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Hard Turning of AISI D2 Steel by CBN, using protecting atmosphere to improve Fatigue life and reduction of White layer thickness

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ABSTRACT: *Hard turning (above 45HRC) has become an economically, environmentally, and technically competitive process when compared with grinding. During hard turning, formation of white layer on turned surface of component. The thickness of the white layer is usually several micrometers; the presence of it causes great component's performance, such as fatigue life. Hard turning is very real due to the existence of white layer, which is presumed detrimental to component life. A component free of a white layer can have a life six times that of a white layer component. As the white layer increases in thickness, the fatigue life decreases [1]. There are some factors that need to be considered for white layer formation during hard turning. The mechanism of rapid heating and quenching resulting in transformation products, Surface reaction with the environment Such as nitriding, carburizing and oxide ploughing, Plastic flow producing a homogeneous structure or one with a very fine grain structure [2]. Experiments were performed machining of hardened D2 Steel under dry and gas using chamfered CBN tool inserts. Experimental techniques were used in the analyzing scanning electron microscopy (SEM), Field emission scanning electron microscopy (FESEM) were utilized for the surface topography characterization; chemical characterization (phase study) was carried out by means of Energy dispersive X – ray spectroscopy (EDAX) techniques; and Surface textures produced by means of non contact techniques. The result shows to improve the fatigue life of component enhancement and achieve improved product's functional performance in hard turning by the reduction of White layer thickness.*

Keywords - *Fatigue life, Hard turning, Hardened steel, Shielding gas, White layer formation*

I. INTRODUCTION

Hard turning is performed on materials with hardness within the 45–68 Rockwell range using a variety of tipped or solid cutting inserts, preferably CBN. Although grinding is known to produce good surface finish at relative high feed rates, hard turning can produce as good or better surface finish at significantly higher material removal rates. Although the process is performed within small depths of cut and feed rates, estimates of reduced machining time are as high as 60% for conventional hard turning . Studies have shown that using the right combination of insert nose radii, feed rate or the new insert technology, hard turning can produce better surface finish than grinding. Multiple hard turning operations may be performed in a single setup rather than multiple grinding setups. This also Contributes to high accuracy achieved by hard turning. During hard turning the White layer formed on machining surface. The white layer is a very thin outer layer of material that is harder than the under lying material. The white layer formation is a phase transformation rich in retained austenite [3].

II. LITERATURE REVIEW

As per the literature survey, studied the causes of white layer by following factors:

(a) The mechanism of plastic flow producing a homogeneous structure or one with a very fine grain structure.

(b) The mechanism of rapid heating and quenching resulting in transformation products.

(c) The mechanism of surface reaction with the environment such as nitriding, carburizing and oxide ploughing[3].

The white layer thickness is depends upon the other factors are cutting parameter, Tool wear VB and BUE.Thus, it was generally believed that to reduce or avoid the white layer formation and, consequently to improve the surface integrity, it is necessary to decrease the temperatures , protect the tool and contact surface from atmosphere at time of turning. This is mainly done with the application of Shield gas. Also, the convective cooling effect of cutting fluids on this affected layer has not yet been clarified. showed that Shield gas spray cooling of cutting tool and tool-work contact would limit the thickness or eliminating white layer.

Therefore, the objective of this paper is to investigate the effects of Shield gas coolant on both white layer formation and surface roughness evolution during hard machining of AISI D2 steel. Experiments were performed under dry and Shield gas coolant conditions using chamfered CBN tool inserts at effective cutting speeds. Several experimental techniques were used in order to analyze the machined surface and subsurface. In particular, Scanning electron microscopes (SEM), Field emission scanning electron microscopes (FESEM) were utilized for the surface topography characterization, the chemical characterization was carried out by means of Energy dispersive X – ray spectroscopy (EDAX) technique, and Non conduct test was used to determine roughness of machined surface (Ra and Rz) and phase changes induced by machining under dry and Shield gas cooling conditions.

III. EXPERIMENTS

Experiments were conducted on a stiff high speed CNC lathe (JOBBER XL) with manual impinging Shield gas (Helium) at 2 bar pressure delivery system provided (Fig. 1 a). In particular, orthogonal cutting operation was performed on AISI D2 steel by using CBN tools, grade CB7015 by Sandvik Coromant. TNGA 160408 S01030 chamfered inserts.. The Shield gas coolant was applied through gas hosepipe show in Figure 1 (a) to provide the cooling effect at the primary, secondary and tertiary shear zones. Circular rod of hardened AISI D2 steel (outer diameter = 34 mm) were prepared, machined and heat-treated.

