CHARACTERIZATION OF NANOCOATING DEPOSITED ON THE CEMENTED CARBIDE TOOL IN DRY TURNING OF SS304

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Abstract: **In this work, cemented tungsten carbide (WC) insert was coated with TiAlN+WC/C by Physical vapor deposition (PVD) and their wear resistance, built-up edge phenomenon and surface roughness of turned SS304 were investigated. The experimental studies have been conducted under cutting speed (vc=130m/min), feed rate (f=0.2mm/rev) and depth of cut (ap=0.2mm). The CNC, tool maker's microscope and surface roughness tester have been used to acquire the data. The results of the present study indicated that coatings have significant influence on the tool wear, built-up edge and surface roughness of turning workpiece. Conformation tests have also been conducted to validate the coating performance. Scanning electron microscope (SEM) / energy dispersive X-Ray spectroscopy (EDS) examination has been done to investigate the coating microstructure and material composition of the tool surface. The results of the present study indicated that the performance TiAlN+WC/C coated tool was better than the uncoated.**

***Keywords*: Physical Vapor Deposition (PVD), Tool wear, built up edge and surface roughness.**

I. INTRODUCTION

Metal cutting is the most important means of part manufacturing, and it occupies a very important position in the manufacturing industry. The cutting tool is the key to the high-efficient machining of material [1]. As the demand for high tolerance manufactured goods is rapidly increasing, the main challenge for the manufacturing industry is decreasing its cutting cost and increase the quality of machined parts [2]. NC machines play a vital role in producing higher quality jobs with lesser machining time and reduced cost. Even though, the product lead time and cost increased due to parameters such as tool wear, tool changing time, etc. [3]. There exist a number of methods aiming at increasing the efficiency of cutting tools. However, the most effective is wear-resistant coating, which in recent years has been widely used [4].

Another challenge faced by metal cutting industry is the health hazard associated with cutting fluids. It is estimated that over 380million liters of metalworking fluids are used annually in the United States alone. According to estimations made by the National Institute for Occupational Safety and Health (NIOSH) 1.2 million employees, for example, simply in the US, are exposed to cutting fluids each year. This has made machining and manufacturing industries look seriously for various environmentally friendly approaches for material removal. For example, dry machining is one of the prominent methodologies [5].

The benefits of cooling lubricants in machining processes are the reduction of friction in the tool–workpiece contact (lubrication effect), removal of chips from the cutting area (flushing effect), transport of thermal energy dissipated in the contact zone (cooling effect) as well as cleaning and anti-corrosive effects [6].The development of tool material by adding alloying elements having sufficient toughness and hardness, improving tool geometries and finally coating the tools can solve the problem. Derflinger et al [7] studied the effect of new hard/soft lubricant coating on high speed drill in the dry machining. It was concluded the use of hard/lubricant coating on cutting reduces the use of the enormous amount of cooling emulsion used in the industry. Ucun et al [8] studied the effect of five separate coating materials (AlTiN, AlCrN, TiAlN + AlCrN, TiAlN + WC/C and diamond-like carbon) on surface roughness in micro machining of Inconel 718 super alloy. Results revealed that DLCand TiAlN + WC/C-coated tools had the best surface roughness performance Sokovica et al [9]. Wear of PVD-coated solid carbide end mills in dry high-speed cutting. It was concluded that the end mill cutters, coated with dry lubricating coating TiAlN + WC/C (producer C), have no place in dry high-speed milling.So in the current study it has been proposed to study the effect of nano structured hard/soft(TiAlN+WC/C) lubricant coating on ISO k10 carbide tool in dry machining of SS304.SS304 is used as common material by industries due to possess a good combination of mechanical properties, form-ability, weld ability, and resistance to stress corrosion cracking and other forms of corrosion. In the current study the coating was developed by Oerlikon Balzers by using a front-loading Balzer's rapid coating system (RCS) machine. The purpose of the current study is to develop wear resistant and laborious coating.

II. EXPERIMENTAL PROCEDURE

In the current work, one coating powder (TiAlN+WC/C) was selected. The coating was produced by Balzer's rapid coating system (RCS) machine as shown in Fig.1. ISO K10 was selected as tool material and SS304 as workpiece material with the dimensions, 60mm in length and 50mm in diameter. The chemical composition of the tool material and workpiece material is given in Table I and table II.

