A Study on the Friction and Wear of Bronze Sintered Friction Materials

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동계소결 마찰재의 마찰마모에 관한 연구

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ABSTRACT

The effect of bronze sintered friction materials on frictional and mechanical properties is studied with the content(8~18 wt,%) and shapes (flake and irregular) of graphite that is used as solid lubricants to meet diverse characteristics such as low coefficient of friction, low wear rate and high bending strength. The content and shapes of graphite are optimized by statistical experiments. Friction test was carried out measure friction coefficient, temperature dependence and wear rate. As a result of experiments, the density, hardness and bending strength with a shape of flake graphite are lower and decrease rapidly than that of irregular, as the content of graphite increases up to 18 wt%. After friction test, coefficient of friction is 0.3~0.4 and wear rate is 0.32~2.98×10^{-7}㎤/kg · m. When the content of graphite increases, coefficient of friction increases in a shape of flake graphite and decreases in a shape of irregular graphite.

Key Words : Sintered Friction Materials, Graphite, Coefficient of Friction, Wear Rate

1. Introduction

The studies of sintered metal friction have been steady progressed and available the early 1930's[1~3]. Today such copper based and iron based sintered friction materials are being used in the heavy industries. Trucks, tractors, tanks and airplanes are now produced which rely on sintered metal clutches or brakes to produce the force vital to their operation and control. These sintered metal friction materials composed of three main components like matrix, solid lubricant and friction modifier ingredients. All of three main components have an important effect on the friction performance. In particular, solid lubricants have an important effect on mechanical and physical properties of sintered friction materials. Typical solid lubricant used under dry friction condition are graphite, lead and molybdenum disulfide, etc. Usually graphite is extremely much used as solid lubricant. It is know, however, that the friction performance of sintered

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friction materials are influenced by the particle sizes, shapes, content of graphite[4~5]. In this paper, using a shape of flake and irregular graphite that particle size is constant, the influence of a shape and content of graphite on friction and wear of cooper based sintered friction materials was investigated.

2. Experiment

The experimental procedures are detailed in Fig. 1. Specimens were prepared from commercial powder. Atomized tin powder was chosen as liquid phase sintering agent to strengthen the matrix. In addition, silica was used as friction modifier and a shape of flank and irregular graphite as a solid lubricant. The particle size distributions of two shapes are similar each other. According to the composition given in Table 1, powders were mixed in a V-cone mixer for 30 minutes. Graphite was added 10 minutes before the

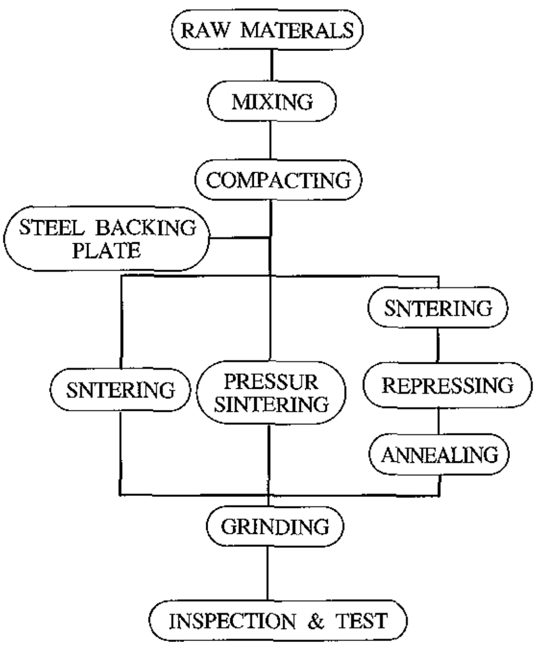


Fig. 1 Flow diagram of manufacturing processes of friction materials

Table 1 Compositions of cu-based sintered friction materials

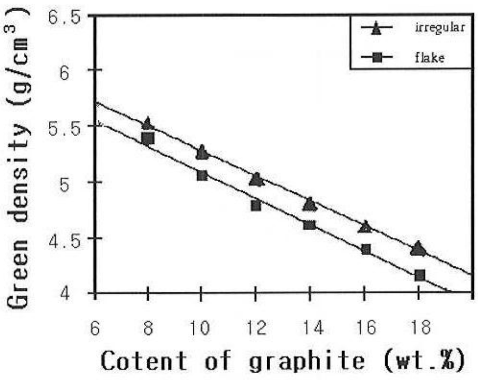
Graphite	Copper	Tin	Silica	Iron	Theoretical density
wt%	wt%	wt%	wt%	wt%	(g/cm^3)
8	76.5	8.5	6	1	6.315
10	74.7	8.3	6	1	6.049
12	72.9	8.1	6	1	5.804
14	71.1	7.9	6	1	5.579
16	69.3	7.7	6	1	5.370
18	67.5	7.5	6	1	5.176

