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Research on Friction and Wear Performance of TiB_2 Based Self-lubricating Ceramic composites

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Abstract. TiB_2 based self-lubricating ceramic composites with the addition of different content of h-BN were prepared by hot pressing technique and their mechanical properties were tested. Friction and wear experiments are conducted on a MMW – 1A configuration control universal friction and wear testing machine. Friction and wear properties of the ceramic composites under different speed and load were studied. The results show that with the increase of the content of h-BN, the hardness, flexural strength and fracture toughness showed a trend of decrease. When load was fixed, with the increase of rotational speed, the friction coefficient rose and the wear rate were first decreased and then increased. When rotational speed was fixed, the friction coefficient and wear rate first decreased and then increased with the increase of load. In nitrogen, the friction coefficient and wear rate of material were higher than those in the air.

Keywords. Self-lubricating ceramic, mechanical properties, friction and wear, nitrogen atmosphere.

1 Introduction

Cause of friction is the relative motion between two surfaces contact each other ,and inevitably produced friction and wear [1].Ceramic tool because of its high wear resistance, heat resistance, oxidation resistance advantages, has been gradually expanded. However, because of its large friction coefficient and fragile, its ues of scope has been limited, so the study of friction and wear properties of ceramic tool materials is very important for development of ceramic cutting tool inspection role.

TiB_2 With high hardness, high melting point and good oxidation resistance, corrosion resistance and other characteristics, also has a good metal gloss [2]. h-BN has very good chemical stability, and it continue to be particularly stable at 2800degrees centigrade temperatures, has good electrical insulation and lubrication, it is very excellent high temperature lubricants [3]. Xu Xiuguo prepared TiB2/WC/h-BN ceramic cutting tools by hot-pressing sintering and experiments for cutting tool materials have good self-lubricating properties [4]. Cao Tongkun prepared Al2O3/TiC/CaF2(ATF) of ceramic materials by hot-press sintering process, used ring-type friction and wear tester for friction and wear properties of test, and analysised the formation processes and mechanisms of self-lubricating film [5].

In this thesis, self-lubricating ceramic material specimens was tested friction and wear, and studied the friction-wear properties and wear mechanisms, comparing different h-BN content wear resistance and wear mechanism of ceramic materials, and studied changes of friction coefficient and wear rate of materials under different loads and different speeds, then analysis the friction-wear properties and morphology.In addition, studied its friction and wear in nitrogen atmosphere compared with in the air, and its wear mechanism in a different atmosphere.

2 The experiment

2.1 Self-lubricating ceramic tool materials preparation

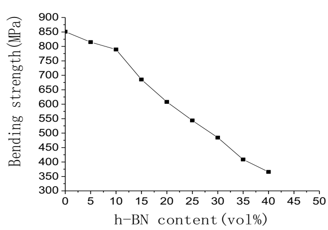
In TiB_2 based Self-lubricating ceramic material, h-BN contents are 0vol.% 、 5vol.% 、 10vol.% 、 15vol.% 、 20vol.% 、 25vol.% 、 30vol.% 、 35vol.% 、 40vol.% , Reinforced phase WC Content for 15vol.% ,Sintering additives Ni Content for 3vol.% , Mo Content for 2vol.% .

Different content TiB_2 powder, WC powder, h-BN powder, Ni powder, Mo powder into the amount of ethanol in the blend, ultrasonic dispersion, mixing, milling, drying and screening, followed by hot-pressing sintering,got different components of TiB2 based Self-lubricating ceramic material. The average size of TiB2 in experiment is 5~8 μ m, purity is 99.0%;WC particle size 1 μ m, purity is greater than 99.9%,h-BN average size of 1.5 μ m, the purity of 99.9%and additives Ni, and Mo purity respectively 99.5% and 99%.

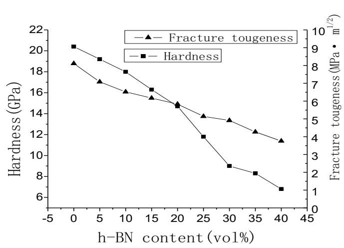
2.2 Mechanical properties of self-lubricating ceramic material

By wire-cut edm machine cut TiB_2 matrix self-lubricating ceramic material, and rough grinding, fine grinding and polishing, tested hardness, bending strength and fracture toughness of samples.

By three-point bending method in measurement of bending strength of electronic universal testing machine, using digital measurement of Vickers hardness to test hardness; fracture toughness specimen is measured by indentation method. Results Figure 1 shows:



(a) Flexural strength h-BN Content changes.



