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Experimental Investigation and Surface roughness Analysis on Hard turning of AISI D2 Steel using Coated Carbide Insert

A.Srithar[a*],K.Palanikumar[b],B.Durgaprasad[c]

[a]*Reseach Scholar, Department of Mechanical Engineering, Jawaharlal Nehru Technological University, Anantapur, A.P, India.*
[b]*Department of Mechanical Engineering, Sri Sai Ram Institute of tecnology, Chennai ,Tamil nadu, India,*
[c]*Department of Mechanical Engineering, Jawaharlal Nehru Technological University, Anantapur, A.P, India*

Abstract

The machining of hard turning is carrying out on hardened steel in the range of 45 to 68 Rockwell hardness. It is substitute to traditional grinding process is a flexible, productive and successful machining process for hardened metals. Hence mainly used in various uses such as dies, moulds, tools, gears, cams, shafts, axles, bearings and forgings. The machining of hardened steel using superior tool materials such as coated carbide inserts, mixed ceramic inserts and cubic boron carbide nitride(CBN) have higher merits than traditional grinding such as high material removal rate, can produce good surface finish, reduced processing costs, ability to machine narrow walled sections and minimum environmental problems without using cutting fluid. Although the process is accomplish with small depth of cut and feed rates, evaluate to minimizing the machining time as high as 60 % in hard turning process.

In this paper, the machining of AISI D2 steel workpiece having 66 HRC hardness is carried out using coated carbide insert. The microstructure shows rolled grains of the steel along the direction of the material. The microstructure shows fine grains of cementite with the grain boundary chromium and other alloys and the presence of carbide, which increases strength and wearresistant..This paper discusses the importance of hard turning of AISI D2 steel. Investigations were carried out on conventional lathe using the prefixed cutting conditions. The graph shows the feed rate is the main impact with increasing feed rate, but reduces with larger cutting speed and rapidly increasing depth of cut. The responses studied in the investigation of surface roughness are studied in the investigation of surface roughness parameters (Ra,Rt and Rz) on responses are studied and presented in detail.

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*Keywords:*Hard turning; AISI D2 Steel;cutting tools; Cutting parameters; hardened steel;surface roughness

Nomenclature

F feed rate (mm/rev.)
vcutting speed (m/min.)
d depth of cut (mm)
$R_a$arithmetic average height (µm)
$R_t$maximum height of the profile (µm)
R_z mean of third point height (µm)

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* Corresponding author. Tel.: 04422512111; fax: 04422512323.
E-mail address: asrithar1972@gmail.com

1. Introduction

Now a day's machining of hard turning is an interesting subject in industry and research and development. Hardened steels are mostly utilized in automobile, die, gear, bearing industries. Therefore, advanced technologies required for machining of hardened steels with higher material removal rate (MRR)[1].Hard turning is carry outon materials with hardness with the range of 45 – 68 using a different types of solid cutting tools such as Coated carbide insert, CBN, coated CBN insert and PCBN .

Even though grinding is producing good surface finish and it related with increasing feed rates and smaller depth of cut, evaluation of minimize machining time as 65 times for conventional turning. From the literature survey, the process is a high speed, low feed and low depth of cut finishing process .In the present study the cutting speed, feed and depth of cut as indicated in the Table 1. Coated carbide insert and CBN tools are the more suitable for this type of operation, because to withstand hot hardness, wear resistance and excellent chemical stability. Hardness enables them to hold out against the thermal and a mechanical load of machining behavior.[2] Coated carbide insert has a more hardness than ceramic tools at both minimum and maximum temperature. Tool configuration is additional main factors infect machining process, especially thrust (radial) force and feed (axial) force elements.

Table 1. Cutting parameters used for the Experiments

Cutting Parameters	Symbol	Unit	Level 1	Level 2	Level 3
Cutting speed	V	m/min	135	215	325
Feed	f	mm/rev.	0.050	0.102	0.159
Depth of cut	d	mm	0.2	0.4	0.6

