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Effect of Ulexiteand Boric acid on the friction characteristics of non-asbestos brakepad

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Abstract
Brake pads are used to slow down or stop the vehicle by applying force to the disc surface. The most important parameter in brake pad is friction coefficient. The higher the friction coefficient, the shorter the braking distance will be. Different materials are used to increase the friction performance of the brake pad. A limited number of studies have been carried out to increase the friction performance of brake pads by using boron mineral with high temperature resistance. In this study, brake pad was produced by using boron mineral ulexite and boric acid and its effect on braking performance was investigated. Four different brake pad samples containing 1%, 3%, 5%, 7% ulexite and boric acid were produced by powder metallurgy method. Production parameters are the same for all brake pad samples. The specific wear rate and friction coefficient of the brake pad samples were obtained with a pin-on-disc type tribometer using a gray cast iron disc. The hardness and density values of the brake pad samples were determined and compared with each other. When compared with the literature data, it has been observed that the use of ulexite and boric acid in brake pad composites significantly and beneficially affects braking performance. In addition, it has been observed that the amount of ulexite and boric acid used has a positive effect on the wear and friction properties of brake pads.
Keywords: *Ulexite,Boric acid, Brake pad, Tribology*

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I. Introduction

It has been determined that asbestos used in vehicle brake pads is harmful to health [1-3]. After the determination that asbestos is harmful to health, the search for alternative materials to asbestos has increased. Studies are carried out on friction materials that can exhibit high performance and do not harm human health as an alternative to asbestos.Organic polymer-based brake pad materials are widely used in automobile brake systems [4-6]. Composite friction materials generally consist of 10 to 20 different components. These components are divided into five different groups in terms of function: structural, binders, fillers, lubricants and friction modifiers [7, 8]. The main purpose of using filler material is to reduce the cost and at the same time increase the manufacturability. The most commonly used minerals are givenvermiculiteand mica. In addition, calcium carbonate, barite mineral and gypsum are other common filling materials. Structural materials form mechanical strength, hardness, thermal stability, wear resistance and stable friction in friction materials. Generally, steel wool, rock wool, glass wool, ceramic and kevlar fibers are used alone or in combination [9]. Binders are used to hold together all the compounds that make up the friction composite material and to form a thermally stable matrix. Phenolic resin, rubber or cashew nut shell liquid modified phenolic resins are widely used [10]. Lubricants have many benefits such as stabilizing the friction coefficient at high temperatures, providing wear control between the brake pad and disc, damping vibration and reducing noise. Graphite, coke, molybdenum disulfide and antimony are commonly used [11]. Friction modifiers are added to the brake disc and brake pad interface to obtain a high and stable friction feature. Although abrasives such as zirconium oxide, zirconium silicate, silicon carbide, aluminum oxide increase the friction coefficient, they increase disc wear if suitable lubricants and structures are not used. In addition, they provide a better friction surface by removing unwanted surface films and iron oxides on the disc surface [12-14].

Boron is one of the most important materials in terms of industrial raw materials and ranks first in the world in terms of mineral reserves, diversity and properties.Although there are more than 150 boron minerals in nature, the main ones with economic importance are Tinkal, Colemanite, Boric acid, Borax and Ulexite. Those with sodium origin are called Tincal, those with calcium origin are called Colemanite, and those with sodium calcium origin are called Ulexite [15].

The increasing use of boron in industrial areas requiring advanced technology increases the use and value of boron as a raw material. Various boron derivatives of boron are used in more than 250 fields. The most important usage areas are detergent, glass, ceramics, agriculture and textile industry and the consumption in these areas covers approximately 80% of the total consumption [16].

The use of boron products with high melting temperatures is becoming widespread in areas with high operating temperatures [17].Brake pads are exposed to high temperatures as a result of the friction of the brake pad on the surface of the disc during braking.The fact that the brake pad is exposed to high temperatures causes a decrease in the expected benefit from it.Boric acid and ulexite, the boron minerals to be used in the brake pad, will contribute to a more effective performance of the brake pad at high temperatures.

