Asian Journal of Chemistry; Vol. 26, No. 5 (2014), 1275-1277

ASIAN JOURNAL OF CHEMISTRY

http://dx.doi.org/10.14233/ajchem.2014.17206

Cutting Performance of Diamond Coated Cemented Carbide by CVD Method†

YUPING MA[1,*], JINLONG WANG[1], GENFU YUAN[1], SHAOFENG ZHU[2] and PING HE[1]

[1]School of Mechanical and Electrical Engineering, Anhui Jianzhu University, Hefei 230022, P.R. China
[2]School of Materials and Chemical Engineering, Anhui Jianzhu University, Hefei 230022, P.R. China

*Corresponding author: Fax: +86 551 3828101; E-mail: wxlmyp@163.com

Published online: 1 March 2014; AJC-14747

Microcrystalline and ultrafine grain diamond films were fabricated on the cemented carbide milling tools using a bias-enhanced hot filament CVD system, respectively. The cutting performance of the uncoated and two kinds of coated milling tools has been evaluated by dry machining SiC particles reinforced aluminum matrix composites. The test results demonstrate that the cutting forces, tool wear and the surface roughness of the uncoated tools are biggest, followed by microcrystalline diamond coated tools and finally are ultrafine grain diamond coated tools. The wear life of ultrafine grain diamond coated tools is 3 times longer than the uncoated milling tools. The improved cutting performance of ultrafine grain diamond coated tools is attributed to its superior tribological properties.

Keywords: Milling tool, Diamond films, Bias-enhanced hot filament CVD, Cutting performance.

INTRODUCTION

Nowadays the cemented carbide mills are used extensively. However, the short tool life and the bad machining quality become the main obstacle of the high efficient production. Many approaches have been studied to overcome these difficulties[1-3]. Diamond film has a lot of unique characteristics which are very close to natural diamond, such as high hardness and high elastic module, good thermal conductivity, low friction coefficient, stable chemical activity and wear resistance, acid resistance, *etc*. and has been widely used in many technological fields. So diamond films are the best alternative materials.

Early works proved the excellent adhesion of microcrystalline diamond film to WC-Co cemented carbide substrates and low surface roughness of ultrafine grain diamond films[4-6]. Ultrafine grain diamond films reveal a lower surface roughness and a higher resistance than that of microcrystalline diamond film and nanocrystalline diamond film, respectively. There are few reports about the ultrafine grain diamond composite films grown on the milling tools. Therefore, it is necessary to study the cutting performance of ultrafine grain diamond coated tools to improve the machined surface quality and prolong the life of mill cutters.

In this work, the ultrafine grain diamond films and microcrystalline diamond films were fabricated on the complex shape cemented carbide milling tools using a bias-enhanced hot filament CVD system. The cutting experiments of the uncoated and two kinds of coated milling tools were carried out and some good results were obtained.

EXPERIMENTAL

Cemented carbide (WC-6 % Co)mills with 6 m in diameter were used for HFCVD process. Prior to pretreatment, the drills were ultrasonically cleaned in acetone for 5 min in order to remove the loose residues from the surface. The following two-step chemical pretreatment procedure for the complexed substrate was applied. The first step was to use Murakami's reagent ([10 g $K_3Fe(CN)_6$] + 10 g KOH + 100 mL water) in an ultrasonic bath to etch tungesten chloride grains in substrate low surface for 10 min, followed by a rinse with distilled water. The second step for the Co-etching was performed. The drills were immersed in methanol solution to remove cobalt for 0.5 h. The substrates were then washed again with distilled water in ultrasonic bath.

In order to get a uniform film, the drills were put centrally and coaxially within the coils of the filament. The ultrafine grain diamond composite films and microcrystalline diamond films were fabricated by adjusting the deposition parameters in the CVD system reported previously[1,4,7].

†Presented at The 7th International Conference on Multi-functional Materials and Applications, held on 22-24 November 2013, Anhui University of Science & Technology, Huainan, Anhui Province, P.R. China

In order to evaluate the cutting performance of three kinds of mills, comparative tests of milling SiC (20 vol %) particles reinforced aluminum matrix composites were carried out under the same conditions. The machining center DMU 70 V were employed. The cutting conditions selected for all the experiments were: cutting speed 38 m/min; feed rate 220 mm/min; the milling depth 1 mm; the milling width 6 mm. Kistler instrument were employed to testing the cutting force.

RESULTS AND DISCUSSION

Cutting force: Fig. 1 presents the relationship between the milling length and resultant force of the three kinds of milling cutters. It can be seen that the uncoated cemented carbide milling tool has the maximum milling resultant force, microcrystalline diamond coated milling tool's is the second and the ultrafine grain diamond coated milling tool has the lowest milling resultant force in comparison. This phenomenon is mainly caused by the different friction coefficients between the chips and the tools. The friction coefficient between the chips and the ultrafine grain diamond coated milling tool is smallest, while the friction coefficient between the chips and uncoated milling tool is largest. The milling forces of the three kinds of milling cutters have the same trend. With the increase of milling length, the milling force grows.

