

Effect of large size graphite on dry friction and wear characteristics of copper-based brake friction lining materials

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Abstract. In order to improve the performance of the brake friction lining materials, the materials are made of six powders of Cu-Sn-Fe-graphite-SiO₂-MoS₂. The graphite content is 6%, 8%, 10%, 12% and 15% respectively. The size of graphite is 400-600 μ m. The dry grinding wear properties are investigated. The results show that the compressive strength decreases as the graphite content increasing. When the content is 10%, the strength is 113.45MPa; it satisfies the performance requirements of high-iron brake pads. The dry friction and wear test of a copper-based friction material containing a large graphite sheet shows that the wear resistance is affected by the graphite contents. When the graphite content is 10%, the wear rate is significantly lower than other contents; the wear resistance is the best. During the wear process, a variety of wear mechanisms coexist. Such as oxidation wear, abrasive wear, adhesive wear, and peeling wear. At low speeds, the main wear mechanisms are abrasive and oxidation wear. At high speeds, the main wear mechanisms are oxidation wear and peeling wear.

1. Introduction

With the rapid development of high-speed railways, the requirements for the performance of high-speed trains have also been correspondingly improved, especially the braking performance. In the disc brake, the brake disc is integrated with the axle of the vehicle. As the axle rotates at high speed, the brake pad is relatively stationary. The pressure is transmitted to the brake pad by the hydraulic cylinder, the brake disc is pressed to generate braking force.

With the increasing of the train speed, in order to improve the heat resistance and wear resistance, it is necessary to innovate research and development.

Yu xiao and Guo Zhimeng[1] using electrolytic Cu powder, reduced Fe powder, and graphite. Studied Fe content and friction elements, such as SiO₂, Al₂O₃ and SiC on friction properties, microstructures and mechanical property. The hardness, compressive strength and bending strength are significantly increased with the increasing of Fe content. Han Xiaoming and He Weidong[2] study the effect of friction pressure (0.5~1.1MPa) on the third body of copper-based powder metallurgy materials using pin-disk friction testing machines. When the friction pressure increases, the friction coefficient shows a downward trend, the wear rate doesn't change significantly. Yao Guanxin, Niu Huawei[3] study copper-based friction materials with nickel content of 0%, 3%, 6% and 9%. As the nickel content increasing, the material wear rate decreases, the stability of the friction coefficient increases. When the nickel content is more than 6%, it can form a dense and uniform nickel oxide layer on the surface during high-speed friction. The nickel oxide has a higher bonding strength with the matrix, which improves the friction stability. The copper-based powder metallurgy brake pads



have the advantage that the friction factor is not affected by the weather and have good wear resistance and thermal conductivity [4-6]. This article mainly studies the friction and wear characteristics of copper-based friction brake pads.

2. Experimental Materials and Methods

The material composition is shown in Table 1. The SiO₂ powder has a particle size of 500 mesh (<28μm). Ball milling the powder, rotating speed of 300 r/min, mixing powder for 0.5 hours. Cold forming with the pressure is 600MPa. Sintering in a vacuum furnace at 830 °C for 1 hour. The hardness of the disc is 51.7 HRC, the test force is 100 N, the friction torque is 2500 N/mm, and the time is 10 min. The rotation speeds are 200 r/min, 400 r/min, and 600 r/min respectively. The samples are weighed and the data recorded after the experiments. The samples are tested by micro hardness testing and X-ray diffraction.

Table 1. Material mass percentage (wt.%)

Sample number	Cu	Sn	Cr	Fe	SiO ₂	MoS ₂	C
1	75	7	5	4	2	1	6
2	72	7	5	4	2	1	8
3	71	7	5	4	2	1	10
4	69	7	5	4	2	1	12
5	66	7	5	4	2	1	15

3. Results and Analysis

Figure 1 shows the sintering organizations SEM images. The white matrix is copper and the black is graphite. Graphite is embedded in the matrix via black strip or flaky structure, because it is insoluble in copper matrix. The graphite is large flaky in the organizations. MoS₂ acts as a solid lubricant, it is similar to the graphite and wrapped in the matrix.

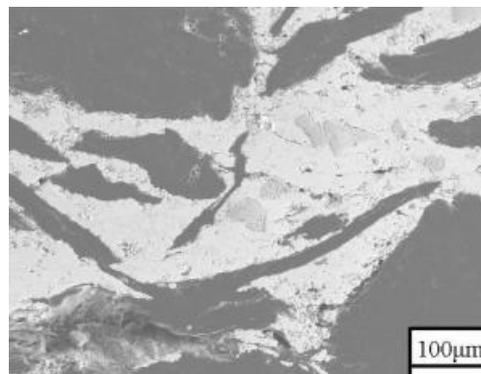


Figure. 1 Copper-based brake friction lining sintering structure

The micro hardness test is performed on the surface. The results are shown in Table 2.

