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Investigation of Tool Life and Chip Formation During Turning Process of EN8 Medium Carbon Steel

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Abstract: EN8 medium carbon steel has wide engineering applications. The chemical composition includes 0.4-0.5% carbon, 0.6-1% manganese, small quantity of silicon, sulphur and phosphorus. It has good strength, hardness and toughness. Turning is a versatile process used in metal cutting in Lathe. During the metal cutting operation, the factors of tool life and chip thickness ratio plays a vital role. This experimental investigation involved the chip formation study and tool life calculation during turning of EN8 medium carbon steel. Response Surface Methodology was applied as the Design of Experiment (DOE). During the process of turning, the factors of Cutting Speed, Feed and Depth of Cut were considered. Lathe turning responses i.e. Tool Life and Chip Thickness Ratio were measured for different combinations of the mentioned factors. Influence of each factor on tool life and chip thickness ratio was evaluated by Analysis of Variance (ANOVA).

***Keywords* -Tool Life, Chip formation, Chip thickness ratio, Response Surface Methodology, ANOVA**

I. INTRODUCTION

The most frequently used machining process during manufacturing of parts comprising of EN8 medium carbon steel is turning. Hence, the machining process mechanism is to be understood vividly which involves the mechanism of chip formation. As the chip formation is an important phenomenon during turning operation, thus, even a minor alteration in the formation process can cause hindrances in tool life, surface finish. One of the most effective parameters of chip formation technology is the chip thickness ratio (t/tc). It stands as a ratio wherein the numerator is undeformed chip thickness (t) and denominator is the cut chip thickness (t_c). Several research work has been performed on chip formation by straight turning on EN8 Medium Carbon Steel over the years. Study of the phenomenon of chip formation during the machining work on EN8 unalloyed steel was made by Kumar and Chakraborty [1]. The procedure of the formation of chip was analysed by studying SEM images of the chips. Khan et al. [2-3] examined the consequences of dry and wet cutting environments. This was accomplished by collating the tool wear rate during turning operation and the surface roughness obtained to infer whether dry cutting condition could be cost effective. An investigation was performed by Murugappan and Arul [4] wherein EN8 (AISI 1040) steel rod underwent turning at various speeds and feeds maintaining 1.5mm depth of cut at subzero (dry ice) cooling and in dry ambience. Chip reduction co-efficient was measured. It was observed that in dry ice subzero turning environment the chip reduction coefficient was less at higher cutting speeds and feed rates. Jagtap and Pawade [5] examined the chip formation mechanism using Response Surface Methodology to calculate chip thickness ratio. It was observed that chip thickness ratio was primarily influenced by feed rate. Diniz and Oliveira [6] investigated on conditions where dry cutting was compared with wet cutting conditions. Experiments were conducted considering factors like cutting speed, feed and depth of cut during rough turning of ABNT 1045 steel for both wet and dry conditions. Davis et. al [7] attempted to optimize cutting parameters in dry turning operation of EN24 steel (0.4% C) with hardness 40 HRC.Khana et. al [8] investigated on the impact of minimum quantity lubrication (MQL) on turning of low alloy steel AISI 9310 in comparison to dry and wet machining process w.r.t. chip–tool interface temperature, chip formation mode, tool wear and surface roughness.Results showed that the MQL process was more effective than the other two and it produced better tool life and surface finish. An attempt to study the effects of machining parameters on tool life in turning operation, under wet cutting conditions, i.e. using a coolant was made by Dasgupta and Mukherjee [9-10]. Tool life characteristics of HSS and brazed carbide cutting tool machined on mild steel and optimization of machining factors were conducted respectively. The input factors considered were spindle speed; fed rate and depth of cut with three levels each. It was observed that in both cases optimal condition was obtained for minimum levels of each factor. Analysis of Variance showed that spindle speed had major impact on tool life during turning by H.S.S. However, feed rate had the most significant effect on tool life followed by spindle speed and depth of cut for turning with brazed carbide cutting tool.

II. EXPERIMENTAL PROCEDURE

The factors considered for Straight turning of Medium Carbon Steel of EN8 Grade are-

i) Cutting speed ii) Feed iii) Depth of cut

The range of values for the above factors was determined by trial runs. Finally, the following levels were considered as depicted in Table 1.

