# INVESTIGATION OF USING ZEOLITE IN AUTOMOTIVE BRAKE LININGS

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## ABSTRACT

Zeolite based brake linings, were produced by powder metallurgy technique and their wear behaviour was investigated. Newly formulated brake pad material with three different ingredients 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 friction coefficient of tested brake linings increased with increase in zeolite rate. The results also indicated that the friction coefficient and specific wear rate of the composites increased with increasing zeolite content. The worn surfaces and wear debris of the composites increased with increasing zeolite content.

**Key Words:** Zeolite, Brake lining, Friction, Wear

## 1. INTRODUCTION

Automotive brake friction materials are basically multicomponent composite materials and should satisfy various requirements, including having a stable coefficient of friction (COF), good wear resistance, small wear to the counterparts, no noise, low cost, environmentally friendly, and reliable strength under a broad range of loading conditions [1]. In this study, friction characteristics of lubrication (graphite) were investigated. Eight different ingredients have been tested under Friction Assessment and Screening Test (FAST). We focused on the change of the average friction coefficient, fade, and wear rate as a function of the relative amount of the ingredient.

The performance of the friction material is strongly affected by selection of the ingredients. Though many ingredients are used for the formulation of such composites, these are mainly classified into four major categories, viz. binder, reinforcing fibers, fillers, and friction modifiers [2].

Friction modifiers are the components added to brake friction materials in order to achieve outstanding brake performance. They are classified into two main classes, namely, solid lubricants and abrasives, which are crucial friction modifiers and play important roles in brake performance [3].

In this work, the tribological performance of brake friction materials containing different types and relative amounts of zeolite was investigated using a type friction tester according to SAE J661 [4]. We focused on friction stability and specific wear rates of the friction materials according to the different types.

## 2. EXPERIMENTAL PROCEDURE

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, lubrication etc., as shown in Table 1, and they were fabricated using a typical manufacturing process for NAO brake pads [5]. 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 min and molded at 180ºC under 15000 kPa for 10 min.

Friction material specimens were produced by a conventional procedure for a dry formulation following dry-mixing, pre-forming hot pressing, post-curing, scratching, and grinding. The size of the brake pad was approximately 25.4 x 10 mm (and had a slot in a vertical direction in the center). 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 [6].

**Table 1**. The amount of ingredients used for friction materials (weight %)

| **Ingredients** | **ZT5** | **ZT10** | **ZT15** |
|---|---|---|---|
| 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 |
| Zeolite | 5 | 10 | 15 |
| Total | 100 | 100 | 100 |

The friction and wear behaviors of the automotive brake friction composites were determined using a friction material testing machine (Fig. 1) using the brake lining quality test procedure as per SAE J661.In order 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.

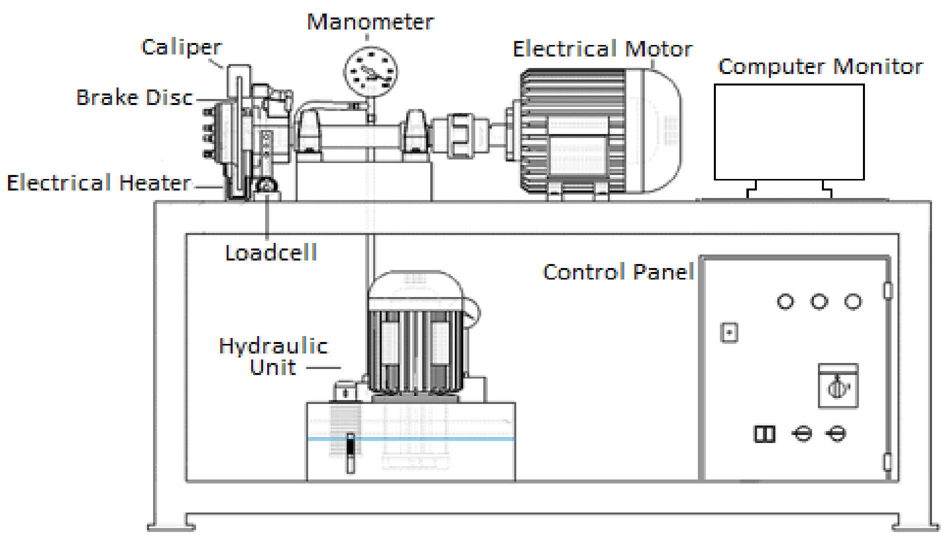


**Figure 1**. The disc test equipment used in this study

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 experiments were carried out a constant friction force. Braking tests were carried out under 1050 kPa pressure, 6 m/s velocity for 600 s. The friction coefficient values were stored in a databank. The tests were repeated three times for each sample. The friction coefficients-time graphs are obtained to identify the effect of these variables.

