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Surface Integrity of Inconel 825 When Turning With Uncoated and CVD Coated Carbide Inserts

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1. INTRODUCTION

During the machining of any materialit is very important to analyse these variables i.e. cutting force, shear angle and surface integrity etc. These are depends on workpiece material, tool material and its geometry, cutting parameters like cutting speed, feed rate and depth of cut.Nature and condition of surface region of a component is defined by a term known as surface integrity. During the machining of nickel-based super alloy surface defects such as surface drag, material pull out/cracking, feed marks, adhered material particle, debris of chips, surface plucking, deformed grain surface cavities and slip zone were found [1]. This type of failure generally depends on the surface quality. Study of surface characteristics has become very important. Nickel based super alloy is highly used in aerospace industry but nickel based super alloy has poor machinability. So it is very difficult to machine nickel based super alloy at high cutting speed with carbide tool. During the machining with higher production rate,cutting parameters play an important role.Higher cutting speed higher will be the production rate. Cutting speed is directly influenced on the surface integrity. So study of surface integrity analysis becomes very important.

Among all nickel based super alloy lots of experiments were done on Inconel 718.Analysis of surface integrity characteristics of Inconel 718 with new and worn coated carbide and PCBN (Polycrystalline cubic boron nitride) tool were investigated. Machining with new cutting tool had better surface integrity than worn tool for both type of tools. PCBN tool performed better than coated carbide tooleven at high cutting speed[3].

During the machining microhardness was also affected with different location. Micro hardness was varied from edge of machined surface to the centre of machined surface. Some of the researchers measured the microhardness with respect to depth surface beneath [4,5]. Hardness decreased with increase depth below machined surface and decrease feed rateat constant cutting speed [6].Microhardness increased with increase of cutting speed keeps other cutting parameters constant [7]. White layer formation also affects the surface integrity. As white layer formation is caused of hard and brittle surface. White layer increases crack propagation and corresponding it effect on surface quality and fatigue strength [8 & 9]. Sometime due to high temperature surface softening occurs at the top of machined surface and that surface has less value of hardness than the layer below to the machined surface [10-12].

In this paper an experimental investigations were performed on Inconel 825. Surface integrity included with surface morphology, microhardness and white layer formation were studying with variable cutting parameters given as variable cutting speed (Vc) of 51, 84 and 124 m/min with constant feed (f) of 0.198 mm/rev and depth of cut (t) of 1 mm. Machining were performed with uncoated and coated(TiN/TiCN/Al_2O_3/ZrCN) cemented carbide tools.

2. EXPERIMENTAL METHODOLOGY

In this experiment Inconel 825 was used as a specimen. Dimensions of the specimen were 75 mm diameter and 195 mm length. Chemical composition of Inconel 825 is given in Table 1.Three different cutting speeds were selected during the machining as 51, 84 and 124 m/min along with a constant feed (f) of 0.198 mm/rev and depth of cut (t) of 1 mm. Uncoated ISO P30 grade cemented carbide insert with ISO designation of SCMT120408 was used and its performance was compared with that of multilayer coated tool of similar designation. The composition of the coated tool was TiN/TiCN/Al_2O_3/ZrCN deposited by CVD. A tool holder with ISO designation of SSBCR 2020K12 (Kennametal, India) was used for both uncoated and coated tools.

Table 1: Chemical composition of Inconel 825

Element	Ni	Fe	Cr	Mo	Cu	Ti
Content	38 -	22 %	19.5 - 23.5%	2.5 -	1.5 3	0.6 -

	46 %	min		3.5 %	%	1.2 %

Comparative performance evaluation of uncoated carbide tool and the coated carbide tool was performed during turning of Nickel-based super alloy (Inconel 825). Heavy duty lathe (Make: Hindustan Machine Tools (HMT Ltd., Bangalore, India; Model: NH26) are used for turning of Inconel 825 with uncoated and coated cemented carbide tools. Fig.1 shows photograph of experimental setup for turning of Inconel 825.

