Experimental Investigation to Evaluate the Machining Performance of En-9 Material

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Abstract*-It was found that conventional cooling techniques, which include flood coolant techniques, tend to be detrimental to tool life. This is due to the inability for the coolant to reach the cutting edge at such high cutting speeds. Moreover, conventional cutting fluids cause environmental and health problems. The disposal of them becomes important environmental and economical issues to be considered by machining industry, because the disposal cost is very expensive. Therefore, new methods of cooling, such as minimum quantity lubrication, solid lubricants and cryogenic cooling have now been used in extending tool life. Another very recent newcomer in the search for extending tool life is the cryogenic treatment of cutting tools. Cryogenic technology on the whole is not a new process, and has been used on several types of materials including plastics and composites to improve their performance in their various applications. The cryogenic treatment improves the properties of the tool material. In the present experimental investigation, study the machining performance of cryogenic cubic boron nitride as a tool and EN-9 material as work piece using environment of Nitrogen. The experimental results reveal that using cryogenic technology has effects on Cutting forces and Tool wear.

Keywords : Cutting speed, Feed, Depth of cut, Tool wear.

I. INTRODUCTION

The cryogenic treatment improves the properties of the tool material. The cryogenic treatment improves tool wear resistance, surface finish of work piece material and reduces cutting forces. The improvement in tool wear resistance may be due to precipitation and distributions of the η-phase particles after cryogenic treatment. The cryogenically treated tools perform better while performing intermittent cutting operations. Generally, longer machining times diminish any beneficial effect of tool life that cryogenic treatment brings about. Cryogenically treated tools perform better when the tool temperature is kept low. Their effectiveness can be extended if coolants or suitable methods of cooling are used to keep the tool temperatures low. Traditionally, high temperature in cutting zone has been controlled by using cutting fluids. But, conventional cutting fluids cause environmental pollution, health problems and high disposal costs. Regulations have been forcing manufacturers to reduce or eliminate the amount of wastes. As technology improves and cutting speeds in machining are increased, it was found that conventional cooling techniques, which include flood coolant techniques, tend to be detrimental to tool life. This is due to thermal shocks, as well as the inability for the coolant to reach the cutting edge at such high cutting speeds.

The review of literature also indicated that application of gases as a cutting fluid reduces the cutting zone temperature very effectively. Gases are pollution-free, eco-friendly and are good coolant and lubricant. The application of gases produced lower cutting force, improves the roughness of the finished surface, and reduces the tool wear. These effects caused the lowest cutting force in carbon dioxide gas application as compared to other gases. The nitrogen gas suitably decreased the cutting temperature, and improved the contact conditions at chip-tool interfaces. Nitrogen gas formed a film on tool surface, chip easily moved away from tool face and lower friction occurred in tool-work piece-chip interface.The cutting force and tool wear were reduced and roughness of the finished surface was improved. Nitrogen gas also helped in tighter chip curl and shorter contact lengths compared to the ambient temperature environments. It is investigated the effect of cryogenic treatment on the mechanical and magnetic properties of WC-8wt. % Co cemented carbides and showed that cryogenic treatment enhances hardness, compression strength, wear resistance and fatigue resistance, while the bending strength and toughness are not changed. The change of the mechanical properties highly depends on the soaking time. The cryogenic treatment improves tool wear resistance, surface finish of work piece material and reduces cutting forces **[1]**. Deep cryogenic treatment has various advantages like increase in wear resistance, reduced residual stresses; increase in hardness, fatigue resistance, toughness imparted by transformation of retained austenite to martensite, precipitation of carbides, eta-carbide formation, perfect distributed/homogenous crystal structure, better thermal conductivity, and reduced chemical degradation. This technology is an eco-friendly, nontoxic, and non explosive **[2]**. In this work aims to study the performance of the cryogenic treatment on the tungsten carbide inserts tools (Shallow cryogenic treated and Deep cryogenic treated) compared to the untreated tool for machining the AISI

1020 Bright rod (work piece). From that machining, the tool wear and surface roughness values of the work piece material was determined. At the same time cutting zone temperature and chip formation methodology were observed. From the tool wear tests deep cryogenically treated tool revealed the less amount of weight loss (10mg). The reason behind that, the formation of ἡ phase particles precipitated on the carbide inserts after the cryogenic treatment. The SEM images and EDX images shows the formation of fine grains**[3].** The tool life of deep cryogenic treated coated cemented tungsten carbide cutting tool inserts was larger by a factor of 1.27 (27% increase) when compared to untreated inserts. **[4].** The main cutting forces for the deep cryogenic treated inserts were lesser by 11% when compared to untreated inserts for cutting speeds in the range between 200 and 350m/min**.**