In the braking tests, 1050 kPa pressure was used and also friction coefficients were calculated for each second. In wear test, braking pads were tested 6 m/s sliding speed, 18.7 cm average frictional diameter and 3600 m path. By weighing the peaks to determine loss of mass in braking pads, wear amount was calculated for each experiment. A pad-on-disk test rig was used, and the counterface was cast iron. The gray cast iron disc specimens had a composition of Fe-3,40C-2,20Si-0,60Mn-0,15S-1,05P. 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 x $mm^{-2}$ using 5 mm ball and 1,471 kN (150 kgf) load. In order to understand the wear behavior of the samples, specific wear is determined to the mass method following the standard of TS 555 and calculated by the following equation:

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

with V: Specific wear [$cm^3$ x $Nm^{-1}$], $m_1$: Mass of brake lining before testing [g], $m_2$: Mass of brake lining after testing [g], ρ: Density of brake lining [g x $cm^{-3}$], Rd: Radius of disc [m], fm: Average friction force [N], n: Total revolution [7].

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

The coefficient of friction of a brake friction material is an important parameter affecting brake performance and can be used to understand various braking phenomena such as stopping distance, fade, noise propensity, pedal feel, and brake-induced vibration [8]. In this study, experiments were carried out to determine the effect of relative amount of zeolite on the change in the coefficient of friction as a function of time, the average the coefficient of friction, and the change in the coefficient of friction.

In series ZT composites, the coefficient of friction of the composites showed a sharp increase after about $100^{th}$ second. The coefficient of friction of the ZT15 sample remained approximately constant at $150^{th}$–$300^{th}$ second. In series ZT composites, the coefficient of friction of the composites generally increased except for ZT5 and ZT10. The coefficient of friction of sample ZT10 increased up to about $100^{th}$ second and decreased continuously above this time (Fig. 2).

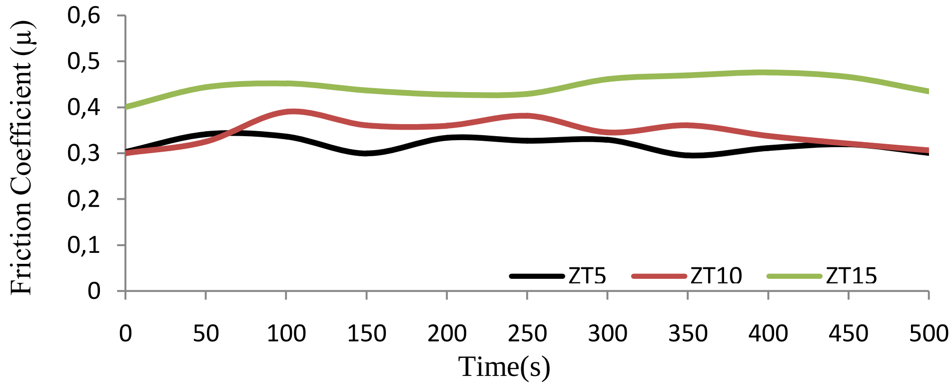


**Figure 2**. Change in the coefficient of friction as a function of time

It is seen from this figure that μ was firstly increased in all samples after it slowly decreased. When Figure 2 is examined, it is seen that the 5% zeolite (ZT5) added specimen resulted in friction coefficient of 0.31 while the 15% zeolite (ZT15) added specimen resulted in 0.44 at $0^{th} \div 600^{th}$ second. Rapid increase or decrease in μ has lead to a rapid increase in temperature on the surface of friction. Ostermeyer also reported that friction coefficient decreases with increase in interface temperature [9].

Table 2 presents the mean coefficient of friction, hardness, density and specific wear of the sample during the tests for 600 seconds. The friction coefficient of surface material couple is desired to be high and stable. As apparent from Table 2, since wear was very small, wear was measured before and after friction test, and wear rates were calculated as a mean value of the weight reduction in three samples.

**Table 2.** Typical characteristics of the brake pad

| **Sample code** | **Brinell hardness (HB)** | **Density [$g \times cm^{-3}$]** | **Specific wear ratio ($x10^{-6}$) [$cm^3 \times Nm^{-1}$]** | **Friction coefficient** |
|---|---|---|---|---|
| ZT5 | 30,3 | 1,67 | 0,112 | 0,317 |
| ZT10 | 39,8 | 1,74 | 0,125 | 0,346 |
| ZT15 | 42,9 | 2,17 | 0,147 | 0,445 |

Wear depends on many factors, such as temperature, sliding distance, applied load, speed, properties of mating materials, and durability of the transfer layer. The wear of a multiphase friction material is a result of damage to the ingredients and its conversion to wear debris with subsequent disposal from the interface [10]. The specific wear rate of the composites was found to increase with increasing zeolite. The specific wear rates of samples were approximately equal.

## 4. CONCLUSIONS

The tribological performance of brake friction materials containing different types and relative amounts of zeolite was investigated using a friction tester machine according to SAE J661. From the tribological tests, the following conclusions were drawn.

- The highest coefficient of friction values was obtained in composite containing ZT15 and ZT5 showed the best wear resistance at the contents.
- It was observed that the addition of the zeolite powder in the samples increased coefficient of friction.

- The highest friction coefficient was obtained in the samples containing zeolite in the range of 15% in during friction.
- The worn surfaces and wear debris increased with increasing the amount of zeolite.
- The highest wear was obtained in the sample containing 15% zeolite, wear resistance of the samples increased with decreasing the amount of zeolite.

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