Tribological Properties of Ti(C,N)-based Cermet after Hot Isostatic Pressing at High Nitrogen Pressure

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Abstract

Sintered Ti(C,N)-based cermets were treated with hot isostatic pressing (HIP) at different nitrogen pressures. The tribological properties of the treated cermets have been evaluated. The results show that a hard near-surface area rich in TiN formed after HIP treatment. The cermets treated at higher pressure had a relatively lower friction coefficient and specific wear rate. In all cases the microhardness of treated cermets is higher than that without HIP natridation. The wear mechanisms of cermets were hard particle flaking-off and ploughing. It was also found that the HIP natridation is well-suited for improving the tribological properties of cermets.

Keywords : cermets, hot isostatic pressing, tribological, nitridation

1. Introduction

To increase the service life of the cermet inserts during metal working, functional gradients in the near-surface areas of tool inserts have been prepared by various techniques [1-3]. Because the formation of the gradient zone is controlled by diffusion of the various elements in the binder and by the thermodynamic properties of the system during the nitridation, the fabrication of a gradient cermet depends strongly on the process parameters such as gas pressure and temperature [4].

Studies concerning nitrided cermets have previously been published [4-5]. Konyashin et al [2] found that adding small amounts of oxygen to nitrogen utilized for carrying out the nitridation process enhances substantially the rate of the nitriding process for TiCN-WC-Ni-Mo cermets. Ucakar et al [5] studied the near-surface microstructural modification of cermets by nitridation above and below the eutectic temperature using nitrogen pressures up to 25 bar.

Although substantial work has been done on natridation of cermets, the wear resistance of the Ti(C,N)-based cermet after hot isostatical pressing at high nitrogen pressure is seldom reported and the tribological properties is of critical importance for cutting tool. Therefore, the primary goals of this preliminary research are to investigate the friction and wear properties of the Ti(C,N)-based cermet after hot isostatic pressing at high nitrogen pressure under different condition.

2. Experimental and Results

The cermets used in this work were a mixture of 38.2 wt.% TiC, 10 wt.% TiN, 6 wt.% WC, 32 wt.% Ni, 13 wt.% Mo, 0.8 wt.% C powders. This mixture was milled, dried, pressed and sintered at 1420 °C for 60 min in a vacuum sintering furnace. The post-treatment was performed at 1000 °C for 3 h at nitrogen pressures of 60 MPa, 80 MPa and 110 MPa in a laboratory autoclave QIH-6.

An X-ray diffractometer was utilized to examine the phases of the treated and untreated samples. Microhardness was assessed using a microhardness tester under a load of 50 gf. Tribological tests were performed at speeds of 0.42 m/s for 1 h under loads of 100 N and 125 N with a block on ring wear tester. Cermet specimens were 25×7×6 mm blocks and the material of the metallic ring was bearing steel GCr15 with hardness of approximately 62 HRC. Surface roughnesses of the metallic ring and the block specimen were R_a = 0.10 ~0.15 and 0.4 ~ 0.6 μm, respectively. Weight loss was measureed by using an analytical balance with accuracy count of 10^{-5} g. Specific wear rate (K_0) was calculated from the following equation:

$$K_0 = \frac{\Delta m}{\rho L d} \ (\mathrm{mm^3 \cdot (Nm)^{-1}}) \quad (1)$$

where Δm is the mass loss in grams, ρ the density of the test material in g·cm^{-3}, L the load in Newton and d the sliding distance in meters. Each sliding test was repeated three times and the mean of three experimental values was calculated. Microstructures of the worn surface of the cermets were inspected with SEM.

All surfaces of the cermets became golden after only 3 h at 1000 °C at the nitrogen pressures of 60 MPa, 80 MPa and 110 MPa. The X-ray diffraction patterns indicates that the phases in the surface of the cermets before nitridation are Ti(C,N) and Ni while TiN, WC and Ni after nitridation. Surface microhardnesses of cermets before and after nitridation at high pressure were 1509.6 HV and 1989.0 HV. And the transverse rupture strengthes of cermets before and after nitridation were 1866.6 MPa and 1702.4 MPa.

