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Comparative Performance Evaluation of Ceramic Tools for Hard Turning of High Chromium High Carbon Steel

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Abstract **- In this reasrach paper, effects of machining parameters (cutting speed & feed rate) on tool life are investigated. For this purpose high Chromium & High Carbon steel is machined at dry condition with ceramic insert at three different cutting speed (95, 130,170 m/min) , feed rate (.005, 0.008,0.1 mm/ rev) & depth of cut 0.2 mm..Two factor three level full factorial design was adopted for the experiment. A total of 11 experiments were conducted.**

Experiments were conducted on ceramic tool to establish whether it can be a better alternate to the CBN tools. It was concluded from the experiments that ceramic tool has lesser tool life than CBN, but its cost is substantially low & unit cost of tooling comes down considerably by using ceramic tools i.e. Rs 10 per component to Rs 1.5 per component. It has been found that effect of feed is more sever on tool life than cutting speed. Another most important observation is that clamping rigidity is very important for ceramic tools in comparison to CBN.

Keywords- ***CBN, Tool ,Ceramic ,Cutting speed.***

INTRODUCTION

HARD TURNING

In the metal cutting industry, turning heat-treated products with hardness above HRC 45 using a single-point tool is referred to as hard turning. The customary method for machining such parts has always been by turning material in the unhardened form, heat treatment and finishing by grinding. The development of new tool material, such as cubic boron nitride (CBN) & ceramic cutting tools has made hard turning possible. Hard turning has proved effective in reducing cost and lead times. The reduction in cost is due to the fact that turning can incorporate more operation into a single operation. Turning also uses less type of dependent tools and has a shorter setup time.

METHODOLOGY

The study was undertaken to evaluate the performance of a ceramic cutting tool when turning hardened steel (HRC 58) at various cutting conditions in terms of tool life of turned part. Two factor three level full factorial designs were adopted for the experiments. Two factors are cutting speed and feed rate. Three levels are low, high & medium level of speed & feed rate. The experiments were conducted under constant depth of cut of 0.2 mm & dry cutting condition. This chapter will also explain the experimental procedure, equipment being used, work piece material and cutting tool.

MACHINE SPECIFICATION

Figure :CNC Machine Tool.

Machine type : GEDEE WEILER 2 axis CNC Lathe.

- Motor horse power 3.7 KW
- Spindle Speed 6000 rpm
- Tool Capacity 8
- Controller Siemens
- Size 120 φ
- Piston area 103 Cm^2
- Stroke 25 mm
- Max Pr 40 bar
- Operating voltage 415 V

CERAMIC INSERT

Figure : Ceramic inserts

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- ISO Code : CNGA 120404
- Make: Taegutec.
- C: insert shape is 80 deg. Rhombic
- N: insert relief angle is 0 deg
- G: high tolerance class
- A: hole of the insert is cylindrical
- 12: size of insert is 12.70 mm
- 04: thickness of insert is 4.76 mm
- 04: corner radius is 0.4 mm

TOOL HOLDER

Figure : Tool holder MCLNL 2020 M12

MCLNL 20 20 M 12.

- M: Type of clamp is combination clamp.
- C: insert shape is 80 deg Rhombic
- L: approach angle is 95 deg.
- N: clearance angle of insert is 0 deg.
- L: left hand cutting
- 20: shank height is 20 mm.
- 20: shank width is 20 mm.
- M: length of tool is 150 mm.
- 12: insert size is 12 mm.

WORK PIECE MATERIAL

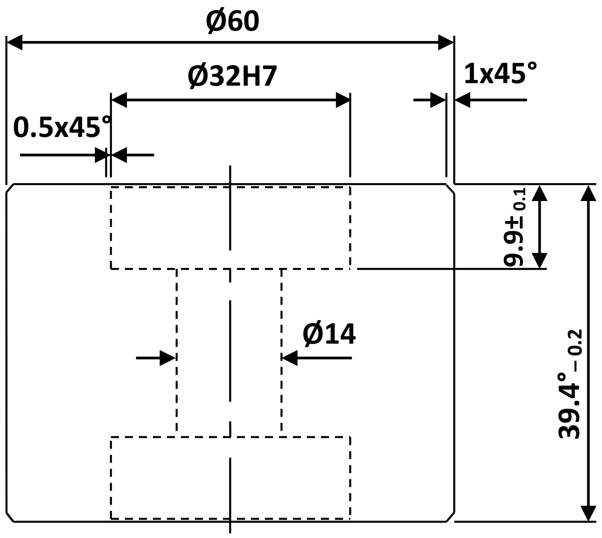

Figure : Work Piece (Roller Guide)

