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Experimental Study of Coolant Temperature Effect on Tool Wear in Turning of Mild Steel

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Abstract: Cost of the product along with the quality of the product is of prime importance sustaining in the market among the consumer. Product cost comprises of several component in which one of the components is manufacturing cost. There are several components in the manufacturing cost and tool cost one of them. A tool will have some initial cost which is fixed but effect of tool cost on over all machining cost depends on tool life. Longer the tool life lesser the impact of tool cost on overall machining cost, and hence lesser the product cost. There are several parameters affects tool life which are not going to be considered here. In the present work effect of coolant temperature is considered on tool life. Coolant is supplied at different temperature while machining for a fixed period of time and keeping all other machining parameters fixed every time corresponds to different temperature. The study shows the lower the coolant temperature higher the tool life.

Keywords: Tool life, tool wear, coolant, tool productivity.

I. INTRODUCTION

Machining cost has various components out of which one of the components is tool cost. The cost of tool depends on tool life. Tool life is broadly inversely proportional to cutting speed, depth of cut and feed rate [1]. Some other significant factors affecting tool life are tool material and work material and the tool shape chosen for machining the particular material and there is well established relation between tool life and cutting speed [2]. The author proposes an approach for optimizing tool life by using optimal value of velocity and feed throughout the cutting process [3]. Cutting parameters are optimized in this work for minimum power consumption and maximizing tool life for Al alloy Si particle composite by considering optimal cutting speed, feed, depth of cut and nose radius [4]. Cutting fluid increases efficiency of machining improves surface finish and cools workpiece and tool, reduces friction which further helps in lowering the temperature and power consumption [5]. The author has addressed the optimization of tool wear and surface roughness simultaneously for CNC micro turning of Inconel 600 alloy with titanium carbide coated tool in this work [6]. An approach is presented using artificial neural network for the prediction of tool wear, surface roughness and vibration in boring operation AISI 316 steel [7]. The authors conducted a study on the effects of various cutting parameters like cutting speed, feed and depth of cut on temperature distribution and tool life [8]. The author reported that the cutting tool characteristics affects the cutting edge temperature in turning operation of case hardened stainless steel [9].
Cutting fluid has important role in machining process but it has environmental impact also it also affects the material to be machined, some researches are making their effects in finding some eco-friendly cutting fluids such as gaseous and liquid nitrogen [10]. Since the cutting fluid has negative impact on environment and it also the use of fluid increases overall production cost therefore there is a need of optimizing the use of cutting fluid, the author done work on minimal use cutting fluid in milling operation [11]. Cutting fluid selection and its application is not optimized in the industry, there are different types of fluids which to satisfy requirements of machining operation under different set of parameters like cutting speed, material to be cut etc [12].
Evidences are always been available that the cutting fluid increases the tool life irrespective of type of fluid by removing heat from the tool workpiece interface and also acts as lubricants which reduces friction and frictional heat is also be reduced. From the study of previous literature, it has been found that a lot of efforts have been made by various researchers for reducing tool wear and improving tool life using optimization of various cutting parameters and tool geometry. The effect of cutting fluid temperature on tool wear is addressed in the literature therefore in this work an effort has been made to study cutting fluid temperature on tool wear and tool life.

II. EXPERIMENTAL SETUP AND MATERIAL USED

A. Lathe
The institute is facilitated with central workshop with several machine tools along with various types of lathe machines. The experimental work has been carried on centre lath as shown in Figure 1 below. The lath machine is of Kirloskar

make and model is Enterprise 1330. Swing of the machine is 355.6 mm, centres are at 177.8 mm and maximum turning distance is 1016 mm, spindle bore is 44.5 mm.

Figure 1 Centre Lath

B. Cutting Tool

A high-speed steel cutting was taken for this study as shown in Figure 2 below.

Figure 2 Single point cutting tool

High Speed Steel High Speed Steel (HSS) is usually carbon steel containing 1.5 to 2% carbon, 18 % tungsten, 4% chromium, 1% vanadium and rest is iron. Tungsten is added to increase hardness. Chromium is added to increase hot hardness. Vanadium is added to increase wear resistance. Method of fabrication for HSS is forging. Cutting velocity of HSS is 40-60 m/min. It gives higher speed than HCS. Hot hardness temperature of HSS is about 600°C.

C. Tool Grinder

The single point cutting tool was used for removing material need to resharpen using a tool grinding machine as shown in Figure 3.

Figure 3 Tool room grinding machine

D. Work Piece

A mild steel rod was used as work piece in this experimental work as shown in Figure 4. Diameter of rod is 34 mm and length of rod is 750 mm.

Figure 4 Workpiece

E. Coolant

Water based coolant is used in machining process and oil-based coolant for reducing friction. The coolant in the experimental work was to be cooled down in refrigerator and low temperature was causing separation of the additives of coolant. Therefore, it was decided to use pure water as coolant.