II. PROBLEM FORMULATION

The review of literature clearly indicated the new cutting tool materials like high-performance ceramics, cubic boron nitride, coated carbides, cryogenically cubic boron nitride have been greatly improved machining of several engineering materials, even in some case of difficult-to-cut metals. The rising of temperature during cutting processes negatively affects tool life. It also adversely changes machine parts quality, such as dimensional accuracy and surface quality. High temperature in cutting zone has been traditionally tried to control by using cutting fluids. The coolant effect reduces temperature in cutting zone and the lubrication action decreases cutting forces. Thus the friction coefficient between tool and chip becomes lower in comparison to dry machining. However, as technology improves and cutting speeds in machining are increased, it was found that conventional cooling techniques, which include flood coolant techniques, tend to be detrimental to tool life. This is due to the inability for the coolant to reach the cutting edge at such high cutting speeds. Therefore, new methods of cooling, such as minimum quantity lubrication, solid lubricants and cryogenic cooling have now been used in extending tool life. The cryogenic treatment improves the properties of the tool material. The cryogenic treatment improves tool wear resistance, surface finish of work piece material and reduces cutting forces. The improvement in tool wear resistance may be due to precipitation and distributions of the η-phase particles after cryogenic treatment. The cryogenically treated tools perform better while performing intermittent cutting operations.

The review of literature indicated that cryogenic treatment has been acknowledged as a means of extending the life of cubic boron nitride but no study has been reported in open literature regarding the effect of gases as a coolant on the performance of cryogenically treated cubic boron nitride in turning. So, the present work is based on some experimental investigation on the effect of nitrogen gas on the performance of cryogenically treated cubic boron nitride in turning. The experiments were performed at different input parameters i.e. cutting speed, feed and depth of cut and compared with dry machining. The effect of these parameters on cutting forces and tool wear were evaluated as per Taguchi design.

III. EXPERIMENTAL SET-UP

In the experimental investigation, we used the EN-9 material as the work piece material and Cubic Boron Nitride as the tool material. In Experimental investigation, Dry and Nitrogen gas are used as varying parameters to evaluate the machining performance.

Fig 1: Photographic view of the experimental set up

The photographic view of the experimental set up is shown in Fig. 4.1. For this experimentation a high power rigid lathe of HMT (LB-17 model) was used.

3.1. Dynamometer

The cutting force was measured by using a dynamometer for each machining condition. The photographic view of the dynamometer is shown in Figure.

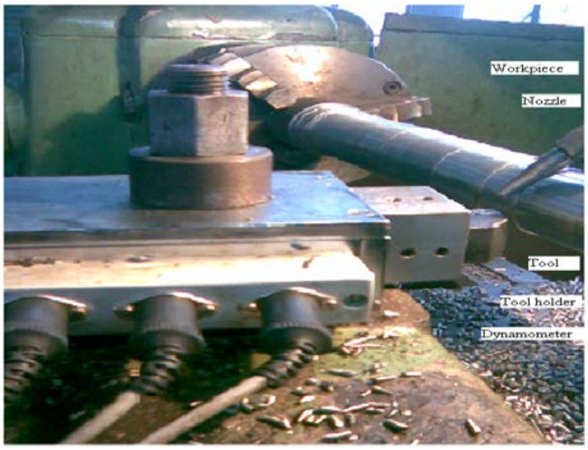

Fig. 2:Dynamometer

3.2. Metallurgical Microscope

The flank wear was measured using metallurgical microscope (YUCON Japan). The photographic view of metallurgical microscope is shown in the figure

Fig3: Metallurgical Microscope

IV. WORK PIECE AND TOOL USED

A material used in this experimental investigation is EN-9. Tool used in this experiment is Cubic Boron Nitride. Cubic boron nitride (CBN) material consists of atoms of nitrogen and boron, was produced in the early 1970s by high pressure, high temperature processing. It has high hardness and high thermal conductivity. It has much higher tensile strength as compared to diamond. It is chemically inert so it can be used as a substitute for diamond for machining steel.

V. GASES USED

The Nitrogen gas is used in this investigation. Nitrogen gas is used to compare its effectiveness with dry environment.

