EFFECT OF RARE EARTH ELEMENT Er ON STRENGTHENING OF INTERFACE OF Ti(C, N) BASED CERMETS①

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ABSTRACT Effects of addition of rare earth element Er on the bending strength and hardness of Ti(C, N) based cermets have been studied. The results have shown that the appropriate addition of rare earth element Er can increase the bending strength and hardness. This is mainly due to the reaction of element Er with impurity element S, which forms compound particles, hence, cleans the interfaces of ceramics / metals and ceramics/ceramics, and the metals, thus increasing the interfacial bonding strength.

Key words rare earth element Er Ti(C, N) based cermets bending strength hardness

1 INTRODUCTION

As a new kind of tool materials which appeared in 1970s, the Ti(C, N) based cermets have a series of advantages such as high wear resistance, high resistance to corrosion and high temperature, and low frictional coefficients[1]. Much research work has been carried out abroad, especially in Japan, due to its importance[2]. Recently, some work about Ti(C, N) based cermets has also been conducted at home[3]. The developing trend of Ti(C, N) based cermets is to increase the strength and toughness. The effects of rare earth element Er on the bending strength and hardness of Ti(C, N) based cermets have been studied in the paper, and the reaction mechanisms of rare earth element Er have been discussed.

2 EXPERIMENTAL

2.1 Experimental materials

The average diameters of all powder raw materials were measured by the Shiamadaz SA—CP3 analysis instrument. The measured average diameters of powders are as follows(μm): TiC-0.93, TiN-1.22, WC-0.84, Mo-6.91, Ni-14.89. The chemical composition of testing powders is shown in Table 1.

Table 1 Chemical composition of testing powders(%)

Powder	C	N	Ti	W	Mo	Ni	S
TiC	18.80	-	81.173	-	-	-	0.027
TiN	0.089	19.9	80.009	-	-	-	0.0012
WC	6.11	-	-	93.887	-	-	0.0026
Mo	0.0094	-	-	-	99.987	-	0.0032
Ni	0.178	-	-	-	-	99.819	0.0033

The chemical composition of Ti(C, N) based cermets used is (%): 26TiC-10TiN-15WC-14Mo-35Ni. The purity of rare earth element powder Er used is greater than 99.9%, and the average diameter is 1.21 μm. The compound powders were mixed with WC-Co cemented carbide balls and alcohol for 24 h with a

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QM- 1F planet ball milling machine. The ball/ powder ratio is 7/1. The specimens of Ti(C, N) based cermets were manufactured with mixed powders through drying $\rightarrow$ forming $\rightarrow$ presintering $\rightarrow$ 1430 ℃, 1h vacuum sintering processes.

2.2 Experimental method

The phase analysis on the Ti(C, N) based cermets was carried out with a D/max- rB X-ray diffractometer. The bending strength tests were conducted with three-point-bend method on a universal testing machine WJ-10B. The testing span is 25 mm, while the falling speed of the loader is 1 mm/min. The specimen size is 5 mm × 5 mm × 30 mm with the surface roughness Ra ⩽0.80 μm. Each datum in this paper is the average value of twelve test pieces. The thin films used for TEM examination were directly cut from the bending specimens. Firstly, they were thinned mechanically below 30 μm, then ion-thinned with an ion-thinning equipment Gatan 600. The thinned films were examined with Hitachi H-800 and Philips CM-12 transmission electron microscopes to study the microstructure. A scanning electron microscope JSM-35C was also used to examine the microstructure. The hardness values were measured with a Rockwell hardness tester. The density of cermets was measured using Archimedes method, and converted into relative density.

3 RESULTS AND DISCUSSION

3.1 Effect of element Er on bending strength and hardness

Effects of addition of rare earth element Er on the bending strength and hardness of Ti(C, N) based cermets are shown in Fig. 1 and Fig. 2, respectively. It is seen from Fig. 1 and Fig. 2 that the effects of element Er on the bending strength and hardness are similar, i.e. the bending strength and hardness increase at the initiation, then decrease after the peak. The optimum addition content of Er is about 0.5%. It increases the bending strength by 240 MPa and hardness by 0.7 HRA compared with the conventional cermets.

