EFFECT OF ZIRCON ON THE FRICTION PERFORMANCE OF AUTOMOTIVE BRAKE LINING MATERIALS

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ABSTRACT

In this study the effects of zircon particles on the friction-wear properties of brake lining materials are investigated. Three new automotive brake friction materials were developed containing 5, 10, 15 wt.% zircon particles and then their tribological properties were examined using a pad-on-disc-type wear tester. Friction and wear characteristics of the specimens against to a disk made of cast iron were studied. Zircon particles improved friction stability and fade resistance.

Key words: Brake lining, Friction, Wear, Zircon

1. INTRODUCTION

Non-asbestos organic friction materials are widely used in automobiles and locomotives as brake linings, brake shoes, brake pads, brake blocks and clutch facings. Performance requirements of the friction materials are very complex and contradictory [1].

Brake friction materials are multi-component composites composed of several basic functional parts abrasives, lubricants, space fillers, fiber or pulp reinforcements, and polymer binders [2].

Abrasive particles are included in the brake linings to control the level of the friction force and to remove pyrolized friction films at the sliding interface [3–5]. It is also known that abrasive particles are closely related to brake noise since they directly abrade the disk surface and play a crucial role in the formation of friction film that can attenuate friction excitation generated at the sliding interface [6].

Abrasives are the ingredients that have higher mohs hardness. Abrasives, classified as functional fillers, are being added to friction composites formulation to increase the friction coefficient and to keep its value stable at higher temperatures. Most commonly used abrasives in brake friction materials are zircon ($ZrSiO_4$), alumina (Al_2O_3), silicon dioxide (SiO_2), silicon carbide (SiC) and zirconia (ZrO_2). Hardness, morphology (particle shape), particle size, and distribution of abrasives in friction composite are the main factors affecting the friction performance of brake friction materials. The selection of abrasives should meet the requirements on service, cost and safety. The comparison of four common abrasives (SiC, ZrO_2, Al_2O_3 and SiO_2) in term of their effect on wear of non-asbestos friction composites is furnished in [7].

In this study, three non-asbestos friction composites were developed in order to understand the effects of zircon particles on the performance properties. The wear test was performed under dry sliding conditions at room temperature using a test equipment. The results showed that zircon dust improved friction stability and fade resistance.

2. EXPERIMENTAL PROCEDURE

In this study, three new automotive brake friction materials were developed containing 5, 10, 15 wt.% zircon particles and then their tribological properties were examined using a pad-on-disc-type wear tester.

Friction and wear characteristics of the specimens against to a disk made of cast iron were studied. The samples were produced by a conventional procedure for a dry formulation following dry-mixing, pre-forming and hot pressing. First, all components were weighed using a precision balance. The combinations were dry-mixed using a blender in order to achieve a homogeneous state ready for molding. Then the mixture was put into 25,4 mm diameter mold for pre-forming under 10000 kPa at room temperature for 2 minute and molded at 180ºC under 15000 kPa for 10 minute. During the hot pressing process, pressure was released several times to release the gases that evolved from the cross linking reaction (polycondensation) of the phenolic resin. The composition of the friction materials produced in this study is shown in Table 1. Sample codes called Z5, Z10, Z15 represent samples containing (5, 10, 15 wt.%) zircon particles respectively.

Table 1. Formulations of the prepared friction materials (weight %)

Ingredients	Z5	Z10	Z15
Phenolic resin	20	20	20
Steel Fibers	12	12	12
Cashew	8	8	8
Brass Particle	5	5	5
Al_2O_3	5	5	5
Cu particles	8	8	8
Graphite	5	5	5
Barite	32	27	22
Zircon	5	10	15
TOTAL	100	100	100

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

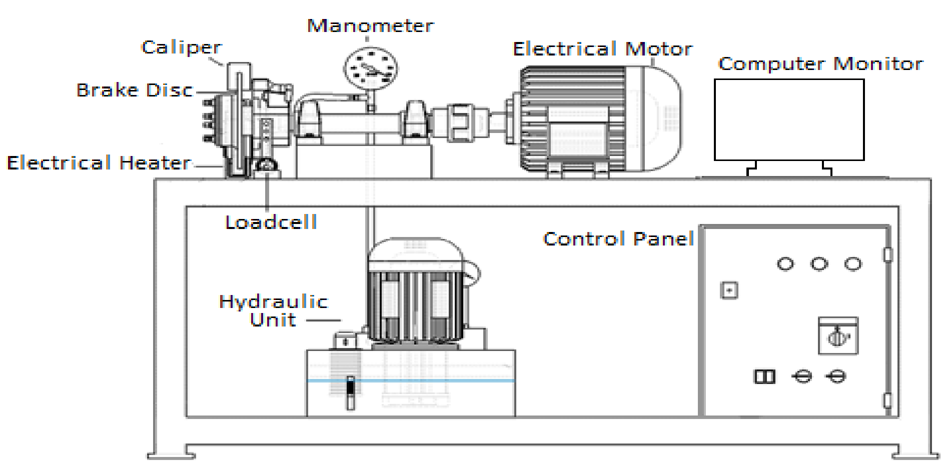

Figure 1. The test equipment

The friction tests were performed using the Friction Assessment and Screening Test (FAST) machine for each material. For each sample, three friction test procedures were applied and the average of these three tests was recorded. For comparison purposes, FAST testing was also repeated with samples obtained. The FAST machine uses a pearlitic gray cast iron disc (diameter of 180 mm, thickness 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 = 7 m/s and the temperature was increased from 50 °C temperature to around 350 °C. Before performing the FAST 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 seconds. The weight and thickness of two pads and a disc for each sample were taken before and after the friction test. In order 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. Wear rate was calculated as weight loss for per mm^2 of the sample during the tests.

