PERFORMANCE OF HIGH PRESSURE COOLANT ON TOOL WEAR

R. A. Patil[1], V. D. Shinde[2]

[1]P. G. student, [2]Associate Professor, Department of Mechanical Engineering, D.K.T.E. Society's Textile and Engineering Institute, Ichalkaranji, Kolhapur, Maharashtra, India,

prahul_05@yahoo.co.in, vasu.metal@gmail.com

Abstract

Present study focuses on performance of high pressure coolant on tool wear while turning EN8 material. In industry common practice is to use low pressure coolant up to 10 bar. In the present experimentation, instead of low pressure, high pressure coolant (70 bar) is used. The set of experiments are conducted on CNC machine during turning operation on cylindrical component made up of EN8 steel. It is observed through set on experiments that with increase in pressure of coolant during turning operation shows reduction in tool wear considerably. With 10 bar pressure of coolant Ra value for 160th component is 2.923 µm, whereas with 20 bar pressure Ra value for 200th component is 1.687 µm and for 70 bar pressure for 520th component is 1.521 µm.

Keywords: *EN8 steel; High Pressure coolant; Tool wear; Turning operation.*

---***---

1. INTRODUCTION

Machining is the process of removing unwanted material from component in the form of chips to produce the desired shape. It is a form of manufacturing used to create objects out of metal. During machining, machine tool cuts the material to alter the appearance and shape of work piece or product.

In the process of machining, a tool penetrates into the work piece and removes the material in the form of chips. A major portion of the energy is consumed in the formation and removal of chips. The greater the energy consumption, the greater are the temperature and frictional forces at the tool chip interface and consequently, the higher will be the tool wear. Flood or conventional coolant is applied to remove the heat generated at the cutting zone. During machining especially of very hard materials, much heat is generated by the friction of the cutter against the work piece, which is one of the major causes of rapid tool wear [1].

2. EFFECT OF CUTTING FLUID ON TOOL WEAR

Cutting tools are subjected to an extremely severe rubbing process in machining processes. They are in metal-to-metal contact with the chip and work piece under very high stress conditions at high temperature [2]. The situation is further aggravated due to the existence of extreme stress and temperature gradients near the surface of the tool. During cutting, cutting tools remove the material from the component to achieve the required shape, dimension and finish [3]. Wear occurring during the cutting action, results in the failure of the cutting tool. Cutting tools may fail due to the plastic deformation, mechanical breakage, cutting edge blunting, and tool cracks due to the rise in the interface temperatures. Due to variations in chemical composition of cutting fluids or under high temperature, high pressure; cutting tool has normally complex wear appearance, which consists of some basic wear types such as crater wear, flank wear, thermal crack, brittle crack, fatigue crack, insert breakage, plastic deformation and build-up-edge. The dominating basic wear types vary with the change of cutting conditions. Crater wear and flank wear are the most common wear types in tools [4].

3. HIGH PRESSURE COOLANT

The application of coolants in machining is undergoing revolution. Many machine shops use coolant in a conventional way, directing a tube which floods the machining zone. Some machine shops question the use of coolant altogether and introduce dry turning. Some use it only to control dust, chip evacuation or for finishing to achieve required surface quality and tolerance.

Flooding the machining zone with coolant is not enough. If coolants are to be applied effectively they need to be applied through high pressure jets which must be exactly directed. Such a jet, when controlled in a laminar flow, shortens the contact length between chip and rake face. In this form, coolants can affect, the generated heat is distributed and removed, the amount of tool wear, the formation of chips and its deformation as well as the amount of smearing of work piece material on the cutting edge. This becomes especially important for materials which are difficult to machine, where heat and chip control need extra measures [5].

High pressure jet of coolant, if applied at the chip tool interface, the wedge formation by the jet may lift up the chip, segregating it and could break the vapor barrier and reduce cutting temperature and improve tool life. The combination of reduced heat and more efficient evacuation of chips prolong tool life and the cutting tool wears out naturally rather than failing prematurely because of excessive heat or chip damage [6].