3.2 Effect of element Er on microstructure

The measured results show that the addition of rare earth element Er has no influence on the relative density. The results obtained are 99.99%. It has also been shown that there are no obvious differences between the microstructure of cermets with and without element Er, see Fig. 3.

This fact shows that the addition of rare earth element Er has no influence on the diameter and distribution of metals and ceramics. The X-ray phase analysis also shows that all cermets consist of ceramics (Ti, W, Mo) (C, N) and metal Ni whether they contain rare earth element Er or not, see Fig. 4.

It is shown that the conventional cermets consist of ceramics and metals by means of TEM examination, which corresponds well with the X-ray measurement, see Fig. 5. But there are some small compound particles with black colour distributed at the interface of ceramics/metals,

ig. 2 Effect of element Er on hardness of Ti(C, N) based cermets

Fig. 3 SEM micrographs showing microstructure of Ti(C, N) based cermets

(a) —without rare earth element Er;
(b) —containing 0.5% rare earth element Er

Fig. 4 X-ray diffraction pattern of Ti(C, N) based cermets

(a) —without rare earth element Er;
(b) —containing 0.5% rare earth element Er

Fig. 5 TEM micrograph showing microstructure of Ti(C, N) based cermets

and in the metals, see Fig. 6. EDS spectrum (see Fig. 7) shows that the chemical compositions (mole percent) of black particles in metals (right upper part of Fig. 6) are as follows: S 15.187, Ti 7.104, Er 1.093, Ni 70.404, W 0.668, Mo 5.544, while those of the black particle at the interface of ceramics/metals (left lower part of Fig. 6) are as follows (mole percent): S 20.485, Ti 19.354, Er 0.950, Ni 48.916, Mo 10.296. Besides these, there are also some black particles distributing at the interface of ceramics/ceramics, whose compositions (mole percent) are: S 19.648, Ti 42.253, Er 0.972, Ni 2.364, Mo 10.474, W 24.289 (see Fig. 8 and Fig. 9).

The above results show that the added Er in cermets can react with impurity element S to form compound particles. In conventional cermets, impurity element S distributes at the interfaces of ceramics/metals and ceramics/ceram-

Fig. 6 TEM micrograph of Ti(C, N) based cermets containing 0.5% element Er showing formed compound particles at interface of ceramics/metals, and in metals

Fig. 7 EDS spectrum of black particles distributed in metals

Fig. 8 TEM micrograph of Ti(C, N) based cermets containing 0.5% element Er showing formed compound particles at interface of ceramics/ ceramics

Fig. 9 EDS spectrum of black particles in Fig. 8

ics, and in the metals, thus reducing the bonding strength of interfaces, decreasingthe properties of metals, hence, decreases the bending strength and hardness. The added Er can react with impurity element S, clean the interfaces of ceramics/ metals, and ceramics/ ceramics, and metals, increase the bonding force of interface, so increase the bending strength and hardness. However, if the adding content of Er is more than needed, it will react with other elements besides element S to form compounds, hence decrease the bending strength and hardness. This mechanism can explain the experimental results of Fig. 1 and Fig. 2 satisfactorily.

4 CONCLUSIONS

The addition of rare earth element Er can increase the bending strength and hardness of Ti(C, N) based cermets. The optimum adding content of Er element is about 0.5%. The reason of increasing the bending strength and hardness is the formation of compound particles containing element S, thus the interfaces of ceramics/ metals and ceramics/ ceramics, and metals are cleaned and the bonding strength of interfaces is increased.

REFERENCES

1 Ettmayer P, Lengauer W. Powder Metall Inter, 1989, 21(2): 37.

2 Suzuki H *et al*. J of Japan Soc Met, 1983, 22(4): 312.

3 Liu Ning. PhD Thesis. Huazhong University of Science and Technology, 1994.

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