(b) Hardness, fracture toughness h-BN content changes.

Fig. 1. Mechanical properties h-BN Content changes.

Figure1 (a), The bending strength of materials decreases with h-BN Content increases, because h-BN Strength is very low, so, as the h-BN content increases, its bending strength is reduced. Figure 1(b), as the h-BN content increases, self-lubricating ceramic material hardness and fracture toughness decreases, this is because h-BN its hardness is very low, 2GPa, so with the h-BN content increasing, the hardness of the material reduce; the h-BN of plate-like structure in the sintering process will prevent the movement of particles and affect the density of the material, leading to the toughness of the material decreases.

2.3 Self-lubricating ceramic material for friction and wear Tester

MMW-1A Configuration control everything using pins on friction and wear testing machine - pairs form of friction and wear testing, taking into account the TiB2/WC/h-BN performance of a self-lubricating ceramic composite material, the inside diameter of ring for this test is Φ38mm Outside diameter is Φ54mm , Ring material 45# Steel, quenched hardness of 44 ~ 46HRC The surface roughness Ra 0.08μm .

Friction and wear test device schematic diagram diagram 2 Shown here:

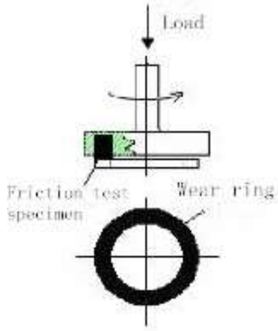


Fig. 2. Schematic diagram of friction and wear Tester.

Friction and wear test:

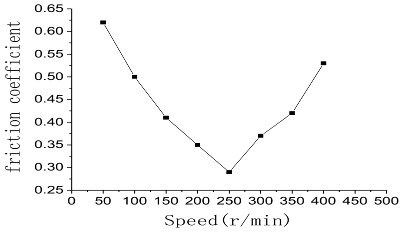
(1)In the case of the same rotating speed and load (v=200r/min 、 FN=30N) conducted friction and wear test in air and nitrogen For different content h-BN Samples;

(2)h-BN Content for 10vol.% to conduct friction and wear test under the same load different speed and the same speed different load;

(3)Records for all experimental coefficient of friction, weighing wear quality, calculate the rate of wear [6].

3 Results and discussion

3.1 Speed of the influence of friction coefficient and wear rate of materials



(a) Friction coefficient increases with the speed of change.

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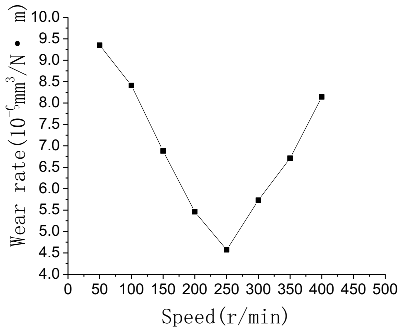


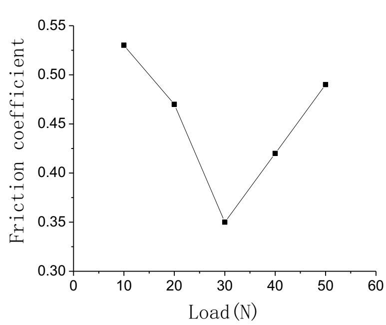
(b) Wear rate changes with speed.

Fig. 3. Coefficient of friction and wear rate and speed of change.

From Figure 3 (a) can directly see that when the load is constant, lower friction coefficient decreases with the speed increases ,and when the speed reaches 250r/min, friction coefficient increases. Because: with speed increasing, self-lubrication ceramic material and on mill deputy contact surface of friction speed gradually speed up, the temperature of contact surface rose, surface formed lubrication film, to reduced friction coefficient of material, when speed reached 250R/min, lubrication film was damaged seriously, the speed of forming lubrication film is lower than its wear, makes friction resistance increases, so friction coefficient increases with the speed up.

Figure 3 (b) can be seen , when speed increase from 50r/min to 250r/min, self-lubricating ceramic material wear rate decreases, when speed increase 250r/min to 400r/min, self-lubricating ceramic material's wear rate gradually reduced. Because when the speed is 50R/min, low speed, the temperature of contact surface is relatively low,h-BN separation more difficult from the ceramic material , cannot form a lubrication film, therefore it has a higher wear rate. As the speed increases (50R/min-250R/min), the grain of the surface damage, contact surface temperature increase, grain formed debris slowly, contact some of the debris at the contact surfaces form a surface layer, reduce the amount of wear of the material. In addition, with the speed continuing to increase,h-BN solid lubricant separated from surfaces more easily, form a lubrication film, which reduced the amount of wear. When the speed continues to increase (250R/min- 400r/min), the temperature of contact surface continued to rise, the damage of lubricating film is more serious, therefore, self-lubricating ceramic material wear rate also increased.