F. Weighing Machine

It is a precision weighing machine used for taking accurate weight of cutting tool after material removal from the work piece. The weighing machine as shown in Figure 5 is of Citizon make and model number is CX220. The instrument has a maximum capacity of 220 gm and readability of 0.0001 gm. The pan diameter of the machines is 90 mm. The machine is enclosed in a glass chamber to avoid any affect of air motion around the machine.

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Figure 5 Weighing machine

G. Vernier Callipers

A 150 mm vernier calliper with 0.02 mm least count was used for measure change in diameter of the workpiece to estimate amount of material removed.

H. Thermometer

A thermometer was used to measure temperature of coolant. Coolant temperature can be measured by dipping probe in the coolant.

I. Coolant dispenser and coolant cooler

A refrigerator was used to pre cool the entire amount of coolant. After cooling the coolant, it was stored in insulated container which has tap for outlet to maintain continuous flow.

II. EXPERIMENTAL PROCEDURE

The experimental work was done to study the effect of coolant temperature on tool wear. A cylindrical workpiece is turned on lathe machine at constant spindle speed of 224 rpm. Before starting machining weight of the tool was taken and initial dimensions of workpiece was also measured. The workpiece diameter was 34 mm and it was reduced to 32 mm with a feed rate of 0.048 mm / revolution and depth of cut 0.5 mm. The coolant temperature of 35ºC was kept for the first set of experiment. The machining is done for 150 minutes. After machining tool weight was again taken with the help of weighing machine to determine loss of tool material. After machining work piece measurement was done to know the volume of material removed during machining.

The experiment was repeated with the same parameters with reduced coolant temperature of 30ºC, 25ºC, 20ºC, 15ºC, 10ºC, 50ºC and 0ºC for constant machining time of 150 minutes. Corresponds to each temperature loss of tool material and volume of workpiece material removed was determined.

The coolant was chilled in refrigerator and some makeup coolant was added at room temperature to achieve desired temperature of coolant. A continuous supply of coolant was maintained at constant flow rate over the tool-workpiece interface.

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III. OBSERVATIONS AND RESULTS

The Table 1 shows tool wear during machining of MS rod with reduction in temperature of coolant. It can be observed that the tool wear is reducing with reduction in coolant temperature form 35ºC to 0ºC.

Table 1 Tool wear at different coolant temperature

S. No	Temperature ^{0} C	Initial weight gm	Final weight gm	Wear rate mg
1	35	92.4236	92.4123	11.3
2	30	92.3942	92.3846	9.6
3	25	96.0415	96.0331	8.4
4	20	94.4430	94.4373	5.7
5	15	93.9075	93.9030	4.5
6	10	93.4753	93.4718	3.5
7	5	93.1979	93.1951	2.8
8	0	92.7533	92.7516	1.7

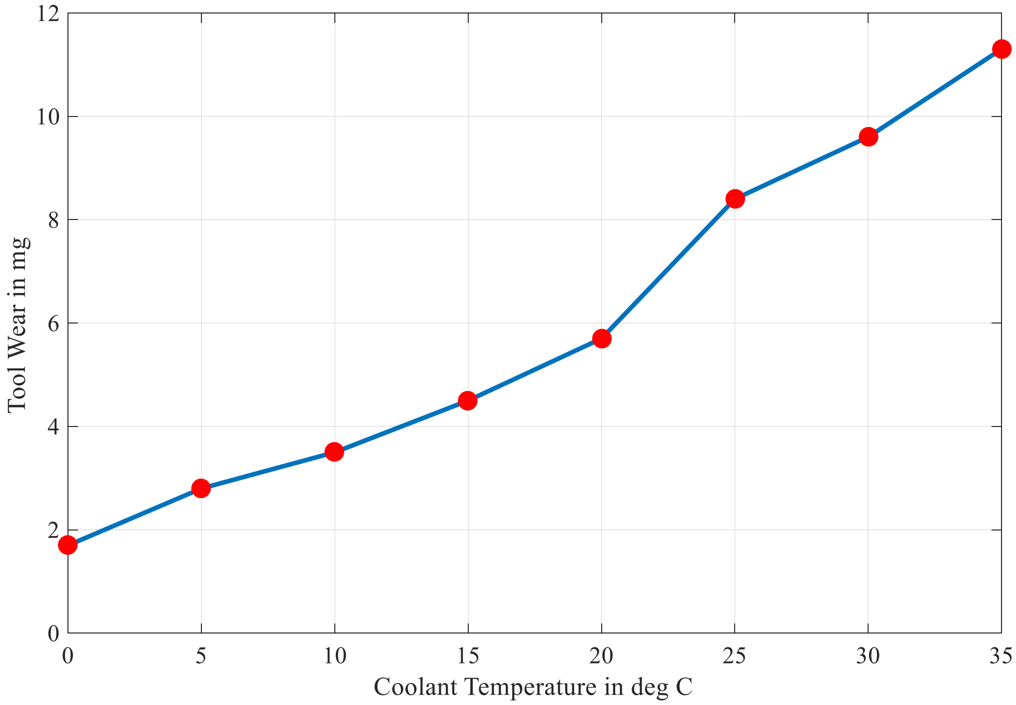

Figure 6 Tool wear with variation coolant temperature

The variation in tool wear with increase in coolant temperature can be seen graphically in Figure 6. The rate of wear is not uniform throughout the coolant temperature range from 0ºC to 35ºC, for every 5ºC difference it varying with a smaller amount.