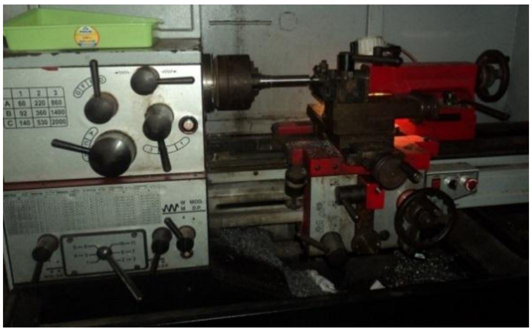
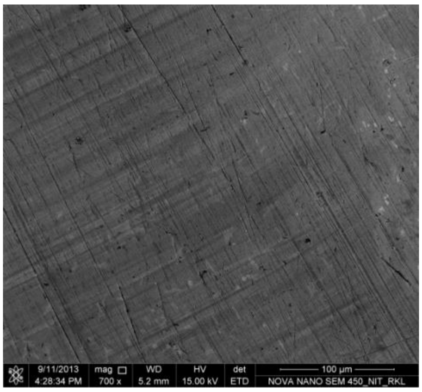


Fig.1 Photograph of experimental setup for turning of Inconel 825.

For measurement of Vickers microhardness and to study the white layers the sample (Inconel 825) were first cut along a plane perpendicular to the axis of rotation and then cross sectional plane was polished using decreasing grades of polishing papers. After polishing the cross sectional plane was studying using Scanning electron Microscopy(SEM, Make: JEOL JSM-6490) to reveal the formation of white layers and measurement the thickness of the same. Energy dispersive spectroscopy (EDS) was used to analyse the chemical composition of workpiece material.
Vickers microhardness (LECO, USA)measurement were taken on the cross sectional surfaces along a straight line from the edge corresponding to the circumference of the machined work piece) to the centre. Each indent was separated from the next one by 0.5 mm. Allthe measurement was taken at a load of 50 gf and dwell time of 10 s.

3 RESULTS AND DISCUSSION

3.1 Characterisation of Machined Surface
Fig. 2 shows SEM images and corresponding EDS spectrum of Inconel 825 before machining. Before machining grains are uniformly distributed.
Fig. 3 shows SEM images of machined surface of Inconel 825 with uncoated and coated tools. From images we can noticed that the grains are invisible incase of surface machined with uncoated tool. Whereas surface machined with coated tool have visible grains but due to temperature effect grains deform.



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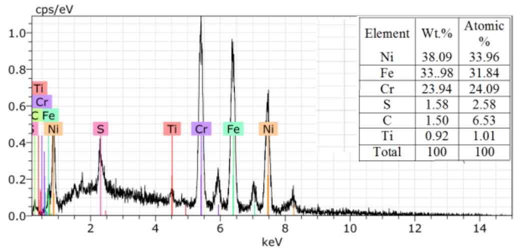
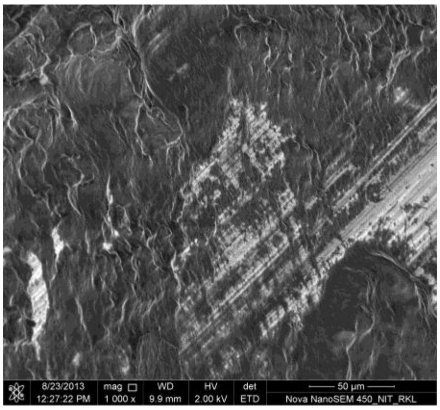


(b)

Fig. 2 (a) SEM images and (b) corresponding EDS spectrum of Inconel 825 before machining



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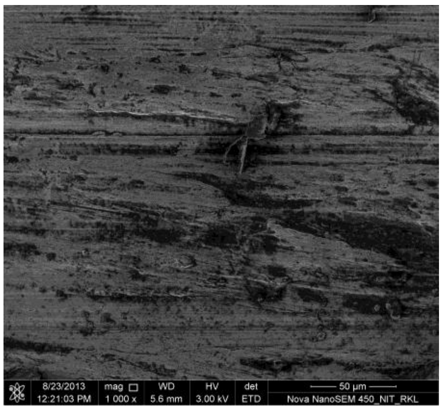


(b)

Fig. 3 SEM images showing surface morphology of machine surface of Inconel 825 with (a) uncoatedand (b) coated, carbide inserts