3.2 Effect of load on friction coefficient and wear rate



(a) Changes in friction coefficient as a function of load.

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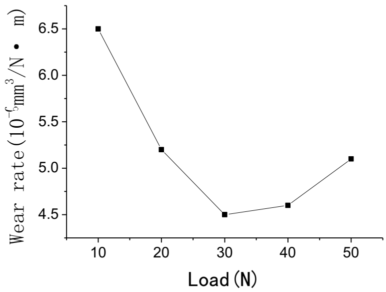


(b) Wear rate as the load changes.

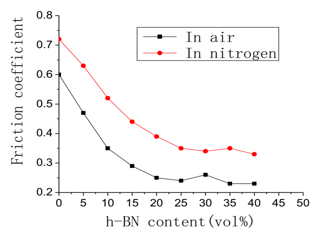
Fig. 4. Trend of the coefficient of friction and wear rate as a function of load.

Figure 4 (a) can be seen, when the speed is constant, with the load increasing, the friction coefficient decreases and then increases. Because:

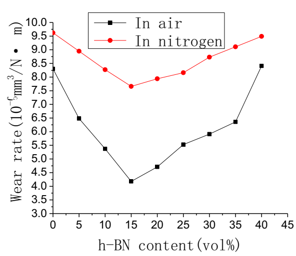
When the load is 10N, the stress of contact surface is relatively small, it is hard for h-BN to separate from the materials, causing friction of contact surface large and relatively high friction coefficient. As the load increases (10N-30N), the pressure between contact surface stress are larger, solid lubricant separate more easily, forming a lubricating film, and with the loss of material and material constant precipitation of solid lubricant, to repair the damaged film, so the friction is greatly reduced, the friction coefficient decreases. When the load continued increasing (30N-50N), the stress of contact surfaces also increases, lubricating film is damaged more seriously, self-lubricating materials wear increases, friction coefficient increases.

Figure 4 (b) can be seen , When the load from 10N 30N, self-lubricating ceramic material wear rate decreases, and when the load from 30N to 50N, self-lubricating film damaged more seriously, wear rate gradually reduced.

3.3 With nitrogen in the air h-BN Content on friction and wear properties of materials



(a) Coefficient of friction h-BN Trends in content.

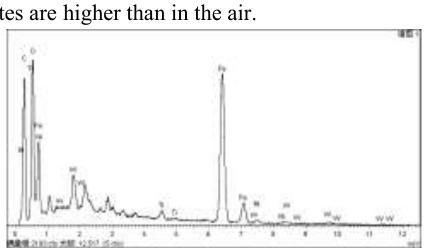


(b) Wear rate with h-BN content trends.

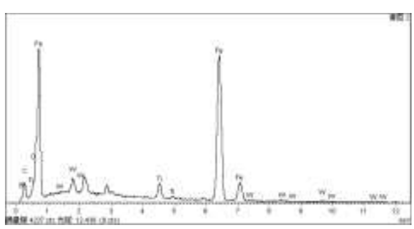
Fig. 5. Nitrogen and air friction coefficient and wear rate h-BN Trends in content.

Figure 5 (a), when the load is 30N, Speed 200r/min , with h-BN Content increases the friction coefficient of the material decreases, when increased to 20vol.%, friction coefficient remained stable in 0.25 .As the h-BN content increases, material produced by the friction of lubricating film has increased. In 20vol.%, self-lubricating film falling off is equal to its producing, so that the friction coefficient of the material remained stable, friction-reducing properties of the material remains stable. In nitrogen, self-lubricating ceramic material friction coefficient is higher than that in the air. Because, in the air,h-BN will be oxidized to B_2O_3,B_2O_3 is good self-lubricating film, it can reduce the friction coefficient of the material, while in nitrogen, material is prevented bing exposed to oxygen in case of friction,h-BN will not be oxidized to B_2O_3 film, just relying on h-BN self-lubricating characteristics of plate-like structure reducing friction, so the coefficient of friction is higher in nitrogen. Figure 6(a) is air friction surfaces in the EDS spectrum, shows that friction surface contains large amounts of oxygen in the air; in Figure 6(b) For nitrogen in the surface of EDS spectrum shows that the oxygen content is much lower than the oxygen content in the air. We can know that it did not form B_2O_3 film in nitrogen.

