IOP Conf. Series: Materials Science and Engineering **338** (2018) 012056 doi:10.1088/1757-899X/338/1/012056

Experimental investigation of various surface integrity aspects in hard turning of AISI 4340 alloy steel with coated and uncoated cermet

Anshuman Das*, S. K. Patel, Ch. Sateesh Kumar and B. B. Biswal

[a] Research Scholar, Department of Industrial Design, NIT Rourkela, Odisha-769008, India

[b] Associate Professor, Department of Mechanical Engineering, NIT Rourkela, Odisha-769008, India

[c] Research Scholar, Department of Mechanical Engineering, NIT Rourkela, Odisha-769008, India

[d] Professor, Department of Industrial Design, NIT Rourkela, Odisha-769008, India

* Email address of the Corresponding author: anshuman.das2009@gmail.com;

Contact no: +91-9437104639

Abstract

The newer technological developments are exerting immense pressure on domain of production. These fabrication industries are busy finding solutions to reduce the costs of cutting materials, enhance the machined parts quality and testing different materials, which can be made versatile for cutting materials, which are difficult for machining. High-speed machining has been the domain of paramount importance for mechanical engineering. In this study, the variation of surface integrity parameters of hardened AISI 4340 alloy steel was analyzed. The surface integrity parameters like surface roughness, micro hardness, machined surface morphology and white layer of hardened AISI 4340 alloy steel were compared using coated and uncoated cermet inserts under dry cutting condition. From the results, it was deduced that coated insert outperformed uncoated one in terms of different surface integrity characteristics.

Keywords: **-** Hard turning; Surface integrity; Cermet; Micro hardness; White layer

1. Introduction

The constantly changing and competitive era of science and technology forcing manufacturing sector to search innovative solutions to reduce the cutting costs, increase the quality of the machined parts. Machining accomplishes desired size, shape, surface finish, dimensional accuracy and other functional features by gradual material removal as chips. The system of machining comprises of cutting tool, workpiece and machine tool. Hence, it is significant to evaluate workpiece-tool interaction that directly affects overall performance with the help of cutting parameters such as cutting speed (V_c), feed (f) and depth of cut (d) which largely depends on the materialistic properties of both cutting tool and workpiece. Use of conventional cutting fluids is harmful for environment. Therefore, now researches are focussed widely on the advanced strategies for machining of different types of material alloys so that better surface quality can be achieved without having its adverse effects on the environment while maintaining high productivity.

Pereira et al. [1] compared the performances of positive and negative CBN inserts in dry and cryogenic cooling environment during hard turning of ASP23 steel from which it was deduced that

Content from this work may be used under the terms of the Creative Commons Attribution 3.0 licence. Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.
Published under licence by IOP Publishing Ltd

roughness was substantially diminished in cryogenic cooling compared to dry condition. Kalam et al. [2] studied different aspects of machinability while hard turning of AISI D3 steel with CO_2 gas as coolant. The results showed that surface roughness and surface temperature were reduced with the application of CO_2 gas compared to liquid cooling and the higher material removal rate was also achieved with gas coolant application. Grzesik et al. [3] studied the effects of cryogenic cooling on surface layer characteristics produced by hard turning and found that cryogenic cooling substantially affected white layer and micro hardness compared to dry turning. However, dry hard turning produced lower surface roughness compared to cryogenic cooling and fine grain structure was produced in dry turning, whereas coarser grain structure was obtained in cryogenic cooling.

Therefore, the objectives of the present experimental analysis are decided as follows. To study the various surface integrity aspects and assess the results comparatively in hard turning of 4340 alloy steel using both coated cermets and uncoated ones. The surface integrity aspects has micro hardness, surface roughness and formation of white layer to be studied in details.

2. Experimental Details (Materials and Methods)

In this section, experimental methodology, the details of equipment used such as machine tools, cutting tools, workpiece material and machining parameters with the experimental set-up have been described.

2.1 Workpiece

AISI 4340 is a low alloy steel having medium level carbon popular for its application where high strength and toughness is required. This type of alloy steel can be machined in all conventional machining processes. This material has wide industrial applications in automotive and aircraft domains.

