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Wear Mechanism of PVD Coated Carbide in High-Speed Turning of Titanium Alloy TA15

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Abstract: PVD coatings (TiAlN) carbide cutting tools of titanium alloy (Ti-6.5Al-1Mo-1V-2Zr) turning test. Observation tool wear morphology using a scanning electron microscope (SEM), EDS analysisinstrument (EDS) analysis tool wear on the surface of the element distribution. analysis tool wear mechanism results show that: with PVD coating (TiAlN) carbide tool material turning titanium alloy Ti-6.5Al-1Mo-1V-2Zr, tool wear early main rake face crater wear and uniform flank wear, with the further wear of the tool, front and rear flank wear is connected to the formation of new irregular cutting edge, the front and rear of the coated cemented carbide cutting tool the flank coating flaking tool main wear mechanism is adhesive wear, oxidation and wear, diffusion wear which the oxidation wear occurs mainly in the edge region of the front and rear flank of the tool and since the temperature of the rake face of the cutting tool in the cutting process than after the flank cutting temperature adhesive wear, oxidation wear, diffusion wear phenomenon is more serious rake.

Key words: High speed turning, titanium alloy, tool wear, coated tools

INTRODUCTION

Titanium alloys are widely used in aviation, aerospace, nuclear power, shipping, ordnance industry and other fields based on its excellent performance (Fu, 2010). The advantages of titanium alloys include lighter mass, high specific strength, resistant to high temperature and corruption. TA15 titanium alloy is imported from Russia in the 90s according to the material requirements in aviation industry of our country. It was developed in 1964 as titanium alloy sheet with higher strength than TA7 (Han, 1996), it has the similar chemical compositions with universal titanium alloy BT20 developed successfully by Former Soviet aviation material research institute in 1964 (Mo and Xie, 2006). The nominal chemical composition of this alloy is Ti-6.5Al-1Mo-1V-2Zr, is part of the high aluminum equivalent alpha type alloy. The room temperature tensile strength of TA15 is between 930 and 930, which belongs to the moderate intensity of titanium alloy. The strength of the alloy decreases gradually with the material specification enlarging. TA15 is the moderate intensity titanium alloy, which has good titanium alloy materials for aircraft and engine structure. TA15 in Taihang engine is mainly used for to make labyrinth gas seal seat (Wu, 2009), bearing block, force bearing ring, etc. In the thrust-weight ratio 10 engine, the alloy is used to make Vectored nozzle cover and also used to make the structure of the plane and siding, etc (China Aviation Materials Manual Editorial Board, 2001).

The main focuses of the current research for TA15 titanium alloy are mostly in the following aspects: High-temperature deformation behavior (Nagi *et al*., 2000), microstructure (Cao *et al*., 2004), high temperature forging (Lin and Tang, 2011), cutting force in high-speed cutting process (Liu and Feng, 2010). But there is less study on the machinability of TA15 during the cutting process. For this reason, PVD coatings carbide cutting tools of titanium alloy (Ti-6.5Al-1Mo-1V-2Zr) turning test was conducted. Based on the observation and analysis of tool wear morphology in the cutting process (Li *et al*., 2011), tool wear mechanism of PVD coated tools turning TA15 titanium alloy is systematically studied (Sharman *et al*., 2004), which provide the guidance for the processing applications of TA15 titanium alloy and extending tool life (Davim and Mata, 2007).

Experiments: Tool wear tests conducted on CAK6150 numerical control lathe, workpiece material for TA15 (v mo Ti-6.5-Al-1-1-2 zr) bar, its chemical composition and physical and mechanical properties are shown in Table 1, are shown in Table 2.

Using Kennametal tool KC5510 grain refinement of coating cemented carbide cutting tools, with advanced

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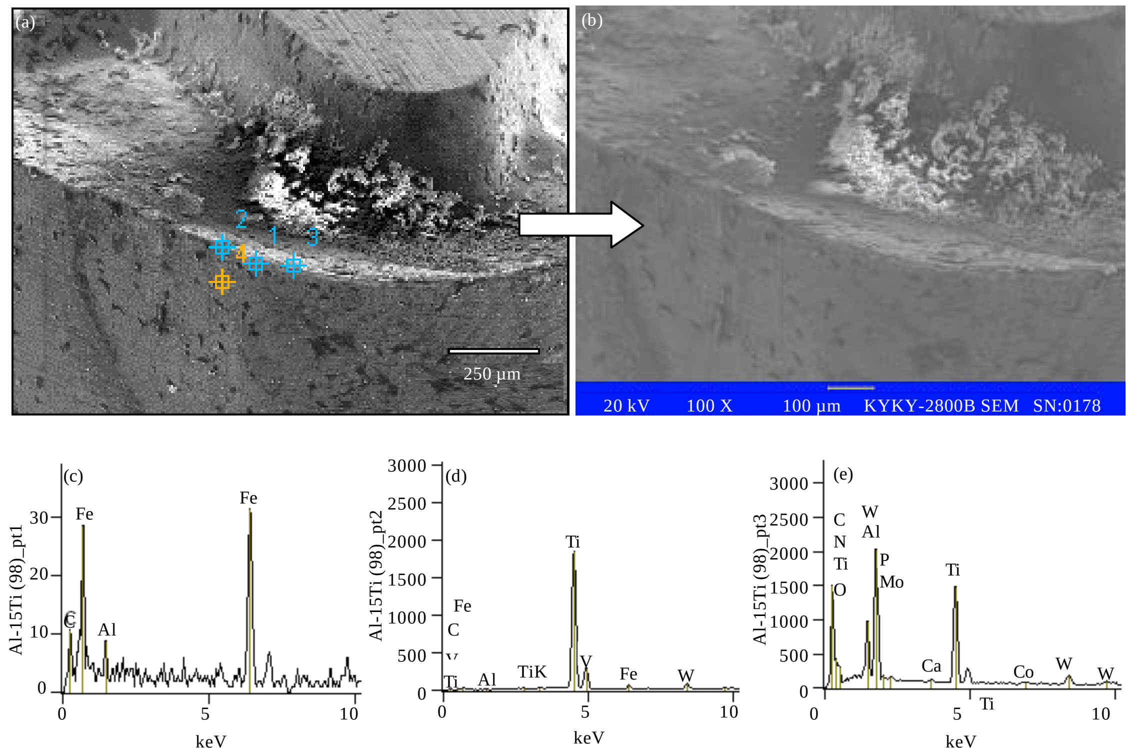