Figure 5 (b), as h-BN Contents of increasing, the wear rate of self-lubricating ceramic material first decreased and then increased, content 10vol.% reached the minimum. Because, joined h-BN, will increased its lubrication performance, improve the wear performance of the material; with continuing to add of h-BN, hardness, and bending strength and the fracture toughness of the material are reduced, load and speed on lubrication film of damage also became large, led to wear degree of material big, the wear rate of material increased. In nitrogen, the wear rate of materials was higher than in the air, because, in the air B2O3 film decreases the wear rate of materials, and in nitrogen, will not produce B2O3 film, material produced abrasion, resulting in increased wear rate. Figure 7(a,) were used in the air friction surfaces, surface scan photos and 3D graph shows it has formed good lubrication film on the surface. Figure 7(b) material surface friction in nitrogen from surface scans photos and 3D , surface has clear grooves, it is abrasion, surface quality is bad, so the wear rates are higher than in the air.

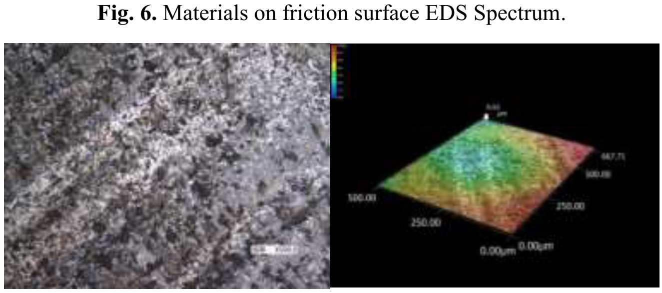


(a) In the air.



(b) Nitrogen.

Fig. 6. Materials on friction surface EDS Spectrum.



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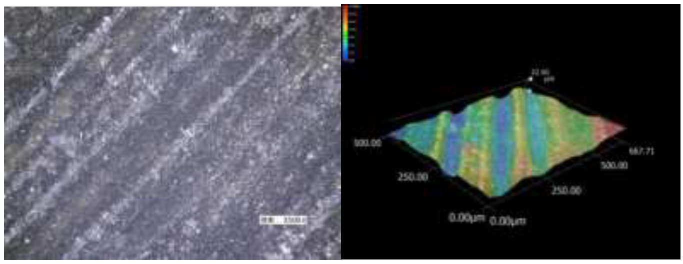
(a) In the air.



(b) Nitrogen.

Fig. 7. Super depth of field image of the friction surface.

4 Conclusion

(1)As h-BN Content increases, self-lubricating ceramic material hardness, flexural strength and fracture toughness are decrease;

(2)h-BN content for 10vol% material speed is 200r/min, as the load increases, friction coefficient first decreases and then increases, friction coefficient reached the minimum at the 30N, and the wear rate decreased at the first then increased, the lowest point is 30N;

(3)The material h-BN Content for 10vol%, when the load is 30N, as the speed increases the first decrease and then increase, wear rate first decreases and then increases, the lowest wear rate was found at 250r/min;

(4)Friction coefficient of lubricate ceramic materials decreases with h-BN content increases, when the content was increased to 20vol.%, stable about 0.25, wear rate lead reduced the lowest when the content is 15vol% Lowest rates of wear, then rise in nitrogen atmosphere, self-lubricating ceramic friction coefficient and wear rates are higher than in the air.

References

1. Wen Shizhu . Principles of Tribology. Beijing : Tsinghua University Press ,1990.
2. Seung-Ho Kim, Soo Wohn Lee. Wear and friction behavior of self-lubricating alumina–zirconia–fluoride composites fabricated by the PECS technique. Ceramics International, 2014, 40(40):779–790.
3. Tanemoto K,Kani T.Hot-pressed hexagonal boron nitride-aluminum nitride ceramic composites. Key Eng Mater,1995,108-110:85-96
4. Xu Xiuguo . Nano/Micro-composite-gradient development of a self-lubricating ceramic cutting tools and their cutting performance. Jinan: qilu University of technology 2013.
5. Cao Tongkun , Gao Wei . Al_2O_3/TiC/CaF_2 ceramic friction and wear and self-lubricating film formation mechanism. Materials engineering ,2009,(9):75-79.
6 Wu Guangyong . Gradient self-lubricating ceramic tool materials and its antifriction mechanism. Jinan : Cheeloo University of technology ,2012.