Specific wear rate is determined by the mass method following British Standard (BS AU142) and the Turkish Standard (TS 555) and calculated by the following equation:

$$V = \frac{m_1 - m_2}{2 \times \pi \times R_d \times n \times f_m \times \rho} \tag{1}$$

and here, n is total revolution, f_m is average friction force (N), R_d is radius of disc (m), ρ is density of brake lining (g/cm^3), m_2 is mass of brake lining after testing (g), m_1 is mass of brake lining before testing (g), V is specific wear (cm^3/N.m) [8].

In order to confirm uniform mixing and proper curing during manufacturing, the distribution of surface hardness was measured using a Brinell hardness tester. 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. 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.

3. RESULTS AND DISCUSSION

Obtained friction coefficient (μ) properties of tested samples are shown in Figure 2. The friction coefficient 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 [9].

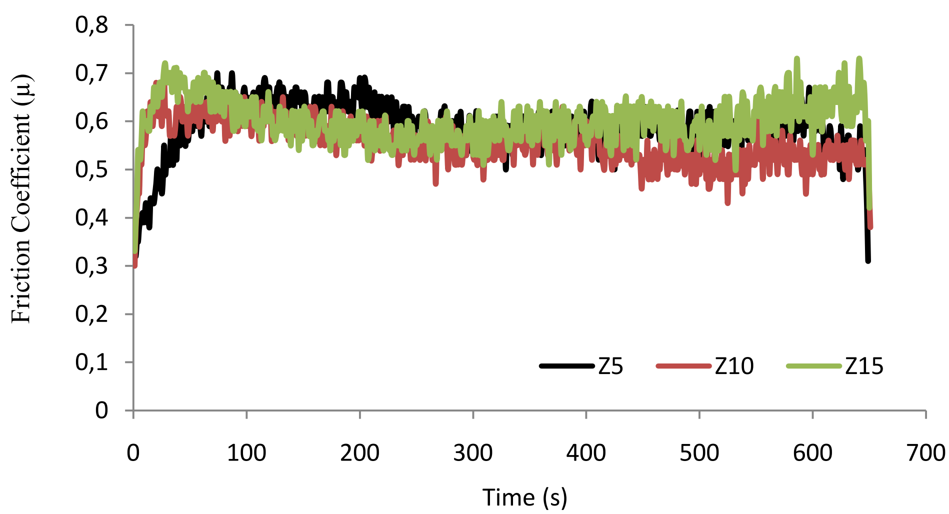

Figure 2. The change of friction coefficient for samples Z5, Z10, and Z15

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 friction coefficient should be minimum for an effective braking [10-12].

It is stated in the literature that friction coefficient (μ) generally varies between 0.1 and 0.7 depending on friction force and disc-lining interface temperature (Ravikiran and Jahanmir, 2001). In addition, it is stated in SAE-J661 that disc-lining interface temperature is about 300–350°C [12; 13].

Fluctuations in friction coefficient data in Figure 2 are observed although these are not significant. In a previous study, Anderson [14] attributed these fluctuations to non-homogenous heat load on lining contact surface. That is because, heat towards the centre of the disc from the contact surfaces changes during the test period. Therefore, friction coefficient changes continuously due to this effect. Stachowiak and Batchelor [15] 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 [12; 13].

Table 2 summarizes the hardness, density, wear and friction coefficient data (average wear percentage of three tests for each brake lining sample) as measured for three investigated brake lining samples. Sample Z15 exhibited the highest wear when compared to samples. In addition, increase of friction coefficient and specific wear ratio of the test specimens depending on the zircon amount is also seen.

Table 2. Properties of the developed composites

Sample Code	Brinell Hardness	Density [$g \times cm^{-3}$]	Friction Coefficient (μ)	Specific Wear Ratio ($x10^{-6}$) [$cm^3 \times N.m^{-1}$]
Z5	36,192	2,369	0,557	0,268
Z10	37,103	2,387	0,589	0,292
Z15	40,179	2,456	0,6	0,312

4. CONCLUSIONS

Friction characteristics of abrasives in the brake linings were investigated by using three new automotive brake friction materials containing 5, 10, 15 wt.% zircon particles. Friction tests were carried out in a pad-on-disk friction tester using gray iron disks. From the present work, the following conclusions can be drawn:

- The value of friction coefficient is significantly enhanced with the presence of zircon abrasive. The sample containing 15 wt.% zircon particles showed the most stable friction coefficient. With respect to these observations, Z15 presents the most favorable formulation.
- The specific wear rate increase with the growing of zircon particles and the lowest value was observed at the sample Z5 abrasive. Among the samples with zircon particles the most resistant to wear is the sample called Z15.
- The highest friction coefficient was obtained in the sample containing 15 wt.% zircon particles. This sample showed stable friction coefficient.

From the results summarized above the formulation zircon is preferred for utilization as automobile brake lining.

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