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Friction and Wear Mechanism of High Temperature Brake Friction Materials

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Abstract. In this paper, the microstructure and frictional wear mechanism of iron based high temperature brake friction materials prepared by powder metallurgy are studied. The results show that iron based friction materials are mainly composed of iron matrix, graphite and hard phase. Under the working condition of rotating speed of 6000r/min, the frictional wear mechanism is mainly abrasive wear and slight oxidative wear. Under the working condition of rotating speed of 8800r/min, the frictional wear mechanism is mainly abrasive wear, adhesive wear and oxidative wear.

1. Introduction

Brake is the most important safety device for traffic vehicles and transportation equipment. It uses the frictional properties of friction materials to convert kinetic energy into thermal energy for braking and stopping [1]. At present, with the increase of high mobility and power density of vehicles, resulting in more severe working conditions and frequent failure of brake friction devices, friction materials for high temperature braking have become one of the key technologies to improve the braking performance and reliability of vehicles.

At present, metal based friction materials are mainly used in high-speed and heavy load conditions. Metal-based friction materials include powder metallurgy and fused metal [2]. Powder metallurgy friction materials have been widely used in various large civil aircraft and high-performance military aircraft and other mechanical braking devices because of their advantages of high strength, long service life, good high temperature and good friction stability[3-7]. Iron-based friction materials have the largest amount of powder metallurgical friction materials, lower cost, good thermal stability, and strong adhesion resistance.

The components and friction velocity of friction materials will affect the friction and wear properties and mechanism of materials. Yu Xiao [8] et al. studied the influence of the friction components of Fe, Al_2O_3 and SiO_2 on the friction and wear properties of sintered alloys, the results show that the friction coefficient of the material with SiO_2 is the smallest and the wear amount is the largest. Chen Jie et al. [9] studied the mechanism of the influence of the friction surface temperature on the friction and wear properties of iron-based friction materials. The results showed that with the increase of friction speed, the temperature of the friction surface kept rising, and the friction coefficient and wear amount of the materials showed a trend of first decreasing and then increasing.

In this paper, the microstructure and wear mechanism of iron-based high-temperature brake friction materials prepared by powder metallurgy method under different working conditions are studied, which provides the basis for the design and application of friction materials.

2. Experimental

The samples of iron-based powder metallurgy friction plate and dual plate are shown in Figure 1. In the experiment, the microstructure of iron-based high-temperature brake friction materials prepared by powder metallurgy was characterized by using quanta 650 scanning electron microscope (SEM) and energy dispersive spectrometer (EDS). Then, the friction and wear experiments of the samples were carried out by using mm3000 friction and wear testing machine at the speed of 6000r/min and 8800r/min respectively. Finally, the friction and wear mechanism of the material was analyzed by the macro and micro morphology of the wear surface and the wear debris of the sample.

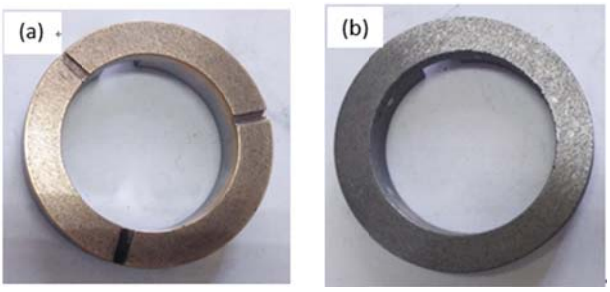

Figure 1. Fe-based powder metallurgy friction part(a) and dual part(b)