VI. SET-UP AND EXPERIMENTAL PROCEDURE

To fulfill the objectives of present work, experiments were perform edon EN9 steel by cryogenically cubic boron nitride under both dry and gaseous cooling environments. For this experimentation a high power rigid lathe of HMT (LB-17 model) was used. The cutting tools were purchased from Mitsubishi, India. The cubic boron nitride cutting tools were treated cryogenically. Cubic boron nitride cutting tool inserts are available in many different tool geometries and material grades.

For cooling and lubrication, nitrogen gas was used. These gases were impinged from a mild steel nozzle having diameter 1.40mm. The pressure of nitrogen and carbon dioxide gases has been kept at 3 bars. The material selected for the experiment was EN9 steel having diameter 67mm and length 640mm.

The response parameters analyzed were cutting force and tool wear. The cutting force was measured by using a dynamometer for each machining condition. The tool was attached on dynamometer and static calibration of the system was completed before experiment. The flank wear was measured using metallurgical microscope (YUCON Japan). The effect of input parameters on cutting force and tool wear were evaluated as per Taguchi design, using L27 orthogonal array.

Table 1 Input Machining parameter

S. No.	Factor	Level-1	Level-2
1	A: Cutting speed (m/min)	28	49
2	B: Feed (mm/rev)	0.050	0.063
3	C: Depth of cut (mm)	0.5	1
4	D: Environment (Catagorial factor)	Dry	Nitrogen gas

Table2. Experimental Observations

Sr. No.	A: Cutting Speed (m/min)	B: Feed (mm/rev)	C: Depth of Cut (mm)	D: Environment	Response-1 Cutting forces (kgf)	Response-2 Tool wear (mm)m((m)
1	28	0.05	0.5	Dry	32.7	0.319
2	28	0.05	1	N2	38.7	0.327
3	28	0.063	0.5	N2	26.8	0.346
4	28	0.063	1.5	Dry	46.7	0.357
5	28	0.075	1	Dry	45.2	0.354
6	28	0.075	1.5	N2	47.3	0.388
7	49	0.05	0.5	N2	26.7	0.361
8	49	0.05	1.5	Dry	35.5	0.399
9	49	0.063	1	Dry	35.2	0.402
10	49	0.063	1.5	N2	45	0.376
11	49	0.075	0.5	Dry	32.5	0.361
12	49	0.075	1	N2	35.8	0.37
13	63	0.05	1	Dry	28.2	0.398
14	63	0.05	1.5	N2	33.5	0.411
15	63	0.063	0.5	Dry	30.7	0.356
16	63	0.063	1	N2	29.2	0.36

17	63	0.075	0.5	N2	25.1	0.37
18	63	0.075	1.5	Dry	38.5	0.453

VII. RESULTS & DISCUSSION

7.1 Effect of cutting forces

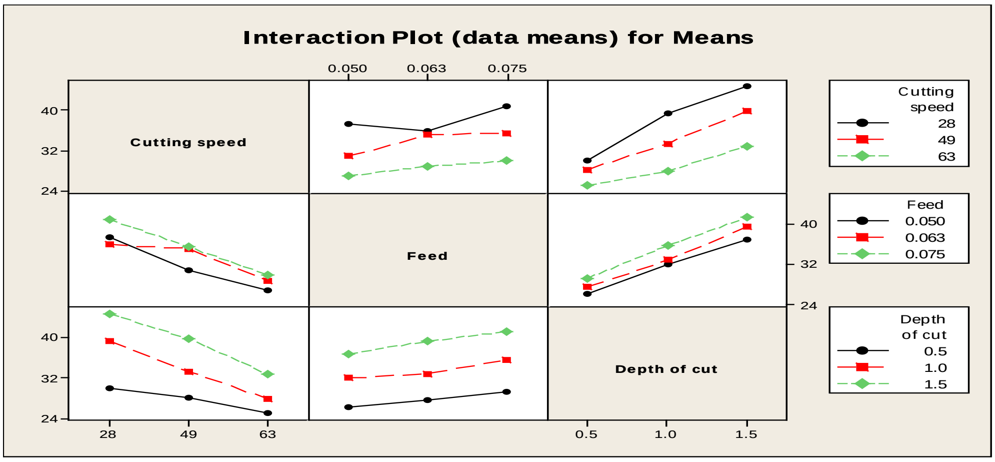

Fig 4: Interaction plot for means for cutting forces (smaller is better)

The cutting force found decreased with the increase in speed. This was due to decrease in the co-efficient of friction at the tool-chip interface on the rake face and an increase in shear angle. In case of gases application, the lowest cutting force was achieved by using carbon dioxide gas as a cutting fluid as compared to nitrogen gas and dry turning.

