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Research Article

INVESTIGATION OF ULEXITE USAGE IN AUTOMOTIVE BRAKE FRICTION MATERIALS

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ABSTRACT
The automotive brake pads are multi-component composites made up of many materials. There are many studies in the literature exploring the use of many different materials in brake pads. In this study, the use of ulexite which is a commercially valuable derivatives of boron that 65% of the total world reservations exists in Turkey were researched for brake pad material. For this purpose, three brake pad specimens containing ulexite differing in amount (3, 6 and 9 wt.%) were produced by a conventional procedure for a dry formulation following dry-mixing, pre-forming and hot pressing. The density of the specimens was determined based on Archimedes principle in water. The surface hardness of all brake pad specimens was measured using Rockwell hardness tester. The friction performance of the brake pad specimens was determined using a real brake disc-type tester with grey cast iron. The weights of each specimen were taken before and after the friction test, and the specific wear rate was determined in accordance to the TSE 555 (1992) standard. The results showed that all specimens are applicable to the industry, consistent with the literature and suitable to the TS 555 standard. Also, the results indicated that ulexite is an ideal material for brake pads.

Keywords: *Ulexite, Brake Lining, Wear, Friction*

1. INTRODUCTION

Boron is an important mineral used in many fields, including nuclear industry, fertilizer industry, the pharmaceutical industry, chemical industry, and automobile industry. Turkey has 65% of the boron reserves in all over the world and manages 32% of the total production (Çalık, 2002). Although boron minerals are used directly in some structures, most of which is processed in factories and converted into the high value-added refined boron derivatives. Some of the commonly used commercial boron derivatives are borax, colemanite, ulexite, kernite, probertite and szaibelyite (Özkan *et al*., 1997).

With the development of automotive technology, the motor forces, speed of movement and the acceleration capabilities of vehicles have increased compared to the past. This has increased the importance of reliably controlling the movements of the vehicles. The most important safety feature of a car is the brake system. Brake pads are the indispensable parts of the brake systems, being the composite materials that are made up of a combination of many materials with different functions. Although many studies on brake friction materials are presented in the literature, studies investigating the use of boron products in brake pads are relatively few. Sugözü (2009) produced the brake pad specimens using ulexite, colemanite, boric acid and borax pentahydrate which are boron derivatives, and then examined the properties of the produced brake pads including the friction, wear, and resistance. Wannik *et al*. (2012), investigated the effects of boron additives on brake pads and found that boron additives have higher friction performance. Kuş *et al*. (2016), investigated the effect of the amount of colemanite on friction-wear properties of 'the volatile ash reinforced bronze matrix brake pad materials' produced by the hot pressing method, and stated that the friction coefficient of the materials with 0.5% colemanite supplement was higher.

In the present study, the usability of ulexite in brake pad materials was investigated experimentally. For this purpose, the brake pad specimens containing 3%, 6% and 9% ulexite were produced by the powder metallurgy method. The density of specimens was determined according to the Archimedes principle and the hardness was determined using the Rockwell hardness tester device (HRL). For friction performance tests, a full-scale brake pad device with grey cast iron disk was used. The specific wear rate was calculated according to the TSE 555 standard by determining the weights of each specimen before and after testing.

2. MATERIALS AND METHODS

The production parameters of the materials and specimens used in brake pads have a significant impact on the brake performance. We determined the materials and production conditions according to the previous studies in the literature. The materials used in the specimens are given in Table 1 in mass percentages. U3, U6, and U9 are specimen codes; U refers ulexite, and its number also refers to the percentage in the composition.

Table 1. Contents of specimens (mass %)

The task of the material	Type of material	U3	U6	U9
Binding material	Phenolic resin	20	20	20
Reinforcing material	Steel wool	5	5	5
Friction modifiers	Cashew powder	10	10	10
Metallic shavings	Brass shavings	5	5	5
	Copper shavings	6	6	6
Solid lubricant	Graphite	3	3	3
Abrasive	Alumina	8	8	8
Friction modifiers	Ulexite	3	6	9
Filling material	Barite	40	37	34

Prior to the production process, the particle size of each material forming the contents of brake pad was primarily determined with the help of sieves shown in Fig. 1 (a). Then, the amount of each material forming the brake pad content was determined by 0.001 g precision scale shown in Fig. 1 (b) and transferred to the powder chamber shown in Fig. 1 (c) for mixing. In order to ensure homogeneity of the mixture, the specimen content was mixed at 150 rpm for 10 minutes on the specially produced powder mixing device shown in Fig. 1 (d). The resulting mixture was carefully placed in the 25.4 mm diameter cold press mold shown in Fig. 1 (e). While doing this, care has been taken not to spread the dust around due to sudden movements. The dust was pressed under 8000 kPa pressure for 2 minutes. The final product was obtained by removing the cold pressed specimens from the mold and placing them in the hot press mold shown in Fig. 1 (f) and pressing them for 12 minutes under 10000 kPa pressure at 150 °C.