Fig.1 shows friction coefficient and specific wear rate of cermets before and after nitriding with bearing steel counterpart for 1 h. It can be seen that the cermet nitrided at 110 MPa nitrogen pressure had lower friction coefficient and specific wear rate. The friction coefficient of the untreated cermet was higher and its specific wear rate was the highest.

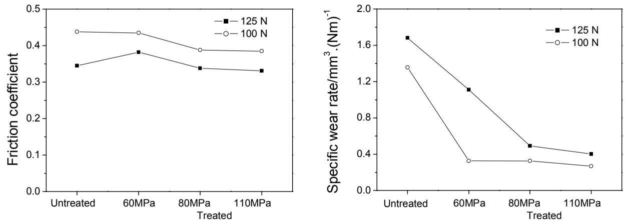
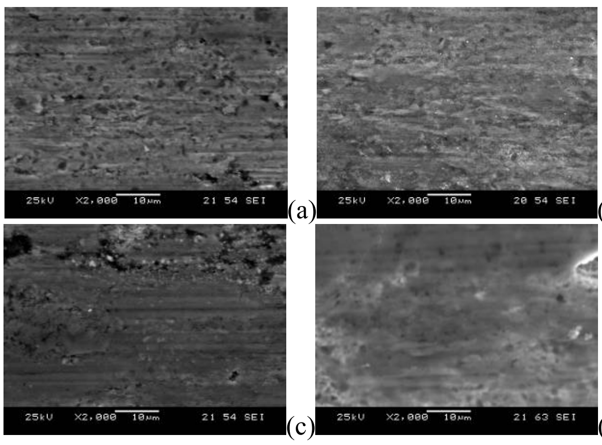


Fig. 1. Friction coefficient and specific wear rate of cermets before and after nitriding.

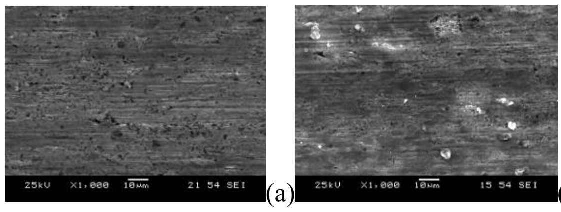
Fig.2 shows the worn surface of the cermets untreated and treated under different nitrogen pressure tested against bearing steel rings for 1 h. There are apparent flake off pits and furrows on the surface of these cermets. The amount of flake off pits increased with decrease of the nitriding pressure and that of the untreated cermets was the highest. The particle flaking off and ploughing worked together during the friction process.

Fig.3 shows the worn surface morphologies of the cermets with different wear time. It can be seen that there were deeper furrow on the worn surface when the wear time was shorter and the furrow became shallow when the wear time was longer. After 30 minutes, little pits appeared with hard particles flaking off. When the wear time reached 60 minutes, there were some larger pits that formed by several particles flaking-off. And when the wear time extended 120 minutes, there were not only larger pits but also crater clusters that formed by the interlink of many little craters.



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

Fig. 2. Worn surfaces of the cermets (a) untreated and (b, c and d) treated under (b) 60 MPa, (c) 80 MPa and (d) 110 MPa nitrogen pressure.



(a) (b)

Fig. 3. Worn surfaces of the treated cermets tested for (a) 30 minutes and (b) 120 minutes.

3. Summary

In conclusion, the HIPing nitridation works well for the wear resistance of cermets. At 110 MPa nitrogen pressure, and 1000 °C temperature, the tribological properties of cermets were better in the test. The wear process of the nitrided Ti(C,N)-based cermets were slide between the surface micro-convex bodies, plastic deformation, plough and adhesive wear. And then due to the brittle failure of the rim phase and the interface between hard phases and the cumulation of the binder's plastic deformation, the crack initiation formed and made the hard particles flake away. The hard particles' flaking-off controlled the wear process.

4. References

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