3. Result and Discussion

3.1. Microstructure

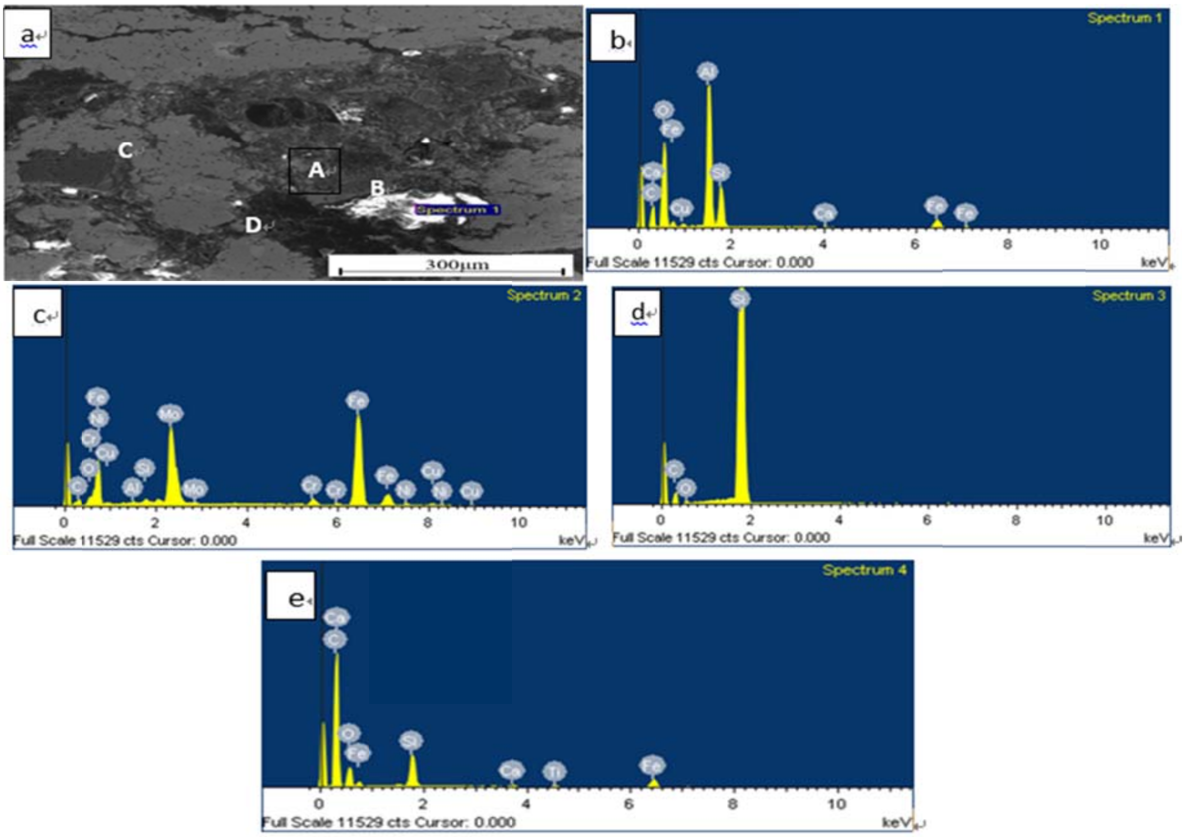

Figure 2. SEM of Fe-based friction material(a) and EDS of pint A, B, C, D(b),(c),(d),(e)

The iron-based friction material is mainly composed of iron matrix, graphite and hard phase, and its microstructure is shown in Figure 2. EDS spectrum analysis was performed on points A, B, C, and D in Figure 2 (a). See Fig. 2 (b), (c), (d) and (E) in turn. The light gray at point C is the iron matrix, which plays a connecting role and determines the strength of the friction material; the black area at point D is graphite, which plays a role in lubrication and wear reduction. The bright block area at point B is Al_2O_3, while the light black area at point A is SiC, which plays a role in increasing friction and improving wear resistance. The iron matrix is surrounded by graphite and SiC, and Al_2O_3 is embedded on the matrix.

3.2. Friction and Wear Mechanism

The macro morphology of the friction part under different working conditions is shown in Figure 3. It can be seen from Fig. 3 (a) that under the condition of 6000r/min, the friction surface of the sample has obvious furrows and slight spalling along the sliding direction. From Fig. 3 (b), it can be seen that there are obvious furrows and spalling along the sliding direction of the material friction surface under the condition of the rotation speed of 8800r/min.

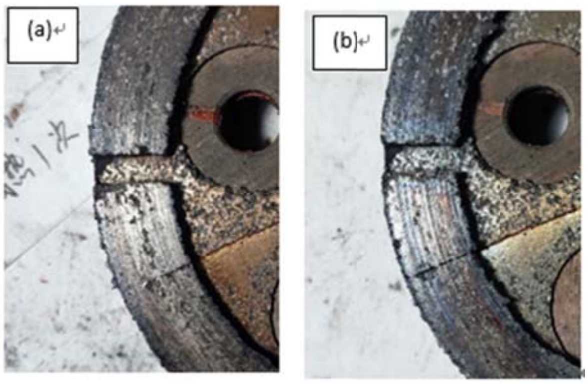

Figure 3. Macromorphology of friction parts under different working conditions (a)6000r/min,(b)8800r/min

The surface morphology and energy spectrum analysis of friction parts and dual parts under different working conditions are shown in Fig. 4 and Fig. 5 respectively. It can be seen from figure 4 (a) and figure 5 (a) that under the working condition of 6000r/min, scratches and slight peeling appear on the surface of the friction member, and the surface of the friction piece contains a small amount of oxygen element. Therefore, under the condition of 6000r/min, abrasive wear and slight oxidation occurred on the surface of the material. From Fig. 4 (b), (c) and Fig. 5 (b), (c), it can be seen that under the working condition of 8800r/min, there are sliding scratches and peeling off along the sliding direction on the surface of the friction piece, there are sliding scratches and peeling off along the sliding direction on the surface of the friction piece, and there are obvious scratches along the sliding direction on the surface of the dual piece, and the oxygen content of the surface of the friction piece and the dual piece is higher than that of the material under the working condition of 6000r / min, and the surface of the counterpart also contains the metal elements contained in the friction member, which proves under the condition of 8800r/min, ploughing, adhesion and oxidation occurred in the friction pair.

