

Investigation of Using Brass Particles In Automotive Brake Linings*

İlker Sugözü

Assistant Professor, Department of Automotive Engineering, Technology Faculty, Mersin University, Mersin, Turkey

ABSTRACT: An experimental investigation was carried out to examine the tribological behaviour of NAO (non-asbestos organic) type brake linings containing brass particles of varying amount. Brake linings with increasing content of brass particles (5%, 10% and 15% wt.) were prepared and produced by powder metallurgy technique. The samples has been tested under Friction Assessment and Screening Test (FAST). In this experimental study, the change of friction coefficient, the temperature of friction surface and the amount of wear were measured. The hardness and density of the samples were also determined. The results of tests showed that amount of brass particles on brake friction composites influenced the friction coefficient and specific wear ratio substantially.

KEYWORDS: Brass particles, Brake lining, Friction, Wear.

I. INTRODUCTION

Automotive friction materials have been formulated for about 100 years [1]. In the early 1920s, asbestos fiber was chosen as a friction material for use in all kinds of vehicles. Nowadays however non-asbestos (NAO) formula becomes mainstream to overcome the negative effect of asbestos on human respiratory system. A typical brake lining formula includes phenolic resin mixed with metal powder, inorganic fillers and fibers [2].

The brakes require the friction materials (FMs) with higher and stable friction coefficient (μ), low wear rate, no noise, low cost, and environment friendly. In order to realize the requirements, the researches on the selection of raw materials and optimization of friction formulations have been done [3,4].

Amongst the ingredients are metallic fillers such as copper, brass, iron etc., which are very important in FMs and are added in various shapes, sizes, amounts and combinations basically to improve the thermo-physical properties [5]. These metallic fillers, however, influence the overall friction and wear properties of FM [6-16].

Kumar and Bijwe [6] studied the sensitivity of friction (μ) towards braking pressure and sliding speed of selected composites based on variation in an inclusion of metallic fillers, viz. brass, copper and iron. They reported that among metallic fillers, copper powder proved very effective in reducing μ -sensitivity to dynamic variations in pressure and speed. Kumar and Bijwe [7] studied the influence of metallic contents on temperature sensitivity of friction composites on reduced scale prototype. They developed three friction composites with identical parent composition (90% by wt.) except metallic filler viz. brass, copper and iron powder (10% by wt.). One more was developed without metallic powder by adjusting 10% amount with barite (space filler). They characterized for physical, chemical and mechanical properties of all composites. They also tribo-tested wear, fade and recovery behavior of all composites. They concluded that with use of metal contents, friction and wear performance of composites improved in general. Kumar and Bijwe [13] studied very systematic and in depth investigations on these aspects by investigating the role of three different metallic fillers with variation in amount, shape, and size on the performance properties of NAO brake-pad materials. They developed composites in such a way that the variation in metallic fillers was managed as; three types (copper, brass and iron) and three amounts (0, 10 and 20 wt%). They characterized for physical, thermal, mechanical and tribological properties of all composites (on brake inertia dynamometer) as per the standard industrial practice.

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They observed that the inclusion of metallic fillers enhanced the performance properties of composites significantly. It was reported that improved thermo-physical properties especially thermal conductivity of composites played an important role in the performance properties as copper powder based composites showed best tribo-behavior followed by brass and iron powder.

In this study, the three different friction materials containing three amounts (5, 10 and 15 wt.%) brass particles were produced and investigated for tribological properties. It was observed that the amount of brass particles affected the performance properties of composites.

II. MATERIALS AND METHODOLOGY

Friction material specimens for this experiment were manufactured based on a typical non-asbestos organic (NAO)-type formulation. The friction material specimens contained a binder, reinforcements, friction modifier, etc., as shown in Table 1, and they were fabricated using a typical manufacturing process for NAO brake pads [17,18]. The prepared composites were designated as B5, B10 and B15.

Table 1. The composition of the brake material samples

Constituent	Weight percent (%)		
	B5	B10	B15
Phenolic resin	20	20	20
Steel fibre	5	5	5
Cashew dust	10	10	10
Brass particles	5	10	15
Graphite	5	5	5
Copper particles	8	8	8
Alumina	8	8	8
Barite	39	34	29
TOTAL	100	100	100

Friction material specimens were produced by a conventional procedure for a dry formulation following dry-mixing, pre-forming hot pressing, scratching and grinding. The size of the brake pad was approximately $\text{Ø}25.4 \times 9$ mm. Three tests were run of each material for each test conditions and average values were reported here. A schematic diagram of the friction tester and its contact geometry has been previously published [18].