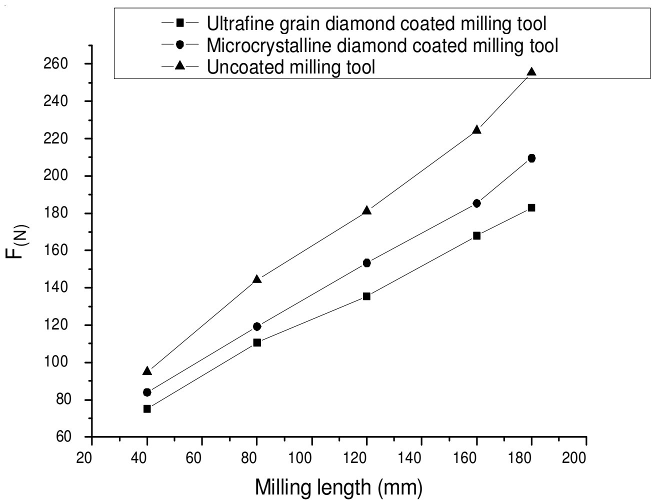


Fig. 1. Relationship between the milling length and resultant force

Tool wear: Fig. 2 shows the measured wear values for all cutters as a function of cutting length. It reveals that the measured wear values of all cutters are almost the same during the beginning of 20 mm, but the wear of the uncoated cemented carbide milling tool shift sharply from 20 to 40 mm. When milling length reaches 80 mm, the flank wear of the uncoated milling cutter is 0.28 mm. The wear of microcrystalline diamond coated milling tool is larger than that of ultrafine grain diamond coated milling tool. As milling length is 200 mm, the wear values of them are 0.22 and 0.25 mm, respectively. Fig. 3 suggested that the failure of diamond coated mill is wear out failure and the wear of ultrafine grain diamond coated mill is normal mechanical abrasion and no peeling is found. This also indicates that the adhesion strength of composite diamond coatings improved significantly.

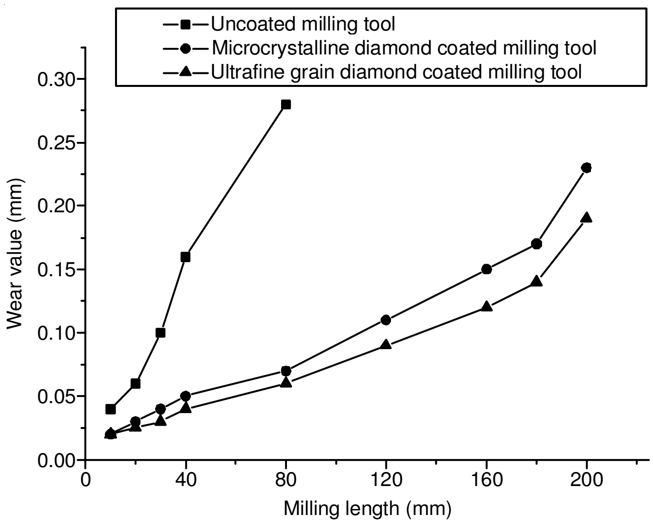
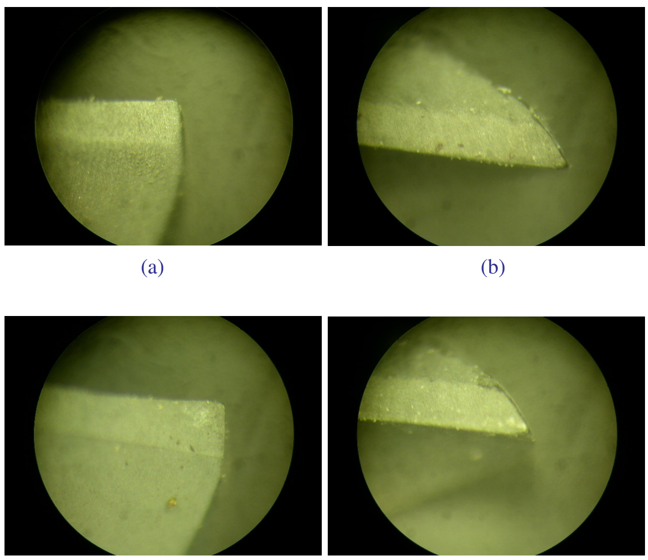


Fig. 2. Relationship between the milling length and wear

The abrasion morphologies (the milling length of 200 mm) of microcrystalline diamond coated and ultrafine grain diamond coated milling tools have also verified this point (Fig. 3). The abrasion morphologies of the bottom edge of flank and side blade flank of microcrystalline diamond coated tool are shown in Fig. 3(A-B), respectively. The abrasion morphologies of the bottom edge of flank and side blade flank of ultrafine grain diamond coated milling tool are shown in Fig. 3(C-D), respectively.