Table 1: Turning Factors and their levels

Factors	Level 1 (-1)	Level 2 (0)	Level 3 (+1)
Cutting speed (mm/s)	1197	1557	2026
Feed (mm/rev)	0.2	0.4	0.6
Depth of cut (mm)	0.5	0.7	0.9

This research assignment involved the use of Response Surface Methodology (RSM) as DOE.The RSM is used to find the optimal combination of factors that will produce the best response.Trial runs were performed using three factors and three levels.

Brazed carbide toolwas used with the following specification-

i) Brazed carbide tool made of SandvikCoromant.

ii) Rectangle shank-metric 20x20 with tool cutting edge angle of 90° and 0.8mm corner radius.

Machine specification-

High Speed Precision Lathe NH 22

i) Height of centers- 220 mm ii) Swing over bed- 500 mm

iii) Swing over cross slide- 270 mm iv) Distance between centers- 1000 mm

II.I MEASUREMENT OF RESPONSES

The turning responses considered here are tool life and chip thickness ratio. Straight turning operation was performed on twenty round bars of length 200 mm each and 32 mm diameter. During turning, three factors were considered as input with the corresponding levels i.e., cutting speed (1197, 1557 and 2026mm/s), feed (0.2, 0.4 and 0.6 mm/rev) and depth of cut (0.5, 0.7, 0.9 mm). During turning operation the tool life was measured with a stopwatch and viewed the quality of turned surface. Also, the cutting edge of the cutting tool was examined.

Uncut chip thickness was calculated as shown in Equation1. After each run, the chips were collected. Thickness of the chips was measured at five different points (t_1, t_2, t_3, t_4, t_5) with a micrometer. Then cut chip thickness (t_c) was measured for each pass as shown in Equation2. The Chip thickness ratio was measured as in Equation3.

$$t = \text{f x } \mathit{sin}\ \varnothing \qquad (1)$$

$$\text{Cut chip thickness } (t_c) = (t_1 + t_2 + t_3 + t_4 + t_5)/5 \qquad (2)$$

$$\text{Chip thickness ratio} = t/t_c \qquad (3)$$

The measured values of tool life in seconds and chip thickness ratio as per Run order are as follows-

Tool life (sec)-146, 18, 128, 149, 72, 103, 50.8, 83, 105, 146, 40, 213, 153, 18.7, 145, 200, 9.2, 144, 133, 149.

Chip thickness Ratio- 0.39, 0.48, 0.33, 0.39, 0.23, 0.47, 0.46, 0.99, 0.35, 0.83, 0.24, 0.45, 0.36, 0.61, 0.36, 0.29, 0.67, 0.39, 0.35, 0.39

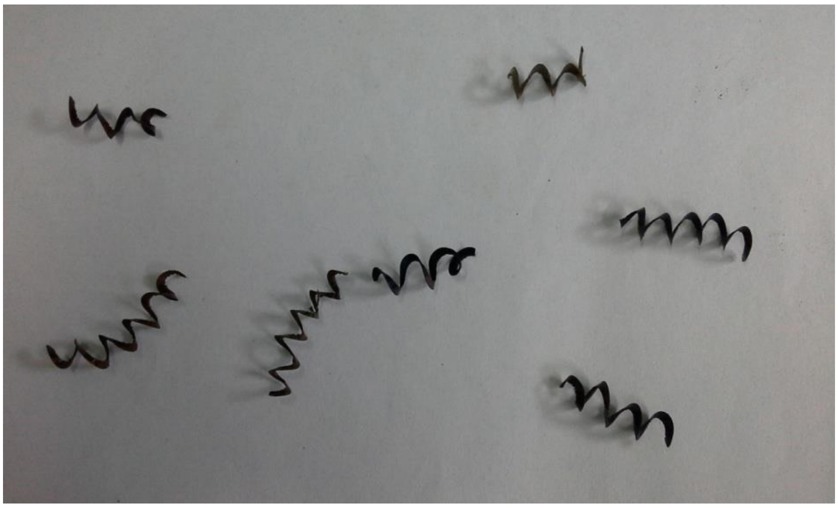

Figure 1: Typical picture of chip formation at
V_c = 1197 mm/s, f= 0.6 mm/rev, doc=0.7mm

Figure 1 shows the typical picture of chip formation at V_c = 1197 mm/s, f= 0.6 mm/rev, doc=0.7mm. The shape and length of the chips varied for each combination of the input parameters.