In this study, boron mineral boric acid and ulexite were used at the rates of 1%, 3%, 5% and 7% in the brake pad content. Thus, the change in braking performance of the brake pad due to the increased temperature change as a result of friction was investigated.

II. Materials and Methods

In the production of the brake pads, components that do not contain asbestos were selected to prevent thermal deterioration at high temperatures and to strengthen the mechanical and tribological properties of the brake pad. Mass ratio was taken as basis in determining material ratios during production. The materials that make up the brake pad content specified in Table 1 were weighed on a precision scale with an accuracy of 0.001 g and filled into the moving chamber of the powder mixer. In order to ensure the homogeneity of the prepared mixtures, it was mixed with a mixer at 120 rpm for 10 minutes.After the mixing process, it was poured into molds prepared for cold forming and shaped in a cold press to form the front shape of the brake pad at ambient temperature for 2 minutes at 80 bar pressure.

The brake pad samples, which have taken their preforms as a result of cold forming, were fired in a baking mold at 100 bar pressure and 150 °C in 10 minutes by ventilating them at intervals of 60 seconds. It is ensured that the vapors and gases formed as a result of the reactions formed by the brake pad components as a result of the temperature in the material are discharged. In order to ensure that the brake padscan be easily removed from the mold after cooking and pressing, hot water with granular soap was sprayed with compressed air as pulverized. Finally, the samples removed from the mold were allowed to cool until they reached ambient temperature. Brakepads produced in four different ratios (1%, 3%, 5% and 7%) using boric acid and ulexite powders were coded as BU1, BU3, BU5 and BU7, respectively.

Table 1. Materials used in brakepad content

	BU1	BU3	BU5	BU7
Phenolic Resin	20	20	20	20
Cashew	10	10	10	10
Alumina	5	5	5	5
Steel Wool	10	10	10	10
Brass Particle	7	7	7	7
Copper	5	5	5	5
Graphite	3	3	3	3
Barite	38	34	30	26
Boric Acid	1	3	5	7
Ulexite	1	3	5	7

In order to determine the braking performance of the produced brakepads, the test device shown in Figure 1, which can transfer the friction coefficient, hydraulic system pressure, brake force, brakepad surface temperature values that occurred during the experiment, to the computer environment was used. There is an inverter so that the brake disc can be used at desired speeds. In order to provide the test standards, a non-contact infrared thermometer, which can operate in the range of -50 to 1000°C and records data every second, was used to determine the disc surface temperature in the experimental setup. The brake disc used in the experiments is made of Ø280 mm gray cast iron and has a hardness of 116 HB (41.86 HRA).

Figure 1. Brake pad test device

The test device was operated at a pressure of 5 bar and a speed of 3 m/s until 95% of the brake pad material contacted the disc surface. Thus, the overlapping of the friction surfaces is ensured. The tests were carried out at 7 bar brakepad surface pressure and 616 rpm. During the test, the friction coefficient, temperature and time data were recorded for 600 seconds at 1-second intervals. According to the TSE 555 standard, the pressure acting on the determination of the friction coefficient of the brake pads is constant and the friction coefficient-temperature-time relationship has been investigated without being exposed to any external influences [18].

At the end of the test, the brake pads were weighed on a precision scale and the mass loss was calculated. Specific wear values were obtained with the formula specified in TSE 9076 and based on mass loss. [19]. Wear, friction, hardness and density tests were applied to the produced brake pads.

The friction coefficient was calculated using the formula specified in TSE 555, taking into account the force applied to the brake padsand the friction force obtained from the test device [18].

The hardness measurements of the brake padswere determined by the Rockwell L (HRL) hardness measurement method. During the hardness measurements, a preload of 10 kgf and a full load of 60 kgf were applied with a 6.35 mm diameter steel ball as the penetrating tip. Hardness measurements were taken from the friction surface of the brakepads. Calculated by taking the values from the middle and near the edge of the brakepads. Measurement values were taken from different regions for each sample and their arithmetic average was taken [19]. Density measurements of the samples were determined using Archimedes' principle in water [20].