While machining hardened steels, chamfered edge and negative rake and inclination angles help to increase the machining force.[3,4,5].
Large nose radius with reduced depth of cut leads to minimum true side cutting edge angle, it results high thrust force. And large nose radius may produce good surface finish and avoid tool vibration.[6]. A worsen surface finish can be a hint to changing surface roughness that may change the service life of component. As hard turning is mostly utilized for final finishing process, it is importantto study about the parameters influence the surface roughness and in turn fatigue life of the component. The conceptual surface roughness variable, R_a, can be given as

$$R_a=\frac{f^2}{18\sqrt{3r_e}} \quad (1)$$

where 'f' is the feed rate in mm/rev. and 'r_e' is the insert radius

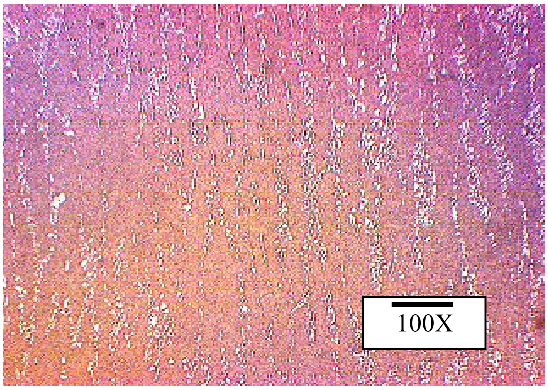
2. Materials and Methods

In this paper, the machining of AISI D2 steel workpiece having 66 HRC hardness is carried out using coated carbide insert Fig.1 indicates the microstructure of the workpiece material used for the investigation. The microstructure shows rolled grains of the steel along the direction of the material. The microstructure shows fine grains of cementite with the grain boundary chromium and other alloys and the presence of carbide.

Table 2. Composition of AISI D2 Steel

Elements	C	Si	Mn	P	S	Cr	Mo	Ni	Al	Cu	Nb	Pb	Sn	V	W	Fe
%Composition	1.574	0.937	0.332	0.034	0,034	11.692	0.119	0.062	0.087	0.110	0.134	0.079	0.018	0.104	0.138	Reminder

The microstructure of the matrix shows fine tempered martensite with uniform dispersion of the alloy carbides. The dissolution of the carbides is even and the microstructure is in confirmation of the micro hardness taken. The composition of the workpiece material used for the investigation is presented in Table 2, which shows the presence of chromium, carbon and other materials.



Speed of traverse	1 mm/sec
Gauge range	± 150 μm
Resolution	0.01 μm
Accuracy	2% of reading
Pickup type	Inductive

Fig. 1.Microstructure of the workpieceMaterialTable 3. Specification of the roughness tester

Surface quality is one of the key concerns in machining. The nature of the machined surface is characterized by the accuracy of its manufacture with reference to the dimensions identify by the designer. Each machining operation produces its own feature confirmation on the machined surface. This confirmation is in the form of fine position of micro unevenness produced by the cutting tool on the workpiece. Every type of cutting tool makes its own pattern which can be identified. This irregularity is known as surface finish or surface roughness. The surface features are indicated in Fig 2. In this diagram the surface height specify the irregularities with respect to a reference line.

The surface roughness width is the measurement of the distance parallel to the formal surface between consecutive peaks or valleys in the machined surface which represent the predominant pattern of the roughness. Surface roughness width indicates the spacing between the surface irregularities and is to be involved in the measurement of the average roughness height. It is always more than the roughness width in order to get the total roughness height position. Lay replace the direction of primary surface pattern produced and it indicates the machining performance used to produce it. Waviness is the surface unevenness takes place on the surface. This is possibly due to the outcome of workpiece or tool deflection through machining due to vibration or tool run out.

The performance of the machining process in hard turning can be estimate either in terms of tool life as defined by tool wear or performance indicators like machining forces, surface roughness, temperature and other related characteristics.[7, 8, 9, 10]

Fig.3 shows the arrangement of experimental setup. Surface roughness is one of the key performance indicators in machining. The surfacefinish of the workpiece promotes the standard of the produced part and precision fits [11]. The different surface roughness parameters are considered for the paper. The surface roughness parameters considered are R_a, R_t and R_z..

