Effect of $BaSO_4$ on Tribological Properties of Brake Friction Materials

Banu SUGÖZÜ[1,*] Behcet DAĞHAN[2]

Abstract: *Automotive brake friction materials are multi-component composites composed of functional materials such as fibers (reinforcements), binder, solid lubricants, friction modifiers, abrasives and space fillers. In this study the effect of BaSO4 (barite) used as filler material for brake lining materials on the tribological properties of brake linings is investigated. Three brake friction composites containing 20, 30 and 40 g barite amount were prepared. The samples were produced by a conventional procedure for a dry formulation following dry-mixing, pre-forming and hot pressing. Friction and wear characteristics of the specimens were examined using a pad-on-disc-type wear tester. The physical properties such as hardness and density of samples were investigated. The results of tests showed that amount of barite on brake friction composites influenced the friction coefficient and specific wear ratio substantially.*

Keywords: Barite, Brake lining, Friction, Wear

1 INTRODUCTION

Non-asbestos organic (NAO) friction materials (FMs) are widely used in automobiles and locomotives as brake pads, brake shoes, brake linings, clutch facings and brake blocks [1]. Automotive brake materials are complex composites consisting of a combination of numerous ingredients (typically 5–30) necessary for the optimization of their friction and wear performance [2]. These multi- ingredient composites containing the right combination of ingredients in the right proportion are manufactured with the right technology to achieve the desired amalgam of performance properties [1,3,4]. These ingredients are frequently categorized into four core classes of binders, fillers, friction modifiers, and reinforcements [1,5].

Fillers are of two types viz. functional fillers (to improve particular characteristic feature of composites such as resistance to fade, etc.) and space/inert fillers (mainly to cut the cost) [6]. $BaSO_4$, $CaCO_3$, and $Ca(OH)_2$ are utilized as space fillers to cut down the cost [7]. Actually, not much is reported in the literature on effect of barite on tribological properties of brake friction materials.

Kim and coworkers [8] studied tribological properties of polymer composites containing barite ($BaSO_4$) and potassium titanate ($K_2O \cdot 6(TiO_2)$) using a block-on-disk tribometer. It was reported that the $BaSO_4$ filled composite produced large frictional oscillations and created severe damage on the gray iron counter surface, while the composite filled with the same amount of $K_2O{\cdot}6(TiO_2)$ whiskers showed smooth sliding without large friction force fluctuation. It also was reported that the friction characteristics of commercial friction materials can be strongly affected by the two ingredients, which have been considered as minor constituents for brake performance. Handa and Kato [9] studied the influence of variation of three fillers (powders of Cu, CNSL and barite) in quaternary composition based on phenolic resin for friction and wear properties on a reduced scale tribometer. They concluded that Cu powder inclusion resulted in increase in fade resistance but decrease in wear resistance while $BaSO_4$inclusion led to the exactly opposite behavior.

The current work aims to evaluate and investigate the tribological properties of the three new produced brake friction materials containing 20, 30 and 40 g barite particles. The friction materials characterized by measuring their hardness and density. Friction-wear tests were carried out using a pin-on-disc type tribometer. All the friction materials were tested against a gray cast iron rotor disc.

2 EXPERIMENTAL

2.1 Fabrication of the composites

Three different types of brake material samples containing 20, 30 and 40 g barite particles (Table 1) were manufactured by mixing, pre-forming and hot pressing. The prepared composites were designated as B20, B30 and B40.

Table 1. The composition of the brake material samples

Constituent	Mass (g)		
	B20	B30	B40
Phenolic resin	20	20	20
Steel fibre	5	5	5
Cashew dust	10	10	10
Brass particles	5	5	5
Graphite	5	5	5
Copper particles	7	7	7
Alumina	8	8	8
Barite	20	30	40

All constituents were weighed accurately using a precise analytical balance (DESIS NHB model). The raw material ingredients were mixed in a mixer for 10 min. The mix was pre-formed at room temperature under 8 MPa for 2 min and molded at 150°C under 10 MPa for 12 min.

2.2 Characterizations

Hardness testing was carried out on a Brinell hardness testing machine using a 62.5 kgf load and 2.5 mm steel ball to determine the hardness variation as a function of braking pad compositions. The surface of the specimens was carefully prepared, and each specimen was tested after production of each braking pad (The surface of the specimens was carefully prepared using SiC papers from coarse (180 grid) to fine (1.200 grid), and each specimen was tested after production.). At least five indentations were made from the center to the edge of the specimens to obtain an accurate value of the hardness for each specimen, and an average value was obtained. Experimental scatter was at most ±2 HB. Therefore, it was concluded that the alloys the braking pads were homogeneous.