Table 2. Micro hardness test (HV)

Sample number	One	Two	Three	Average
1	120.91	128.91	125.38	125.07
2	117.22	122.39	125.84	121.82
3	127.76	112.46	125.06	121.76
4	117.26	122.39	121.06	120.49
5	102.99	97.78	102.34	101.04

The micro hardness of the material is between 101-130 HV. With the increase of graphite content, the micro hardness gradually decreases. When the graphite content is 15%, the micro hardness reaches minimum value which is 101.04HV. Graphite is insoluble in Cu matrix. With the increment of graphite content, the segmentation of the matrix intensifies and the hardness decreases. Figure 2 shows the sample curve with different graphite contents, the material density between 5-5.9g/cm³. As the graphite content increasing, the material density decreases. The density of the graphite is much smaller than that of the copper matrix, the increasing of the graphite content causes the average density decreased. Graphite doesn't combine with the matrix and exists in the free state. With the increasing of graphite content, it leads the decreases of the density.

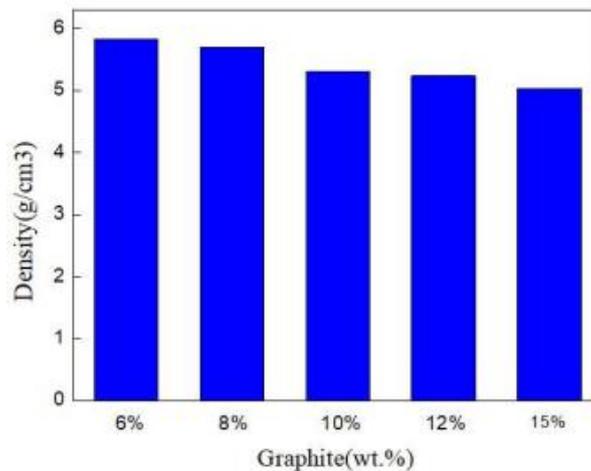


Figure 2. Density curve.

Figure 3 are the compression curves of different graphite contents. As the graphite content increasing, the compressive strength decreases significantly. Graphite is insoluble in the copper matrix and can cause micro-cracks. The crack diffusion forms fracture eventually with the increase of pressure. Graphite is lamellar and low in strength. The increase of graphite content destroyed the continuity and the porosity increases, the degree of separation increases and strength reduces. The degree of fragmentation is relatively low and the compressive strength is high. The compressive strength of the 10% carbon-containing material is 113.45MPa, which satisfies the strength requirement of high-iron brake pads. The strength of 12% and 15% is lower than that.

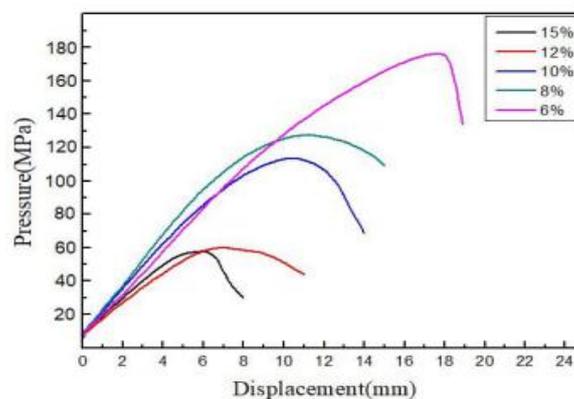


Figure 3. Compression curve.

Figure 4 are the SEM images of different graphite component samples at 200 r/min. The wear of "soft" matrix is more serious, the extent of surface damage is larger with the content of 6% and 8%.

Because of multiple cyclic action, the wear surface locally repetitively deforms and generates fatigue cracks, the cracks continue to spread until partial shedding of the surface. The surface of 10%, 12% and 15% are smooth, only a few spot peeling pits. The higher of the graphite contents, the smoother of the surface. According to wear theory and experimental results, the abrasive wear and oxidation wear are the main wear mechanisms.