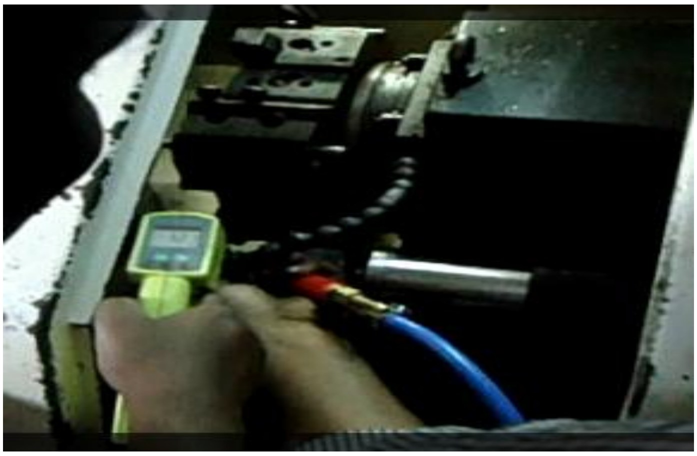


Figure 1: Hard turning of D2 steel using Helium gas impinging as coolant

Heat treatments were performed in order to through-harden the Circular rod to 61±1HRC. The samples were turned by using CBN insert in effective cutting speeds (160 m/min) at a fixed feed rate of 0.2 mm/rev with depth of cut 0.2mm in dry and gas coolant conditions;. In such conditions surface temperature was measured as 175ºC in dry condition and 96ºC in gas coolant condition respectively with the help of IR sensor (Infra red sensor). After machining, samples of 5 mm depth were sectioned in the shape of crescent by wire-EDM for microstructure analysis and micro hardness measurements. The grinding was performed in all the samples on EDM cutting side. The cutting fluid was used as coolant to reduce thickness from 5mm to 2.5mm in order to make use of mounting in FESEM. It was also etched for about 10 s using 4% Nital solution to observe white layer using a Field emission scanning electron microscope (FESEM) with gas and in dry condition. EDAX techniques were also applied to conduct a qualitative elemental analysis on the machined surface of one sample with gas.

IV. RESULTS AND DISCUSSION

4.1. White layer and surface micro hardness

From the literature survey (more thickness WL formation in between cutting speed 100 to 300m/ min) produced by varying the cutting speed and the cooling condition. Figure 2 (c) shows the experimental white layer thickness at cutting 160m/min. It was found experimentally the thickness of white layer with gas is less than that of 2 µm in dry state. Furthermore, the white layer decrease with the increasing cutting speed. However, what is new is that the thickness of white layer was reduced using shield gas cooling method.

The average of grinding surface hardness value 54 HRC , average of non grinding surface hardness value 61 HRC shield gas surface hardness value 51 HRC and average of dry turned surface hardness value 54HRC. White layers were observed with hardness more than that of the bulk material. There was depletion of iron and chromium while increase in carbon and oxygen content in the white layer. While tool wear increased with the increase in cutting speed, the white layer depth and hardness actually reduced (Fig. 2).This may be due to the fact that at high speeds the temperature of the work piece material reduces while that of the chip increases. Reduction in the temperature of machined surface may be due to faster chip removal and insufficient contact time. Due to this lesser heat is conducted into work piece while most of it is carried away by the chip. This was also observed. While analyzing white layer during the hard turning of AISI 52100 steel with CBN insert , TEM results suggested that white layers produced at low-to-moderate cutting speeds were largely due to grain refinement induced by severe plastic deformation. Whereas the white layer formation at high cutting speeds was mainly due to thermally-driven phase transformation [3].