The selected work piece material was high carbon high chromium steel $T_{160}Cr_{12}$ (D_2). This material is general purpose oil hardened which has good machinability, dimensional stability in hardening, high surface hardness and toughness after hardening. The hardness of this material is 58 HRC. The percentage composition are shown in table

Table : Percentage composition of work piece material

Composition	Carbon	Silicon	Manganese	Chromium
Percentage	1.60	1.0	1.0	12

CUTTING INSERT MATERIAL

Cutting insert used were rhombic ceramic tools from Taegutec manufacturer. These have been selected for use during the machining experiments, and its code is CNGA 120404 AB 20 and the nose radius is 0.4 mm. The ceramic tool was placed on left-hand tool holder MCLNL 2020M12. The geometry of the insert is as under.

- Back rake angle (α) = -5°
- Side rake angle (γ) = -5°
- End cutting edge angle= 5°
- Side cutting edge angle(SCEA) = 5°
- Clearance or relief angle= 0°

CUTTING CONDITIONS

The cutting condition recommended by Taegutec for insert with a depth of cut 0.2 mm are feed rate are 0.04 to 0.12 mm/rev. & cutting speed 90 to 180 m/min.
It is recommended by international organization for standardization (1977) that cutting speed follows the geometric series of preferred numbers other conditions recommended as shown in table:

Table 4.2: Limits of cutting conditions.

maximum depth of cut	10 times feed
maximum feed	0.8 times corner radius

Taking these recommendations into consideration while incorporating the design of experiment aspects, the cutting parameter are summarized below. Only the cutting speed & feed rate were varied. Other variables were controlled to their test effect & were set constant throughout the experiments Factorial experiments involving 3 levels were selected. Table shows the cutting conditions taken

Table : Cutting conditions for the experiment.

Cutting speed (m/min)	95	130	170
Feed rate (mm/rev)	0.05	0.08	0.10
Depth of cut (mm)	0.2		

EXPERIMENTAL PLAN

Two factors, three-level, full factorial design was adopted for the experiment. Two factors which are cutting speed and feed rate will be investigated, while depth of cut is set constant. Center point was replicated twice to allow estimation of pure error for lack of fit test and deduction of curvature. A total of 11 experiments will be conducted. Figure 4.5, Tables 4.4 and 4.5 show the arrangement of the design of experiment

Two Factor Three-Level Full Factorial Design

Statistical design of experiments technique is a collection of mathematical and statistical techniques that are useful for the modeling and analysis of problems in which response of interest is influenced by several variables and the

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objectives is to optimize this response. Two-factor three-level full factorial design is a particular design and it can quantify relationships among one or more measured response and the vital input factor. The two factors three-level full factorial design is practical, economical and relatively easy for use.

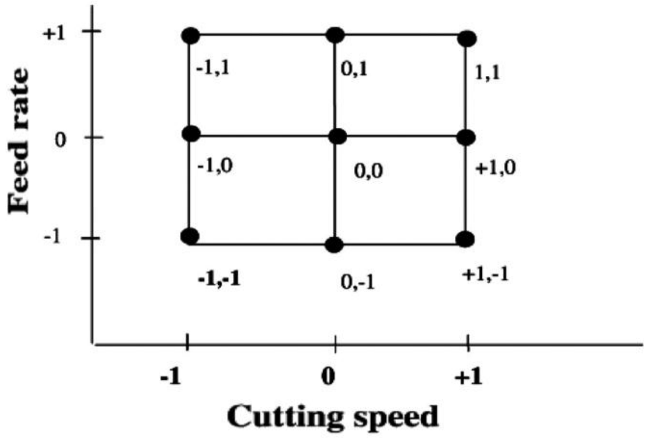

Figure 4.5: Arrangement of 3^2 full factorial design.

Table 4.4: Levels for the independent variables.

Levels	Low	Centre	High
Coding number	-1	0	+1
Cutting speed (m/min)	95	130	170
Feed rate (mm/rev)	0.05	0.08	0.1
Depth of cut (mm)	0.2		

Table 4.5: Design matrix for the experimental cutting condition.