Application of pressurized coolant jet for effective cooling without polluting the environment is becoming more popular day by day. But in addition to pollution control, the industries also reasonably insist economic viability through technological benefits in terms of product quality, tool life and saving power consumption by the application of pressurized jet cooling. So it is necessary to study the role of high pressure cooling on cutting temperature, chips, cutting force, tool wear, tool life and surface quality of the product in machining where high cutting temperature is the major concern. There have been several studies on applying coolant at high pressure, at the tool chip interface, focused on a stationary single cutting edge in a turning operation. Cooling is important in reducing the severity of the contact processes at the cutting tool-work piece interfaces [7].The performance of high-pressure coolant is investigated by focusing on surface finish, tool wear which are compared for low and high pressure of coolant.

Two main basic conditions are in place to improve machining with high pressure coolant. Many CNC machines have coolant supply at low pressures and high flow rate as standard and many have a tool holding system that is suited for high pressure coolant supply. Handling tools equipped with high pressure coolant is as easy and efficient as ordinary tools, with no operator settings of coolant jets. The benefits apply to both external and internal operations as well as grooving, profiling and pocketing [5, 7].

4. BENEFITS OF HIGH PRESSURE COOLANT

High pressure coolant can provide the following benefits especially in difficult of machine materials [5, 7].

a) Consistent machining process.
b) Fewer machine stoppages
c) Better component quality
d) Improved surface finish
e) Better chip control
f) Faster cycle time and short machining time
g) Better utilization of machine capabilities
h) Increase in tool life

These benefits can also be applied to milling and drilling operations also. The principle behind the application of high pressure coolant is that a reduction in the fluid outlet (nozzle on tool holder) produces an increase in the fluid velocity coming out of the nozzle. Larger the nozzle, the higher will be the flow rate of the fluid. Moreover, the number of nozzles (accumulated outlet area) will affect the resulting fluid outlet pressure [8,9].

The Bernoulli's proven theory expresses the relationship between pressure, velocity and flow rate of a fluid, such as a coolant. As the fluid passes from a larger diameter to a smaller diameter tube, the flow rate requirements are smaller to achieve a high velocity jet. The larger the nozzle outlet diameter, the greater the flow rate requirement needed to deliver a certain amount of pressure on coolant [6].

5. METHODOLOGY

The Fig. 1 shows flowchart of the methodology used to perform the experiments in current work. To study the effect of high pressure coolant on tool wear while turning to manufacture the threaded oil nipple of EN8 steel.

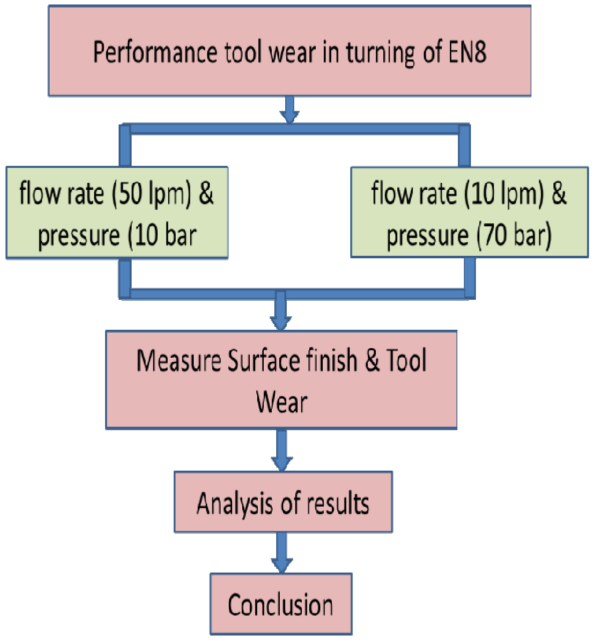

Fig.1: Flow diagram of experimental work

6. EXPERIMENTATION

The high pressure coolant attachment is designed to supply high pressure coolant during turning operation. The fixed parameters in the experimentation are as follows

- Work material – EN8 Steel
- Machining method – Turning
- Tool – Single point cutting tool
- Tool insert – DNMG (IC320), WNMG (IC9015)
- Cutting Conditions –
  - Speed – 2000 rpm
  - Feed – 0.1 mm/rev
  - Depth of cut – 0.2 mm
- Coolant – Water base Ashoka LD-700

The Pressure of coolant is varied while conducting the set of experiments.