Fig. 1(a-e): SEM image and EDS analysis of initiative wearing stage of the coated cutting tool

Table 1: Chemical compositions of titanium alloy TA15

Alloying element					Impurity≤						
Al	Zr	Mo	V	Ti	Fe	Si	C	N	H	O	Other
5.5-7.0	1.5-2.5	0.5-2.0	0.8-2.5	Margin	0.25	0.15	0.10	0.05	0.015	0.15	0.30

Table 2: Thermo-mechanical properties of TA15 alloy

Property	Specification
Density, ρ (kg m^{-3})	4450
Brinell hardness, HBS	255~341
Reduction of area, Ψ (%)	36~52
Elastic modulus, E (Gpa)	102~116
Yield strength, $\delta_{0.2}$ (Mpa)	875~1006
Elongation, δ (%)	14.2~16.4
Tearing strength, σ_b (Mpa)	953~1019

Table 3: Tool signature of PVD insert used in experiments

Rake angle (γ_0)	Clearance angle (α)	Cutting edge angle (κ_r)	Auxiliary angle (κ'_r)	Inclination angle (λ)	Nose radius (r), mm
8°	15°	45°	15°	0°	0.5

PVD TiAlN coating. Cutting tool geometry parameters as shown in Table 3; Amount of tool wear using push around reading microscope observation. After cutting test with Scanning Electron Microscopy (SEM) and energy spectrum analyzer (EDS) on tool wear morphology and chemical composition were analyzed. Select test optimization of cutting parameters, cutting speed Vc = 60 m min^{-1}, the cutter feeding f = 0.2 mm rev^{-1}, cutting depth a_p = 1 mm for cutting test, to test the grinding blunt standard VB = 0.3 mm.

RESULTS AND ANALYSIS

Initiative wearing stage of the coated cutting tool: Machining process, the wall surface, after the knife before constantly contact with the chip and workpiece, the intense friction in contact area, at the same time in the contact area and has a high temperature and pressure. Knife surface before and after the knife surface, therefore, will gradually produce wear with cutting, Fig. 1 for PVD coated tools initial wear stage the SEM and EDS analysis, analysis diagram is shown in Fig. 1a-b. One can see PVD coated tools early turning titanium alloy TA15, tool wear is mainly for the rake face of crater wear evenly and the blade surface wear form; Due to titanium alloy, high chemical activity and strong affinity of tool material, under the action of high temperature and high pressure in the machining process, workpiece materials easily and tool