Table I: Chemical Composition (wt %) of ISO K10

ISO CODE	Composition (%)			Density	Hardness
	WC	**Ta(Nb)C**	**Co**	(g/cm^3)	(HV)
K10	92	2	6	14.9	1730

Table II: Chemical Composition (wt %) of SS304

S No.	C	S	P	Si	Mn	Ni	Cr	Mo	Fe
1	0.020	0.010	0.035	0.230	1.30	10.130	16.290	2.060	Bal

Two of the six sources were used to deposit a thin and 0.3 μm thick sub layer of TiN sub-layer with the help of the RCS machine which is equipped with 6 cathodic arcs to improve adhesion of coating. Remaining four sources were used to deposit the main layer of coating, which was obtained with the help of customized sintered targets. Most of these combined layers — hard coating+lubricant coating — have been deposited in two different coating devices. However, innovative equipment has now been designed to allow for a higher coating productivity. With this system, it is possible to use arc and sputter sources simultaneously. This was the optimal configuration for developing a coating consisting of a TiAlN hard layer and on top of a WC/C. The Coating was characterized and analyzed using scanning electron microscopy of coated, carbide insert after continuous machining application for 10 minutes. An add-on device for energy dispersive spectrometry (EDS) was used to measure element composition of coating layers. It allowed obtaining the distribution of elements along a line within a given area.

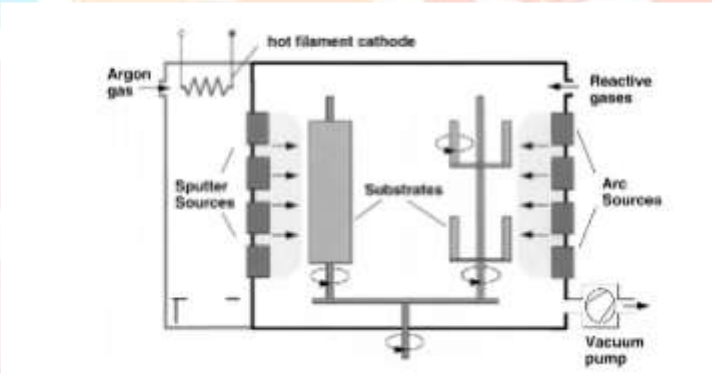


Fig. 1 Schematic illustration of film deposition by PVD.