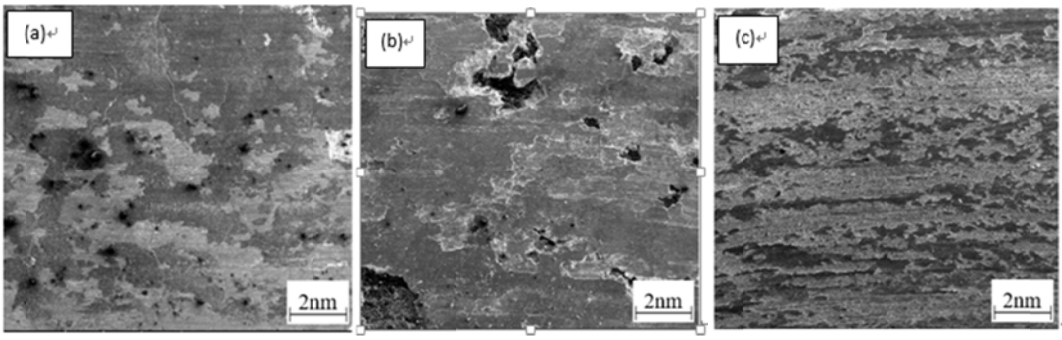

Figure 4. Surface Micromorphology of friction part and dual part under different working conditions (a)6000r/min, friction part,(b)8800r/min, friction part,(c)8800r/min, dual part

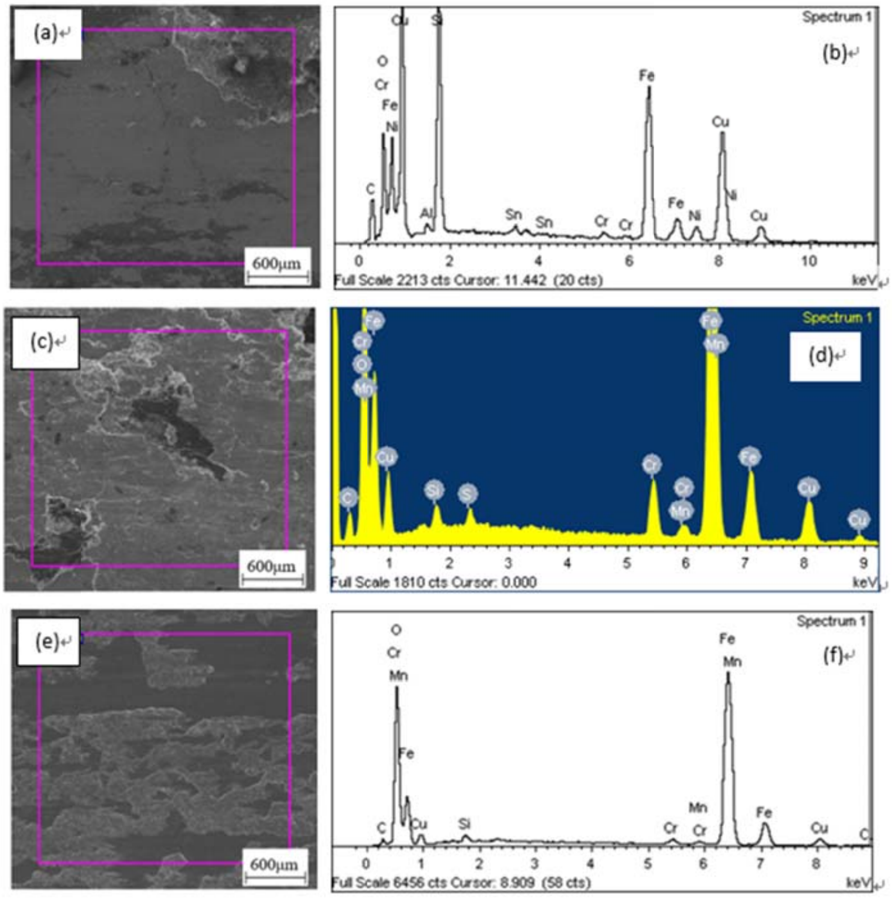

Figure 5. Surface Micromorphology-EDS analysis of friction part and dual part under different working conditions
(a)6000r/min, friction part,(b)8800r/min, friction part,(c)8800r/min, dual part

