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Machining Performance on Hardened Steels

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***Abstract*—This paper is about the tribology factor regarding the chip formation in machining hardened carbon steels using coated carbide tool. The machining parameters considered for the investigation are cutting speed, feed rate, and depth of cut under dry cutting condition using coated carbide tools. The chip shape formed is due to the combined effect of machining parameters. The favorable type of chip which gives good surface finish is formed when the depth of cut is high. The small value of coefficient of friction shows that the shear angle is larger which results in smaller shear plane angle that gives lower value of cutting force needed to remove the chips and lower cutting temperature results during the machining process The interaction effects of the variables have been considered to draw the graph. Three levels of the feed, speed, and the depth of cut is used to generate readings.**

***Index Terms*— Surface roughness, Chip formation, Coefficient of friction, machining, Hardened steel, Shear plane angle.**

I. Introduction

The cutting of high melting point steel alloys shows that the problem of machineability becomes most important in the economic aspect of engineering production. In high melting point alloy steels the heat generated in cutting becomes the controlling factor. It creates constraint on the amount of metal removal. Alloying elements in steel like carbon, manganese, chromium etc increases the strength. The effect of alloying additions to iron is to reduce the tool forces. When the cutting tool of high speed steel is used the chip is thinner, the shear plane is larger and the area of shear plane is much smaller. The yield stress of steels is influenced by both composition and heat treatment. To permit high metal removal rates steel materials are heat treated to reduce the hardness. The heat treatment for medium or high carbon steel often consists of annealing just below the transformation temperature below 300^0C.This spheroidizes the cementite to form in which it has less strengthening effect. In machining of low carbon steel consisting of lot of proeutectoid ferrite slow cooling from annealing temperature is essential. Iron and carbon can be alloyed in the form of steel. Carbon steels contain varying percentage of carbon. The medium and high carbon steel can be heat treated.EN31 steel is very hard and has scratch resistance. Case hardening can be done on EN36 steel. Applications include load bearing structures, roller bearing components such as brakes, cylindrical, conical & needle applications. RavinderTonk and Jasbir Singh Ratol [1] investigated the effects of parametric variations of machining EN31 steel alloy. Aggarwal, A. and Singh, H [2] wrote the review of optimization techniques for machining techniques. Ghosh, S, Murugan, B. and Mondal, B [3] worked on process parameter optimization of hard machining of hardened steel. Ahmed S. G. [5] worked for the development of prediction

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model for surface roughness in finish turning of steel. Ravi raj, Laxmikanth Pai and, Kamath V [6] studied the chip formation mechanisms in machining composite materials.

II. EXPERIMENTAL DETAILS

Experiments were performed by turning EN 31 and EN 36 Steels using coated carbide tool in lathe. Experiments were conducted by varying the cutting speed, feed rate and depth of cut.
Chemical composition of the alloy steels of samples (EN 31 and EN 36 samples) is presented in Table.I.

TABLE I. CHEMICAL COMPOSITION FOR THE STEEL ALLOYS

Type	C%	Si%	Mn%	P%	S%	Cr%
EN 31	1.13	0.31	0.62	0.03	0.02	1.01
EN 36	0.14	0.20	0.33	0.02	0.01	1.06

The measurement of temperature was done while machining at tool chip interface using non contact IR sensor gun. The surface roughness Ra in microns was measured offline at Mascot laboratory services a NABL accredited unit at peenya, Bengaluru by using Tallysurf. Chip thickness was measured by micrometer.

A .Results and Discussions

The results of experiments performed by turning EN 31 and EN 36 steels using coated carbide tool is shown in Table 2.The resulting temperature at tool chip interface and surface roughness is also shown.

TABLE II. TEMP AND SURFACE ROUGHNESS OF THE EXPERIMENT CONDUCTED

SL NO	SPEED rpm	FEED mm/rev	D.O.C mm	EN 31		EN 36	
				TEMP °c	S R microns	TEMP °c	S R microns
1	310	0.101	.1	32	1.4	32	0.5
2	310	0.096	.2	32	1.4	33	0.6
3	310	0.092	.3	35	1.2	37	0.4
4	480	0.101	.1	36	0.8	33	1.6
5	480	0.096	.2	39	1.0	39	1.4
6	480	0.092	.3	41	1.8	37	1.2
7	760	0.101	.1	60	1.4	70	1.4
8	760	0.096	.2	65	1.3	53	1.3
9	760	0.092	.3	67	1.8	45	1.6

B. Effect of cutting conditions on surface roughness

The test results have indicated that the value of surface roughness Ra is high at low cutting speeds and low at high cutting speeds. At lower cutting speeds the surface roughness is high due to the inability of the cutting tool to cut these particles, therefore, a high cutting speed is required to machine this hardened steels. Sometimes during turning, it was observed that the surface roughness value is abruptly higher than the trend value. The abrupt irregularity in the values of surface roughness may be due to the presence of hard ceramic reinforcement particles i.e. coated carbide tool which rolls over the surface.

C. Chip Parameters

Shear plane: Most of the studies in metal cutting modeling are based on study of shear plane. Ernst and Merchant called the deformation zone which is shown by a plane as shear plane. The shear plane is an inclination at an angle in the direction of cutting and it is called as shear angle Ø.
Coefficient of friction: Generally in engineering the coefficient of friction is defined as the ratio of force in the metal cutting sliding direction and the force normal to the sliding interface. But this definition is too simple to describe the complex nature of seizure during metal cutting. By controlling the contact area between tool and chip the coefficient of friction can be controlled.