end of the mixing cycle in order to reduce the build up of a barrier layer on the matrix metal particle. The presence of the barrier layer on the matrix metal particle would obstruct the formation of interparticle bonding during sintering[2]. The mixed powders were compacted into a cylinderical shape in a floating die using a 100 tons hydraulic press. The compacting pressure of 4 $tons/cm^2$ was maintained for all specimens. The green compacts were placed on cooper eletroplated backing plates and sintered for 60 minutes at 840℃ in nitrogen atmosphere. The sintering pressure was 25 kg_f/cm^2. The density of compacted and sintered specimens was measured using oil immersion method[6]. The Rockwell hardness was measured using 1/2 inch diameter steel ball indenter at 100kg_f load.

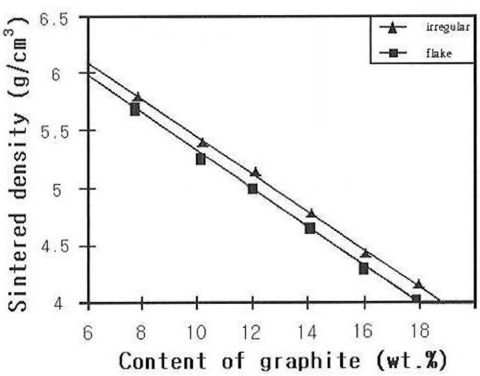
The bending strength was measured with 13 × 32 mm specimen using bending strength test apparatus[7]. Before friction and wear test, the uneven surface were ground flat in order to increase the initial contact area with the mating friction surface. Friction and wear test were performed with 25 × 25 ㎜ specimen on a cast iron disk using a constant speed friction tester under 5 kg_f/cm^2[8]. The rotating friction disk was heated by external heating system. The testing temperature was raised from 100℃ to 350℃ at 50℃ interval. Wear rate was measured in terms of the decrease of the specimen thickness after 5000 cycles test.

3. Results and Discussion

The density with a shape and content of graphite is shown in Fig. 2. The density with increasing the content of graphite reduces linearly regardless of shapes of graphite. The porosity of compacts added 8~18 wt.% flake and irregular graphite is 14~18%, 12~14% respectively. The difference is probably due to apparent density of graphite. The apparent density measured with Hall Flowmeter[9] is 0.41 g/㎤ in the case of flake graphite and 0.77 g/㎤ in the case of irregular graphite. As shown in Fig. 2, the sintered density improves with increasing green density and the porosity reduces with increasing the apparent density of graphite.



(a) Green denssity



(b) Sintered density

Fig. 2 Green and sintered density with the content of graphite

The hardness decreases with increasing the content of graphite, as shown in Fig. 3, The difference of hardness on a shape of graphite is little at 8 wt.% of graphite, but is remarkable at the higher content. The main causes on the difference are probably due to the porosity of specimen and a particle strength of graphite[3]. Fig. 4 shows the bending strength with the content of graphite. When the content of graphite is 8 wt.%, the bending strength is 20~23 kgf/㎟. With increasing the content of graphite, Krysin and Lebedeva[10] reported that hardness of sintered friction materials increased with the bending strength decreases linearly and then decreases to 10~12 kgf/㎟. After friction test during 10 minutes at the temperature of 100℃, Wear rate and coefficient of friction with the content of graphite are shown in Fig. 5 (a) and (b),

