Wear Characteristics of Diamond Tool in Cutting of Al-17mass%Si Alloy

Tadahiro Wada, Junsuke Fujiwara* and Hideki Koizumi*

Proceedings of The 1st International Conference on Design Engineering and Science (ICDES2005), 181-185
(October 28 -31, 2005, Vienna, AUSTRIA)

As aluminum alloys have both the high strength-to-weight ratio and the good corrosion resistance, it is used for automobile parts or motorbike parts. However, because the aluminum alloy is slightly poor wear-resistance, Si is added to improve the wear-resistance. High silicon aluminum alloys are generally machined for the improvement of the dimensional accuracy. It is reported that the hardness of the primary Si particle is HV870-HV1350 [1]. In cutting of the high silicon aluminum alloy with the conventional cutting tool, the wear progress becomes faster because of the primary Si particle, which has the high hardness. Therefore, the diamond cutting tools are used [2] - [6]. The diamond cutting tools are generally the diamond coated cemented carbide tools, whose substrate is the WC-Co alloy, and the polycrystalline diamond compact (PCD) tool. The cutting performance of the diamond coated tool depends on the Co content of the WC-Co alloy [7]. The performance of the PCD tool depends on the diamond particle size [6].

In this study, in order to clarify an effective tool material for the cutting of the high silicon aluminum alloy, the surface roughness and the tool wear are experimentally investigated. The high silicon aluminum alloy is turned with four kinds of the diamond coated WC-Co tools, which had the combination of the different Co contents of the WC-Co alloy and the different the diamond film thickness, and four kinds of the polycrystalline diamond compact tools, which had the different particle size. The work-piece material used is the Al-17mass%Si alloy. This will be benefit for the improvement of the productivity.

The main results obtained are as follows;

In the case of the diamond coated WC-Co tool:

(1) The wear progress of the diamond film thickness 20 μm was slower than that of the diamond film thickness 14 μm.

(2) In the case of the diamond film thickness 20 μm, the wear progress of the diamond coated tool having the substrate of the WC-5%Co alloy was slower than that of the WC-1%Co alloy.

In the case of the polycrystalline diamond compact tool:

(1) Both the initial wear and the surface roughness decreased with the decrease of the diamond particle size.

(2) In the steady wear, the wear progress of the PCD tool with the particle size 30 μm was slowest.

The authors would like to appreciate the cooperation of TUNGALOY Corporation for the supply of the cutting tools, and KOBE STEEL LTD for the supply of the work-piece materials.

* Osaka University

References

[1] Kamio A., "Microstrucuture and property of Aluminum", Japan Institute of Light Metal, Tokyo, (1991), pp.231.

[2] M. Watanabe, M. Yoshikawa, "Cutting of Hypereutectic Al-24%Si Alloy by Diamond Coated Cutting Tools", J. of JSPE, (1990), 56-12, pp.2237-2242.

[3] J. Watanabe, N. Ohtake, M. Yoshikawa, "Fabrication and Performance of a Thin CVD Diamond Plate Bonding Tool", Journal of JSPE, (1992), 58-5, pp.797-802.

[4] F. Okuzumi, J. Matsuda, I. Miyoshi, "Chemical Vapor Deposition of Diamond on Cemented Carbide", J. of JSPM, (1988), 35-3, pp.114-117.

[5] M. Yagi, K. Saijo, Y. Katsumura, H. Suzuki, "Cutting Performance of diamond deposited tool for Al-18mass%Si alloy", J. of Japan Institute of Light Metals, (1989), 39-6, pp.417-422.

[6] Japan Society of Powder and Powder Metallurgy, Powder and Powder Metallurgy Term Encyclopedia, Tokyo, NIKKAN KOGYO SHIMBUN LTD., (2001), pp.295.

Cutting Performance of (Ti, W, Si) N Coated Cemented Carbide Tool

Tadahiro Wada

Proceedings of The 43rd Symposium on Powder Science and Technology, 75-79
(November 2 -4, 2005, Busan, KOREA)

A machine part having a complicated shape can be mass-produced accurately by powder metallurgy. A diffusion alloyed powder or a completely alloyed powder is usually used as an alloyed powder for sintered steel. The compressibility of diffusion alloyed powder is better than that of a completely alloyed powder. After sintering, the sintered material is quenched and tempered to improve the mechanical properties and wear-resistance. For dimensional accuracy, it is often necessary for sintered steel machine parts to be machined by the metal removal process [1]. As sintered machine parts are often cut at high cutting speed for the mass-production, it is necessary that the tool materials have good wear resistance. Furthermore, the tool material is required to be excellent in both the fracture toughness and the wear-resistance. The coated cemented carbide tools, which have good fracture toughness and wear resistance, seem to be effective tool materials. TiN and (Ti, Al)N are generally used as the coating film. (Ti, Al)N coating film exhibits both superior hardness and excellent oxidation resistance as compared with TiN coating film [2]. In cutting carbon steel JIS S50C, the wear progress of a (Ti, Al)N coated cemented carbide tool is slower than that of a TiN coated tool [3]. Furthermore, a (Ti, Al)N coated cemented carbide tool was evaluated through cutting various hardened work materials, and showed greatly improved performance, especially for high-hardness work materials [4]. So, (Ti, Al)N coated tools seem to be an effective tool material because it has good heat resistance and wear resistance. On the other hand, (Ti, W, Si)N coating film, which is a new type coating film, has been developed.