2.2 Tool

Cermet is a composite material made out of ceramic and metallic binders. It is preferably intended to have the ideal properties of both ceramic particles and binder materials. For the present experimental investigation, square shaped cermet inserts were used which were of two types, i.e. uncoated and coated. Nomenclature of both coated and uncoated cermets are tabulated below.

2.3 Experimental procedure

The workpiece was heated to heat treament process. After this whole process of heat treatment, there was a significant change in hardness from 18 HRC to 48 HRC of the sample.

- *First stage of experiment*

  First dry turning was performed on 4340 alloy steel having diameter of 50 mm and length of 700 mm with uncoated insert as depicted in Fig. 1. Experimental condition is provided in Table 1.

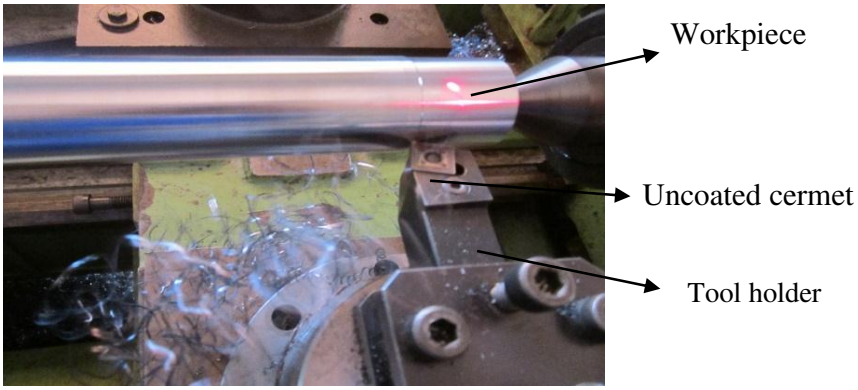


Fig. 1. Experimental Setup.

Table 1. Experimental condition during the first stage of the experiment.

Experimental condition	Details
Cutting tools	Uncoated Cermet tools
Tool designation	SNMG 120408
Tool holder designation	PSBNR 2525K12
Cutting Speed (V_c) (in m/min)	80,100,120
Feed (f) (in mm/rev)	0.05,0.1,0.15
Depth of Cut (d) (in mm)	0.1,0.2,0.3
Environment	Dry
Machining-length (in mm)	120

- *Second stage of experiment*
  Dry turning was performed on the same material i.e. 4340 alloy steel with coated cermet inserts. And the procedure adopted in first stage repeated here. The experimental condition for second stage of experiment was identical to first one. Combinations of machining parameters for each run using coated and uncoated cermets were given in Table 2. The combinations of machining parameter was set in alignment with Taguchi's L_9 orthogonal array. Every variation has three variations, low, medium and high.

Table 2. Combinations of machining parameters for various runs.

Run No.	Speed (m/min)	Feed (min/rev)	Depth of Cut (mm)
1	80	0.05	0.1
2	80	0.1	0.2
3	80	0.15	0.3
4	100	0.05	0.2
5	100	0.1	0.3
6	100	0.15	0.1
7	120	0.05	0.3
8	120	0.1	0.1
9	120	0.15	0.2

3. Results and discussions

3.1 Surface Roughness

Surface roughness is one of the remarkable parameter to analyze surface integrity aspects. The surface roughness variation at different cutting speeds, depth of cuts and feeds with both coated cermet and uncoated ones is exhibited by Fig.2. It was likely evident that coated inserts enhanced the surface quality than uncoated inserts regarding surface roughness. At higher speed of 120 m/min, higher degree of surface roughness was observed while machining with uncoated inserts.