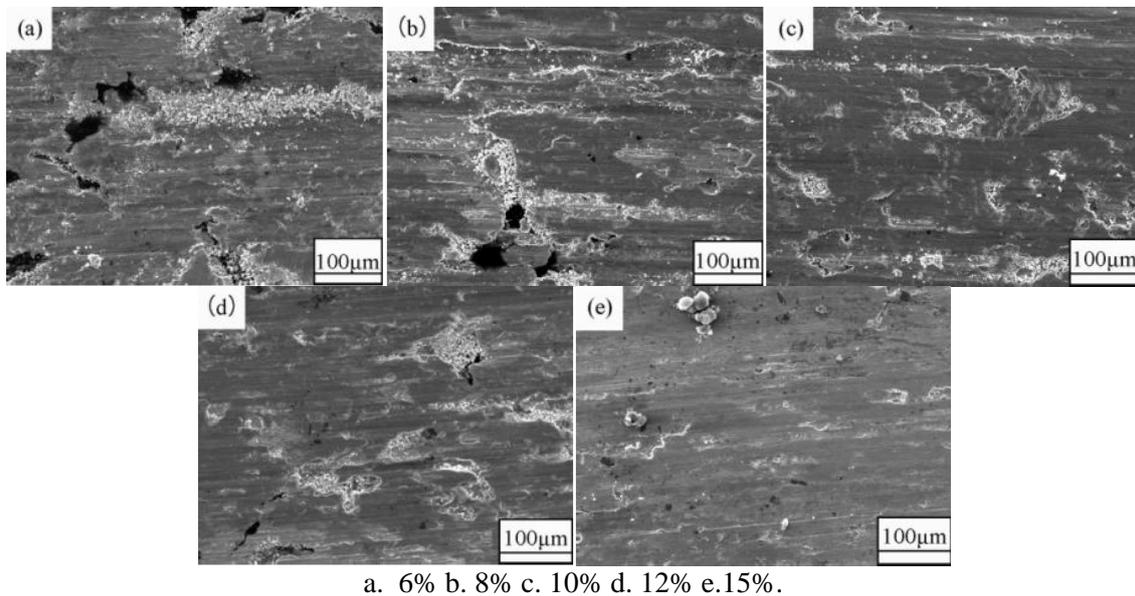


Figure 4. 200r/min friction surface scanning topography

Figure 5 are the SEM images of the different samples at 400 r/min. As the friction speed increasing, the surface temperature increases and the strength decreases. The surface film slightly peels under the effect compressive stress. With the increasing of graphite contents, the strength decreases. The wear is more serious and the surface is relatively rough.

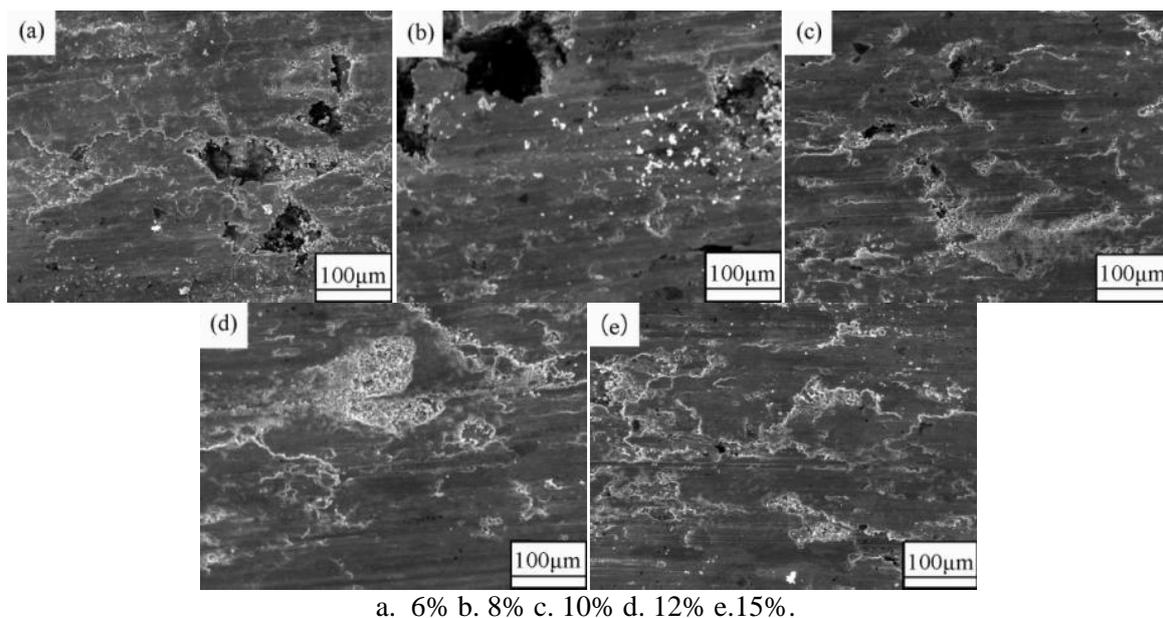
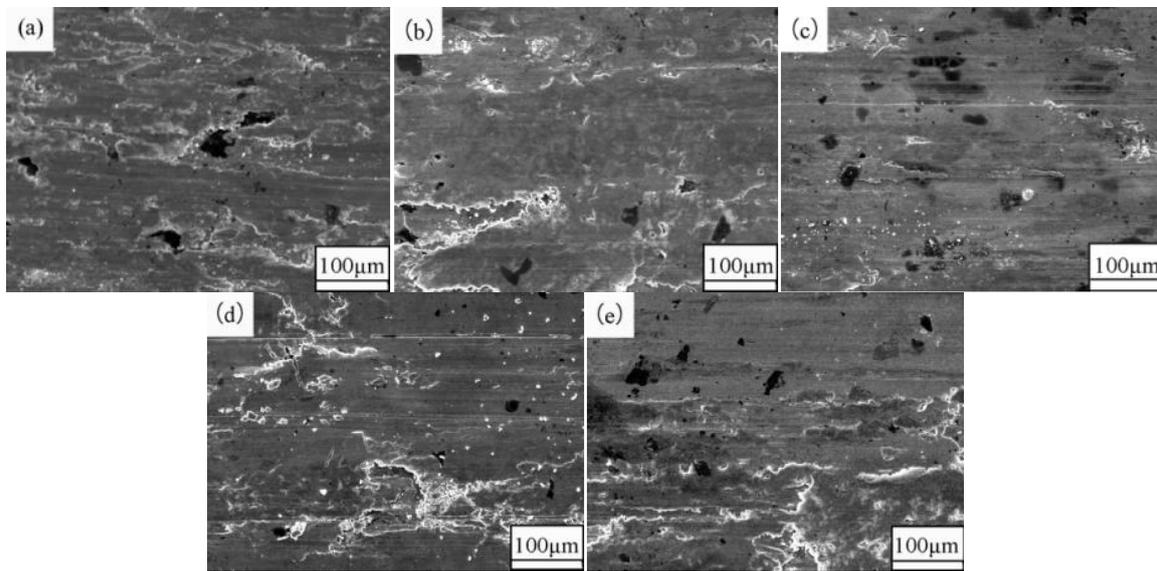