Fig.2 shows the high pressure coolant system with all the attachments. Pressure relief valve, pressure gauge and motor are mounted on the top of reservoir. The pump is attached inline below the motor, inside the tank.

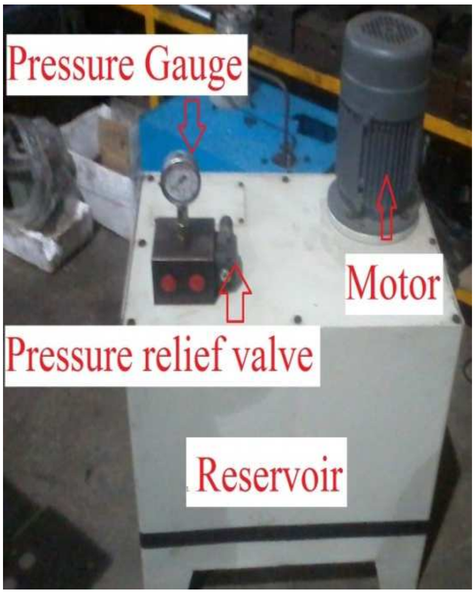

Fig. 2: High pressure coolant system

Fig. 3 shows the insert used for turning of threaded oil nipple. The details of insert are.

Type of tool : Single point cutting tool
Tool Insert : DNMG (IC320)

Fig. 3: Triangular insert

The experiments are performed on CNC with high pressure pump attachment as shown in Fig. 4, with high pressure coolant system attachment. The externally high pressure coolant supplying nozzle is also attached to the CNC as shown in Fig. 4.

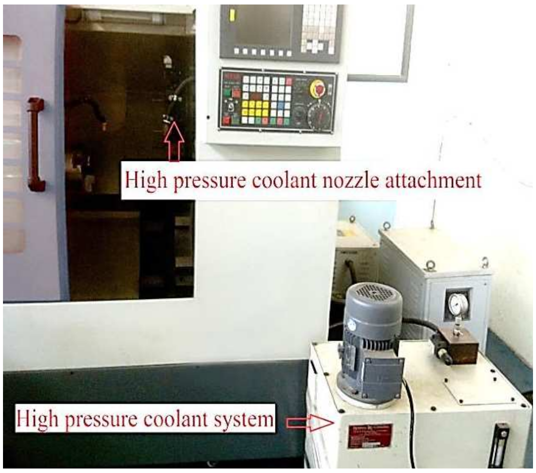

Fig. 4: Experimental Set up

The component for study is threaded nipple shown in Fig. 5. This is used for supplying the oil to the engine. On this component various machining operations are performed. For present study the turning operation on hexagonal bar of 25mm size is under study.

Fig.5: Machined Component

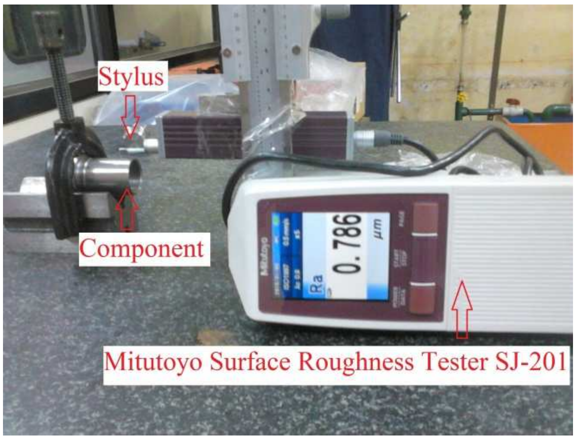

Fig.6: Mitutoyo Surface Roughness Tester used for testing surface roughness of machined components

The Surface finish of machined component is measured by Mitutoyo Surface Roughness Tester SJ-201 as shown in Fig. 6. At 10 bar pressure, the tool performs well to machine 160components with the necessary surface finish. In the whole experiments, every 10thsuccessive component is checked for its surface finish. The surface roughness is checked for the batch of 160 components with 10 and 70 bar pressure of coolant supply.