The densities of samples were measured by Archimedes' method.

2.3 Temperature measurement

Counter disc temperature was measured during the tests by using non-contacting infrared (IR) thermometer. The thermometer is placed at approximately 2 cm away from the trailing edge of the brake lining samples.

2.4 Friction and wear tests

The pin-on-disc type test device shown in the Figure 1 schematically was used to examine the friction and wear properties of the developed composites. As a rotor, the disc made of cast iron was used. The data of the friction coefficients and specific wear rates of friction materials were obtained.

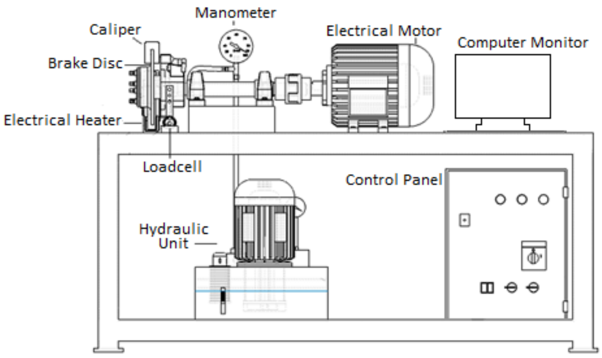

Fig. 1. Schematic of brake friction test equipment [10]

For each sample, three friction test procedures were applied, and the average of these three tests was recorded. The test machine uses a pearlitic gray cast iron disc (diameter of 180 mm, thickness of 38 mm) and a brake lining test sample with 25 mm diameter. The test sample was mounted on the load arm and pressed against the flat surface of the rotating disc. The rotating cast iron disc moved with a constant sliding speed of v = 6 m/s for 10 min, and the temperature was increased from 50°C to around 350°C. Before performing the friction testing, the surfaces of the test samples and the cast iron discs were ground with 320-grid sandpaper. The normal load was varied to achieve a constant friction force. The friction coefficient was calculated by measuring normal and tangential pressures every 5 s throughout the test of 10 min. From the values of the normal load applied on the pin f_n, and the frictional frictional force f_s measured by the pin-on-disc type test device, the friction coefficient μ is calculated as follow:

$$\mu = \frac{f_s}{f_n} \tag{1}$$

The weight and thickness of two pads and a disc for each sample were taken before and after the friction test. To obtain average thickness, six measurements (three at the beginning and three at the end) were taken at different locations on the pads and disc before and after the friction test.

Specific wear rate was determined in accordance to a TSE 555 [11] standard by using the following equation:

$$V = \frac{1}{2.\pi.R} \cdot \frac{m_1 - m_2}{n.f_s.\rho} \tag{2}$$

where V is the specific wear rate (cm^3/Nm), R is the distance between centers of the sample and the rotating disc (m), m_1 and m_2 are the average specimen weights before and after the test (g), respectively, n is the rotating number of disk, ρ is the density of the brake lining (g/cm^3), and f_s is the average frictional force (N).

Friction stability (%) was determined by using the following equation [12]:

$$FS = (\mu_{avg}/\mu_{max}) \times 100 \tag{3}$$

3 RESULTS AND DISCUSSION

Fig. 2, Fig. 3, and Fig. 4 show the changes in the coefficient of friction related to the time. The friction coefficient varied significantly in the initial stage of testing, as the size of the contact area increased, and the friction layer was developed on the surface [13].

In brake linings, heat is generated due to friction during braking. This heat increases the interface temperature, and this, in turn, decreases friction coefficient. Therefore, the decrease in the friction coefficient should be minimum for an effective braking [14-16].

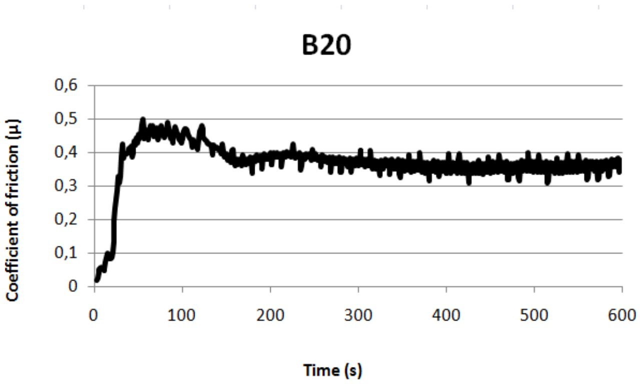

Fig. 2. The change of friction coefficient as a function of time for B20 sample

When friction test results are examined, it is seen that the average coefficient of friction of the sample containing 30 g barite is 0.369.

Ostermeyer [17] also reported that the friction coefficient decreases with increase in interface temperature.