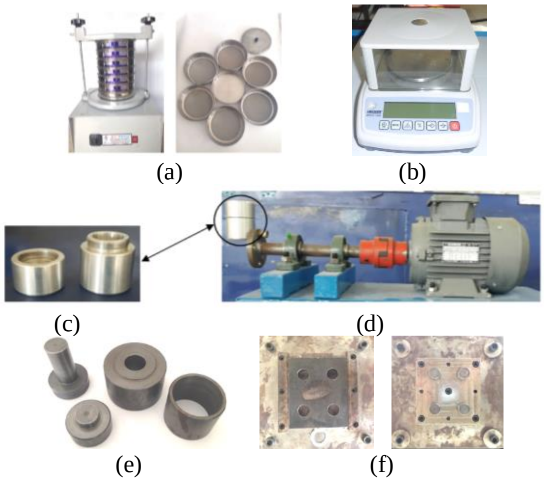


Fig. 1. The materials used in the production of specimens (a) the sieve-shaker and sieves (b) the precision scales (c) the powder chamber (d) the powder mixing device (e) the cold press mold (f) the hot press mold

The density of the specimens was determined according to the Archimedes principle and the hardness was determined using the Rockwell hardness tester device (HRL). During the hardness measurement process, a preload of 10 kgf and a full load of 60 kgf was applied with a steel ball in diameter 6.35 mm at the submersible end (Başar *et al*., 2017). Hardness measurements were taken from the frictional surface of the specimens. A full-scale brake pad test device with grey cast iron disc having a diameter of 280 mm and hardness of 116 HB, whose schematic drawing is shown in Fig. 2, was used to determine the abrasion and friction properties of the specimens. The device can be fully controlled by a computer and includes data collection software. The specific wear rate was calculated according to the TSE 555 standard by determining the weights of each specimen before and after testing.

During the experiments, the temperature increases due to friction between the disk and the brake pad. In order to investigate the effect of temperature increase on the performance of the brake pad, the non-contact thermometer measured the surface temperature of the brake pad at a distance of about 2 cm from the friction surface to the disc. A digital thermometer was used to measure temperature. The surface temperature of the disc is automatically transferred to the computer environment in seconds during the experiment (Sugözü, 2016).

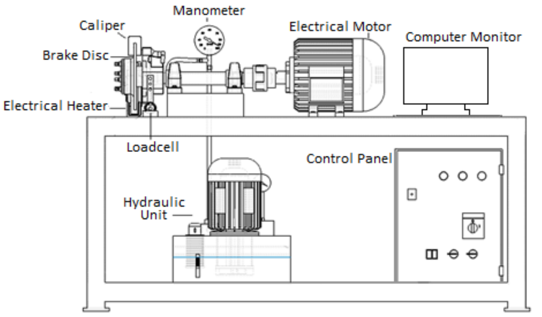


Fig. 2. Brake pad test device (Sugözü, 2015)

The coefficient of friction and wear of specimens was obtained by conducting experiments as specified in the TS 555 (1992) and TS 9076 standard (1991). In experimental conditions, first of all, 310 rpm, 700 kPa pressure, and a temperature not exceeding 100 °C were provided; and then the grinding process was applied, until the surface contact of the specimen to the disc is at least 95%. Thus, the surface got ready for the experiment. Then the tests were completed with the pressure of 1050 kPa and speed of 6 m/s for 30 minutes.

3. RESULTS

The coefficient of friction for automotive brake pads is the most important parameter affecting the brake performance. The coefficient of friction-temperature-time graphs of specimens are given in Fig. 3 for U3 coded specimens, and in Fig. 4 for U6 coded specimens, and also in Fig. 5 for U9 coded specimens. In figures, the coefficient of friction was low at the initial of the test because the applied pressure does not influence suddenly but gradually. Sudden pressure application will cause damage to the brake pads, so the pressure was gradually increased. In addition, at the initial of the test, the disc and the brake pad are in the running-in period (grinding) and the friction layers in which the friction force is effective are not yet formed (Sugözü, 2016). Therefore, there is a continuous change in the coefficient of friction. In the literature, this situation has been reported to occur with the transition of heat to the inner part of the contact areas on the surface of the disc during friction (Anderson, 1992). Another explication is that the adhesion on the surface roughness of the friction couples results in the repetition of the adhesion-release, causing fluctuations in the coefficient of friction (Stachowiak and Batchelor, 2001).