III.RESULTS AND DISCUSSIONS

The measures values of tool life and chip thickness ratio for different cutting speed and feed at a particular d.o.c. were plotted in Contour and Surface Plots.

III.1 Tool Life

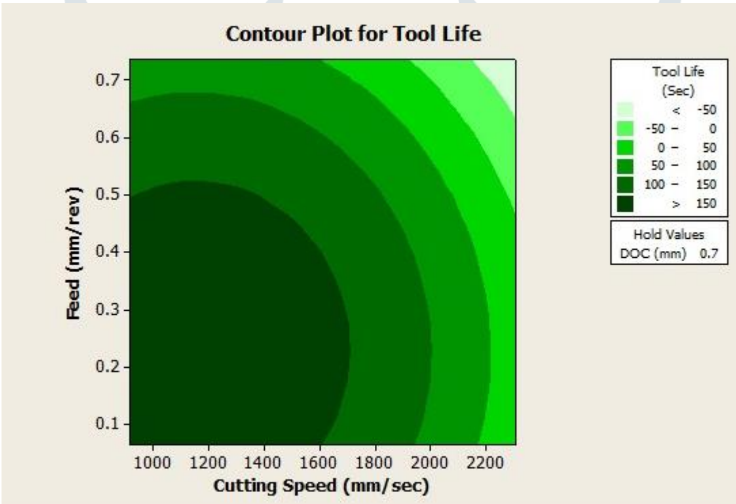

Figure 2: Contour Plot of Tool LifevsCutting Speed and Feed at d.o.c. 0.7 mm

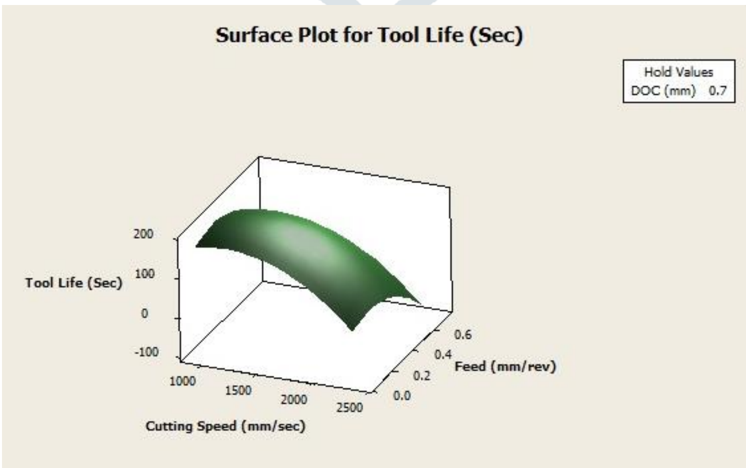

Figure3: Surface Plot of Tool Life vsCutting Speed and Feed at d.o.c. 0.7 mm

III.II Chip Thickness Ratio

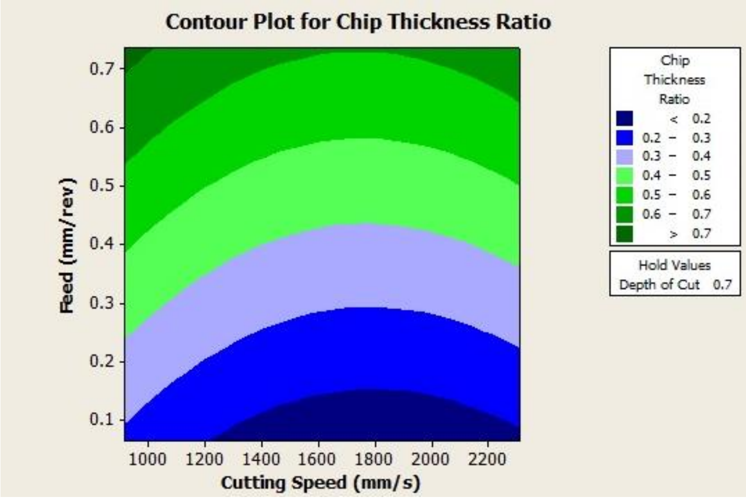

Figure4: Contour Plot of Chip Thickness RatiovsCutting Speed and Feed at d.o.c. 0.7 mm