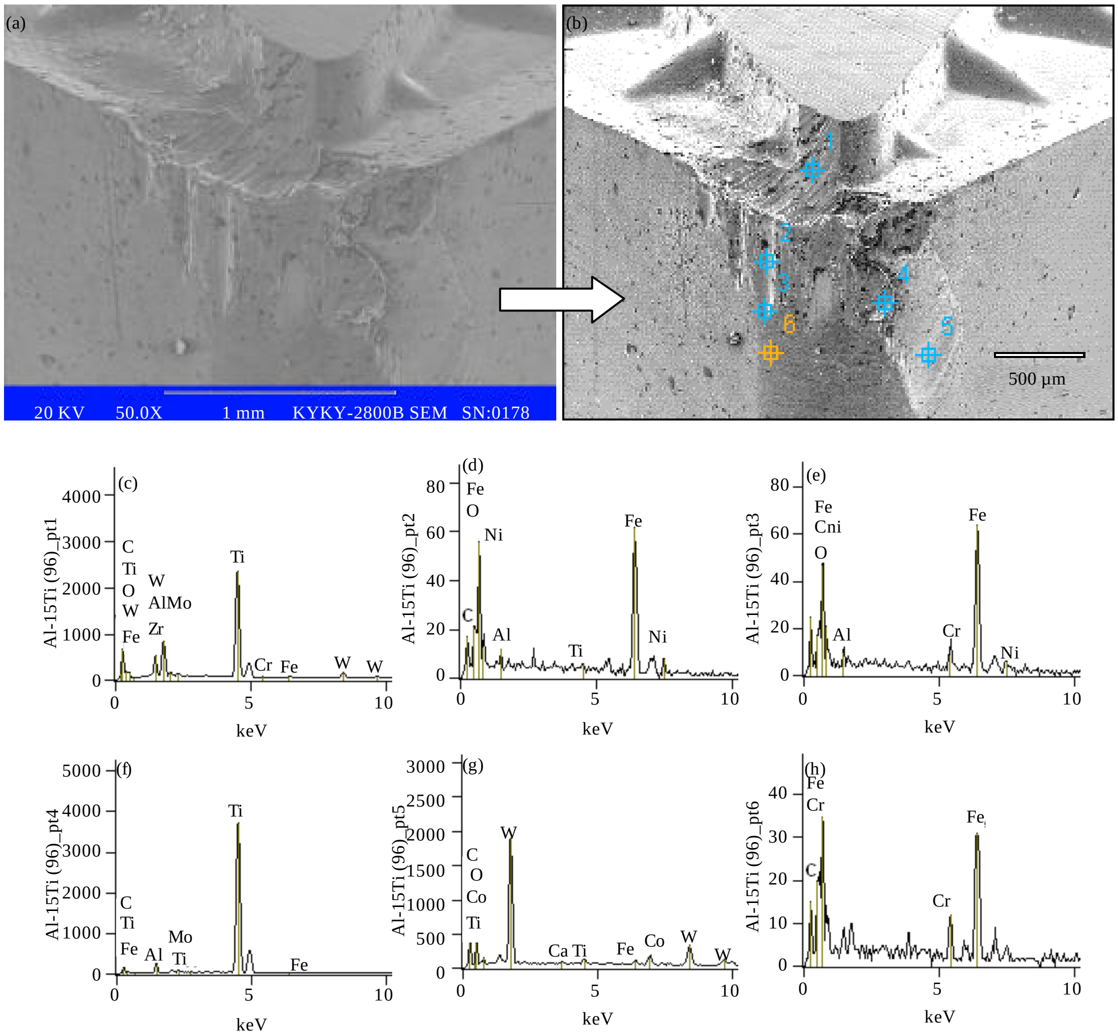

Fig. 2(a-h): SEM image and EDS analysis of Sharp wearing stage of the tool

surface adhesive failure. Figure 1c-d can see obvious cutter blade surface before and after are bonded with a lot of titanium alloy material, cutting tool surface layer material performance changes, when the relative movement between workpiece and tool, cutting tool material bonded particles formed tool surface adhesion wear before and after being taken away.

Because the air is not easy to enter the cutting area and easy to stay close to the work piece machining on the surface of the cutter blade position after formation of oxide film, so the cutter knife before and after the friction and wear of the area found no oxygen element, as shown in Fig. 1c, as shown in Fig. 1d; In tool wear on the surface of the knife edge area before and after, when cutting the work piece surface oxide skin, cold hard layer and hard miscellaneous points for continuous friction oxidation film, caused in processing oxidation wear at the surface of the blade surface, as shown in Fig. 1e.

Sharp wearing stage of the coated cutting tool: KC5510 the outermost composition for TiN and TiCN coated tools and then is to control the grain size of Al2O3, then coated with a layer of TiCN. As a continuation of the cutting time, before and after the blade surface wear, rake face of crater wear depth increase, even after the blade surface wear width increased, as shown in Fig. 2a, as shown in Fig. 2b. Before finally, after surface and cutter surface wear is linked together, form a new irregular cutting edges, chip morphology changes, increase surface roughness, tool into the severe wear phase, at the same time, coated tools found in the SEM for morphology before and after the coating peeling off phenomenon. By energy spectrum can find component elements such as Al, C, coating materials for cutting tools. Figure 2d-e here, we can see points 2, 3 have clear coating peeling phenomenon and contains the elements such as Al is bare ceramic coating after coating is peeling, 2, 3 points more O elements at the same time, the instructions in the cutting zone under the action of high temperature oxidation phenomenon exists. In addition, in addition to the 2, 3, 6, contain more Fe elements, for diffusion and bonding of high strength steel alloy, 1, 5 contains more W elements, explain dao has damaged phenomenon, from the above analysis to see, adhesion wear, oxidative wear, diffusion wear and coating peeling coating tools is the main wear mechanism.

CONCLUSION

Using PVD TiAlN coated tools for titanium alloy v mo Ti-6.5-Al-1-1-2 of zr turning tool wear mechanism are studied. It is proved that the tool wear mechanism of high-speed turning alloy is felt wear, oxidative wear, diffusive wear, coat shed.

The PVD coated tools before and after oxidation wear mainly occurred in the wear on the surface of the knife edge. Due to cutting tool rake face in the process of cutting temperature is higher than the knife of the cutting temperature after, lead to cutting tool rake face oxidation wear and adhesion wear and diffusion wear than the blade.

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