III. Results and Discussion

In this study, four different ratios of Boric acid and ulexite added brake pads were produced. The mass increase of Boric acid and ulexite powders used in brake pads was achieved by reducing barite powder, which has no effect on brakepad performance. The friction coefficient-temperature-time graphs of the produced brake padsare given in Figure 2, Figure 3, Figure 4 and Figure 5.The most important feature sought in an ideal vehicle brake pad is; The change in the frictioncoefficient of due to the increase in the interface temperature due to friction during braking is at a minimum level [21, 22]. The friction stability of the brake pad (%) should be high and close to 100, and the slope and fluctuations of the obtained curve should be low [23]. When the friction coefficient-temperature changes in the range of 0-600 seconds of the BU coded brakepad samples shown in Figures 2, 3, 4 and 5 are examined, the brakepad sample coded BU1 shows the lowest average friction coefficient value, while the brakepad sample with BU7 additive shows the highest average friction coefficient value has shown.In the figures, the frictioncoefficient is indicated with the code BU, and the temperature is indicated with the code BUT.

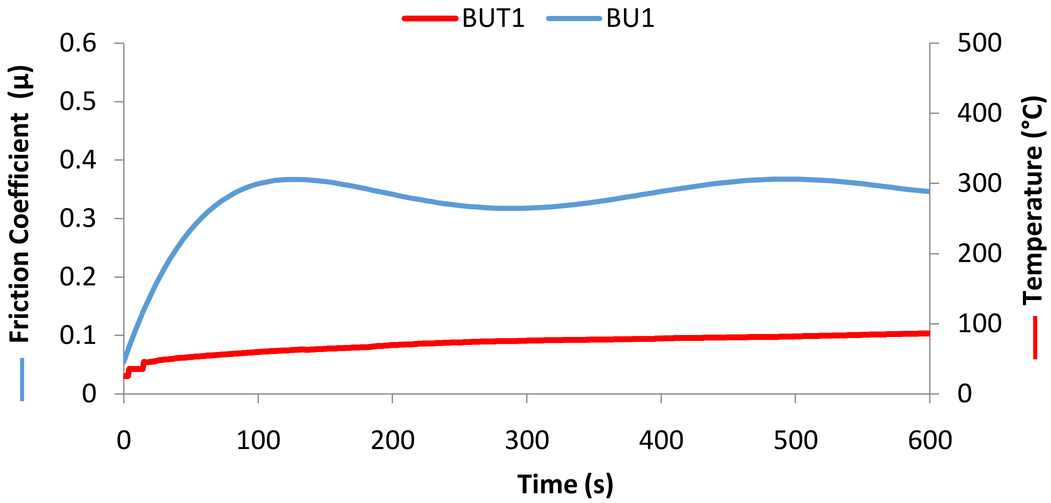

Figure 2. Friction coefficient-temperature-time graph of BU1 brake pad sample

Figure 2 shows the friction coefficient-temperature variation of the BU1 coded brake pad, which contains 1% Boric acid and ulexite, depending on time. The temperature formed at the interface between the brakepad and the disc is the lowest 25˚C, the highest 88˚C and the average 74˚C. During the friction test, the highest friction coefficient value is 0.41, the average friction coefficient value is 0.32, and the friction stability is 78%.