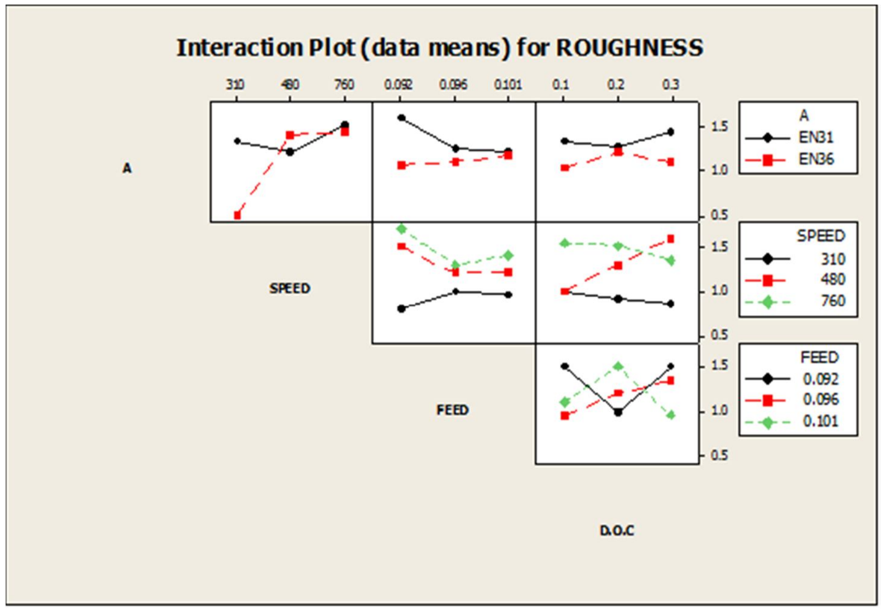


Figure 1. Interaction plot for surface roughness

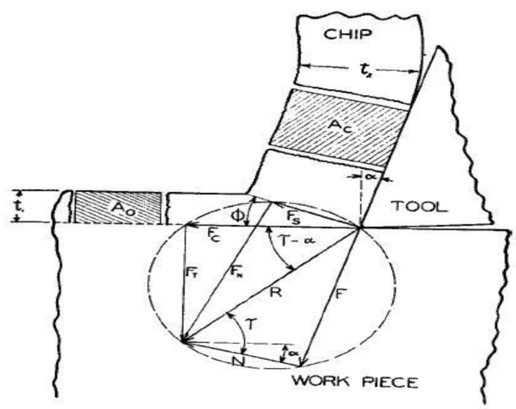
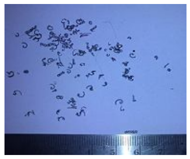
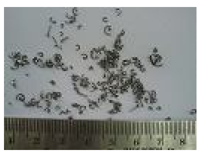


Figure 2. Merchant's Circle Diagram with cutting forces

Chip thickness ratio r can be calculated as r= to/tc, where to is undeformed thickness i.e. the feed and tc is the measured value of chip thickness.
Chip formation process where Ø is the shear angle, r is the cutting ratio, and α is the rake angle of the insert. and μ is the coefficient of friction.
The shear angle can be calculated as $\tan Ø = r \cos \alpha/1-r \sin \alpha$ where Ø is shear angle and α is rake angle. The coefficient of friction can be calculated $\mu = \tan \beta$, where μ is coefficient of friction and β can be calculated as $\beta= 90 + \alpha - 2Ø$. Timothy S.P [8] has described the shear bands formed on the chips in his review paper.
The cutting of hardened steels with coated carbide tool results in various types of chip formation.
The chips formed when turning of EN 31steel are similar to EN 36 steel except that chips are shorter in EN31 and frequently cracks are formed on the outside surface of the chips.
The hardening of steels reduces the ductility and makes the material ideal for producing saw-toothed and segmental type chips during machining. At low speeds, the BUE is formed and also the chip fracture readily producing the surface roughness. As the speed increases, the BUE vanishes, chip fracture decreases and hence the roughness decreases.

TABLE III. CHIP FORMATION STUDIES

Sl no	Speed rpm	EN 31 STEEL				EN 36 STEEL			
		Chip formation	tc	Ø	µ	Chip formation	tc	Ø	µ
1	160		0.39	14.51	0.739		0.39	25.83	0.63
2	240		0.39	13.82	0.554		0.37	26.97	0.58
3	310		0.39	13.60	1.108		0.36	27.57	0.55
4	480		0.22	18.36	0.63		0.33	29.20	0.48
5	760		0.22	17.85	0.86		0.30	32.35	0.28

The depth of cut induces high normal pressure and seizure on the rake face of the tool, which promotes the BUE formation. The propagation of crack along transverse as well as longitudinal direction is well visualized. Furthermore, crushed and fragmented particles were noticed

The cutting speed plays an important role in deciding the surface roughness. At high cutting speeds, the surface roughness decreases. At low speeds, the built-up edge (BUE) is formed and also the chip fracture formed. Lower temperature results in formation of hard chips and therefore slides over tool rake. High temperature will make chip soft and chips start seizing to the rake surface and the friction is high in tool chip interface during shearing. When machining speed is higher thin chips are produced and thus it lowers coefficient of friction. Coated cutting tool reduces the coefficient of friction between tool andchip due to lubrication effect of coating. The effect of chip thickness, shear angle and shear plane are related to each other. A small shear angle results in long shear plane indicating thin chip is formed. Lower coefficient of friction means less force is required to shear the chip. The increase in shear angle will reduce friction in the process.

III. CONCLUSIONS

The effect on surface roughness of machining parameters such as cutting speed, feed, and depth of cut while turning EN 31 & EN 36 alloy steel was discovered. The most prominent parameter affecting surface roughness is the feed rate. The cutting speed and the depth of cut are less significant for surface roughness than the feed rate. The interaction graph of parameters affecting surface roughness is found. The shear plane angles and coefficient of friction under various cutting speeds is also found by chip measurement and analysis.

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