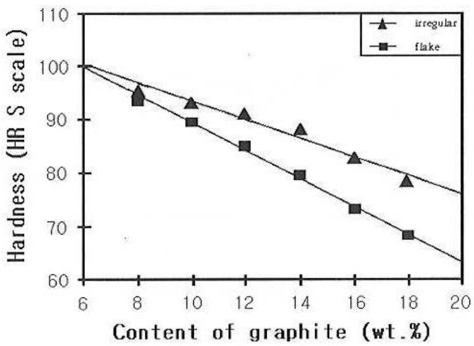


Fig. 3 Hardness with the content of graphite

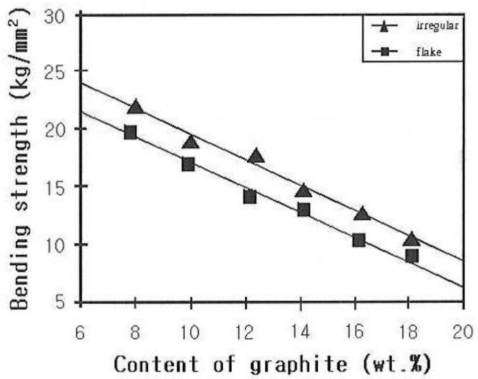
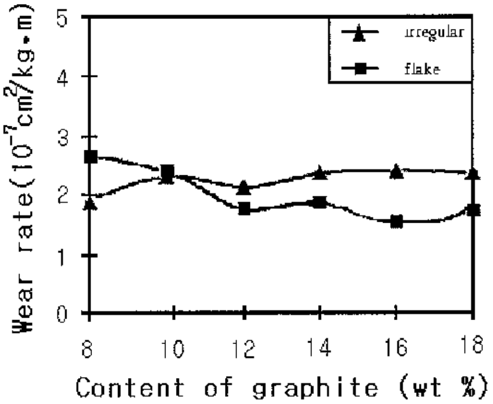


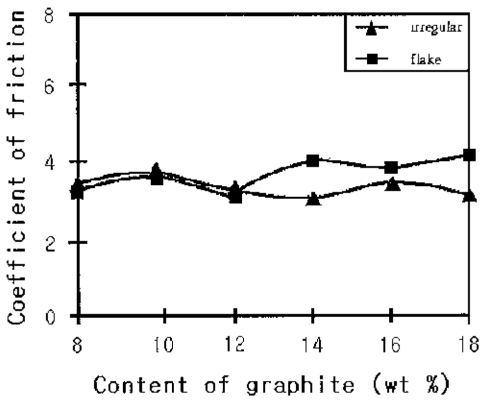
Fig. 4 Bending strength with the content of graphite

respectively. Wear rates are about 1.54~2.65 ㎠/kgm. When the content of graphite increases. The wear rate of flake graphite is relatively lower than that of irregular graphite.

The coefficient of friction was obtained by averaging 5 values measured for two minutes during test. In the case of flake graphite, the coefficient of friction is about 0.3~0.4 and similar to that of 8, 10, 12 wt% added irregular graphite. The coefficient of friction of flake graphite have high values than that of irregular graphite above 14 wt.%. To investigate friction properties at high test temperature, the friction test of 8, 12, 16 wt% added graphite was carried out during 10 minutes at the test temperature of 100~350℃. From Fig. 6 and Fig. 7, we can see the variations of wear rate and coefficient of friction with test temperature. The wear rate of flake and irregular graphite have the same trend. When test temperature of about 200℃ and decreases remarkably at the temperature of above 300℃ as shown in Fig. 6. The sliding surface was examined by XRD (X-Ray Diffraction) and surface oxides like Cu_2O and SnO_2 after grinding of surface layer can be seen in Fig. 8. AT the high temperature of above 300℃ wear rate seems to decrease as a result of the formation of a protective surface oxide layer like Cu_2O and SnO_2. The range of coefficient of friction is 0.3~0.4 and the variation of coefficient of