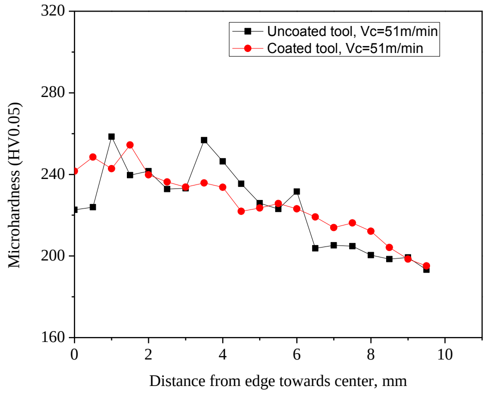
3.2 Micro Hardness

Fig.4 shows optical microscopic images of Vickers indents on surface machined with different cutting speeds and constant feed, depth of cut and distance from edge of machined surface, machined with uncoated and coated carbide inserts. As the indentation diameter increased hardness also increase.

Cutting speed, m/min	Uncoated tool	Coated tool
	Microhardness ($HV_{0.05}$)	
51		
84		
124		

Fig.4 Optical microscopic images of Vickers indents on surface machined with different cutting speeds using uncoated and coated carbide inserts

Fig.5 shows the effect of micro hardness with distance from edge towards centre of machined surface Inconel 825 with variable cutting speeds and constant feed of 0.198 mm/rev and depth of cut of 1mm.Micro hardness decreased with distance takenfrom edge towards centre of machined surface. Hardness generated at the machined surface increased than the hardness of the bulk material. This is mainly due to the high temperature generated during machining with increase of cutting speed that increase hardness like a heat treated surface.Microhardness at the beneath of machined surface upto 3mm is more than 200 for all the cutting speed accept for cutting speed of 124 and machined with uncoated tool. The explanation behind this may be due to excess temperature generated at the machined surface during the high speed machining that turned the surface softening due to work hardening caused by plastic deformation. Surface softening decreased the hardness of top surface than the bulk hardness of the material. Surface that machined with uncoated tool has more micro hardness than surface machined by coated tool. The superior mechanical characteristics of the different coating material like hot hardness and hot strength of Al_2O_3 coating, antifriction and wear resistance due to TiN and TiCN coating and good toughness due to ZrCN must have contributed to the overall control the hardness of the machined surface which is generated mainly due to high temperature generation.



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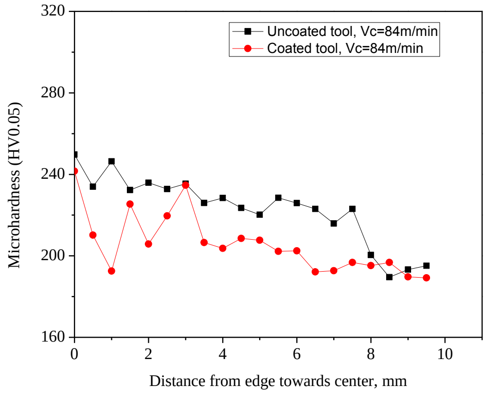

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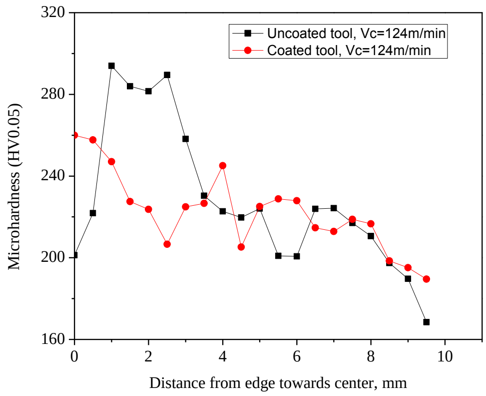
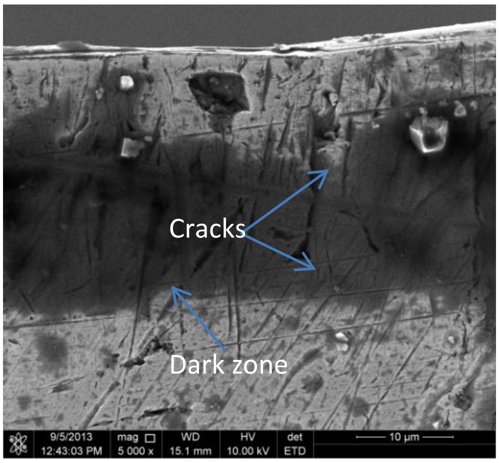