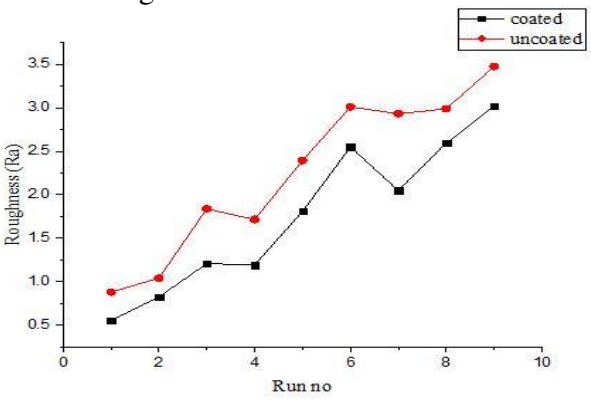
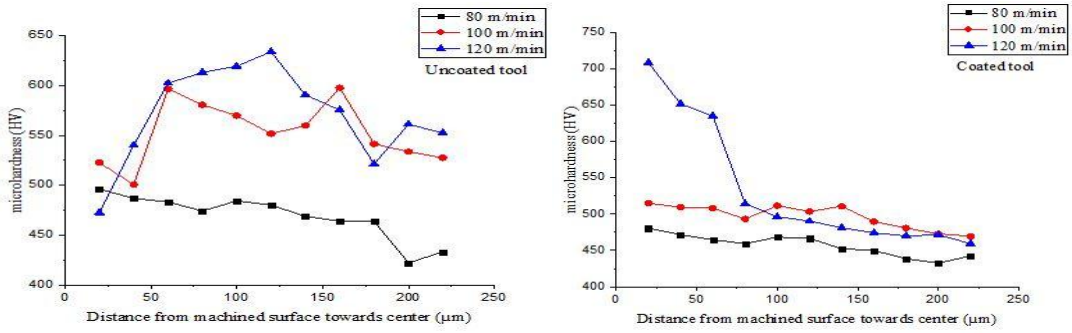


Fig. 2. Variation of surface roughness (Ra) with run numbers.

3.2 Micro hardness

The degree at which machined surface work hardening takes place, highly depends on various machining parameters. Fig.3. is the graph where abscissa depicts distance towards center from edges of the machined specimen and ordinate depicted microhardness. From the graphs, it was observed that there was enormous difference between hardness of subsurface regions and machined surface to that of bulk material. The graph also proved that microhardness caused more by uncoated cermet than with coated ones.



(a) **(b)**

Fig. 3. Variation of Vickers microhardness with reference to the distance from the machined surface towards the center (µm) for **(a)** uncoated insert **(b)** coated insert at variable speeds of 80,100 and 120 m/min.

3.3 Surface and sub-surface analysis

White layer, the unwanted formation on machined surface is observed due to many reasons. Plastic deformation during machining, rapid heating due to steep inclination in cutting speed, quenching and surface tension are prominent phenomena that causes white layer formation. Where higher degree of stress and temperature is required, white layer is highly undesirable. At various cutting speeds, surface analysis and subsurface regions formed during the machining operation are substantiated by Fig. 4. Using both coated and uncoated inserts. White layer is more visible at comparatively higher magnitude of cutting speed, say 120 m/min. With uncoated cermet, whiter layer was shown at relatively lower cutting speed than coated inserts. Coated cermet has anti-friction property that protects the tool to deform by thermal and mechanical properties of work. No white layer was seen when turning was carried out with coated cermet at lower cutting speed. It seemed visible for speed nearly 120 m/min and higher.

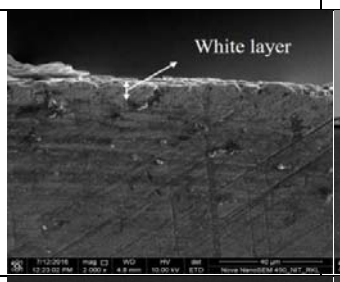
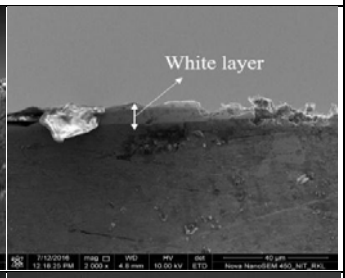
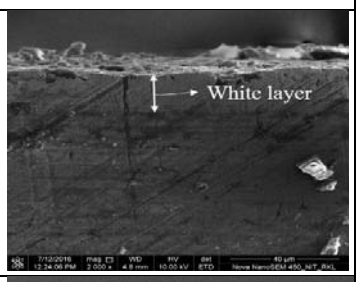
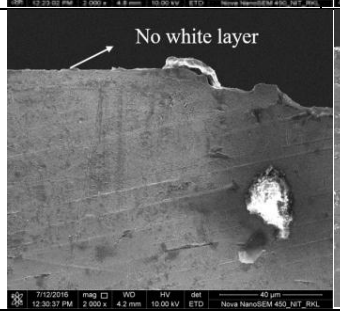
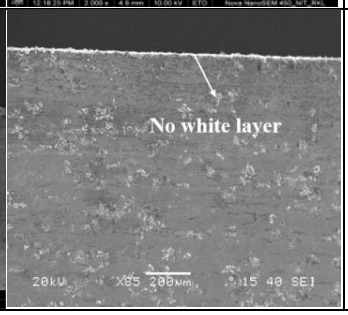
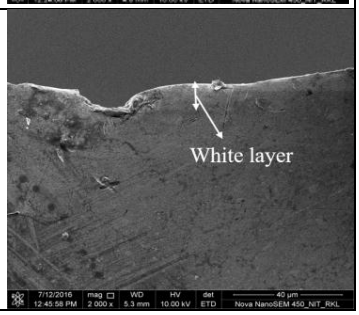
V_c (in m/min)	80	100	120
Uncoated cermet insert			
Coated cermet insert			