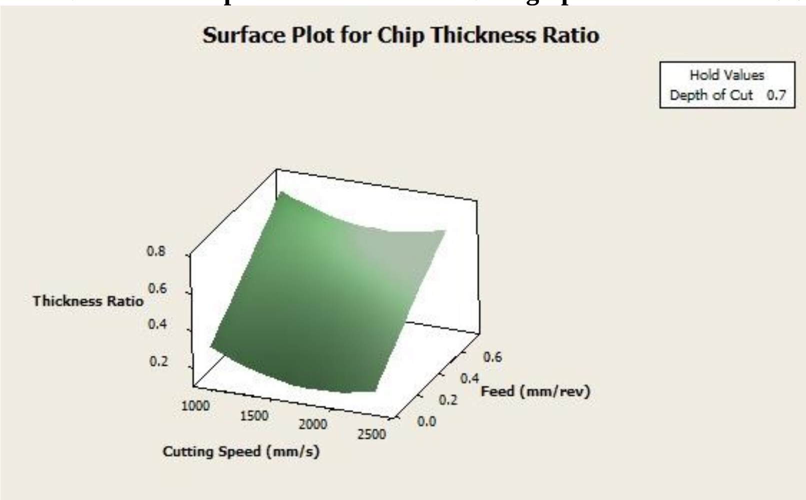

Figure5: Surface Plot of Chip Thickness RatiovsCutting Speed and Feed at d.o.c. 0.7 mm

As a case study, the Contour Plot and Surface Plot of Tool Life vs Cutting Speed and Feed at d.o.c. 0.7 mm. are shown in Figure2 and Figure3 respectively. The graphs revealed that maximum tool life (>150 second) existed within the range of cutting speed 1000-1600 mm/sec and feed 0.1-0.5 mm/rev.Tool life decreased with increasing cutting speed and feed. Similar inference could be drawn from surface plot also.

The Contour Plot and Surface Plot of Chip Thickness Ratio vs Cutting Speed and Feed at d.o.c. 0.7 mm. are shown in Figure 4 and Figure 5 respectively. The graphs revealed that maximum chip thickness ratio (>0.7) was obtained at cutting speed less than 1000mm/sec and high range of feed rate. Minimum ratio (<0.2) existed for cutting speed range of slightly above 1200 to 2200 mm/sec and above and for feed rate upto 0.15 mm/rev.

III.III ANALYSIS OF VARIANCE (ANOVA)

ANOVA was applied with an objective to examine the individual effect of process parameters on tool life and chip thickness ratio as shown in Tables 3 and 4 respectively. The analysis was conducted at a confidence level of 99.5% (α=0.005).

Table 3: ANOVA Table for Tool life (sec)

Source	DF	SS	MS	F	P
Cutting speed	1	29535.7	29535.7	27.40	0.000
Feed	1	12318.9	12318.9	11.43	0.007
Depth of cut (d.o.c.)	1	534.7	534.7	0.50	0.497
Error	5	55.3	11.1		
Total	19	67053.9			

Table 4: ANOVA Table for Chip thickness ratio

Source	DF	SS	MS	F	P
Cutting speed	1	0.008064	0.008064	0.53	0.485
Feed	1	0.261648	0.261648	17.04	0.002
Depth of cut (d.o.c.)	1	0.115026	0.115026	7.49	0.021
Error	5	0.001133	0.000227		
Total	19	0.696348			

It is observed that in the ANOVA table for tool life the P-value for cutting speed is less than 0.005. This means that tool life is primarily influenced by cutting speed and then by feed. P-value for d.o.c. is very high and thus has less impact. As for chip thickness ratio, feed (P-value=0.002) has the highest impact followed by d.o.c.

IV.CONCLUSION

The investigation revealed that the maximum tool life was acquired within cutting speed range of 1000-1600 mm/sec and feed 0.1-0.5 mm/rev. Maximum chip thickness ratio was obtained at cutting speed less than 1000mm/sec and high range of feed rate. The contour plots and surface plots for both tool life and chip thickness ratio reiterated the same. ANOVA study revealed that for tool life and chip thickness ratio, cutting speed and feed had the highest impact respectively.

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