The morphology and energy spectrum analysis of wear debris under different working conditions are shown in Figure 6 and Figure 7, respectively. It can be known from Figure 6 (a) and Figure 7 (a) that under the working condition of 6000r/min, the wear debris generated by friction material braking has flakes and granules, and the size of the wear debris is less than 200 μ M. During the braking process, the hard particles fall off and produce granular wear debris. The flake wear debris is mainly caused by the failure to effectively generate continuous oxide layer on the wear surface, and the formed oxide layer does not combine with the substrate firmly, easy to fall off from the substrate in the subsequent braking. It can be known from Fig. 6 (b) and Fig. 7 (b) that under the working condition of

8800r/min, the wear debris produced by material braking mainly consists of particles and flakes, and the size of the wear debris is large and less than 500 μ M. The oxide layer is not firmly combined with the substrate, which is easy to fall off and form flake debris. The granular debris is formed by hard falling off.

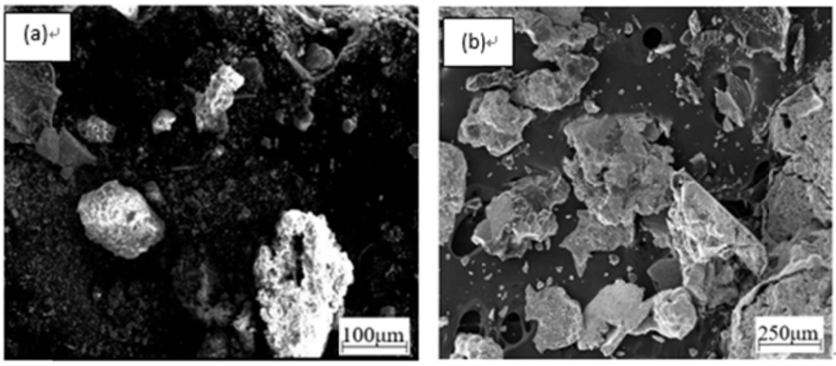

Figure 6. Debris morphology under different working conditions
(a)6000r/min,(b)8000r/min

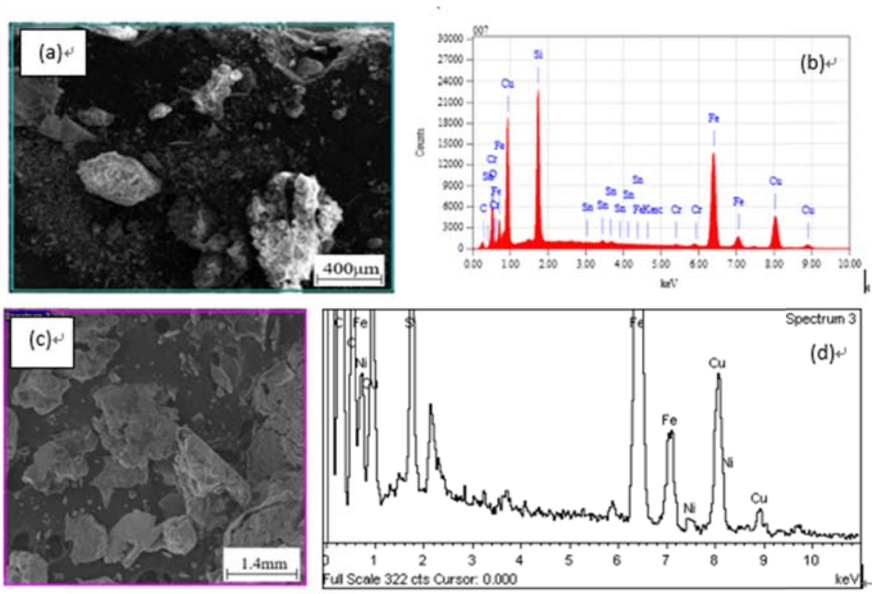

Figure 7. Debris morphology-EDS analysis under different working conditions
(a)6000r/min,(b)8800r/min

To sum up: under the condition of rotating speed of 6000r / min, the friction and wear mechanism of the material is mainly abrasive wear and slight oxidation wear; under the condition of rotating speed of 8800r /min, the friction and wear mechanism of the material is mainly abrasive wear, adhesion wear and oxidation wear.

4. Conclusions

The iron-based friction material is mainly composed of iron matrix, graphite and hard phase. Under the working condition of the speed of 6000r/min, the friction and wear mechanism is mainly abrasive wear and slight oxidation wear. At the speed of 8800r/min, the friction and wear mechanism is mainly abrasive wear, adhesion wear and oxidation wear.

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