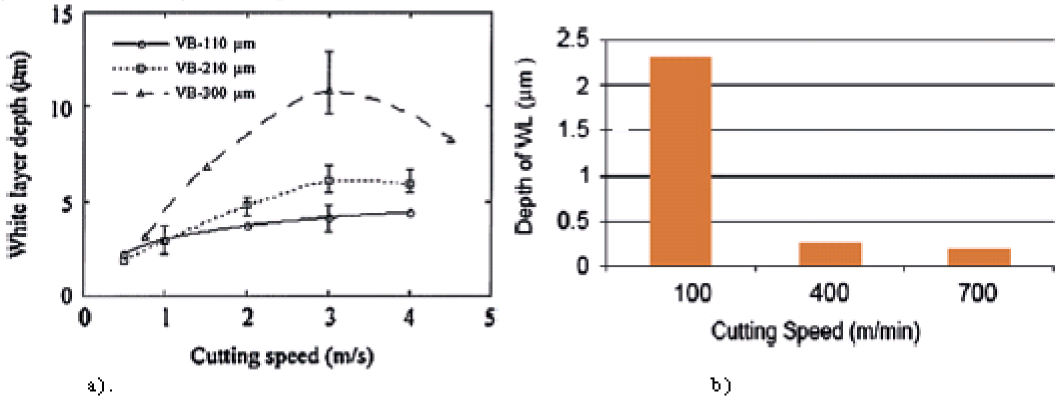


Fig 2 a) Effect of cutting speed on white layer depth and tool wear V_B [4]. b) Effect of cutting speed on white layer depth [3]

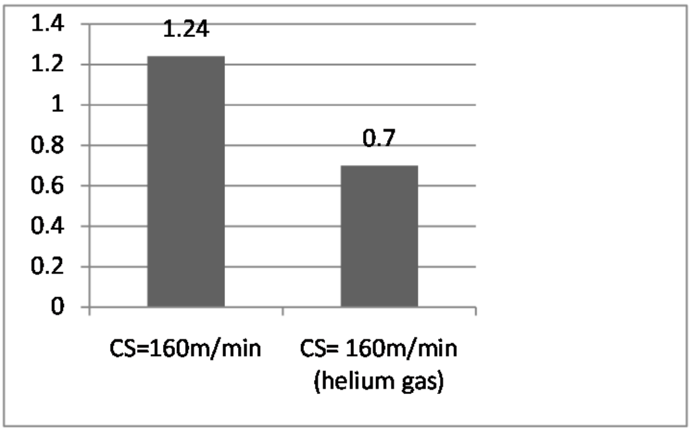
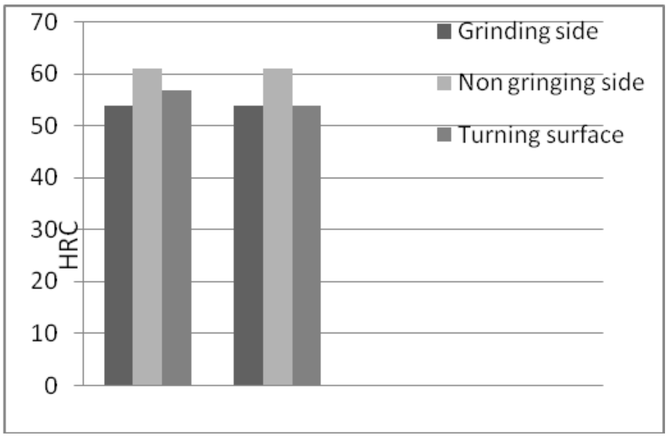


Fig 2 (c) White layer thickness by dry turning and using helium gas



Vc 160 without gas 160m/min Helium gas

Fig 2 (d) Cutting speed(m/min)/ constant Feed rate(0.2mm/rev)/Hardness(HRC)

Fig. 2. (c) Experimental white layer thickness and (d) surface hardness modification at varying cutting speeds and the cooling methods.

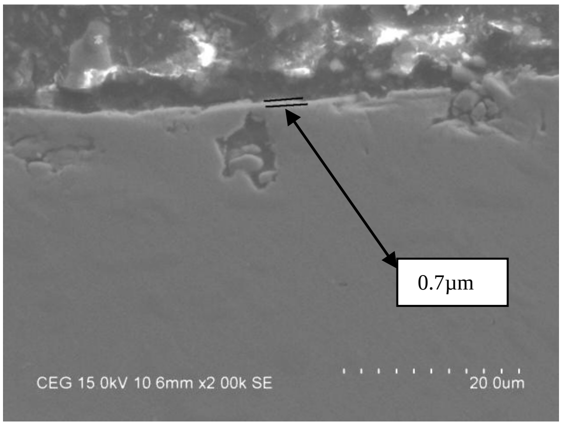


Fig 3 SEM images of turning with gas (White layer avg. thickness 0.7µm at cutting speed 160 m/min)

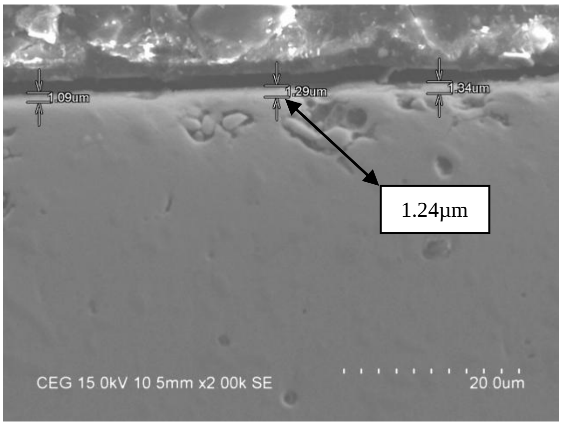


Fig 4 SEM images of dry turning (White layer avg. thickness 1.24µm at cutting speed 160 m/min)