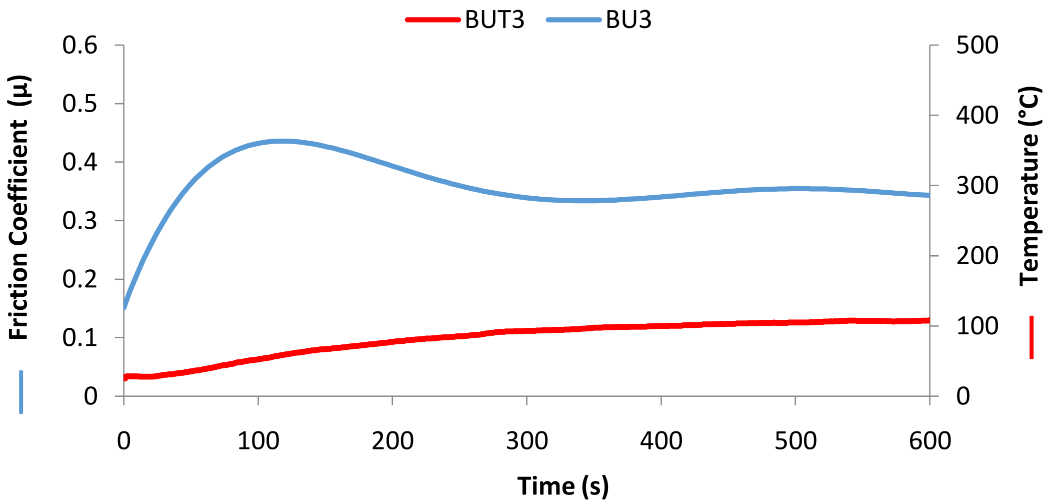

Figure 3. Friction coefficient-temperature-time graph of BU3brake pad sample

Figure 3 shows the friction coefficient-temperature variation of the BU3 coded brake pad, which contains 3% Boric acid and ulexite, depending on time. The temperature formed at the interface between the brakepad and the disc is the lowest 25˚C, the highest 108˚C and the average 86˚C. During the friction test, the highest friction coefficient value is 0.43, the average friction coefficient value is 0.35 and the friction stability is 81%.

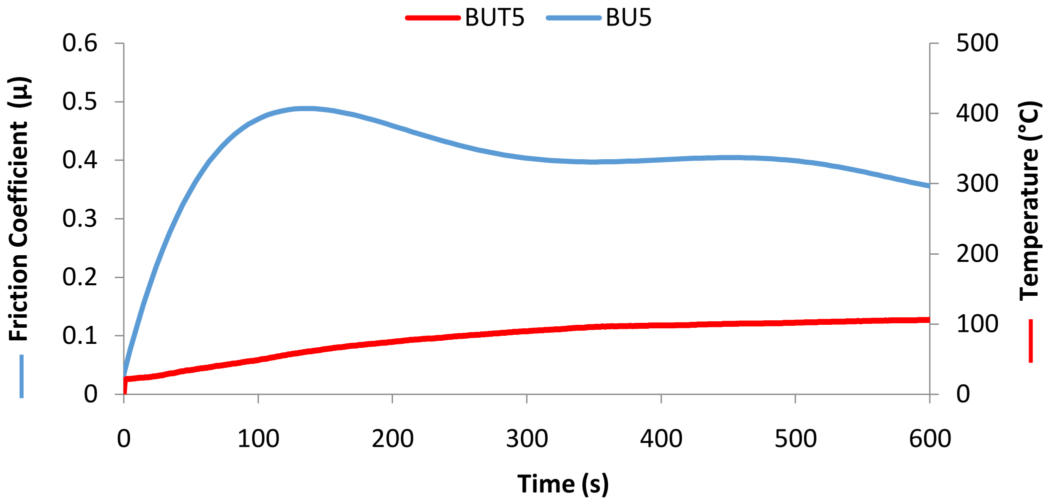

Figure 4. Friction coefficient-temperature-time graph of BU5brake pad sample

Figure 4 shows the friction coefficient-temperature variation of the BU5 coded brake pad, which contains 5% Boric acid and ulexite, depending on time. The temperature formed at the interface between the brakepad and the disc is the lowest 25˚C, the highest 109˚C and the average 85˚C. During the friction test, the highest friction coefficient value is 0.47, the average friction coefficient value is 0.39, and the friction stability is 83%.