7.2 Effect on Tool Wear

The cutting speed, feed, depth of cut and environment have considerable effect on tool wear as shown in main effects plot for means of tool wear in Figure. Interaction plots for mean tool wear are shown in the Figure. Flank wear is the most important tool wear occurring in machining operation. The flank wear is primarily attributed to rubbing of the tool along the mechanical surfaces, causing abrasive, diffusive and adhesive wear mechanisms and also high temperature, which affect the tool material properties as well as the work piece surface. The main effect plots for means for tool wear (Figure) show that the tool wear increased frequently with the increase in depth of cut.

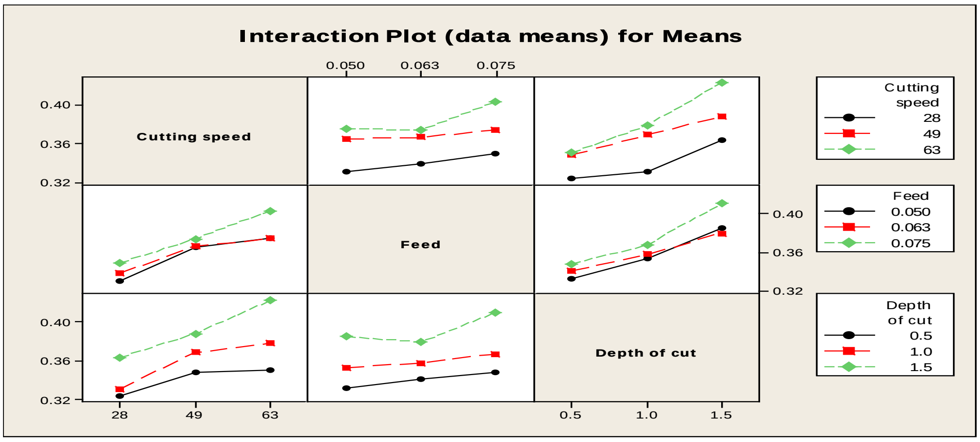

Fig 5: Interaction plot for means for tool wear (smaller is better)

This was due to high quantity of material removed, which had flown over the tool tip at higher depth of cut. The strength of the tool was also reduced because high cutting temperature was produced due to increase in the rate of plastic deformation. The tool wear increased with the increase in cutting speed because quick shearing took place at higher cutting speed result higher cutting temperature. As a result the strength of the tool was reduced and flank wear increased rapidly. In case of gases application, the lowest tool wear was achieved by using Nitrogen gas as a cutting fluid as compared to dry turning. This was due to more cooling and lubrication effect produced by the use of nitrogen gas which reduced the coefficient of friction at the interface of the tool and chip over the rake face. The cooling effect produced by the nitrogen gas appears to be more effective in reducing tool wear at comparatively higher cutting speed. It was probably due to the reason that at lower cutting speeds, the temperature of the tool tip may never be high enough compared to ambient temperature to cause the noticeable positive effect of the coolant. It is apparent that the cooling effect produced by gases neutralized the adverse effect of possible higher tool chip interface temperatures during machining. This reduction in the temperature thus helped in restricting flank wear of the cutting inserts. The tool wear for dry machining and nitrogen gas application were close. This was due to machining at atmospheric conditions and atmosphere contains more than 70% of nitrogen gas. Also, the cooling effect was increased by the flow of nitrogen gas in cutting zone and this would provide reduction in tool wear as compared to dry machining. The highest tool wear was observed in dry machining as compared with nitrogen environment in each machining parameter. The interaction plots (Figure) show the interaction between cutting speed and feed, cutting speed and depth of cut, feed and depth of cut.

VIII. CONCLUSIONS

In the present research work, an attempt has been made to study the effect of nitrogen and carbon dioxide gases on the performance of cryogenically Cubic boron nitride insert in turning EN-9 steel. The results were compared with dry turning. The following conclusions are drawn.

Application of gases has reduced the tool wear and cutting force when compared with dry machining.

Depth of cut has the maximum influence under all machining conditions.

Cryogenically cubic boron nitride performs better by using nitrogen gas as compared to dry turning environment.

The cutting forces increased with increase in depth of cut and feed and decreased as speed increased.

The flank wear increased with increase in depth of cut, cutting speed and feed.

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