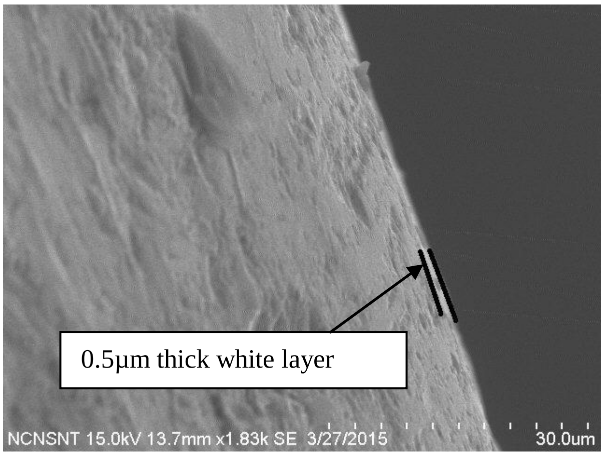


Fig 5 FESEM images of turning with gas at cutting speed 160 m/min (Helium gas)

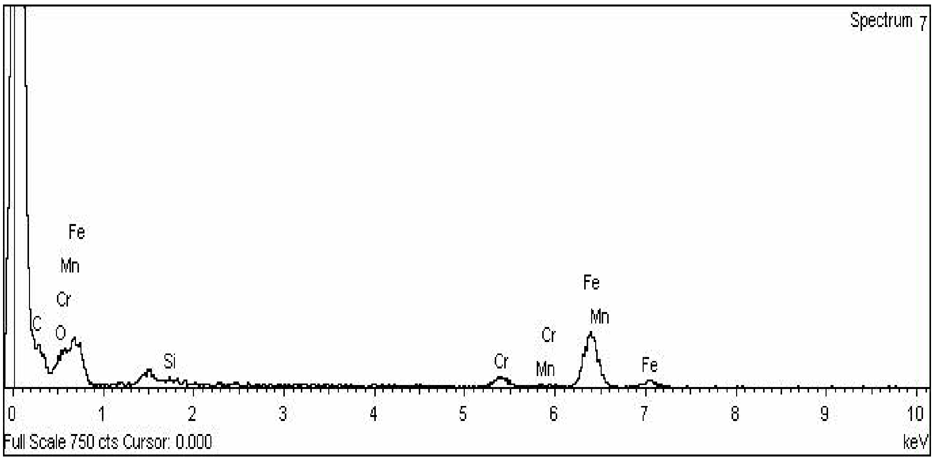


Fig. 6. EDAX phase analysis on specimens machined at cutting speed 160m/min (Helium) with shield gas cooling for hardness 61 HRC, CBN chamfered tool , feed rate of 0.15 mm/rev and depth of cut as 0.2mm.

Table :1 Chemical composition of material

Element	Weight	Atomic %
C k	27.48	67.72
O k	12.73	23.55
Si k	0.65	0.69
Cr k	7.34	4.15
Mn k	0.73	0.39
Fe k	74.53	39.50
Total	100	

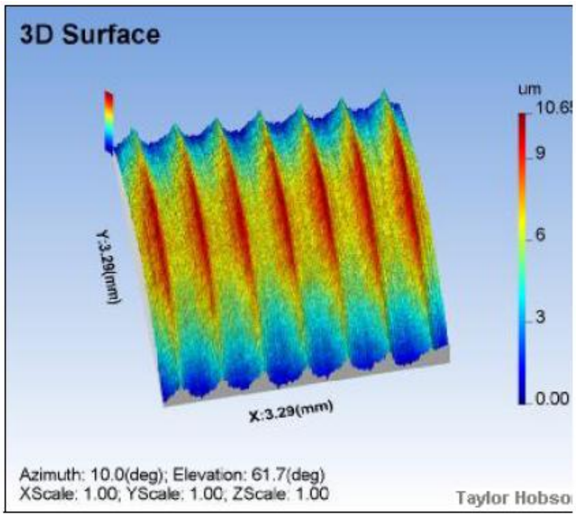
4.2. Analysis of Chemical composition:

Any chemical compositional changes during transformation are analyzed by the EDS and EDAX etc. but EDAX is very commonly employed method for analyzing chemical compositional changes by FESEM images. In general main elemental compositional changes are taken into consideration. For instance, there will be a significant amount of depletion (reduction) of iron and chromium but there will be a substantial increase in carbon as well as oxygen .The changes will be expressed in weight percentage since the compositional variation were taken in weight percentage .Whenever there is a white layer formation iron and chromium was so evidence. Hence the increase in carbon and oxygen also obvious.