7. EFFECT OF COOLANT PRESSURE ON TOOL WEAR

Tool wear is measured in terms of surface finish of tool after machining of 160 components. During machining, heat is generated at the primary deformation zone due to shearing of metal, secondary deformation zone and the flank (clearance) surfaces due to rubbing, but the temperature attains maximum at the chip-tool interface. High pressure coolant can penetrate effectively into the chip-tool interface and reduce this chip-tool interface. The scanning electron microscope (SEM) studies of tool are performed with water based coolant with different pressure especially with 10 bar (50 lpm of coolant supply) and high pressure of 70 bar (10 lpm of coolant supply).

8. SURFACE ROUGHNESS PARAMETERS

Surface roughness is measured by using Ra, Rq and Rz which gives the surface roughness value in micron. Ra is the universally recognized parameter of roughness. It is the arithmetical mean of the departures of the profile from the mean line. For technical drawings the surface roughness value is indicated directly in micron as Ra value or by grade numbers.

$$R_a = \frac{1}{l}\int_0^l |Z(X)|dx$$

Rq is the square root of the arithmetic mean of the squares of the deviations from the mean line to the evaluation profile. The Root Mean Square roughness is commonly specified for the surfaces of optical component. In general, lower the RMS roughness of an optical component, the less stray light and higher the quality of the component.

$$Rq = \sqrt{\frac{1}{l}\int_0^l Z^2\ (x)dx}$$

Rz value is measures over a single sampling length and is itself an average of positive and negative peak values. It is useful parameter when only a short length of the surface is available for assessment. The Rz divides the evaluation profile into segments based on the sampling length. For each segment, the sum of the highest and the lowest point from the mean line is calculated. Rz is the average of these sums.

$$Rz = \frac{(R_1+R_3+R_5+R_7+R_9)-(R_2+R_4+R_6+R_8+R_{10})}{L}$$

Table 1 shows the surface roughness (Ra, Rq and Rz) values of the tool after machining of 160 components by using water based coolant. The use of high pressure coolant (70 bar, 10 lpm) improves the surface finish significantly. The Ra, Rq and Rz values should be as low as possible, for better surface finish.

Table 1: Surface finish of tool after machining of 160 components at varied coolant pressure

Coolant Pressure (bar)	Flow rate (lpm)	Ra (µm)	Rq (µm)	Rz (µm)
10	50	2.923	3.790	13.798
70	10	0.786	1.157	4.497

The tool wear at low pressure (10 bar) and high pressure (70 bar) is given in Table 2.

Table 2: Tool Wear

Pressure (bar)	Flow Rate(lpm)	Distance of 100 µm Scale	Tool wear (µm)
Low(10)	50	55 pt	73.47
High (70)	10	55 pt	46.49

9. SEM STUDIES OF TOOL TIP FOR SURFACE FINISH

Scanning electron microscopy (SEM) uses a focused electron probe to extract detailed information point-by-point from a region of interest in the sample. The high spatial resolution of an SEM makes it a powerful tool to helps morphological study of thin films, powders, pellets of Metals, Metal oxides, polymers, alloys. The JEOL JSM-6360 make SEM is used to capture the tool tip images. These images are taken at X 250 magnification at 20 kV. The Fig. 7 shows the SEM images of tool tip after machining of 160 components at 10 bar pressure. Tool wear is measured with the help of SEM images captured during study.

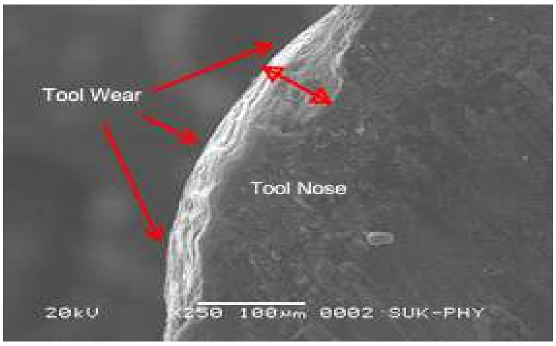

Fig. 7: SEM image of tool insert tip at 10 bar pressure, after machining of 160 components

Fig. 8 shows the SEM images of tool tip after machining of 160 components with 70 bar pressure.