No	Cutting speed (m/min)	Feed Rate (mm/rev)	Coded Form	
			XI	X2
1	170	0.05	1+	1-
2	130	0.08	0	0
3	170	0.10	1+	1+
4	95	0.05	1-	1-
5	95	0.10	1-	1+
6	170	0.08	1+	0
7	130	0.08	0	0
8	130	0.05	0	1-
9	130	0.10	0	1+
10	130	0.08	0	0
11	95	0.08	1-	0

EXPERIMENTAL RESULTS & DISCUSSION

It is observed that the tool life is influenced by the feed rate and cutting speed. Increased cutting speed caused tool life to decrease because of the effects of temperature on the physical and mechanical properties of material. In addition when the cutting speed increases, temperature at tool tips becomes high, this results in having a soft tool tip with tendency to fail while rubbing with the work surface.

During this study, the maximum tool life was recorded at 95 m/min cutting speed and 0.05 mm /rev feed rate, whereas the minimum tool life was recorded at the highest condition of 170 m/min cutting speed and 0.1 mm / rev feed rate. The experimental results obtained are shown in Table 5.1.

Table : Experimental results for tool life.

N	Cutting Speed (mm/rev)	Feed Rate (mm/rev)	Depth of Cut	Tool Life No of piece/Edge
1	170	0.05	0.2	379
2	130	0.08	0.2	383
3	170	0.10	0.2	189
4	5	0.05	0.2	861
5	95	0.10	0.2	230
6	170	0.08	0.2	368
7	130	0.08	0.2	400
8	130	0.05	0.2	505
9	130	0.10	0.2	196
10	130	0.08	0.2	435
11	95	0.08	0.2	872

Effect of Cutting Speed and Feed Rate on Tool Life.

Ceramic tools have relatively shorter tool life in comparison of CBN. This may be attributed to the nature of the material (high hardness) which produces high cutting force and cutting temperature especially while the cutting speed is higher. Thus, this causes the ceramic tool to suffer rapid wear, chipping or even fail catastrophically.

This may be caused by the amount of the adhered layer increases with increase of cutting speed, and acts as a protective film to reduce tool wear, which leads to an increase of the tool life with the cutting speed up to a certain limit. However, when the cutting temperature is higher due to even higher cutting speed, the layer on the tool face softens. At such conditions it can be easily abraded by the hard particles of the work material, tool wear is influenced. Thereafter, the tool life of the ceramic tools would be decreased. The tool life decreases with a corresponding increase of cutting speed from 95 m/min to 170 m/min. As illustrated in following figures trend of cutting speed and tool life is shown

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Figure: Tool life vs Cutting speed at 0.05 mm/ rev feed rate.