The carbon increase from 1.5% to 27.48%, Chromium decrease from 12% to 7.34%, Iron reduced from 81% to 74.53% and Oxygen react up to 12.73%. So that the shield gas helium was not completely protected the cutting surface from atmosphere during hard tuning. But it was reduced White layer thickness with considerable amount.

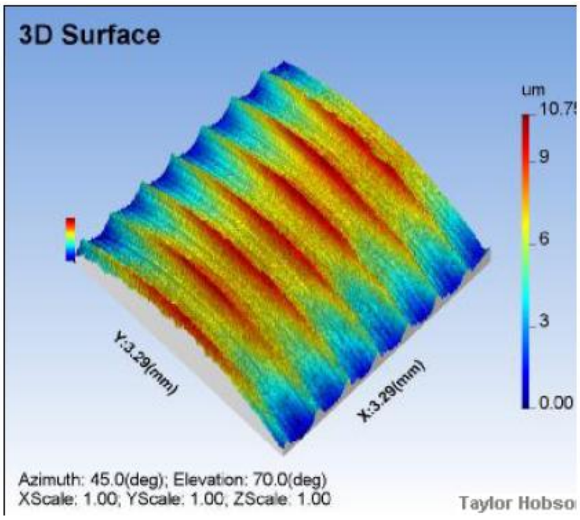
4.3.Characterization of surface topography:

Surface topographies generated by HT with gas and dry operations through only one pass were recorded using a Non contact test. The determination of 3D roughness parameters and 3D visualization of machined surfaces were performed .HT dry turning performed by CBN ,TNGA 160408 S01030 chamfered insert. By grinding operation Al_2O_3 Ceramic wheel (350 x 25 x 127 32A) with water soluble emulsion as a coolant. Machining conditions for cutting and abrasive operations were performed with 5 pass and achieved surface roughness of Ra = 0.27µm, Rz = 4 µm. [4]



Ra = 0.651 µm

Fig 5 3D visualization of machined surfaces (With gas): Vc =160m/min



Ra = 0.626 µm

Fig 6 3D visualization of machined surfaces (Without gas): Vc =160m/min

Table :2 Comparison of Surface roughness of grinding operation Al2O3 Ceramic wheel (350 x 25 x 127 32A) by 5 pass Ra = 0.27µm, Rz = 4 µm [4], grinding Ra average is 1.6µm [5] and turning (with and without gas)

S.No	Parameter Dc=0.2mm,Feed rate = 0.2mm/rev	With gas		Without gas	
		Ra in µm	Rz in µm	Ra in µm	Rz in µm
1.	CS = 160 m/min	0.651	3.65	0.626	3.25

From the Surface roughness table, we observed the surface finishing of HT was as better as grinding operation. The time consumption was also more than HT. Surface finishing in HT which depends on tool wear , nose radius and cooling gas was better than liquid cutting fluid. Because the parameters such as BUE (Built up edge) and V_B (flank wear) were minimized by the use of gas pressure.

V. CONCLUSIONS

The following facts were observed after reviewing the works discussed above:

- The shield gas used as a coolant which reduced the cutting temperature and also protected the machining surface partially from atmosphere. As a result, the phase transformations were minimized.
- By using helium gas, the white layer thickness was reduced with considerable amount as shown, from SEM image (without gas)1.24 µm to 0.7 µm (with gas) and FESEM image shows 0.7µm at 160m/min but it was not completely eliminated. Because of the density of helium is (0.00018 gm/cm³) less than density of atmosphere air (0.001292 gm/cm³).
- Surface roughness table observed that the surface finishing of HT is as better as grinding operation. Surface finishing in HT which depends on tool wear, nose radius and cooling gas was better than liquid cutting fluid. Because the parameters such as BUE (Built up edge) and V_B (flank wear) were minimized by the use of gas pressure.
- MRR material removal rate by HT operation was also more as compared to the grinding operation.
- Hardness of dry turning Surface (57HRC) was more than the surface turning in gas coolant condition (54HRC) because oxygen reaction and carbon content was less.

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