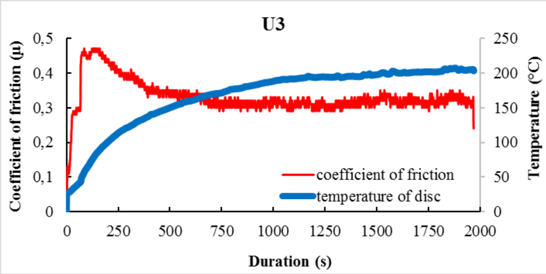


Fig. 3. The coefficient of friction and temperature graph of the specimen containing 3% ulexite, according to the friction time

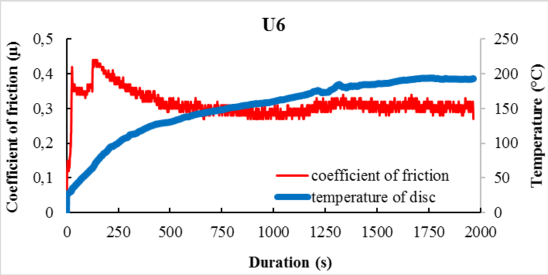


Fig. 4. The coefficient of friction and temperature graph of the specimen containing 6% ulexite, according to the friction time

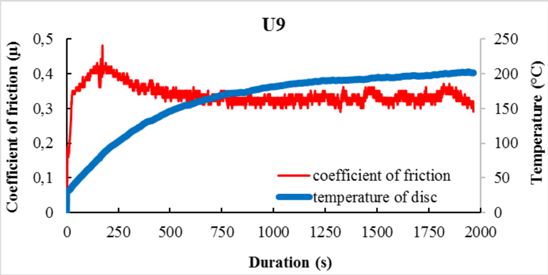


Fig. 5. The coefficient of friction and temperature graph of the specimen containing 9% ulexite, according to the friction time

Fig. 3 shows the coefficient of friction and temperature graph of the specimen containing 3% ulexite, according to the friction time. The highest coefficient of friction obtained during the tests was 0.47, and the highest temperature was 206.8 °C. Fig. 4 shows the coefficient of friction and temperature graph of the specimens containing 6% ulexite, according to the friction time. During the tests, the highest temperature occurred between the disk and brake pad is 193.3 °C. The highest coefficient of friction of the brake pad specimen is 0.44. However, the friction stability was found to be 71%. Fig.

5 represents the coefficient of friction and temperature graph of the specimen containing 9% ulexite. The highest coefficient of friction obtained in the tests is 0.48 °C, and the highest temperature between the disc and brake pad is 202 ° C. The friction stability was calculated as 70%. According to the literature, the friction stability (%) should be as high as possible and close to 100, the slope and fluctuations of the obtained curve should be low level (Bijwe *et al*., 2012). It is desirable that the coefficient of friction of the automotive brake pads is high, the wear is low and the friction stability is stable. Physical and tribological properties of specimens are shown in Table 2 and Table 3.

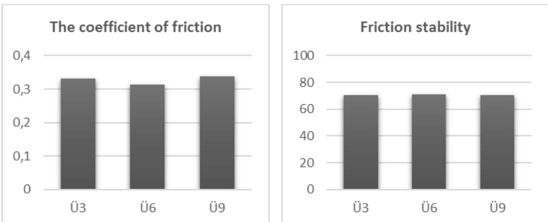
Table 2. Tribological properties of specimens

Specimen Code	Specific wear rate (cm^3/Nm)	The average coefficient of friction
U3	2.054×10^{-6}	0.331
U6	2.109×10^{-6}	0.313
U9	1.893×10^{-6}	0.337

Table 3. Physical properties of specimens

Specimen Code	Rockwell hardness (HRL)	Density (g/cm^3)
U3	81	1.9
U6	88	2.16
U9	90	2.22

Table 3 shows that the hardness and density of the specimens are increased by increasing the amount of ulexite in the composite. Considering the average coefficient of friction and the specific wear rate, it was found that the specimen containing 9% ulexite was better. The coefficient of friction of the specimens is obtained by dividing the coefficient of friction by the highest coefficient of friction obtained during the test and expressed as a percentage.



(a) (b)

Fig. 6. (a) The coefficient of friction (b) friction stability graphs of specimens

4. CONCLUSION

In this study, the usability of ulexite, which is a boron mineral, in automotive brake pads was investigated by experimental studies. Three different specimens containing 3%, 6% and 9% ulexite were prepared for this purpose. A full-scale brake pad device was used for the wear and friction tests of the specimens. The results obtained from the tests are summarized below;

- The highest average coefficient of friction value for all specimens undergo friction test is 0.337, belonging to the U9-coded specimen containing 9% ulexite, the lowest average friction coefficient is 0.313, belonging to the U6-coded specimen containing 6% ulexite.
- It was reported that as the amount of ulexite increased, the hardness and density increased. The direct proportion between the hardness and density was determined to be consistent with the literature.
- The friction stability of specimens was observed to be almost the same for each specimen, and it was concluded that the friction stability does not depend on the amount of ulexite content.
- According to the results obtained from the friction and abrasion tests, all specimens can be utilized in the industry in accordance with the literature and conform to the TS 555 standard. Accordingly, ulexite which is a boron derivative could be used as an alternative material in automotive brake pads.

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