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Effect of Cutting speed & feed on Material Removal Rate (MRR) of High Chromium High Carbon Steel in Hard Turning

Sushil Kumar, Lecturer,
D.N. Polytechnic Meerut
D. P. Singh, Lecturer, SCRIET C.C.S.
University Meerut

Abstract **- In this paper, effects of machining parameters (cutting speed & feed rate) on MRR are investigated. For this purpose high Chromium & High Carbon steel is machined at dry condition with ceramic insert at three different cutting speed (90, 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.. This paper reveals that MRR was observed more when tool life was largest.

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 MRR 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.

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 5 show the arrangement of the design of experiment

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 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.

MACHINE SPECIFICATION

Figure 1: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 2: Ceramic inserts

- 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 3: 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.

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WORK PIECE MATERIAL

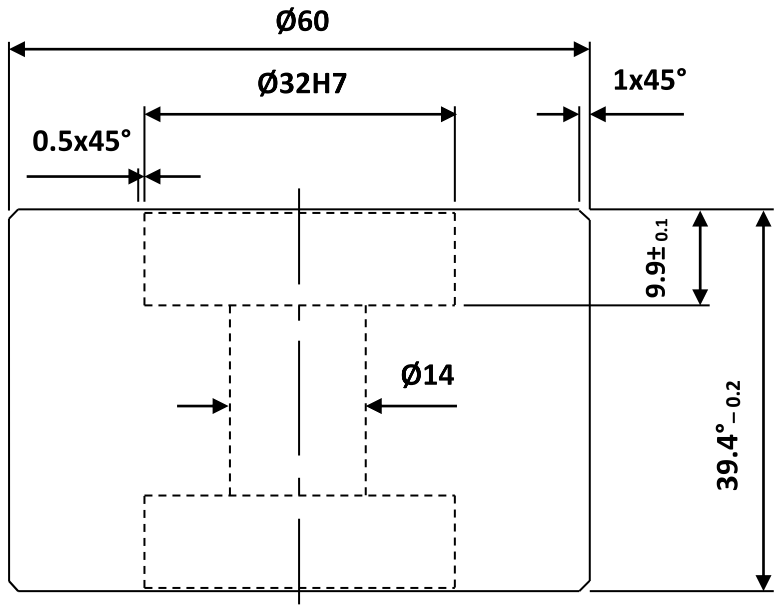

Figure 4: Work Piece (Roller Guide)

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 1: 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 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

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Table 3: Cutting conditions for the experiment.

Cutting speed (m/min)	90	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.

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 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.

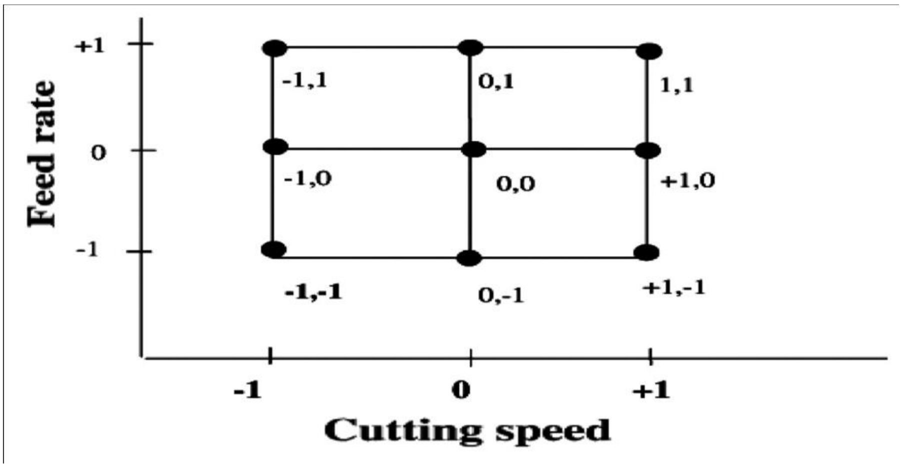

Figure 5: Arrangement of 3^2 full factorial design.

Table 4: Levels for the independent variables.

Levels	Low	Centre	High
Coding number	-1	0	+1
Cutting speed (m/min)	90	130	170
Feed rate (mm/rev)	0.05	0.08	0.1
Depth of cut (mm)		0.2	

Table5: 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	90	0.05	1-	1-
5	90	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	90	0.08	1-	0

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EXPERIMENTAL RESULTS & DISCUSSION

MRR is calculated using the following equation.

MRR= V*F*D*T

Where

MRR:Material removal rate(cm^3)

V:cutting speed(m/min)

F:feed rate (mm/rev)

D: depth of cut(mm)

T:tool life(min)

The optimal parameter for maximum MRR were as cutting speed 90 m/min and feed rate 0.08 mm/rev.Thus if we want much removal amount of chip, we must use the lowest level of cutting speed 90 m/min and medium level of feed rate 0.08 mm/rev as shown in table 6.The highest value of MRR was observed when tool life was longest this happened at 27.6 cm^3 while tool life was 1090 seconds .