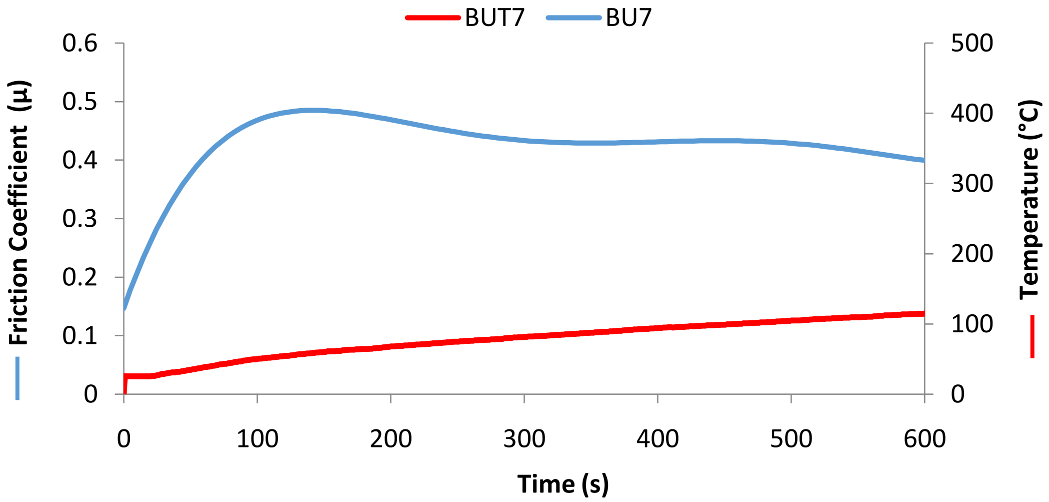

Figure 5. Friction coefficient-temperature-time graph of BU7brake pad sample

Figure 5 shows the friction coefficient-temperature variation of the BU7 coded brake pad, which contains 7% Boric acid and ulexite, depending on time. The temperature formed at the interface between the brakepad and the disc is the lowest 25˚C, the highest 121˚C and the average 85˚C. During the friction test, the highest friction coefficient value is 0.50, the average friction coefficient value is 0.43, and the friction stability is 86%.

When the figures are examined, a fluctuating change in the frictioncoefficient is seen continuously during the development of the friction layer. It is thought to be caused by the periodic continuous change in temperature towards the inside of the contact areas on the disc surface during friction [24]. For this reason, there is a continuous change in the coefficient of friction.

Table 2. Test results of the produced brakepads

Sample code	Specific wear ratio ($x10^{-6}$) (cm^3/Nm)	Density (g/cm^3)	Rockwell hardness (HRL)	Average friction coefficient (μ)	Friction stability (%)
BU1	1,30	1,99	75	0,32	78
BU3	1,62	2,04	80	0,35	81
BU5	1,80	2,10	85	0,39	83
BU7	2,12	2,21	89	0,43	86

The specific wear, density, hardness, average friction coefficient and friction stability of the produced brake pad samples are shown in Table 4.In the literature, it has been stated that the friction coefficient (μ) varies in the range of 0.3 to 0.7 depending on the friction force and the temperature of the disc-brakepad interface [25]. The results obtained from the friction-wear tests were determined to be in accordance with TSE 555 [18]. It has been determined that there is a direct proportional relationship between the density and hardness values among the physical properties of the samples.

IV. Conclusions

In this study, brakepads were produced by hot pressing method by adding Boric acid and ulexite powder at different rates (1%, 3%, 5% and 7%) and the friction-wear characteristics of the produced brakepads were examined and determinations were made.

Depending on the increase in the amount of boric acid and ulexite added to the brake pad content, the friction coefficient, which is the most important criterion of braking performance, has increased positively.

Depending on the increase in the amount of boric acid and ulexite, the friction coefficient increased and exhibited a desired stable friction performance.

It has been observed that the undesirable fluctuating change in the friction coefficient due to the increase in the interface temperature due to friction during braking is at a minimum level.

The increase in the amount of boric acid and ulexite increased the friction coefficient and caused an increase in the amount of wear proportionally.However, it was determined that the wear rates were between the standard values.

It was determined that the hardness values of the brake pad increased due to the increase in boric acid and ulexite.

It has been observed that there is no high increase in the temperature change occurring at the interface of the brakepad and the disc due to the increase in Boric acid and ulexite in the brakepad samples, and this situation directly affects the friction stability in a positive way.

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