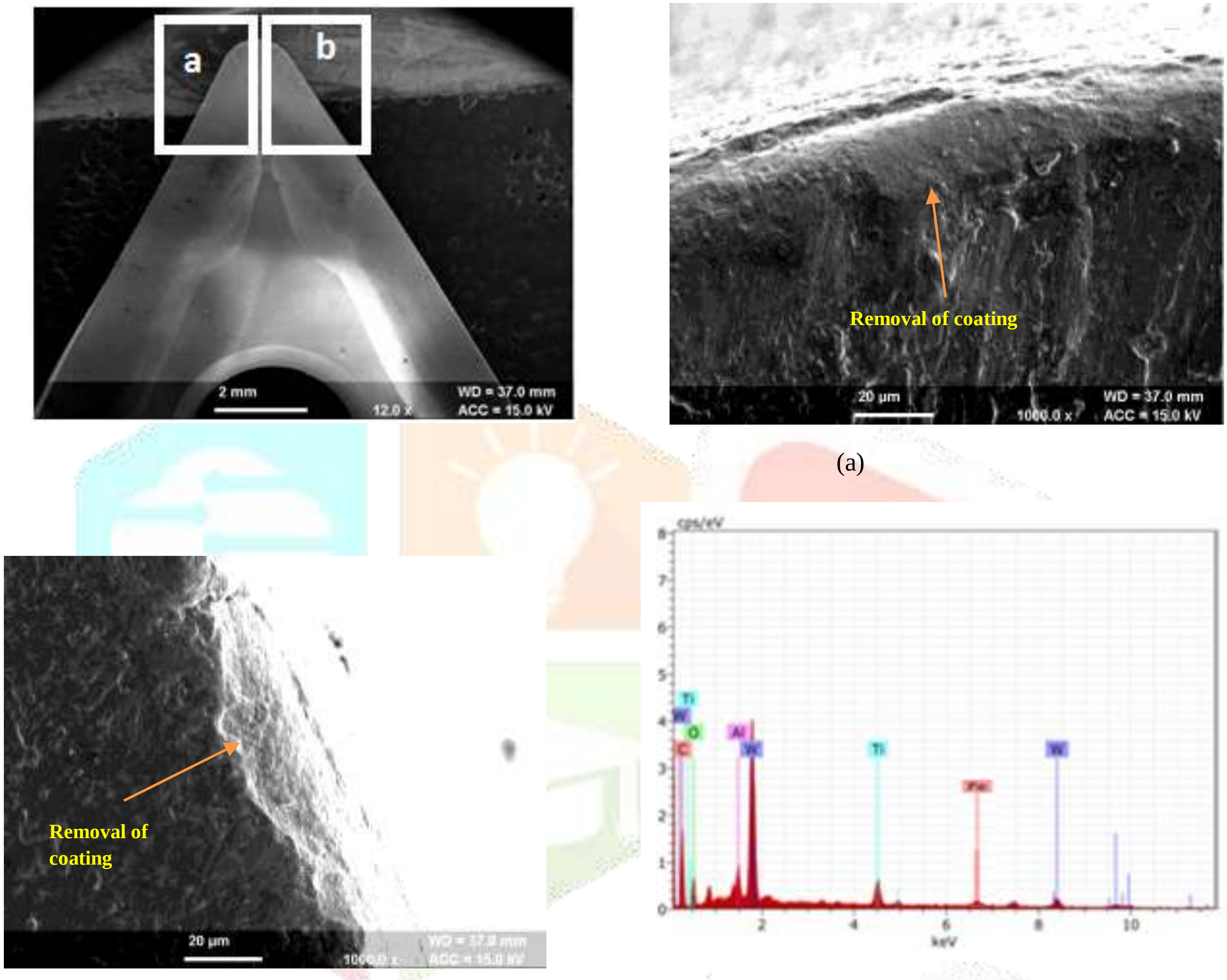
This study focused on the cutting properties of carbide insert type K10 coated with the TiAlN+WC/C coating. The investigation was conducted in dry turning of SS304 on a CNC type vantage 800 LM designed by ACE designers. The following machining parameters were used: cutting speed, v = 130 m/min; feed rate, f = 0.2 mm/rev; and depth of cuts, ap = 0.2 mm. The flank wear was measured with tool maker's microscope. The working efficiency of the coated inserts was evaluated by wear resistance coefficient with to an uncoated insert k10 taken as baseline. During the tests, a limiting flank wear VBmax = 0.5 mm was considered.

III. RESULTS AND DISCUSSION

A. Flank wear of coated tool

By a combined catholic arc evaporation and magnetron sputtering deposition of the hard/lubricant coating resulted in a dense adherent hard coating having a functional layer for machining plus a softer layer of low coefficient of friction for chip transportation and torque reduction during the machining process. Fig. 2 shows the results of a dry turning test. In this case, turning was performed for 10 minutes. This test presents the relative performance of the uncoated tool on the one hand and on the other hand tool with a combined hard/lubricant coating.

The maximum flank wear for TiAlN+WC/C coated tool measured was 0.038mm. As from SEM micrographs possible mechanism of the role of the low-friction coating during this turning application is that during machining, the chips slide along this surface. It can be seen that after 10 minutes of continuous turning the lubricant WC/C coating that is deposited on exposed chip contact areas is removed early in the operation and will partially be pushed into the depressed areas. As a result, the surface will be planed, and additionally, grooves and a strong crater in the areas of cutting edge will be formed. This effect plays an important role mainly during the running-in period in the tribological wear mechanism.As stainless steel is the very sticky material for machining applications due to which the transferred material (built up edge) on the edge was seen, the reason behind it was the removal of WC/C coating layer, exposing the hard TiAlN layer with a higher coefficient of friction, due to which adhering of material takes place. This theory is supported by the results shown in Fig. 2 (a) and (b) and seen to be similar to the results as reported by Solzak et al [10]. It was evident from the EDS analysis shown in Fig 2 (c) coated edge has a higher presence of Ti, W, Al and lower presence Fe elements. Availability of Fe may be diffusion of workpiece material during turning.