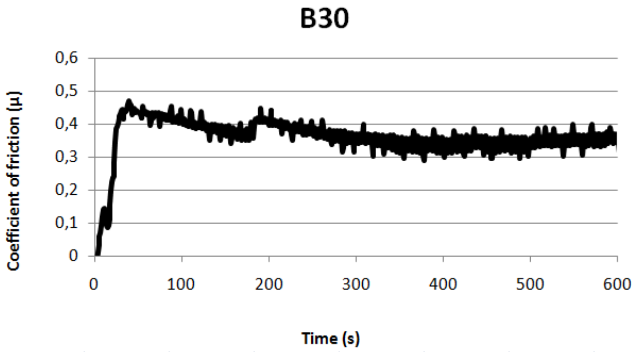

Fig. 3. The change of friction coefficient as a function of time for B30 sample

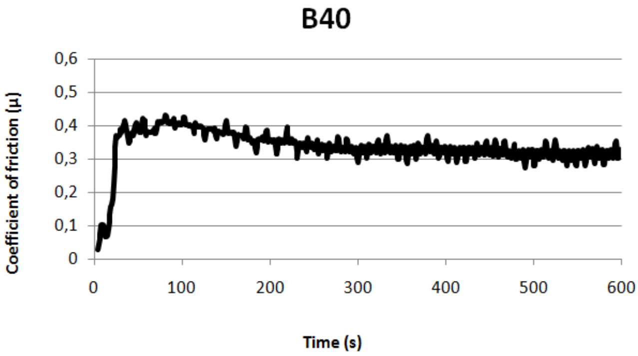

Fig. 4. The change of friction coefficient as a function of time for B40 sample

Fluctuations in the friction coefficient data in Fig. 2, Fig. 3, and Fig. 4 are observed, although these are not significant. Anderson [18] attributed these fluctuations to non-homogenous heat load on lining contact surface. That is because heat toward the center of the disc from the contact surfaces changes during the test period. Therefore, the friction coefficient changes continuously due to this effect. Stachowiak and Batchelor [19] explained this by sticking of the friction surfaces. The sticking surface slips after a while due to the relative movement, and therefore, this, in turn, results in changes in the friction coefficient.

The sample containing 20 g barite (B20) showed the highest values of μ while the sample containing 40 g barite (B40) showed the lowest values of μ.

The average coefficient of friction, specific wear rates and friction stabilities of samples are given in Table 2.

Table 2. Friction properties of the samples

Sample	Average coefficient of friction (μ_{ort})	Specific wear rate (cm^3/Nm)	Friction Stability (%)
B20	0.369	0.348×10^{-6}	69.6
B30	0.361	0.463×10^{-6}	72.1
B40	0.339	0.634×10^{-6}	53.2

It is stated in the literature that the friction coefficient (μ) generally varies between 0.1 and 0.7 depending on friction force and disc-lining interface temperature [20].

As can be seen from Table 2, an decrease in average coefficient of friction of the samples with increasing barite amount is observed

Magnitude of % friction stability should be as high as possible and near to 100. Slope and undulations in the curve should be minimum [12]. Temperature occurred on lining contact surface during the friction test affected friction stabilities of the samples.

No wearing cannot be expected from brake linings. Even if very high wear resistant materials are used, this results in wear on the counter surface. Therefore, a variation of the friction coefficient with the temperatures is considered to be much more important than the wear resistance in the friction materials [15].

Table 3 contains physical properties such as density and hardness.

Table 3. Physical properties of the samples

Sample	Density (g/cm^3)	Brinell hardness (HB)
B20	5.111	45
B30	4.791	42
B40	2.287	33

Almost all properties are correlated. If hardness is high, density increases. If barite amount high, average coefficient of friction tends to be low.

4 CONCLUSIONS

In this study, the effect of barite amount on the friction and wear behavior of brake pad is experimentally analyzed and the following conclusions can be drawn:

- Barite amount added to the brake lining materials influenced wear and friction behaviors of brake linings.
- In the specimens, the specific wear rate increased with decreasing density and hardness.
- If barite amount of the samples high, average coefficient of friction tends to be low.
- Temperature occurred on lining contact surface during the friction test affected friction stabilities of the samples.
- The highest friction coefficient was obtained in the sample called B20.
- The highest wear was obtained in the sample called B40.

REFERENCES

[1] Jayashree, Bijwe., (1997). Composites as friction materials: recent developments in non-asbestos fibre reinforced friction materials-A review. *Polymer Composites*, vol. 18, ISSN 0272-8397 p. 378–396.

