iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 5 **Issue:** XII **Month of publication:** December 2017

DOI:

The Effect of Cryogeni C Cooling in the Machining Performance of Tungsten Carbide

C. Sathish kumar[1], A. Elango[3], K. Arunkarthikeyan[3], P. Keerthivasan[4]
[1,2,3,4] *Alagappachettiar college of engineering and technology, karaikudi, tamilnadu, india.*

Abstract: The term cryogenic means "producing things in very low temperature" Cryogenic coolants are used in conventional machining in material removing process for reduce the cutting zone temperature. Main objective of this work is to reduce the cutting zone temperature, reduce the surface roughness, and to increase the tool life. The work piece material as EN24 and tool material as tungsten carbide. Liquid nitrogen is used as cryogenic coolant for reducing the cutting temperature. Temperature of liquid nitrogen is -196^{O}C. While Machining the EN24 high temperature was generated; this may affect the tool performance, so the temperature has to be reduced. Turning operation was carried out in dry condition and cryogenic cooling condition. Comparison study was made between dry and cryogenic coolant machining. This work analyses the cutting temperature, surface roughness of the work piece and tool life and also compared the results of dry machining and cryogenic coolant machining. It is observed that cryogenic coolant is most favourable method for machining hard to cut materials. From the results of this work it is concluded that the cryogenic cooling method is more suitable for high speed machining.

Keywords: Cryogenic, LN_2, machining, EN24, tungsten carbide, cutting zone temperature, surface roughness

I. INTRODUCTION

The main problems of high speed machining are high cutting zone temperature and rapid tool wear. Conventional cutting fluid is used to cool and lubricate the machining process, which could reduce the cutting zone temperature to some extent. Some materials are classified as hard to cut materials. The main disadvantages of these hard to cut materials are high heat generation during machining this will reduce the tool life. In order to reduce the cutting zone temperature and to increase the tool life cryogenic cooling is used instead of conventional cooling.

II. LITERATURE SURVEY

K.A. Venugopal et al [1] done an investigation in the present investigation, the tool wear and tool life of uncoated carbide cutting tool inserts in machining of Ti-6Al-4V alloy have been studied under dry, wet and cryogenic cooling environments. A substantial improvement in tool life was obtained under cryogenic cooling compared to dry and wet machining in all the machining trials undertaken. YakupYildiz et al [2] have analysed and point out the effect of cryogenic liquid nitrogen cooling on cutting performance in material removal operations and its application methods. Other conventional coolants, heat generation and temperature distribution in a cutting process have been also discussed. In addition, liquid nitrogen as a cryogenic coolant was investigated in detail in terms of application methods in material removal operations and its effects on cutting tool and workpiece material properties, cutting temperature, tool wear/life, surface roughness and dimensional deviation, friction and cutting forces. As a result, cryogenic cooling has been determined as one of the most favourable method for material cutting operations due to being capable of increasing the tool life.

M. Dhananchezian et al [3] investigated the experimental study of the effect of cryogenic cooling on cutting temperature, cutting force, chip thickness and shear angle in the orthogonal machining of AISI 1045 steel and Aluminium 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% then 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%. M. Dhananchezian, et al [4] made an attempt to investigate the effect of liquid nitrogen when it was applied to heat generation zones through holes made in the cutting tool insert during the turning of Ti-6Al-4V alloy with TiAlN coated tungsten carbide cutting tool inserts. The cryogenic results of the cutting temperature, cutting force, and surface roughness for the modified cutting tool insert have been compared with wet machining. They found that the cutting temperature was reduced by 64 – 67% in cryogenic cooling over wet machining. The cutting force was decreased by 43 - 53% in cryogenic cooling with modified cutting tool insert over wet machining. It was also observed that in the cryogenic cooling method, the surface roughness was reduced to a maximum of 33% over wet machining

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor :6.887
Volume 5 Issue XII December 2017- Available at www.ijraset.com

Kyung-Hee Park, et al [5] investigated the machining performance of a variety of cooling methods, cryogenic, Minimum Quantity Lubrication (MQL), and flood cooling are performed on solid end milling of titanium alloy, Ti-6Al-4V. In particular, the effect of internal and external spray methods on cryogenic machining is analysed with a specially designed liquid nitrogen spraying system by evaluating tool wear and cutting force at cutting conditions. The cutting force is also analysed for tool breakage detection. As a result, the combination of MQL and internal cryogenic cooling improves tool life by up to 32% compared to conventional cooling methods. M. Percin et al [6] presented a series of experimental investigations of the effects of various machining conditions [dry, flooded, minimum quantity lubrication (MQL), and cryogenic] and cutting parameters (cutting speed and feed rate) on thrust force, torque, tool wear, burr formation, and surface roughness in micro-drilling of Ti–6Al–4V alloy. Set of uncoated carbide twist drills of diameter 700 µm were used for making holes in the workpiece material. Both machining conditions and cutting parameters were found to influence the thrust force and torque. It was observed that the burr height was at a minimum level in cryogenic drilling. Increasing feed rate and decreasing spindle speed increased the entry and exit burr height.