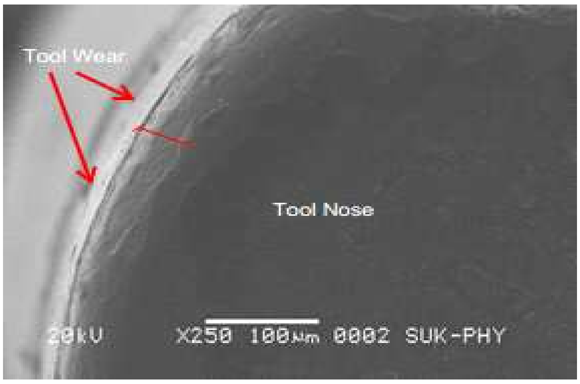

Fig. 8: SEM image of insert tool tip at 70 bar, 10 lpm after machining of 160 components

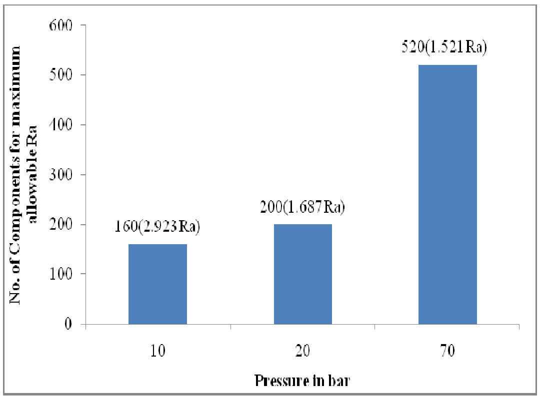

Fig. 9: Number of component v/s Pressure

From Fig. 9shows the number of components machined with different pressure conditions. It can be seen that for maximum allowable Ra value the number of components turned at 10 bar, 20 bar and 70 bar pressure (with flow rate 50, 30, 10 lpm respectively) are 160, 200 and 520 respectively.

CONCLUSIONS:

- Tool wear at 70 bar coolant pressure is 46.49 µm whereas for 10 bar it is 73.47 µm.
- High pressure with low flow rate water based coolant (70 bar, 10 lpm) results in less tool wear compared to low pressure and high flow rate water based coolant (10 bar, 50 lpm) during turning of EN8 steel.
- Use of high pressure water based coolant reduces the tool wear, with improvement in surface finish of the component.
- With 10 bar pressure of coolant Ra value for 160th component is 2.923 µm, whereas with 20 bar pressure Ra value for 200th component is 1.687 µm and for 70 bar pressure for 520th component is 1.521 µm.

REFERENCES:

[1] M. M. A. Khan and N. R. Dhar, “Effect of High-Pressure Coolant on Temperature, Chip, Force, Tool Wear, Tool Life and Surface Roughness in Turning AISI 1060 Steel”, G.U. Journal of Science (2009) 22(4): 359-370

[2] J. Kaminski and B.Alvelid, “Temperature reduction in the cutting zone in water-jet assisted turning,” International Journal of Machine Tools and Manufacture, (2010)52, 925-932

[3] V. P. Astakhov, “Cutting Fluids (Coolants) and Their Application in Deep-Hole Machining”,STEN, No 2, Moscow, (1994) 30-35.

[4] International Organization for Standardization, “Tool-life testing with single-point turning tools”, 1993, ISO 3685.

[5] AB SandvikCoromant “High pressure coolant machining” catalog, (2010)-06.

[6] X. Li, “Study of the jet-flow rate of cooling in machining Part 1.Theoretical analysis” Journal of Materials Processing Technology,(1996) 62,149-156.

[7] A. Senthil Kumar, M. Rahman and M. S. Ling, “Effect of High-Pressure Coolant on Machining Performance”, International Journal of Advanced Manufacturing Technology, (2002)20, 83-91.

[8] L. N. Lopez, de Lacalle, J. Perez Bilbatua, J. A. Sanchez, J. I. Llorente, A. Gutiérrez and J. Alboniga, “Using High Pressure Coolant in the Drilling and Turning of Low Machinability Alloys”, International Journal of Advance Manufacturing Technology, 16(2000)85–91.

[9]X Li. “Study of the jet-flow rate of cooling in machining”, Part 2: simulation study, Journal of Materials Processing Technology 62: 157-165, 1996.