Figure 1 shows the disc test equipment used in this study. To define friction coefficients of automotive brake pad under different temperatures, a test device was designed and manufactured. The detailed test equipment is shown in Figure 1.

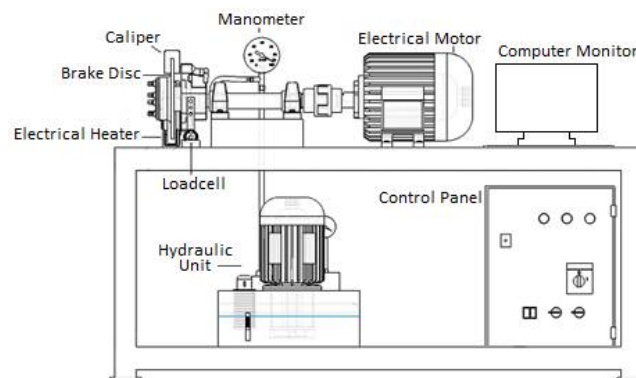


Fig. 1. Schematic of brake friction test equipment[19]

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Using a real brake disc-type tester, the friction coefficient characteristics of the pad next to the disc made of cast iron were investigated by changing the pad. The test sample was mounted on the hydraulic pressure and pressed against the flat surface of the rotating disc. Before performing the friction coefficient test, 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. Braking tests were carried out under 1050 kPa pressure, 6 m/s sliding speed and at temperatures from 50 to 400°C for 600 s. Electrical heater was used to achieve 400°C in friction surface temperature. The temperature and friction coefficient values were stored in a databank. Friction coefficients–temperature–time graphs are obtained to identify the effect of these variables [20].

A pad-on-disk test equipment was used, and the counterface was cast iron. The grey cast iron disc specimens had a composition of Fe-3,40 per cent C-2,20 per cent Si-0,60 per cent Mn-0,15 per cent S-1,05 per cent P. Disc samples of 22.7 cm in diameter and 0.975 cm in thickness were obtained from a domestic company in Turkey. The roughness of cast iron disc was also Ra=1.40 μm. The Brinell hardness of the disc samples was 191.13 kgf/mm² using 5-mm ball and 1,471 kN (150 kgf) load [20].

From the values of the normal load applied on the pin f_n , and the frictional force f_s measured by the pin-on-disc type test device, the friction coefficient μ is calculated as follow:

$$\mu = \frac{f_s}{f_n} \quad (1)$$

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 [21] standard by using the following equation:

$$V = \frac{1}{2 \cdot \pi \cdot R} \cdot \frac{m_1 - m_2}{n \cdot f_s \cdot \rho} \quad (2)$$

where V is the specific wear rate (cm³/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/cm³), and f_s is the average frictional force (N).

Friction stability (%) was determined by using the following equation [22]:

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

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 density of the specimens was determined based on Archimedean principle in water.

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.

III. RESULTS AND DISCUSSION

The coefficient of friction μ varied significantly in the initial stage of testing, since the size of the contact area increased and the friction layer was developed on the surface [23]. The characteristic time dependences of the coefficient of friction as detected in pin-on-disc type tribometer for all samples are shown in the Figures 2 to 4.

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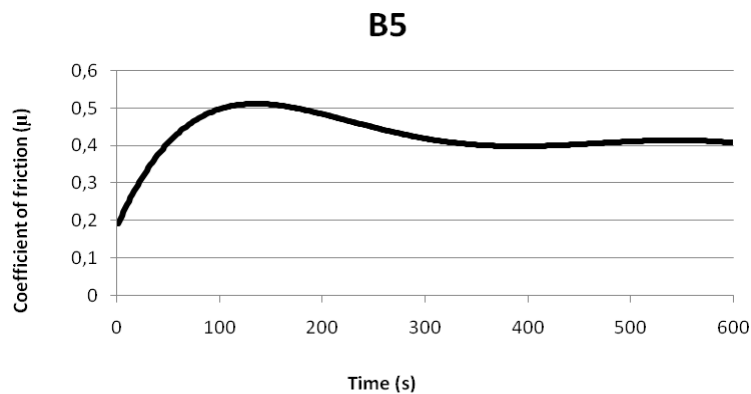