III. EXPERIMENTAL PROCEDURE

Turning operations were carried out on the workpiece of EN24 with tungsten carbide cutting tool inserts under dry machining and cryogenic cooling. ISO PDJNR 2020 K15 tool holder is used for machining. The turning operations were performed on NAGMATI-175 lathe machine at the depth of cut 0.5mm, feed rates 0.159mm/rev and 0.102mm/rev, cutting velocities of 188m/min and 120m/min. table shows the experimental details.

Table 1: Experimental details

SI .NO	CUTTING SPEED (m/min)	FEED RATE (mm/rev)	DEPTH OF CUT(mm)
1	188	0.159	0.5
2	188	0.120	0.5
3	120	0.159	0.5
4	120	0.120	05

In cryogenic cooling approach liquid nitrogen (LN2) was applied on the cutting zone by using a nozzle. Experiments are carried out in the NAGMATI-175 lathe machine. Figure 1 shows the NAGMATI-175 lathe machine.

Figure 1: NAGMATI-175 lathe machine with cryocan setup

The temperature of the cutting zone was measured by using non-contact infrared thermometer with an accuracy of ±1% reading. The surface roughness of the workpiece was measured by roughness tester Mitutoyo SJ-310. Tool wear was calculated in weight basis by electronic weighing machine.

IV. RESULTS AND DISCUSSIONS

This project involving the experimental study on turning of E24 material with tungsten carbide tool inserts under dry and cryogenic cooling. The results of dry and cryogenic cooling were compared. Cutting zone temperature, surface roughness of cryogenic cooling have been compared with dry machining

A. Comparison of cutting zone temperature

The cutting zone temperature of cryogenic cooling was reduced by the application of liquid nitrogen (LN2). Liquid nitrogen is directly applied in the cutting zone. Cutting zone temperature was measured by non-contact type infra-red (IR) thermo meter. Reduction in the cutting zone temperature was shown in the figure 2. The cutting zone temperature at the velocity of 188m/min and feed rate 0.159m/rev was 97oC and 30oC. Reduction in the cutting zone temperature in cryogenic cooling was 69% over dry machining.

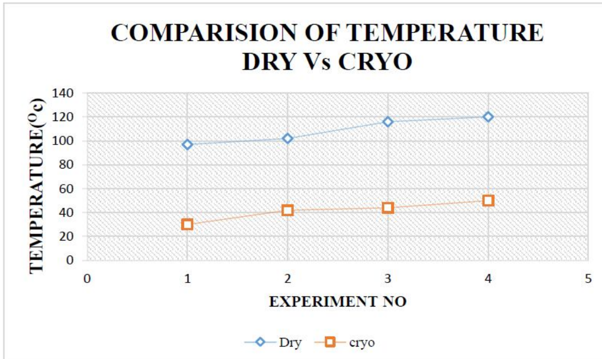
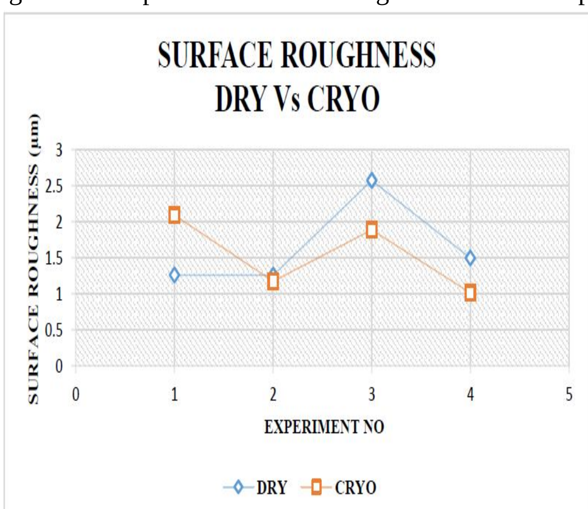


Figure 2: Comparison of cutting zone temperature

B. Comparison of surface roughness

The variations in surface roughness with different machining conditions are shown in figure 3. Surface roughness of the workpiece was measured by surface roughness tester Mitutoyo SJ-310. The value of surface roughness at a cutting speed of 770 rpm and feed rate of 0.102 mm/rev was 1.497μm and 1.016 μm for dry and cryogenic machining. For cutting speed of 1200 rpm and feed rate of 0.102 mm/rev was 1.259μm and 1.176 μm for dry and cryogenic machining. So the reduction in surface roughness over dry machining was obtained as 7%-32% but at the same time the surface roughness at 1200rpm and feed rate of 0.159mm/rev was 1.264μm and 2.094 μm for dry and cryogenic machining. The cryogenic cooling was not an efficient method for machining EN24 for thecombination of high speed and high feedrate.