(a)

(b) (c)

Fig. 2 SEM micrographs and EDS spectrum of the worn flank face for uncoated tool after 10-min dry machining (v=130 m/min, ap=0.2 mm, f=0.2 mm/r)

B. Flank wear of uncoated tool

In the case of uncoated tool, flank wear measured was 0.17mm. As from SEM micrographs shown in Fig. 3 (a) and (b) wear either occurs gradually by abrasive or adhesive wear, through plastic deformation, by more discrete losses of material through discrete fracture mechanism, or by a combination of these. The adhesive wear can take place when one solid material is sliding over the counteracting surface, the interaction between two surfaces can be represented by the metallurgical weld or adhesion joint. When this adhesion joint is braked discrete pieces are pulled out from the tool surfaces during sliding forming a deep cavity known as crater. The observed effect is seen to be similar to the results as reported by Xavior et al [11]. It was evident from the EDS analysis shown in Fig. 3 (c) that uncoated edge has a higher presence of W, C, Nb and lower presence of Fe elements. The percentage of Fe was higher as compared to the TiAlN+WC/C coated tool, which may be the diffusion of workpiece material during turning application.

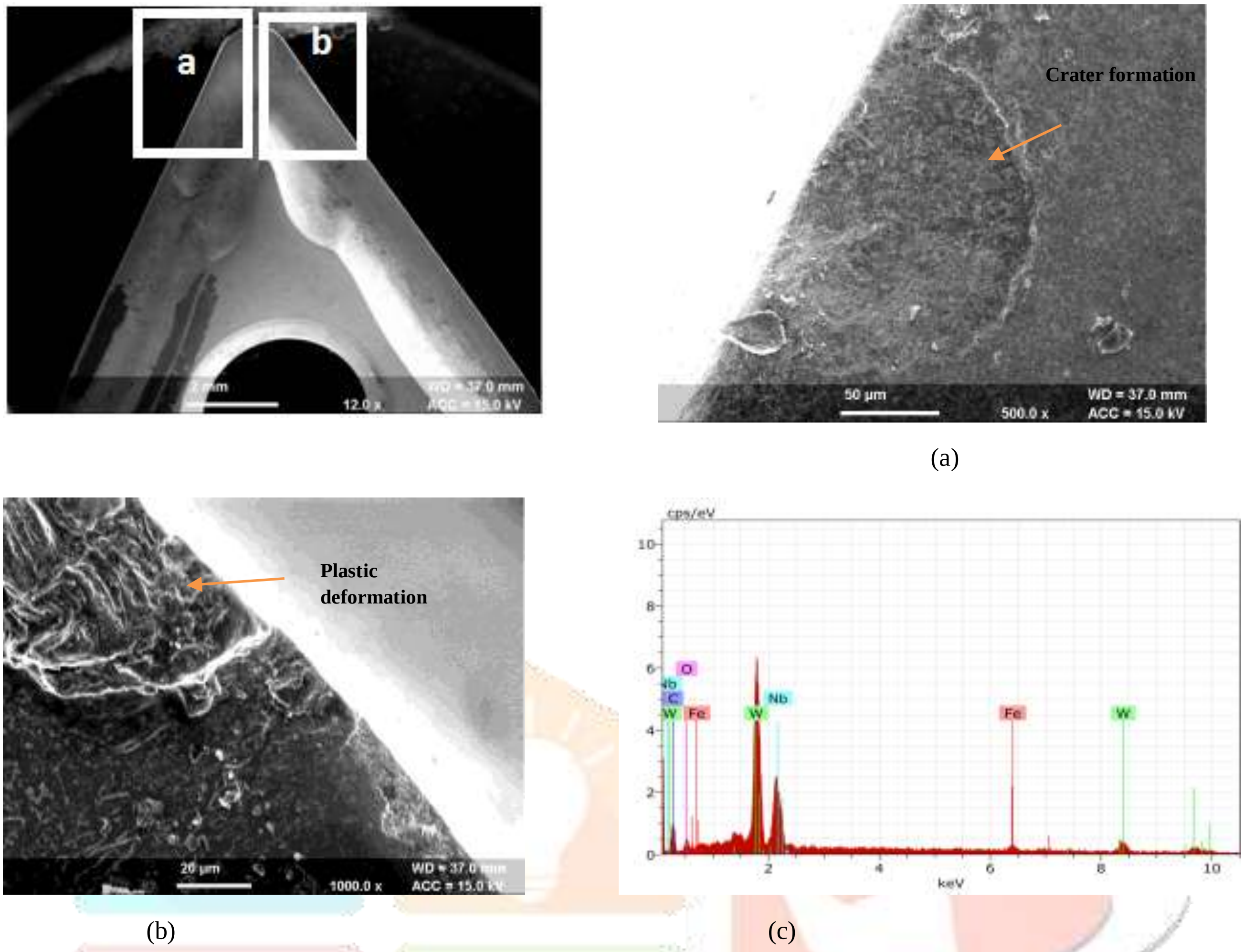
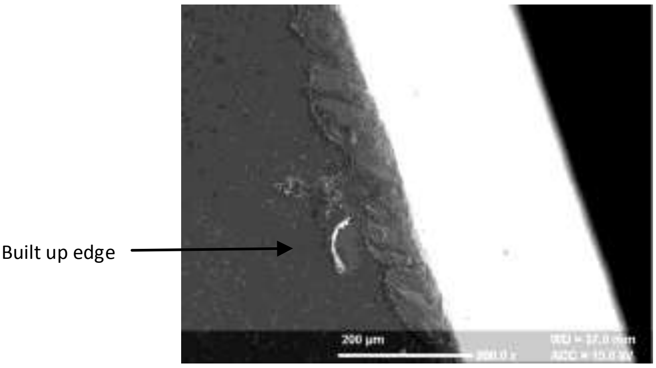