Fig. 4. Images of white layer formed during machining at various speeds with coated and uncoated inserts

3.4 Macromorphology of machined surface

Machined surface morphology manifests the most precise analysis of surface quality. Fig. 5 shows the forms and structures of machined surface examined under Scanning Electron Microscope (SEM). The work used in the experiment was AISI 4340 low carbon alloy steel using both coated and uncoated cermet as cutting inserts. Somewhere material were redeposited. Some debris and feed marks were also found. Marks of material being smeared has been observed at lower cutting speed, nearly 80m/min. At higher cutting velocity, temperature get enhanced and plastic deformation caused feed marks visible on machined surface.

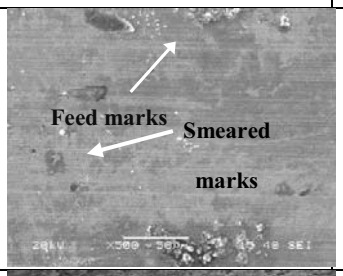
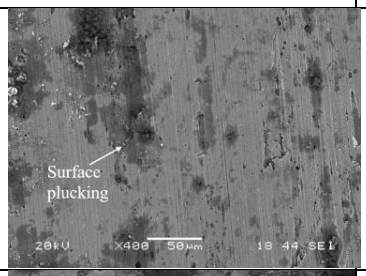
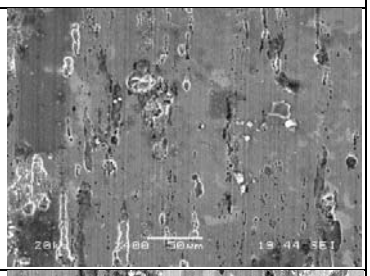
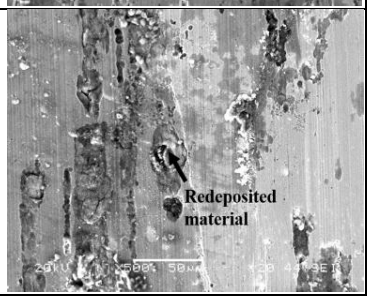
V_c (in m/min)	80	100	120
Uncoated cermet insert			
Coated cermet insert			

Fig. 5. SEM images of machined surface morphology at different speed levels using coated and uncoated inserts.

4. Conclusions

Every experimental investigation ends with some rational conclusions and here they are.
Machining with coated tool deliveres better surface finish in comparison to uncoated tools. Micro-hardness increases with cutting speed for both the tools. The machined surface hardness is found greater for uncoated cermet than coated one for the given identical cutting speeds. The magnitude of white layer thickness on the machined surface is found lower with coated insert than with uncoated cermet.

References

1. O. Pereira et al. 2015, Cryogenic Hard Turning of ASP23 steel using Carbon Dioxide. *Procedia Engineering*, Volume **132**, Pp. 486 – 491.
2. S. A. Kalam et al. 2015, Elimination of White Layer formation during Hard Turning of AISI D3 Steel to improve Fatigue life. *IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)*, Volume **12**, No (3), Pp. 07-14.
3. W. Grzesik et al. 2012, Effects of cryogenic cooling on surface layer characteristics produced by hard turning. *Achieves of Materials science and Engineering*, Volume **54**, No 1, Pp.5-12.