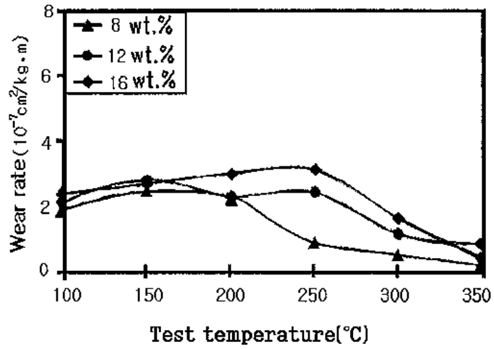


(a) Wear rate

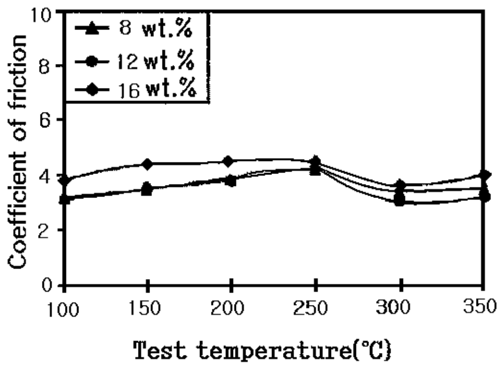


(b) Coefficient of friction

Fig. 5 Friction properties with the content of graphite



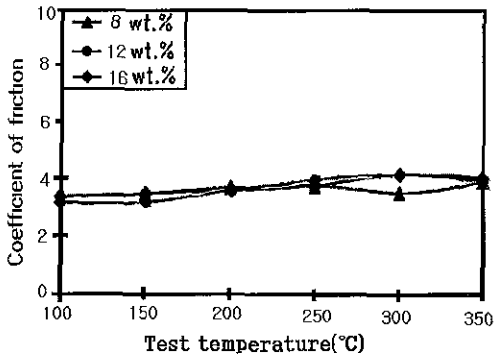
(a) Irregular graphite



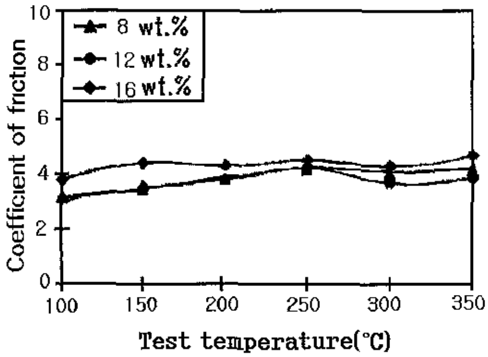
(b) Flake graphite

Fig. 6 Wear rate of specimen with 8, 12, 16 wt.% added graphite as a function of test temperature

friction with the content of graphite have the same trend as shown in Fig. 7

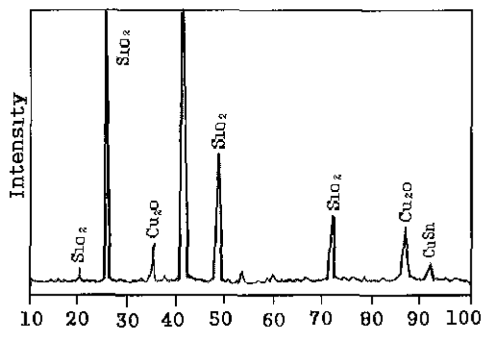


(a) Irregular graphite

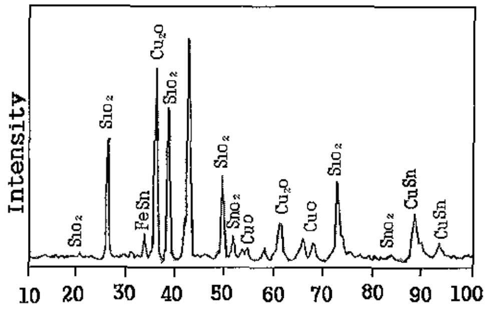


(b) Flake graphite

Fig. 7 Coffiction of friction of specimen with 8, 12, 16 wt% added graphite as a function of test temperature



(a) Before grinding of surface layer



(b) After grinding of surface layer

Fig. 8 XRD analysis of sliding surface

4. Conclusions

1. Specimens added flake graphite have lower density and higher porosity than irregular graphite Higher compacting pressure needs to reduce porosity of specimens added flake graphite
2. The hardness and bending strength of specimen added flake graphite are lower owing to porosity
3. In friction test, the wear rate of specimen added flake graphite is slightly lower than irregular graphite, *but the coefficient of friction is relatively higher*
4. At high test temperature of above 300℃, wear rate decreases rapidly because of the formation of a protective surface oxide layer, but the coefficient of friction is higher than that at low test temperature
5. coefficient of friction is 0.3~0.4 and wear rate is 0.32~2.98× 10^{-7}㎤/kg · m When the content of graphite increases, coefficient of friction increases in a shape of flake graphite and decreases in a shape of irregular graphite.

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