(c)

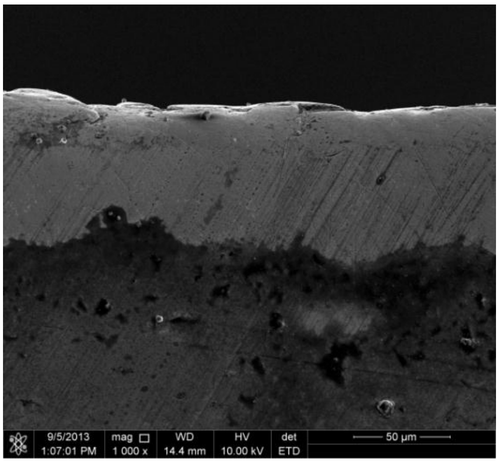
Fig.5Variation of micro hardness with distance from edge towards centresof machined sample with different cuttingspeeds (a) 51 m/min, (b)84 m/min, and (c)124 m/min, using uncoated and coated carbide inserts

3.3 White Layer

Fig.6 shows SEM images of surface morphology and cracks developed on the cross section of machined surface. As the cutting speed increased machined surface become brittle due to increase in work hardness.As the material become brittle it has a tendency to develop cracks on surface and cracks propagate from edge towards centre of workpiece. Cracks propagation also affects the fatigue strength as well as surface quality of the machined surface.Fig. 7 shows SEM images of white layer formation with variation of cutting speed with constant feed and depth of cut for the surface machined with uncoated and coated carbide inserts. This can be notice that as the cutting speed increased white layer thickness increase. Cutting speed increased with increase of temperature at the machined surface. Due to increased temperature, heats generate. Inconel 825 has low thermal conductivity heat may not dissipated to the surroundings as early as possible, that increased the hardness of machined surface and convert the machined surface into very hard and brittle surface. White layer thickness of surface machined with uncoated insert has more than the surface machined with coated insert accept for high cutting speed of 124 m/min. The explanation can be given as due to coating of mainlyAl_2O_3hot hardness and strength maintained and that easily dissipate the excess heat to the bottom layers. That layer called as heat effected zone.



(a)



(b)

Fig.6 SEM images of machined surface (a) cracks and (b) surface morphology

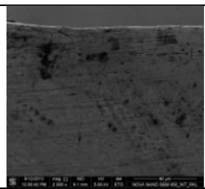
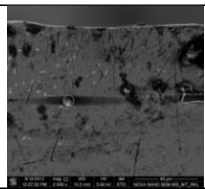
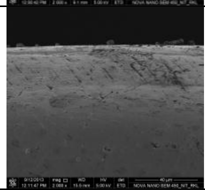
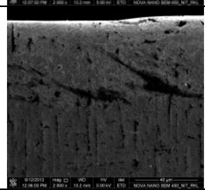
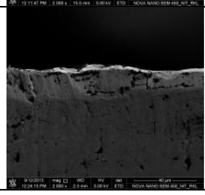
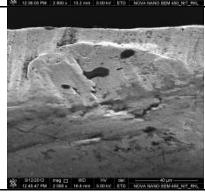
Cutting speed m/min	Inconel 825 machined with uncoated insert	Inconel 825 machined with coated insert
51		
84		
124		

Fig.7 SEM images of white layer thickness with varying cutting speed

4 CONCLUSIONS

The current research work investigates the effect of cutting speed on surface morphology, micro hardness and white layer formation of the surface machined with uncoated and coated inserts. The following conclusions may be drawn from the study

1. At high speed machining grains deformed.
2. Microhardness increased with distance from the machined surface to the centre.
3. Cutting parameters also influenced the microhardness value as the cutting

speed increased microhardness also increase.

4. The multilayer coating of TiN/TiCN/Al_2O_3/ZrCNplays a major role in improving resistance to surface softening particularly at high cutting speed.
5. White layer formation is one of the causes of surface quality and fatigue strength.
6. As the cutting speed increased white layer thickness also increase.

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