[2] P. Filip, L. Kovarik, M.A. Wright, (1997). Automotive brake lining characterization, in: Proceedings of the 15th Annual SAE Brake Colloquium 1997, SAE, Warren- dale, PA, , p. 41–61.

[3] I. Mutlu, M.H. Alma, M.A. Basturk, C. Oner, (2005). Preparation and characterization of brake linings from modified tannin-phenol formaldehyde resin and asbestos-free fillers. *Journal of Material Science*, vol. 40, ISSN 0022-2461 p. 3003-3005.

[4] Q.F. Guan, G.Y. Li, H.Y. Wang, (2004). Friction-wear characteristics of carbon fiber reinforced friction material. *Journal of Material Science*, vol. 39, ISSN 0022-2461 p. 641-643.

[5] K.Pugh, (1991). Brake linings—the past,present and future, Industrial Minerals, p.49.

[6] Gurunath, P.V., Bijwe, J., (2007). Friction and wear studies on brake-pad materials based on newly developed resin. *Wear,* vol. 263 ISSN 0043-1648 p. 1212-1219.

[7] Ma, Y., Martynková, G. S., Valášková, M., Matějka, V., & Lu, Y. (2008). Effects of ZrSiO 4 in non-metallic brake friction materials on friction performance. *Tribology International*, vol. *41*(3), ISSN 0301-679X p. 166-174.

[8] Kim, S. J., Cho, M. H., Basch, R. H., Fash, J. W., & Jang, H. (2004). Tribological Properties of Polymer Composites Containing Barite (BaSO4) or Potassium Titanate (K2O· 6 (TiO2)). *Tribology Letters*, vol. 17(3), ISSN 1023-8883 p. 655-661.

[9] Y Handa, T. Kato, (1996). Effects of Cu powder $BaSO_4$ and cashew dust on the wear and friction characteristics of automotive brake pads. *Tribol. Trans.*, vol. 39 (2), ISSN 1040-2004 p. 346–353.

[10] Sugözü, I. (2015). Investigation of using rice husk dust and ulexite in automotive brake pads. *Materials Testing*, vol. 57(10), ISSN 0025-5300 p. 877-882.

[11] TS 555 (1992) Highway Vehicles - Brake System – Brake Pads for Friction Brake, TSE, Ankara, Turkey

[12] Bijwe, J., Aranganathan, N., Sharma, S., Dureja, N., & Kumar, R. (2012). Nano-abrasives in friction materials-influence on tribological properties. *Wear*, vol. 296(1), ISSN 0043-1648 p. 693-701.

[13] Filip, P., Weiss, Z. and Rafaja, D., (2002). On friction layer formation in polymer matrix composite materials for brake applications, *Wear*, vol. 252, ISSN 0043-1648 p. 189-198.

[14] Boz, M. and Kurt, A. (2006). The influence of stibium tri sulfut content on friction-wear behaviour of bronze-based friction materials. *Technology ZKU*, vol. 9, p. 79-90.

[15] Boz, M. and Kurt, A. (2007). The effect of Al2O3 on the friction performance of automotive brake friction materials. *Tribology International*, vol. 40, ISSN 0301-679X, p. 1161-1169.

[16] Tabor, D. (1996). Friction as a dissipated process. *Friction of Organic Polymers in Fundamentals of Friction, Macrosc Microsc Process*, Vol. 220 No. 3.

[17] Ostermeyer, G.P. (2003). On the dynamics of the friction coefficient. *Wear*, Vol. 254 No. 9, ISSN 0043-1648 p. 852-858.

[18] Anderson, A.E. (1992). Friction, lubrication and wear technology. *ASM Handbook*, Vol. 18, p. 569-577.

[19] Stachowiak, G.W. and Batchelor, A.W. (2001). *Engineering Tribology*, Heineman, Boston, MA, pp. 36-44.

[20] Ravikiran, A. and Jahanmir, S. (2001). Effect of contact pressure and load on wear of alumina. *Wear*, Vol. 251, ISSN 0043-1648, p. 980-984.

Authors addresses

[1]*Banu Sugözü, Effect of $BaSO_4$ on Tribological Properties of Brake Friction Materials, Institute of Natural and Applied Sciences, Selcuk University, Konya, Turkey, banusugozu@gmail.com*

[2]*Behcet Dağhan, Effect of $BaSO_4$ on Tribological Properties of Brake Friction Materials, Department of Mechanical Engineering, Faculty of Engineering, Selcuk University, Konya, Turkey, bdaghan@selcuk.edu.tr*

Contact person

[*] *Banu Sugözü, Effect of $BaSO_4$ on Tribological Properties of Brake Friction Materials, Institute of Natural and Applied Sciences, Selcuk University, Konya, Turkey, banusugozu@gmail.com*