Although there are studies on the tool wear characteristic of PVD coated cemented carbide tools in the cutting of hardened steel or sintered steel [5], there are few studies on tool wear in the cutting of hardened sintered steel. In order to determine an effective tool material for cutting hardened sintered steel, the tool wear and the surface roughness were experimentally investigated. Hardened sintered steel was turned with two kinds of PVD coated cemented carbide tools.

The main results obtained are as follows:

(1) The critical load of (Ti, W, Si)N coating film was higher than that of (Ti, Al)N coating film.
(2) The hardness of (Ti, W, Si)N coating film was higher than that of (Ti, Al)N coating film.
(3) In the cutting of the hardened sintered steel, the wear progress of the (Ti, W, Si)N coated tool was slower than that of (Ti, Al)N coated tool.
(4) In the cutting with the (Ti, W, Si)N coated tool, the surface roughness was almost constant under a cutting distance to 510 m.

The author would like to appreciate the cooperation of MITSUBISI MATERIAL Co., LTD,. for the supply of workpiece materials.

References

[1] JSPE, Handbook of Precision Machining, Tokyo, CORONA PUBLISHING CO., LTD., 1992, 139 (in Japanese).
[2] Yasuyuki Yamada, Taiitu Aoki, Yusuke Tanaka, Yasushi Onishi, Kazuhiro Kotani and Koichiro Wakihira, Cutting performance of (Al, Ti)N Coated High Speed Steel Tools, J. of JSPE, 1996, 62(2), 215～218 (in Japanese).
[3] Tsutomu Ikeda and Hiroshi Satoh, High-Temperature Oxidation and Wear resistance of Ti-Al-N Hard Costing, J. Japan Inst. Metal, 1993, 57(8), 919～925 (in Japanese).
[4] Yasuyuki Yamada, Taiitu Aoki, Yusuke Tanaka and Koichiro Wakihira, Cutting performance of Coated Carbide Tools for Hard Work Material, Trans. of JSME, Series C, 1994, 60(577), 2906～ 2910 (in Japanese).
[5] S. Hanasaki, J. Fujiwara, T. Wada and K. Hiro, TOOL WEAR OF PVD COATED CEMENTED CARBIDE TOOL IN TURNING OF FORGED SINTERED MATERIAL, 5th International Conference Progress of Machining Technology, 2000, 42～47.

Surface Modification of Aluminum Alloys

WADA Tadahiro and FUJIWARA Junsuke*

Proceedings of The 10th International Conference on Aluminum Alloys,765-770
(July 9 -13, 2006, Vancouver, CANADA)

There are various methods in the surface modification technology for the purpose of giving high function characters such as wear-resistance, lower or higher friction coefficient, corrosion-resistance and thermal-resistance on the surface of the material. Generally, the coating of a hard material like ceramics on the surface of the material is well used as one of the surface modification technology. The physical vapor deposition (PVD) method, which is one of the coating technologies, is used widely because it is possible to be coated at the lower treatment temperature namely 470K - 870K.

As aluminum alloy has both the high strength-to-weight ratio and the good corrosion resistance, it is used for automobile parts or motorbike parts. Recently, it is going to be used for mechanical parts, but the aluminum alloy is slightly poor wear-resistance. So hard material, such as diamond like carbon (DLC) is coated on the surface of aluminum alloy to improve the wear-resistance. As compared with single-layer coating method and the multi-layer coating method, the multi-layer coating method is effective for the improvement of both mechanical properties and the wear resistance. In the PVD methods, there is ion plating, sputtering and vacuum deposition method. The ion plating method is being used for the cutting tool in many industries. Because of the difference of thermal expansion between the substrate of aluminum alloy and the coated materials, the flaking of coating layers is easily occurred.

In order to improve the wear resistance of aluminum alloy, new surface modification method is presented in this study. To clarify the effectiveness of this surface modification method, the cross section of coating layer was observed with SEM, scratch load and flaking load were measured to estimate the degree of adhesion and then wear resistance of the layer were also experimentally investigated.

The substrate of the test pieces was aluminum alloy JIS A6061 (ASTM 6061). The chemical compositions and mechani1cal properties of aluminum alloy are shown in Table 1. Table 2 shows the surface treatment of the test pieces.

The main results obtained are as follows:

(1) The critical load of the coated aluminum alloy with the alumite layer in the scratch test is higher than that without the alumite layer.
(2) The wear amount of the coated aluminum alloy increased with the increase of the thickness of the alumite layer.
(3) This combined surface treatment method is new surface modification method because this method provided excellent adhesive strength and good wear-resistance.

Table 1 Chemical compositions and mechani1cal properties of aluminum alloy JIS A6061

Chemical compositions (mass %)						
Si	Fe	Cu	Mg	Cr	Zn	Ti
0.67	0.19	0.24	1.0	0.05	0.01	0.02

Mechani1cal properties		
Hardness	Tensile strength	Elongation
HRB62	301 (MPa)	20.3 (%)

Table 2 Coating layers of test pieces

Test piece	Coating layers
No.1	Substrate- Alumite (20 (μm))- CrN- DLC
No.2	Substrate- Alumite (50 (μm))- CrN- DLC
No.3	Substrate- Alumite (60 (μm))- CrN- DLC
No.4	Substrate- CrN- DLC
No.5	Substrate- DLC

* Substrate: Aluminum alloy, No.4: without alumite, No.5: without both alumite and CrN layer

* Osaka University