Fig. 2. The change of friction coefficient as a function of time for B5 sample

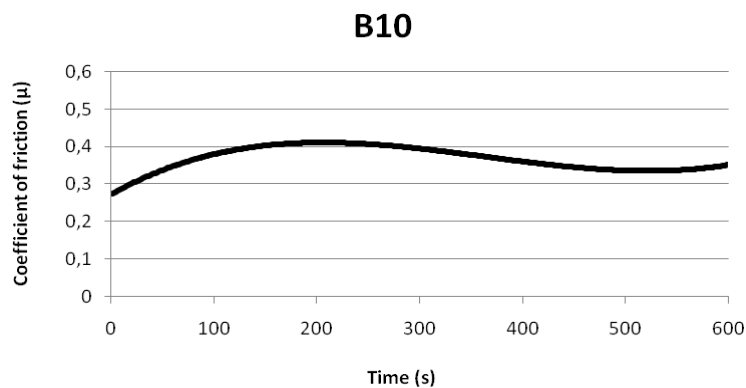


Fig. 3. The change of friction coefficient as a function of time for B10 sample

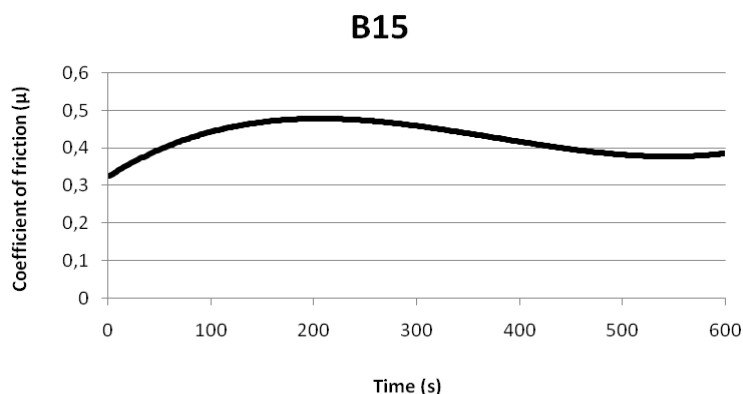


Fig. 4. The change of friction coefficient as a function of time for B15 sample

Ostermeyer [24] reported that the friction coefficient decreases with increase in interface temperature. Fluctuations in the friction coefficient data in Fig. 2, Fig. 3, and Fig. 4 are observed, although these are not significant. Anderson [25] 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

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continuously due to this effect. Stachowiak and Batchelor [26] 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 friction properties of samples are given in Table 2. The sample containing 5 wt.% brass particles (B5) showed the highest values of μ while the sample containing 15 wt.% brass particles (B15) showed the lowest values of μ .

Table 2. Friction properties of the samples

Sample	Average coefficient of friction (μ_{ort})	Specific wear rate (cm^3/Nm)	Friction Stability (%)
B5	0.424	1.952×10^{-6}	75.7
B10	0.368	1.448×10^{-6}	78.3
B15	0.359	1.438×10^{-6}	81.7

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 [27].

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

Temperature occurred on lining contact surface during the friction test affected friction stabilities of the samples. Magnitude of % friction stability should be as high as possible and near to 100. Slope and undulations in the curve should be minimum [22].

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 [28].

The physical properties of samples are given in Table 3. Almost all properties are well correlated. If hardness is high, density increases. If brass amount high, average coefficient of friction tends to be low.

Table 3. Physical properties of the samples

Sample	Density (g/cm^3)	Brinell hardness (HB)
B5	2.265	35
B10	2.126	33
B15	1.673	28

IV. CONCLUSIONS

Three brake lining composites were developed using brass particles (5, 10, 15 wt.%). Based on tribological performance evaluation on a pin-on-disc type friction tester. From the present work, the following conclusions can be drawn:

- The highest friction coefficient was obtained in the sample containing 5 wt.% brass particles while the lowest specific wear rate was obtained in the sample containing 15 wt.% brass particles.
- The specific wear rate increased with increasing density and hardness for all samples.
- Temperature occurred on lining contact surface during the friction test affected friction stabilities of the samples.
- If brass amount of the samples high, average coefficient of friction tends to be low. Brass particles amount added to the brake lining materials influenced wear and friction behaviors of brake linings.

REFERENCES

- [1] G. Nicholson, (1995). Facts about Friction: 100 years of Brake Linings & Clutch Facings, Geodoran America, Winchester, VA.
- [2] Liu, Y., Fan, Z., Ma, H., Tan, Y., & Qiao, J. (2006). Application of nano powdered rubber in friction materials. *Wear*, 261(2), ISSN 0043-1648 p. 225-229.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Special Issue 12, May 2016