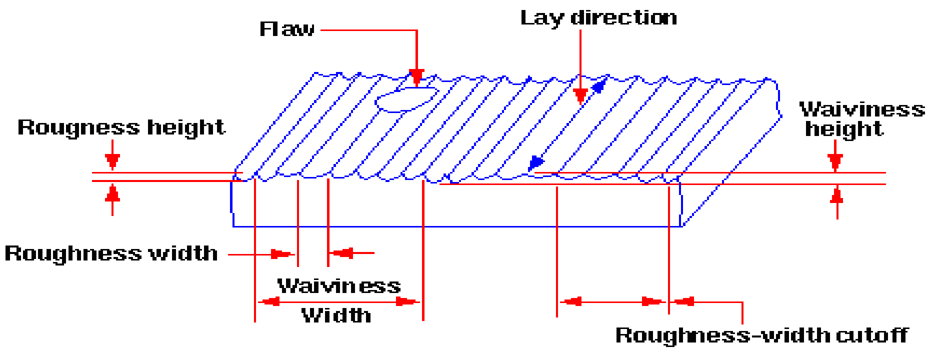
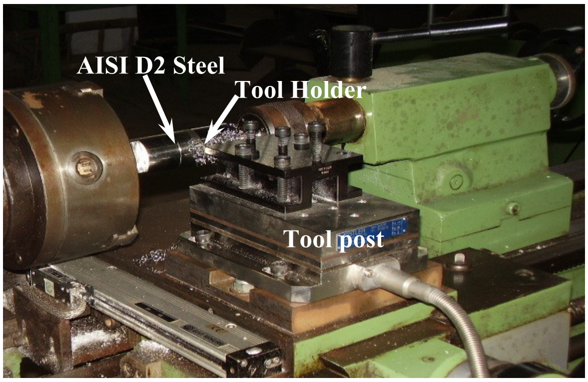


Fig.2. Surface characteristics in machining (Courtesy: ANSI B46.1-1962)

The surface roughness of the hardened steel is studied by using a Surtronic 3+ stylus-type instrument manufactured by Taylor Hobson with a cut-off length of 0.8 mm. The measurement setup is shown in Fig.4. The measurements were taken for triple times and the average values are utilised for the investigation. The specification of the roughness tester is presented in Table 3.



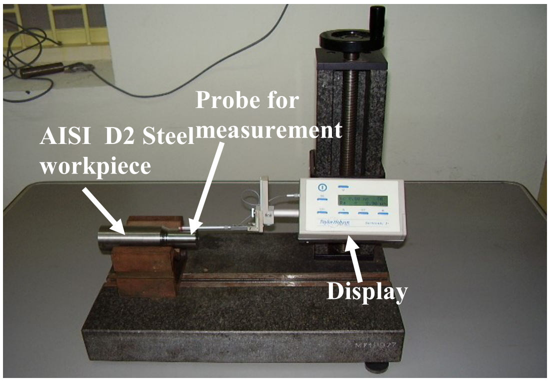


Fig. 3 Experimental set-up Fig.4. Surface roughness measurement using roughness meter

3.Results and discussion

The graph shows for different surface roughness parameters R_a, R_t, R_z is indicated in Fig 5 - 7.Fig.5 shows the graph for surface roughness parameters with reference to the cutting speed. The figures indicate that the surface roughness parameter reduces with the gradually increase of cutting speed. The surface roughness observed is comparatively more at 135 m/min. When the speed increases from 135 to 325 m/min, the surface roughness slightly decreases.

Fig 6.Shows the graph for surface roughness parameters with reference to the feed rate. From the graph, it can be notice that the roughness parameters values are more at high feed rate (0.159 mm/rev.). An experimental result revealsthat the effect of feed rate on surface roughness parameters is high, when estimate to the other parameters considered .Fig.7 shows the graph for surface roughness parameters with reference to the depth of cut. From the graph it can be asserted that the surface roughness parameter value increases when the depth of cut increases from 0.2 to 0.6 mm.

The increase in surface roughness is not in coincidence with the feed rate. Depth of cut shows comparatively low increase in surface roughness than feed rate. In machining operation of hardened materials, vibration on machine tool and cutting tool also have impact on the surface roughness, and are not examine in this paper.