(a) (b) (c) (d)

Fig. 3. Wear morphologies of diamond coated tools

Surface roughness of machined workpiece: Fig. 4 shows the relationship between the milling distance and surface roughness of milled surface of specimens by the three kinds of cutters. It can be seen that the surface roughness of all milled surfaces have small increases during 40 mm milling length. But the surface roughness of specimen milled by the uncoated slot miller sharply leaped to 0.284 μm when the milling length reaches 80 mm and the surface roughness of the specimen is up to 0.317 μm when milling length is 200 mm. The surface roughness of specimens milled by the two kinds of diamond

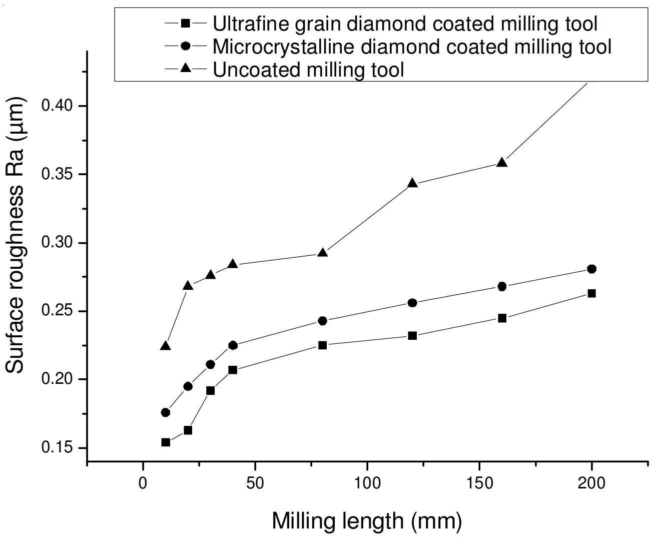


Fig. 4. Relationship between the milling length and surface roughness of milled surface

coated cutters increases gradually along with the increasing of milling length. When the milling length reaches 200 mm, they achieve 0.263 and 0.281 μm, respectively. It is further proved that the diamond coated milling cutters have excellent machining performance and they can improve the machining quality of the machined surface. It is demonstrated that there is significant improvement on the cutting performance of the two kinds of mills, especially the ultrafine grain diamond coated mills. This mainly depends on the surface roughness of milling cutters.

Conclusion

The cutting performance of ultrafine-microcrystalline composite diamond coated tools, microcrystalline diamond coated tools and uncoated tools were investigated. The wear of ultrafine-microcrystalline composite diamond coated tools is smallest, while the wear of uncoated tools is biggest. The milling resultant force and the milled surface roughness obtained with the ultrafine-microcrystalline composite diamond coated tools shows a great advantages than those obtained with microcrystalline diamond coated tools and uncoated tools. The main reason for this is that the ultrafine-microcrystalline composite diamond films not only display good adhesion and wear resistant properties, but also have low surface smoothness.

ACKNOWLEDGEMENTS

The work is supported by Anhui Provincial Natural Science Foundation (1208085ME63, 090414166), the National Natural Science Foundation of China (No.50675134, No. U0734007) and Key Laboratory of Anhui Jianzhu University (Fault Diagnosis and Early Warning Technology).

REFERENCES

1. F.H. Sun, Z.M. Zhang, M. Chen and H.S. Shen, *J. Mater. Process. Technol.*, **129**, 435 (2002).
2. X.M. Meng, W.Z. Tang, L.F. Hei, C.M. Li, S.J. Askari, G.C. Chen and F.X. Lu, *Int. J. Refract. Metals Hard Mater.*, **26**, 485 (2008).
3. K. Shibuki, K. Sasaki, M. Yagi, T. Suzuki and Y. Ikuhara, *Surf. Coat. Technol.*, **68-69**, 369 (1994).
4. F. Sun, Y. Ma, B. Shen, Z. Zhang and M. Chen, *Diamond Rel. Mater.*, **18**, 276 (2009).
5. E. Salgueiredo, F.A. Almeida, M. Amaral, A.J.S. Fernandes, F.M. Costa, R.F. Silva and F.J. Oliveira, *Diamond Rel. Mater.*, **18**, 264 (2009).
6. J. Gabler, L. Schafer and H. Westermann, *Diamond Rel. Mater.*, **9**, 921 (2000).
7. Y. Ma, *Adv. Mater. Res.*, **530**, 95 (2012).