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REVIEW ARTICLE

CRYOGENIC EFFECT ON MACHINING – A REVIEW

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ABSTRACT

There is a significant importance to improve the productivity and tool life as preferred by the manufacturers. The most emerging needs of modern metal cutting operations are to increase the Material Removal Rate with surface finish and high accuracy. These objectives can be achieved by reducing the tool wear rate, this rate of tool wear can be reduced by the reduction of heat generated during the metal removal process. This reduction of heat generated can be done by use of coolant for more effective cooling a special sub cooling process known as cryogenic cooling is used while machining.

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INTRODUCTION

The process of metal removal from a stock is known as machining and the process of machining causes the generation of huge amount of heat due to the continuous contact of the tool with the work piece, this leads to the considerable reduction in the life of the tool by accelerating the tool wear. To overcome the problem of excessive heat generation, many researchers carried research and proposed many methods and cryogenic cooling is one of the proposed methods which have US origin (Hemant, 2013). Cryogenics stems from Greek and means, "the production of freezing cold". Cryogenics is the branch of physics and engineering that involve the study of very low temperatures, how to produce them, and how materials behave at those temperature (-150 C, -238 F or 123 K). Cryogenics was first introduced in 1960's. Cryogenic materials are liquefied nitrogen, oxygen, hydrogen, neon and helium among this liquid nitrogen is most commonly used in many cryogenic applications. Cryogenic treatment is one time permanent process and it is one among the properties improvement technique (Mathai et al., 2013; Amoljit Singh Gill, 2012). The main theme behind the use of cryogenic cooling on the machining process involves improvement of the tool life which is subjected to more wear under the conventional machining process.

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The tool life improvement under the cryogenic machining process is done by reduction of tool wear and improvement other cutting parameters by effective heat removal and it also associated with transformation of austenite (soft and unstable in low temperature) to martensite (Hemant, 2013). Cryogenic process is most practical and effective way to enhance the machining performance in cutting difficult-to-cut materials is to reduce the cutting temperature (Ramji et al., 2010). The main function of cryogenic machining is to lower the cutting temperature by removing the heat. Modifying the chip tool interface frictional characteristics. Changing the property of tool and work piece (Ramji et al., 2010).

Literature survey: Hemant B. Patil *et al.* (2013) says that wear is the most determining factor for the precision, quality of the surface finish. Also cryogenic processing has no effect on low carbon steel, cast iron and non ferrous metal and the changes due to the cryogenic process depends on the composition of the material, it performs three things; retained austenite turned to martensite, carbide structures are refined and stress is relived. Patil also proposed the result of effect of cryogenic on tool steels as considerable increase in the wear resistance, near absence of retained austenite leads to marginal increase in hardness of the tool steel and reduction in chip tool interface temperature up to 34% by using liquid nitrogen jet which leads to dimensional and surface finish increase with reduction in wear and damage to tool tip. Mathai *et al.* (2013) investigate the effect of cryogenic treatment on tool electrode during Electro Discharge Machining with copper as tool electrode and inferred that the cryogenic treated tool electrode has better shape retention capacity over the non treated electrode; also the cryogenic treatment improves the machinability of the beryllium work piece material. In the terms of machining parameters the material removal rate was relatively higher for non treated tool electrode than the cryogenic treated tool electrode since cryogenic treatment increase the thermal and electrical conductivity of electrode which in turns reduces the bulk heating and melting of tool and electrode. Cryogenic treatment has a positive effect on surface hardness of the tool electrode and reduces the tool wear rate over the non treated tool electrode. Amoljit Singh Gill and Sanjeev Kumar (Amoljit Singh Gill, 2012) say cryogenic treatment is one time permanent process. They use AISI H11 hot die steel for their study of wear reduction in the electrode by cryogenic treatment in Electrical Discharge Machining. By experimenting, they found there is a considerable reduction in the tool wear over the non cryogenic treated aluminium electrode and improvement in the surface roughness.

