APPROCHES

Cryogenic cooling approaches in material processing could be classified into four groups depending on the applications of the researchers:

5.1. Cryogenic pre-cooling of the part

cryogenic pre-cooling, the process of cooling the workpiece and the chip, the objective is to cool the workpiece or the chip to change the properties of the material, from ductile to brittle, because the material of the ductile chip can become fragile when the temperature of the chip is lowered. The formation of chips and its effect on productivity in the cutting of the metal were however. However, these methods may not be practical in the production line and negatively increase the cutting force and abrasion, in addition to causing dimensional changes of the workpiece and, in particular, a high liquid nitrogen content. consumption may be required in an uneconomic way.

5.2..Indirect cryogenic refrigeration

This method has also been called cryogenic tool cooling and conduction remote cooling. In this distinctive cryogenic cooling approach, the objective is to cool the cutting point by thermal conduction from an LN2 chamber located on the face of the tool or on the tool holder. In other words, the LN2 is not pushed back to the tool or workpiece.

5.3. Cryogenic vaporization and jet cooling

The objectiveof this method is to cool the cutting zone, in particular the tool-chip interface with liquid nitrogen, using nozzles. The consumption of LN2 and therefore the cost of production could be raised by a general flood or a spraying of the coolant on the general cutting area during a machining operation. Figure 4.1.illustrates such a cryogenic supply system developed by Zurecki et al. In such an application, the refrigerant can also lead to a cooling of undesirable areas and an increase in cutting forces.

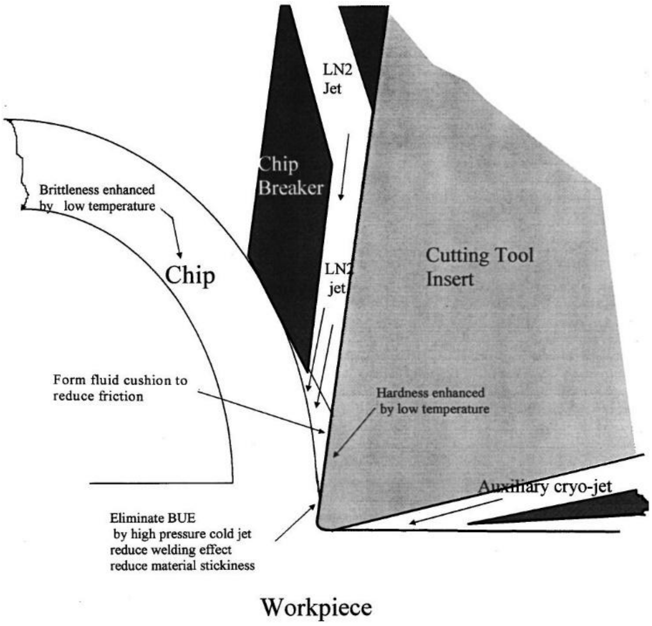

Figure 4.1.Cutting Zone

5.4. Cryogenic treatment

Cryogenic treatment is a process similar to heat treatment. In this method, the samples are cooled to a cryogenic temperature and maintained at this temperature for a long time, and then heated to room temperature to improve their wear resistance and dimensional stability. For example, Hong et al. method of processing the tools cryogenically as follows: the inserts are placed in a chamber; the temperature is gradually lowered over a period of 6 hours from room temperature to about 1841C; the temperature is then kept stable for about 18 hours; The temperature is gradually raised for 6 hours at room temperature and the inserts are tempered. Steps followed by Silva et al. for cryogenic treatment: the tools were soaked and quenched in a conventional manner for a total of 43 hours; cooling at 1961 ° C (20h); heating at + 1961C [2].

VI. EFFECT OF CRYOGENIC MACHINING ON CUTTING FORCES

Liquid nitrogen is an effective lubricant in cryogenic machining if used properly. This lubricationThe effect is demonstrated by the reductions in the feed force, the actual coefficient of friction betweenthe chip and the face of the tool, as well as the thickness of the secondary deformation layer in the microstructure of the chip.

Cryogenic machining tends to increase the cutting force because the working material becomesharder and stronger at low temperatures. However, the lower temperature makes the materialless tacky, reducing the frictional force inherent in the cutting process. An intelligent approach toCryogenic lubrication would reduce LN2 spraying on the part while improving coolingat the tool-chip interface. LN2 is very efficient when passed to the chip-tool interfacevia the primary nozzle. This efficiency can be further improved by positioning thechip breaker / nozzle to lift the chip, allowing LN2 to reach the area and forma fluid cushions.

VII.EFFECT OF CRYOGENIC MACHINING ON SURFACE FINISH

In cryogenic machine the surface finish obtained is high. There are two main reasons behind get high surface quality first is no feed marks produced on surface & second is no chips redeposite. We know that in cryogenic machining there is low temperature in cutting zone so there is no plastic deformation of body so tool marks not produced on the surface ,so we get high surface quality. In conventional machining the small particles of product get stick on surface of product & surface finish is damaged. But in cryogenic machining there is no redeposite the material on the surface so we get high surface quality.

Cryogenic machining effect on surface integrity parameters (surface quality, topography, surface roughness, microstructure and phase transformation temperature) were studied & explained below. Cryogenic machining process helped improve the surface quality of machined parts components more than dry machining. Although not a machining-induced layer was observed dry and cryogenically machined samples of optics microscopy, further examination is needed to determine the exact depth of the affected layer. Martensite with austenite transformation temperatures are higher and the peak of transformation is wider cryogenically machined sample as the dry machined sample that indicates that cryogenic machining has more severe effects on the surface integrity characteristics of alloys by introducing a high dislocation density and residual stresses on their surfaces and sub-surface.