- [3] Lu Y, Tang C.F, Zhao Y, Wright M.A. (2004). Optimization of a semimetallic friction material formulation. *J Reinf Plast Compos*, vol. 23, p. 1537– 45.
- [4] Lu Y. A., (2003). Golden Section approach to optimization of automotive friction materials. *J Mater Sci*, vol. 38:1081– 5.
- [5] Sharma, S., Bijwe, J., & Kumar, M. (2013). Comparison between nano-and micro-sized copper particles as fillers in NAO friction materials. *Nanomaterials and Nanotechnology*, 3 (Godište 2013), 3-12.
- [6] H. Jang, K. Koa, S.J. Kim, R.H. Basch, J.W. Fash, (2004). The effect of metal fibers on the friction performance of automotive brake friction materials. *Wear*, ISSN 0043-1648 vol. 256, p. 406-414.
- [7] S.C. Ho, J.H.C. Cu Lin, (2005). Effect of fiber addition on mechanical and tribological properties of a copper/phenolic-based friction material. *Wear*, vol. 258, ISSN 0043-1648 p. 861-869.
- [8] M. Kumar, J. Bijwe, (2011). Composite friction materials based on metallic fillers: sensitivity of μ to operating variables. *Tribology International*, vol. 44, ISSN 0301-679X, p. 106- 113.
- [9] M. Kumar, J. Bijwe, (2010). Studies on reduced scale tribometer to investigate the effect of metal additives on friction coefficient-temperature sensitivity in brake materials. *Wear*, vol. 269, ISSN 0043-1648 p. 838-846.
- [10] M. Kumar, J. Bijwe, (2010). Role of different metallic fillers in non-asbestos organic (NAO) friction composites for controlling sensitivity of coefficient of friction to load and speed. *Tribology International*, vol. 43, ISSN 0301-679X, p. 965-974.
- [11] M. Kumar, J. Bijwe, (2010). NAO friction materials with various metal Powders: tribological evaluation on full scale inertia dynamometer. *Wear* vol. 269, ISSN 0043-1648 p. 826 -837.
- [12] M. Kumar, J. Bijwe, (2011). Non-asbestos organic (NAO) friction composites: role of copper; its shape and amount. *Wear*, vol. 270, ISSN 0043-1648 p. 269-280.
- [13] M. Kumar, J. Bijwe, (2013). Optimized selection of metallic fillers for best combination of performance properties of friction materials: a comprehensive study. *Wear*, vol. 303, ISSN 0043-1648 p. 569-583.
- [14] X. Qu, L. Zhang, H. Ding, G. Liu, (2004) The effect of steel fiber orientation on frictional properties of asbestosfree friction materials. *Polymer Composites*, vol. 25, ISSN 0272-8397 p. 94-101.
- [15] Y. Handa, T. Kato, (2006). Effects of Cu powder BaSO₄ and cashew dust on the wear and friction characteristic of automotive brake pads. *Tribology Transactions*, vol. 39, ISSN 1040-2004 p. 346-353.
- [16] W. Österle, C. Prietzel, H. Kloß, A.I. Dmitriev, (2010). On the role of copper in brake friction materials. *Tribology International*, vol. 43, ISSN 0301-679X, p. 2317–2326.
- [17] M.G. Jacko, S.K. Rhee, (1992). Brake linings and clutch facings in: Kirk–Othmer Encyclopedia of Chemical Technology (fourth ed.), p. 523–536 ISBN 9780471238966
- [18] Kim, S.J. and Jang, H. (2000). Friction and wear of friction materials containing two different phenolic resins reinforced with aramid pulp. *Tribology International*, Vol. 33 No. 7, ISSN 0301-679X, p. 477-484.
- [19] 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.
- [20] Sugoza, I., mutlu, I., & Sugoza, K. B. (2016). The effect of Colemanite on the friction performance of automotive brake friction materials. *Industrial Lubrication and Tribology*, vol. 68(1) ISSN: 0036-8792 p.92-98.
- [21] TS 555 (1992) Highway Vehicles - Brake System – Brake Pads for Friction Brake, TSE, Ankara, Turkey
- [22] 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.
- [23] D. Gultekin, M. Uysal, S. Aslan, M. Alaf, M. O. Guler, H. Akbulut, (2010). The effects of applied load on the coefficient of friction in Cu-MMC brake pad/Al-SiCp mmC brake disc system. *Wear*, vol. 270, No. 1-2, ISSN 0043-1648 p. 73-82.
- [24] Ostermeyer, G.P. (2003). On the dynamics of the friction coefficient. *Wear*, Vol. 254 No. 9, ISSN 0043-1648 p. 852-858.
- [25] Anderson, A.E. (1992). Friction, lubrication and wear technology. *ASM Handbook*, Vol. 18, p. 569-577.
- [26] Stachowiak, G.W. and Batchelor, A.W. (2001). *Engineering Tribology*, Heineman, Boston, MA, pp. 36-44.
- [27] 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.
- [28] 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.