euspen's 20th International Conference & Exhibition, Geneva, CH, June 2020
www.euspen.eu

Investigation on grinding of tungsten heavy alloy with the assistance of electrochemical modification

Lin Niu [1], Zhuji Jin [1], Zhongzheng Zhou[1], Jiang Guo [1]*

[1]*Key Laboratory for Precision and Non-Traditional Machining Technology of Ministry of Education, Dalian University of Technology, Dalian 116024, China*

guojiang@dlut.edu.cn

Abstract
Tungsten heavy alloys (WHAs) are typical two-phase alloys consisting of tungsten grains and matrix phase. WHAs have many important applications in various fields due to their excellent physical, chemical and mechanical properties. With the development of defense industry and precision instruments, the demand for WHA components with complex shapes and high surface quality is increasing. Conventional machining methods can not satisfy the demand. Because of the bad machinability of tungsten grains, many problems are encountered, such as severe tool wear, large cutting force and low processing efficiency. To solve these problems, a new processing strategy has been proposed including modifying the surface with selective electrochemical etching of tungsten grains, and mechanical machining. The modification is conducted, and the surface morphologies of 95W-3.5Ni-1.5Fe samples before and after the modification are presented to verify the electrochemical effect. Then the experiment is conducted combining the modification with grinding. The results of processing quality show that the assistant of electrochemical action can remove the difficult-to-machine tungsten grains. Thus, the surface roughness, cutting force and residual stress are reduced. This paper provides a reference for the processing of WHAs.

Keywords: Selective electrochemical etching, modification, grinding

1. Introduction

Tungsten heavy alloys (WHAs) are generally composed of tungsten grains and matrix phase [1], in which the content of tungsten can reach 90% [2]. They are widely used because of their excellent properties [3]. However, the machining of WHAs encounters many problems especially the large cutting force and the tool wear due to the bad machinability of the tungsten grains [4].

Some research on improving the processing quality in the cutting process of WHAs has been reported [5-7]. The effectiveness of ultrasonic vibration and nitrogen cooling has been verified, nevertheless, the processing efficiency is still low or complex device is essential in these methods.

In our previous research [8], a new processing strategy was proposed: modifying the surface with selective electrochemical etching of tungsten grains, followed by mechanical machining. The Na_2CO_3 solution and the potential in oxygen region were used and the modification of 95W-3.5Ni-1.5Fe alloy was achieved as expected. Tungsten grains were selectively etched and only the matrix phase was remained, which left a porous modified layer. This method is expected to avoid the machining problems caused by tungsten grains.

In this paper, the electrochemical assisted grinding experiment based on the proposed processing strategy is carried out. The conventional grinding experiment is conducted for comparison. The surface quality, grinding force and residual stress are evaluated to verify the feasibility of the strategy.

2. Experimental

The experimental setup is as shown in Figure 1. In the experiment, the workpiece made of 95W-3.5Ni-1.5Fe alloy with a size of 25 mm * 10 mm * 20 mm was the anode. The cathode was a copper block with a size of 15 mm * 6 mm * 10 mm. Before the experiment, the sidewall of the cathode was insulated with epoxy resin. The electrolyte used in the experiment was 20% Na_2CO_3 solution. The surface of workpiece was firstly electrochemically modified, and then it was grinded by 150# ceramic bonded diamond cup wheel. The dynamometer (Kistler 9257B) was used to detect the grinding forces. The residual stress was detected by X-ray diffraction (XRD). The current applied in electrochemical modification is 4 A. Other experimental parameters are shown in Table 1.

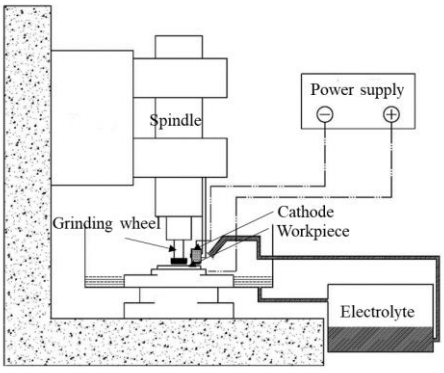

Figure 1. Experimental setup for grinding with electrochemical modification.

Table 1 Experimental parameters.

Wheel speed	Feed rate	Feed depth
10000rpm	0.5 mm*s^{-1}	70 μm

3. Results and discussion

The effect of modification is shown in Figure 2. The 95W-3.5Ni-1.5Fe alloy consists of two phases: tungsten grains and matrix phase. Compared with unmodified workpieces, tungsten grains are selectively removed by the modification, leaving the skeleton of the matrix phase. The modified surface has a porous structure.

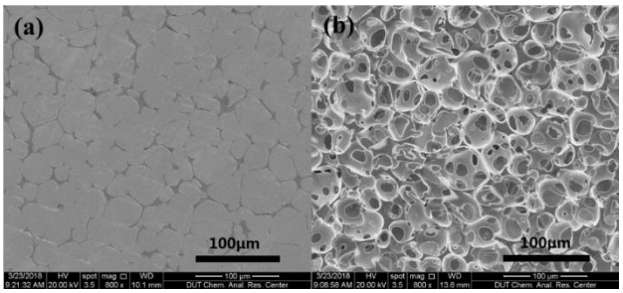

Figure 2. Morphologies of the workpiece before (a) and after (b) modification.

As shown in Figure 3, the surface quality of grinding after electrochemical modification is better than that of conventional grinding. The surface roughness is improved from Ra 196 nm to Ra 121 nm. The porous structure formed in the modification step is removed. The improvement of surface quality may be caused by the prevention of grinding wheel wear.