It was also found that, as cutting speed remain fixed while feed rate various from lower value of 0.05 mm/rev through 0.1 mm/rev,the MRR fluctuates from a value at mid range to highest value then eventually to the lowest value. This is illustrated in the graphs in figures 6 &7.

Table 6: Experimental results for tool life.

No	Cutting Speed (mm/rev)	Feed Rate (mm/rev)	Depth of Cut	Tool Life	MRR(cm^3)
1	170	0.05	0.2	474	13.4
2	130	0.08	0.2	479	16.6
3	170	0.10	0.2	237	13.4
4	90	0.05	0.2	1076	17.0
5	90	0.10	0.2	287	9.1
6	170	0.08	0.2	459	20.8
7	130	0.08	0.2	500	17.3
8	130	0.05	0.2	631	13.7
9	130	0.10	0.2	244	10.6
10	130	0.08	0.2	545	18.9
11	90	0.08	0.2	1090	27.6

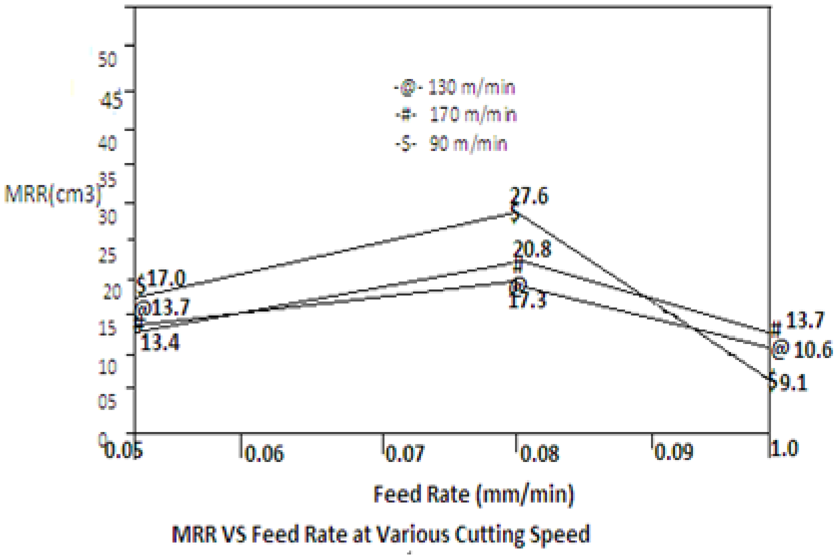

Figure 6: MRR VS feed rate at various cutting speed

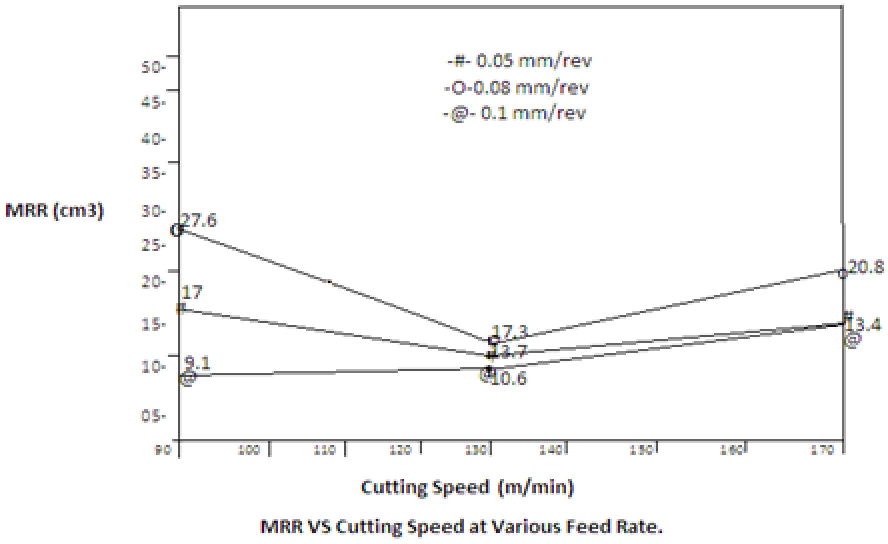

Figure 7: MRR VS cutting speed at various feed rate

CONCLUSION

The present study has overviewed the hard tuning of high chromium high carbon steel that are used by manufacturing industries. Hard turning offers a number of potential benefits over grinding including lower setups times, lower equipments costs, flexibility & geometry and elimination of high usage of cutting fluid. The highest value of MRR was observed when the tool life was longest. It has been found that effect of feed is more severe on MRR than that of cutting speed. The company Morgardshammar Ltd. Meerut where the work 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. 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.

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