Muammer Nalbant and Yildiz (2011) investigated the cryogenic effect in the milling process of AISI 304 stainless steel under dry and cryogenic cooling conditions with four cutting speeds (80,120,160,200 m/min). As the result of their study Nalbant and Yildiz say the maximum cutting forces and torque in cryogenic machining are observed to be more than those in dry cutting 3.3%, 6.5% and 7.9% respectively. And they observed a considerable increase in hardness of the AISI 304 stainless steel work piece. Ranajit Ghose *et al.* (2003) analyses the effect of cryogenic coolant technique on tool life with brittle tools by using Poly Crystalline Boron Nitride and Poly Crystalline Diamond as tool materials under three conditions (dry, flood coolant, (LIN)liquid nitrogen). Thus at the end of the study they conclude that the cryogenic machining has positive effect on tool life improvement over the two conditions also an effective heat removal was performed and increases the wear resistance, hardness, toughness was achieved by cryogenic machining. In the study it is also clear that the cryogenic machining have more effectives on the alumina ceramics tool material in its life.

Gopal Krishna *et al.* (2012) evaluated the performance of cryogenic treated tools in turning with an objective of life enhancement of HSS tools. Their investigations were carried on different work materials such as AISI 1040, EN8 and EN24 to benefiting the small industries. By experiments carried to evaluate the performance of the cryogenic treated tools they infer a significant influence of cryogenic treatment on tools with an increase of 90%, 50%, and 39% respectively in tool life for AISI 1040, EN 8 and EN 24. Dhananchezian *et al.* (2009) investigate the cryogenic cooling by LIN in the orthogonal process to determine the effect on cutting temperature, cutting force, chip thickness and shear angle of AISI 1045 steel and Al 6061-T6 alloy. It has been observed that in cryogenic cooling method, the temperature was reduced to 19-28% and the cutting force was increased to a maximum of 15% than dry machining of AISI 1045 steel. In machining of aluminium 6061-T6 alloy, the temperature was reduced to 27-39% and the cutting force was increased to a maximum of 10%. Adem Çiçek *et al.* (2012) study performance of cryogenically treated M35 high speed steel (HSS) twist drills in drilling of AISI 304 and 316 stainless steels was evaluated in terms of thrust force, surface roughness, tool wear, tool life, and chip formation. To present the differences in tool performance between untreated and treated drills, and machinability between AISI 304 SS and AISI 316 SS, a number of experiments were performed at different combinations of cutting speed, and feed rate. As the results of the conducted experiments, the treated drills showed better performance than untreated drills in terms of thrust force, surface roughness, and tool wear and tool life for both types of stainless steels. Tool lives of treated HSS drills in drilling of AISI 304 SS and AISI 316 SS improved 32% and 14%, respectively, when compared with untreated drills. Experimental results also showed that machinability of AISI 304 SS was harder than the machinability of AISI 316 SS. Shivdev Singh *et al.* (2012) works on investigation of cryogenically treated, coated and uncoated tungsten carbide cutting tool inserts in turning of AISI 1040 steel. Three different tungsten carbide inserts coated with aluminum chromium nitride (AlCrN), titanium nitride (TiN) and uncoated WC were taken and treated cryogenically. Experiments were performed to evaluate the cutting forces and tool wear at different machining conditions. Results indicated that treated TiN coated tools have lower tool wear and cutting forces followed by treated AlCrN coated and treated uncoated tools. It has been observed that cutting forces increased with the increase in feed, depth of cut and decreased with increase of cutting speed in all cases. Also it is observed that flank wear increased with the increase in depth of cut, cutting speed and feed. Ramji *et al.* (2010) conducted experiments to study the performance of cryogenically treated HSS drills for drilling gray cast iron using drill tool dynamometer measure the trust force torque and talysurf to measure the surface roughness (Ra, Rz, Rq and Rt) of the drilled specimens. After analysis it is found that treated drills were found superior to the non-treated in all the test conditions in terms of lesser thrust force, torque and also superior surface roughness of the specimens.

Conclusion

From the review carried on the cryogenic effect on machining by literatures from various researchers on the various materials under different conditions and different methodology with cryogenics, it is clear that cryogenic is one time permanent additional heat treatment process which act as a refiner for austenite structure in the material and it has a positive effect on the aluminium based metals and others ferrous materials in terms of improvement of wear resistance capacity of the tool materials by increasing the surface hardness, and improvement in the machinability of the work materials.

Cryogenic process has an extended application in the field of manufacturing is found and future study can be held on the cryogenic effect is required.

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