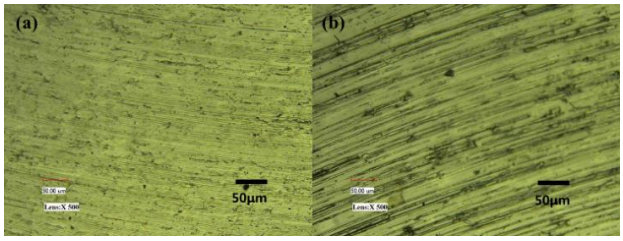

Figure. 3. Morphologies of the workpieces after grinding with electrochemical modification (a) and without modification (b).

Figure 4 compares the grinding forces. After the modification, the grinding force decreases obviously. The difference between the hardness of two phases in the tungsten alloy is significant. Through the modification, tungsten grains with higher hardness are removed, and the remaining matrix phase is soft and porous, so the reduction of grinding force meets the expectation.

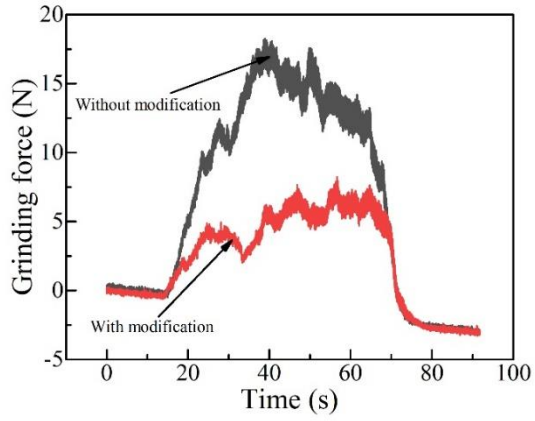

Figure 4. Forces in the grinding experiments.

95% of the materials are tungsten grains, and these tungsten grains are removed by electrochemical action. Electrochemical action is a stress-free method, so the reduction of residual stress is foreseeable. As shown in Figure 5, the residual stress reduced from approximately 2176 MPa to 1349 MPa.

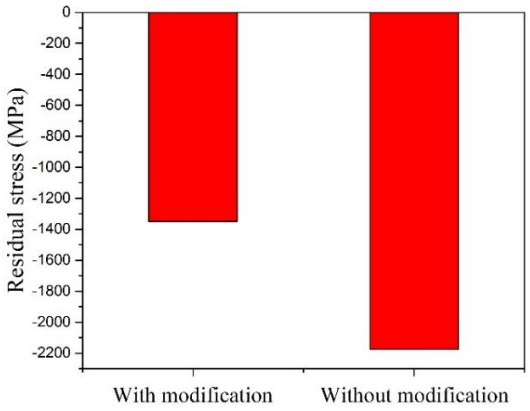

Figure 5. Residual stresses after the grinding experiments.

Although the grinding force and residual stress have been reduced, the reduction is less than expected. The cause is speculated to be the incomplete removal of some tungsten grains in the bottom of modified layer.

4. Summary

In this paper, experiments are carried out to verify the effect of the proposed modification method. The results show that the removal of the tungsten grains can reduce grinding force and residual stress, and surface quality can be improved. The modification method by selective electrochemical etching of tungsten grains shows a good prospect in the processing of tungsten heavy alloys. However, the machining mechanism and tool wear mechanism after modification have not been revealed. Future work will focus on revealing the mechanism and improving processing quality.

Acknowledgments

The authors acknowledge the financial support from Science Challenge Project (No. TZ2018006-0101-01) and Science Fund for Creative Research Groups of NSFC (No. 51621064), LiaoNing Revitalization Talents Program (No. XLYC1807230).

References

[1] Şahin Y 2014 Recent progress in processing of tungsten heavy alloys *J. Powder Technol.* **2014** 1-22.

[2] Senthilnathan N, Annamalai A R, and Venkatachalam G 2017 Sintering of Tungsten and Tungsten Heavy Alloys of W–Ni–Fe and W–Ni–Cu: A review *Trans. Indian Inst. Met.* **70** 1161-1176.

[3] Bose A 2003 Netshaping concepts for tungsten alloys and composites *Powder Metall.* **46** 121–126.

[4] Norajitra P, Boccaccini L, Gervash A, Giniyatulin R, Holstein N, Ihli T, Janeschitz G, Krauss W, Kruessmann R, and Kuznetsov V 2007 Development of a helium-cooled divertor: material choice and technological studies *J. Nucl. Mater.* **367** 1416–1421.

[5] Suzuki N, Haritani M, Yang J B, Hino R, and Shamoto E 2007 Elliptical vibration cutting of tungsten alloy molds for optical glass parts *CIRP Ann.* **56** 127–130.

[6] Zhang Y, Zhou Z, Lv Y, Wang J, Shao L, and Iqbal A 2013 Wear behavior of natural diamond tool in cutting tungsten-based alloy *Int. J. Adv. Manuf. Technol.* **69** 329–335.

[7] Nandam S R, Ravikiran U, and Rao A A 2014 Machining of tungsten heavy alloy under cryogenic environment *Procedia Mater. Sci.* **6** 296–303.

[8] Niu L, Jin Z, Han X, Zhou Z, and Guo J 2019 Modification of tungsten heavy alloy by selective electrochemical etching in sodium carbonate electrolyte *J. Electrochem. Soc.* **166(14)** E496-E501