Fig. 3 SEM micrographs and EDS spectrum of the worn flank face for coated tool after 10-min dry machining (v=130 m/min, ap=0.2 mm, f=0.2 mm/r)

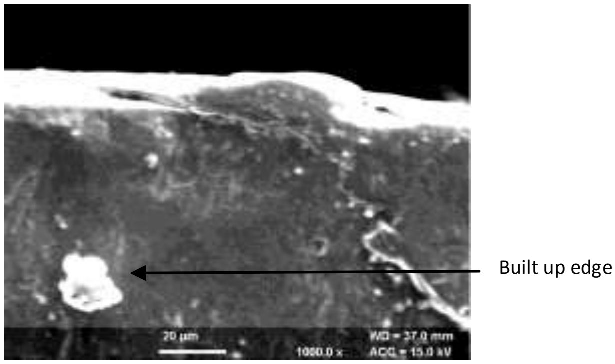
C. Built-up edge and surface roughness of turned workpiece

Surface finish in turning has been found to be influenced by a number of factors such as cutting speed, feed rate, depth of cut and tool material. In this work cutting conditions, i.e. cutting speed, feed rate, depth of cut was kept constant for all coated as well uncoated tools. The surface roughness of workpiece machined with TiAlN+WC/C coated tool after 10 minutes of continuous dry turning at speed 130 m/min, having feed of 0.2 mm/rev and depth of cut 0.2 mm was measured 2.73 µm it is less as compared to uncoated tool. From SEM micrograph shown in Fig. 4 (a) of TiAlN+WC/C coated tool the built up edge on the tool was formed after continuous turning, reason behind it was during turning the chips adhere to tool surface, changing the tool geometry which effect the surface finish of workpiece.

The surface roughness of workpiece machined with uncoated tool after 10 minutes of continuous dry turning at speed 130 m/min, having feed of 0.2 mm/rev and depth of cut 0.2 mm were measured 2.78 µm it is more as compared to TiAlN+WC/C coated tool. From SEM micrograph shown in Fig. 4 (b) of uncoated tool the built up edge on the tool was formed after continuous turning. The built up edge on uncoated tool is more as compared to the coated tool. In the case of TiAlN+WC/C coated tool the built up edge is less, this is due the lower coefficient of friction and lubricant effect of coating. This effect is responsible for better surface finish as compared to uncoated tool. The observed effect is seen to be similar to the results as reported by Sokovic et al. [12]



(a)



(b)

Fig. 4 SEM micrographs showing built up edge on the tool flank face

IV. CONCLUSION

In this study, dry turning of SS304 was done with TiAlN+WC/C coated and uncoated tool. The cutting conditions, i.e, cutting speed, *v* = 130 m/min; feed rate, f = 0.2 mm/rev; and depth of cuts, ap = 0.2 mm, for both coated as well as uncoated tool were kept constant. The effect of coating on tool wear and surface roughness was investigated. The following important conclusions were derived:

1. The coated tool has lower flank wear as compared to uncoated tool. The wear was 0.038mm with coated tool and 0.17mm with uncoated tool after 10 minutes of continuous turning.
2. The built-up edge formation is less with coated tool.
3. The surface finish was better with a coated tool as compared to uncoated tool. The measured values of surface finish are 2.73 with coated tool and 2.78 with uncoated tool.
4. From SEM micrographs of the coated tool, removal of coating layer was seen, this possibly caused by poor coating adhesion or relatively thin low friction WC/C overcoat.

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