Volume of material removed and tool wear is shown in *Table 2*. The ratio of material removed to tool wear in this table with reducing coolant temperature indicates that the material removal rate is increasing per unit tool wear with the reduction in coolant temperature. This ratio can be considered as **productivity** of the tool corresponds to particular temperature and machining parameters.

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Table 2 Material removal capacity of tool with coolant temperature variation

S. No	Temperature ° C	Material Removed (mm^3)	Tool Wear (mg)	Tool Productivity (mm^3/mg)
1	35	77754.4182	11.3	6880.922
2	30	73042.0292	9.6	7608.945
3	25	77754.4182	8.4	9256.478
4	20	87179.1960	5.7	15294.596
5	15	82466.8072	4.5	18325.957
6	10	77754.4182	3.5	22215.548
7	5	68329.6402	2.8	24403.443
8	0	63617.2512	1.7	37421.912

The ratio of volume of the material removed during maching to tool wear occurred to remove that much volume is shown *Figure 7*. It can be seen in that a the coolant temperature increases the productivity of the tool decraeses.

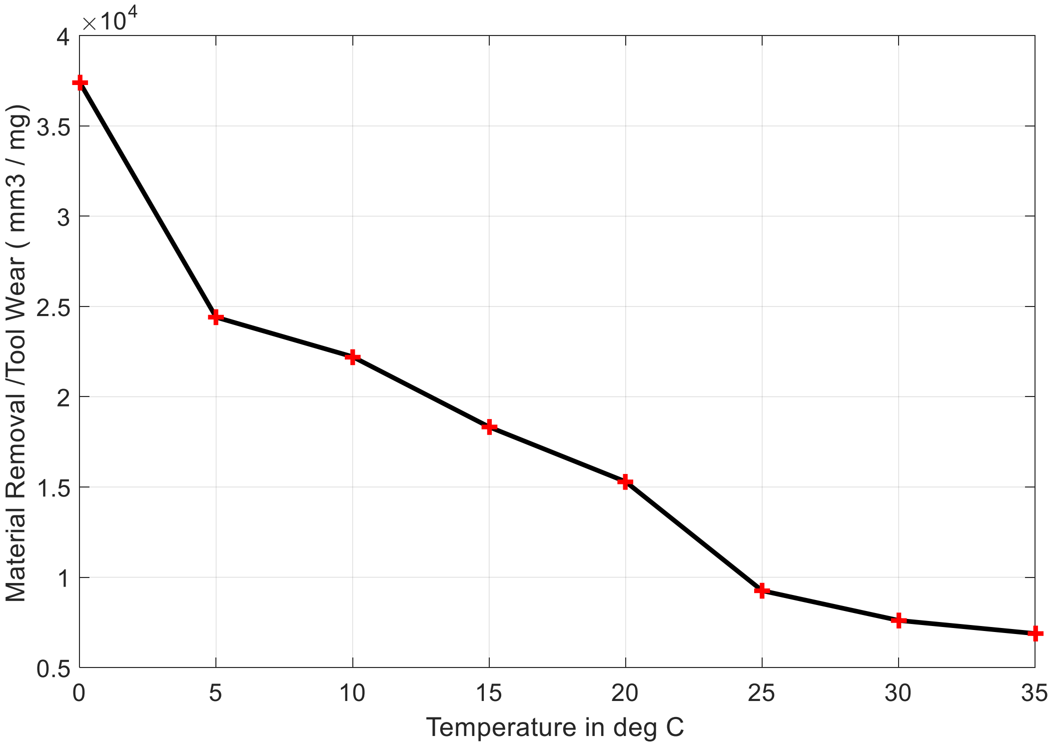

Figure 7 Material removal to tool wear ratio with increase in temperature

IV. CONCLUSION

The study is focused on tool wear corresponds to different temperature of coolant, from the Table 1 tool wear seen with different coolant temperature and the it is shown graphically in Figure 6. As it is clear from the Figure 6 that the tool wear is lowest at the lowest temperature of coolant and it is increasing as the coolant temperature is increasing. The wear at the highest (35^{0}C) temperature is 6.6 times the wear at lowest coolant (0^{0}C) temperature.

The effect of coolant temperature on productivity of tool is given in the Table 2 and it is represented graphically in Figure 7. Tool productivity is increasing as coolant temperature lowers down from 35^{0}C to 0^{0}C. The tool productivity at 0^{0}C is 5.4 times the productivity at 35^{0}C.

The study shows that the lower the coolant temperature higher the tool life and lower the tool wear therefore the coolant which used to be recirculated must be passed through some cutting fluid cooler to achieve good tool life.

The present study was conducted for a single point cutting tool on a lathe machine by keeping various machining parameters fixed except coolant temperature. Effect of coolant temperature on workpiece surface, machining quality, chip formation, power consumption etc was not taken into account.

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