VIII. EFFECT OF CRYOGENIC MACHINING ON TOOL WEAR RATE

In machining of hard material there is large tool wear is observed so to decrease tool wear rate cryogenic cooling is used. In cryogenics machining liquid nitrogen is sprayed in cutting zone which acts as coolant &lubricant also.so low cutting zone temperature reduces the tool wear rate. The tool life increases two times more than conventional machining.

Abnormal or excessively aggressive to wear, which hasMain problem behind machining of hard material, this is the main reason for reducing consumption or conventional application machining process innovation of hard material.cryogenic cooling used to reduce wear of clothingspeeds and reduction of fatigue in the fatigue zoneand recesses in the basket with relatively slow cutspeeds when machining of hard material alloy.work has also been identified as a cause of non-wear and flow damagein hard material machiningmachining and demonstrated that cryogenic cooling isvery efficient of appreciationcethosetool-wearbehaviors.Inaddition, byconsidering other machining parameterscomponents and surface quality of the part, advantagescryogenic cooling to improve overall machiningperformance of hard material.

IX. EFFECT OF CRYOGENIC MACHINING ON CHIP BREAKING PROPERTIES

Ductile materials generally have a low chip breakage in conventional machining practices. Environmentally clean cryogenic machining process that improves the lowering the temperature of the chip to its embrittlement temperature. Chip breakage in the hard machining material can be improved using LN2 to cool the room before and during the cut, given the geometry of the tool and the chip the position of the circuit breaker is well chosen. The use of LN2 expands the power range in which chip shapes can be produced if the chip breaker the position is correctly set in relation to the power supply.The potential improvement in small food fragmentation is very important for fine cutting because of damage to the the surface of the workpiece by badly broken chips should be minimized.

Although preheating the room is easy to use With regard to cryogenic machining, certain limits have been observed. Cryogenic preheating of the part works well to improve chip fragmentation only to moderate cutting speeds. Using LN2 simply pre-cool the room while the cutting process, it is theoretically possible to fully or partially carry the chip to the embrittlement temperature in hard material, depending on the cutting speed.

X.CONCLUSION

Cryogenics machining is more effective than the conventional machining. In cryogenic machining thecutting zonetemperature is maintained bout -196 degree Celsiustemperature so chip breaking, surface finish properties are increased & tool ear rate is reduced.

- In cryogenic machining process which improves the breakability of hard material chips by lowering the chip temperature to its embrittlement temperature.
- In cryogenic machining process redeposition & tool feed marks problems are eliminated which increases surface finish.Incryogencsmachining surface finish is four times more than conventional machining.
- In cryogenic machining the tool wear rate is low compared to conventional machining because of cutting zone temperature is low & built up edges not welded to tool. Tool life two times more than conventional machining.

REFERANCES

1]FranciPuavec," The Role Of Cryogenics In Machining Processes" , Ulogakriogenika postupcima obrade rezanjem, Tehnikivjesnik ,Vol. 16, (2016), PP.4 -10.

2]ShaneHong,"Economical and Ecological Cryogenic Machining",Journal of Manufacturing Science and Engineering,Vol. 12.(2016),pp.331-339.

3]I.S.Jawahira,"Cryogenic machining of biomedical implant materials for improved functional performance, life and sustainability", 7th HPC 2016 – CIRP Conference on High Performance Cutting, Procedia CIRP 46 ,(2016),pp.7–14

4]A.Bordin,"Analysis of tool wear in cryogenic machining of additive manufactured Ti6Al4V alloy", Wear,Vol.329,(2015),pp.89–99.

5]Y. Kaynak,"Surface integrity characteristics of NiTi shape memory alloys resulting from dry and cryogenic machining", 2nd CIRP Conference on Surface Integrity (CSI), Procedia CIRP 13,(2014),pp.393–398.

6]Y.Kaynak,"Tool-wear analysis in cryogenic machining of NiTi shape memory alloys :A comparison of tool-wear performance with dry and MQL machining", Wear,Vol.306,(2013),pp.51–63.

7] F. Pusaveca,"Analysis of the influence of nitrogen phase and surface heat transfercoefficient on cryogenic machining performance",Journal of Materials Processing Technology,Vol.233, (2016),pp.19–28.

8]Florian Ambrosy,"An Experimental Study of Cryogenic Machining on Nanocrystalline Surface Layer Generation", 2nd CIRP Conference on Surface Integrity (CSI), Procedia CIRP 13,(2014),pp.169–174.

9]Shane Y. Hong,"Friction and cutting forces in cryogenic machining of Ti–6Al–4V", International Journal of Machine Tools & Manufacture,Vol.41,(2001),pp.2271–2285.

10]Shane Y. Hong,"Improvement of Chip Breaking in Machining Low Carbon Steel by Cryogenically Precooling the Workpiece",Journal of Manufacturing Science and Engineering, Vol.120,(2018),pp.76-84.

11]Amin Bagherzadeh,"Investigation of machinability in turning of difficult-to-cut materials using a new cryogenic cooling approach",Tribology International,Vol.119,(2018),pp.510–520.

12] Ampara Aramcharoen,"Influence of cryogenic cooling on tool wear and chip formation in turning of titanium alloy",7th HPC 2016 – CIRP Conference on High Performance Cutting, Procedia CIRP 46, (2016),pp. 83 – 86.