Figure 5. 400r/min friction surface scanning topography

Figure 6 are the SEM images of the different samples at 600 r/min. When the speed increases,

surface cracks appear on different materials due to repeated friction. The frictions surfaces are relatively rough, coarser furrows have appeared in parts.



a. 6% b. 8% c. 10% d. 12% e.15%.

Figure 6. 600r/min friction surface scanning topography

Figure 7 is a bar graph of different graphite samples at different speeds. At the speed is 200r/min and the graphite content is 10%, the wear rate is the lowest. The wear of materials is mainly caused by the shear of micro bumps at low speed. The higher of the shear frequency, the friction coefficient is more higher [7]. The amount of wear is relatively high. Graphite can form a lubricant film on the friction surface reducing the wear extent. When the speed is 400r/min, the wear extent increases with the increasing graphite contents. The surface softens, the friction layer falls off and the wear is faster. The increasing of graphite reduces the strength and intensifies the peeling of the surface films. At the speed of 600r/min, the overall wear rate is high. The frictional surface temperature is high, the softening is more serious. The surface atomic activity increase and forms an oxide film [8]. The oxide film is gradually thickened in friction. When the oxide film reaches a certain thickness, it begins to fall off with the effect of stress. The exfoliated oxide layer is sandwiched between the two interfaces, eventually forming abrasive wear.

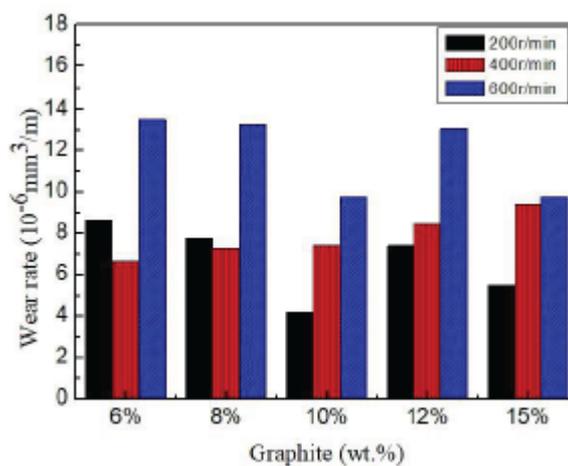


Figure 7. Wear rate different graphite content at different speeds

4. Conclusion

1) The compressive strength decreases as the graphite content increasing. When the content is 10%, it reaches 113.45MPa, which satisfies the performance requirements of the high-iron brake pad.

2) Dry friction and wear tests of copper-based friction materials show that the wear resistance is affected by the graphite contents. When the graphite content is 10%, the wear rate is significantly lower than other contents, the wear resistance is the best.

3) The wear test shows that various wear mechanisms such as oxidation wear, abrasive wear, adhesive wear and peeling wear coexist. At low speeds, the main wear mechanisms are abrasive and oxidative wear. At high speeds, the main wear mechanisms are oxidation wear and peel wear.

Acknowledgments

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