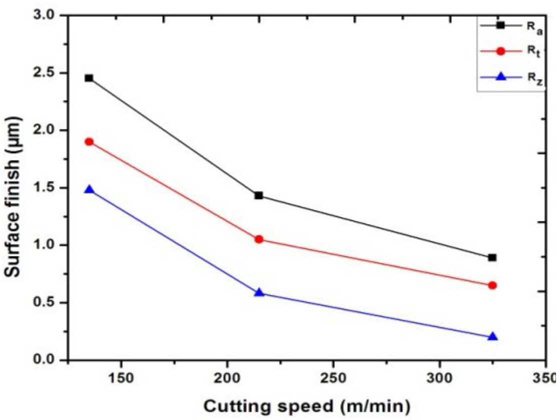


Fig 5.Graph shows surface roughness parameters with respect to cutting speed

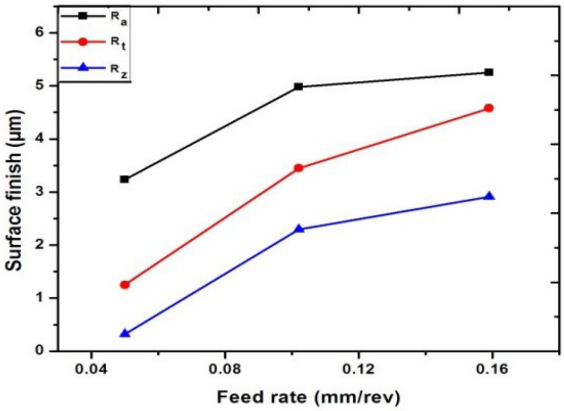


Fig.6 Graph shows surface roughness parameters with with respect to feed rate

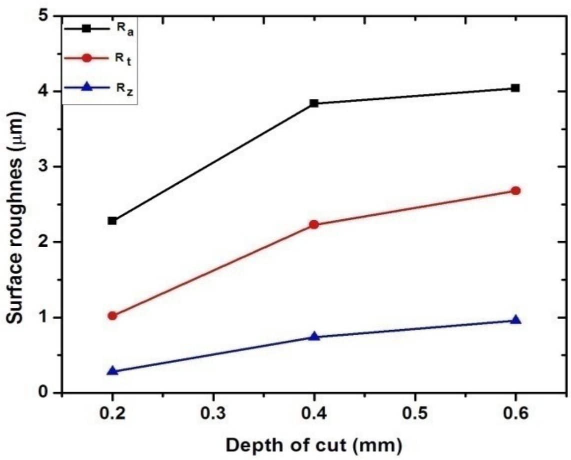


Fig.7. Graph shows surface roughness parameters with respect to depth of cut

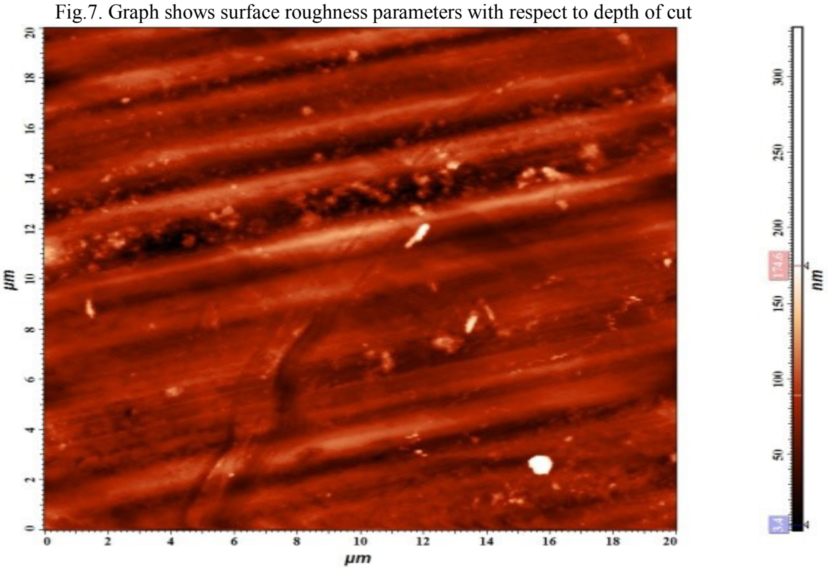


Fig. 8 AFM profile observed for surface roughness

Fig. 8 shows the atomic force microscope structure observed in the machining of hardened steel. The figure indicates the variation of surface profile in the top surface. Eventhough smooth surface can be obtained, there is a change takes place in the section of the workpiece. By adopting the suitable machining parameters the surface roughness can be reduced.

4. Conclusion

The surface roughness parameters in machining of AISI D2 steel by coated carbide insert is analysed in the investigation. The cutting parameters considered for the experiment such as cutting speed, feed rate and depth of cut. From the analysis of the investigation results, the following finding worn:

1. The results specify that the increase of cutting speed decreases the surface roughness in machining of hardened steel.
2. The gradual increase of feed rate and depth of cut increases the surface roughness in machining of AISI D2 steel by coated carbide insert.
3. The results shows that the feed rate is highly control the parameter, which influencethe surface roughness parameters in machining of AISI D2 steel.

4. AFM image indicates the changes in the workpiece structure, which can be reduced by adopting proper cutting conditions, but cannot be fully eliminated.

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