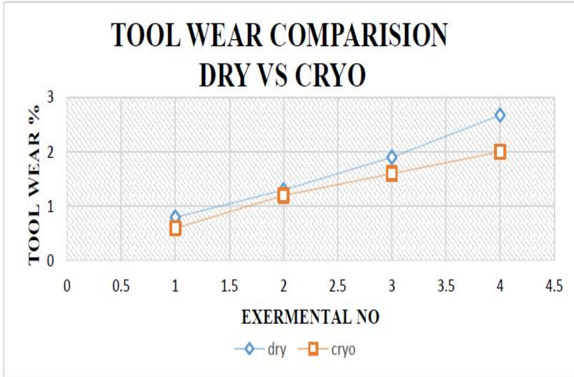
Figure 3: Comparison of surface roughness of the workpiece



C. Comparison of tool wear

Here tool wear is calculated by weight basis. After each machining the tool wear is calculated in terms of reduction in tool weight. Difference in tool wear is shown in figure 4.Tool weight is observed before machining and after each machining the tool weight is measured. From the results obtained the tool wear is reduced upto 33% in cryogenic cooling over dry machining.

Figure 4: Comparision of tool wear



V.CONCLUSION

The experiments on the turning of EN24 with tungsten carbide tool inserts were carried out in dry machining and cryogenic cooling. Cryogenic cooling using liquid nitrogen reduced the cutting temperature by up to 69% over dry machining. Cryogenic cooling provided the benefits mainly by substantially reducing cutting temperature. Cryogenic cooling by liquid nitrogen reduced the surface roughness by 7%-32%. Cryogenic cooling reduced the tool wear by 25%-33%. This may be attributed due to control of cutting zone temperature and favourable chip-tool interaction.

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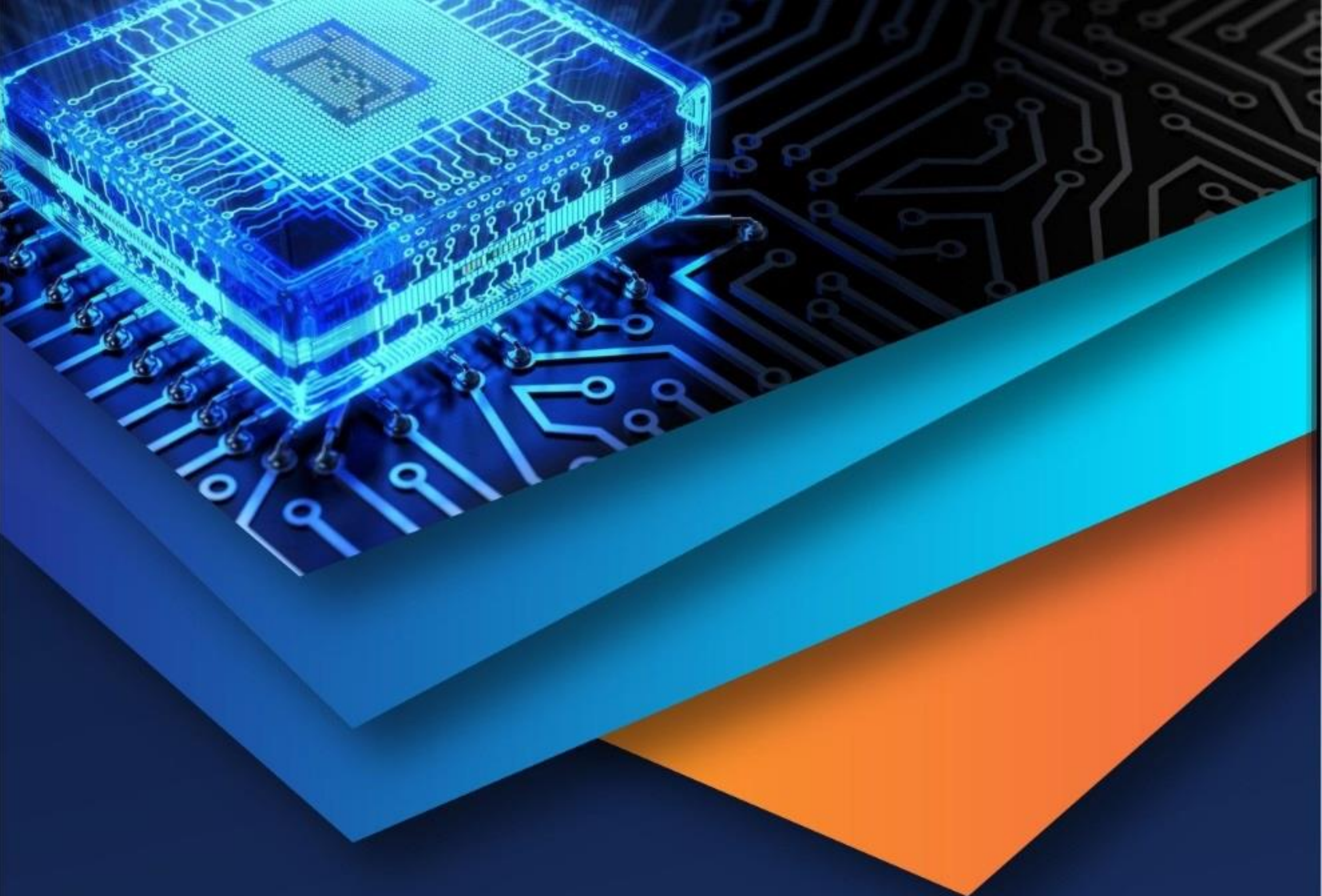

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