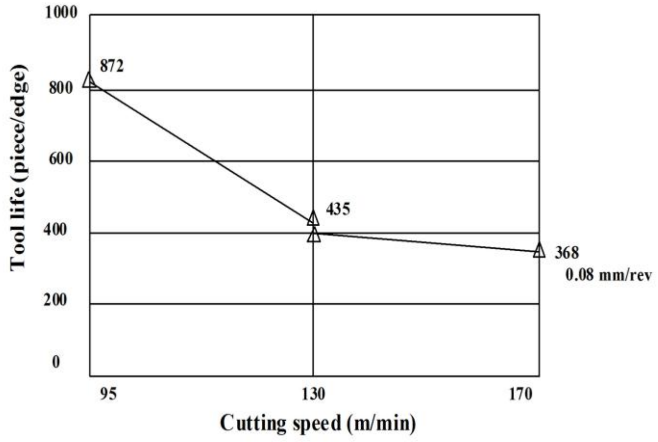


Figure : Tool life vs Cutting speed at 0.08 mm/ rev feed rate

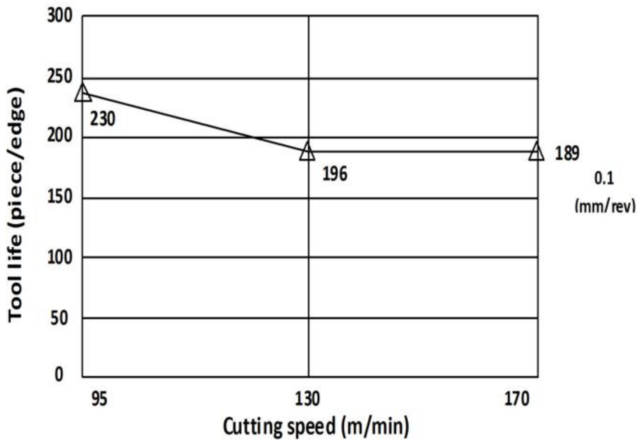
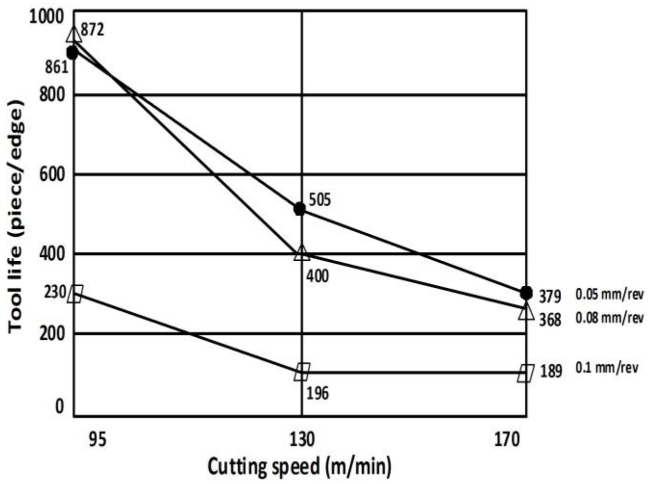


Figure : Tool life vs cutting speed at various feed rate.



Tool life decreases with corresponding increases in cutting speed and of the feed rate used. Similarly, tool life decreased with corresponding increases of either cutting speed or feed rate while the other remained constant. Both cutting speed and feed rate shows significant effect on inserts tool life.

Figure shows the effect of the feed rate on the tool life.

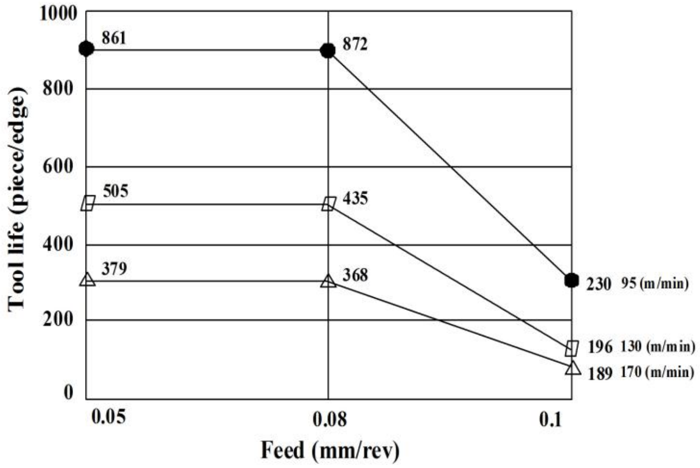


Figure : Tool life vs feed rate at various cutting speed.

The general trend has been that tool life decreases when cutting speed is increased or when feed rate is increased. Higher cutting speed or higher feed rate causes higher wear rate that eventually resulted the tool life to decrease.

- Experiments revealed that longest tool life were obtained at low cutting speed & low feed rate while shortest tool life were at highest cutting speed & highest feed rate.
- Experiments revealed that feed rate is the most significant variable which influences the tool life.
- Experiments revealed that success in hard turning is largely a measure of the machine construction & design along with the work holding & tool holding. The level of rigidity in hard turning application by ceramic cutting tools in comparison of CBN is of utmost importance.

CONCLUSION AND SCOPE FOR FUTURE WORK

The company where the project was carried out was using CBN tool for machining of hard material & the performance of this tool was already known. Experiments were conducted on ceramic tools to establish whether it can be a better alternate to the existing CBN tool. As indicating by the result of the experiments the ceramic tool has slightly lesser tool life than CBN but its cost is substantially low and the unit cost of tooling comes down considerably by using ceramic tool, i.e. from Rs 2.50 per component to Rs 0.375 per component.

It has been found that effect of feed is more severe on tool life than that of cutting speed.

Another observation is that the clamping rigidity is very important for ceramic tool. By using M type clamp in place of P type clamp gives better results. While the P type clamp totally failed to perform.

The result of the study & experiments are likely to benefit the concerned industry & they may switch over to Ceramic tools for hard turning in near future & may be, inspired to conduct more experiment to improve the machining performances.

The performance evaluation of ceramic tool for hard turning has been carried out with influence of cutting speed & feed on tool life. There is a scope of conducting more and more experiments in this field and the following is recommended for future work.

The effect of edge preparation on tool life. Comparison may be made with other type of edges in order to have a better understanding of different edge formations such as chamfer for ceramic insert.

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