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Investigation of Friction and Wear Behavior of Composite Brake Pads Produced with Huntite Mineral

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Abstract

Huntite ($CaMg_3(CO_3)_4$) is a calcium magnesium carbonate mineral and is a mineral in the dolomite group. Although studies on Huntite's flame retardant raw material feature stand out, it is used in the paint industry, and the industrial sectors such as plastics, polymers, special rubbers, and pharmaceuticals. In this study, experiments were carried out by producing brake pad samples in different mixing ratios from huntite mineral and glass fiber, kaolin, graphite, phenolic resin, and rubber powder to be used for brake pads in the automotive industry. Friction coefficient and wear rate which is an important feature for the produced pad samples were measured in the brake pad testing device. According to the Archimedes principle, the specific gravity and disc roughness values formed by the brake pad samples on the disc were measured with a roughness tester. According to the measured values, the highest average friction coefficient was obtained in the A45 sample, the minimum wear value was obtained in the A10 sample, and the minimum roughness change was obtained in the A25 sample.

Keywords: Friction coefficient, Wear, Huntite, Brake pad, Automotive

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1. Introduction

Brake pads are one of the most important parts of the automotive brake system. Depending on the conditions of use, the brake pad replacement periods vary according to the content of the materials that make up the pad. In recent years, studies have been carried out on brake pad components in which asbestos is not used at all or the copper content is reduced or not used at all [1]. The most important feature sought for the brake pad is that the friction coefficient value is high and the wear rate value is little. In addition, the materials that make up the brake pad content should not abrade the disc in a short time. Brake pad friction coefficient values should not change with different fluid contact. At high temperatures, the friction coefficient of the linings must be stable [2].

Brake pad composites have been specially formulated to provide better friction and wear performance in the slip caused by the contact between the disc and the brake pad. In the composite material structure, resin-based materials were generally used as binders and asbestos-type materials were used until the 1980s to provide the necessary mechanical properties. After 1980s, cotton, mineral, metal or organic materials were used instead of asbestos type fibrous materials due to lesser known environmental and health problems. In addition to resin and fibrous materials, materials such as fillers, friction modifiers, and lubricants are added to the composite material to improve its mechanical, thermal, friction, and wear properties. Even a very small amount of the component has a large effect on friction and wear performance [2].

Brake pad composites are produced with different techniques from the combination of 5 to 20 different materials with different properties. The materials to be used in the composite composition are mixed with a mixer at different weight ratios at different cycles and time intervals. Mixed materials are produced in different pressure, temperature and time intervals either by cold + hot or just hot molding methods [2- 4]. In addition to the production methods, curing or sintering processes have also been carried out in different studies in the second stage [5- 6].

Phenolic resin is mostly used as a binder in scientific studies in the literature [7- 22]. Basalt fiber, organic fibers, banana peel fiber, aramid fiber, glass fiber, steel fiber, carbon fiber, fibrous vegetable products, flax fiber, and are used as reinforcing materials. As a friction modifier, organic juniperus drupacea cone powder, coleamanite, cashew powder, zirconium, alumina, potassium titanate, brass, silica, copper, and plant-derived substances are used. Coke, and graphite were used as lubricants. Calcium carbonate, vermiculite, granite powder, clay, and barite were used as fillers [23- 63].

The friction and wear properties of brake pads are determined by Pin or dynamometer tests on the disc. Pin-on-disk tests are performed on sample-sized brake pads, and dynamometer tests are performed on real-size brake pads. The friction and wear mechanisms are determined by comparing the data obtained as a result of the experimental studies [61].

In the study, brake pad composites were produced from six materials in ten different mixture ratios. The materials forming the samples were mixed and the production was carried out by the hot molding method. In order to determine the friction coefficient and wear rates of the samples produced by the hot molding method which are the most important features sought for the brake lining, measurements were carried out in the brake lining tester. In addition to these measurements, the disk roughness values were measured before and after the experiment in order to measure the density for the samples and to determine the roughness of the samples on the disk.

2.Material and method

2.1 Substances in the sample composition

In the study, glass fiber, phenolic resin, rubber powder, and graphite materials which made up the brake pad composites were used in fixed proportions while kaolin and huntite were used in different proportions. Huntit was increased by 5% and used in ten different composite brake pad samples up to 50% (Figure. 1.). It was named from A05 to A50 according to the amount of huntite in the sample components. The ratio at the end of the letter A indicates how much huntite was in the composition.

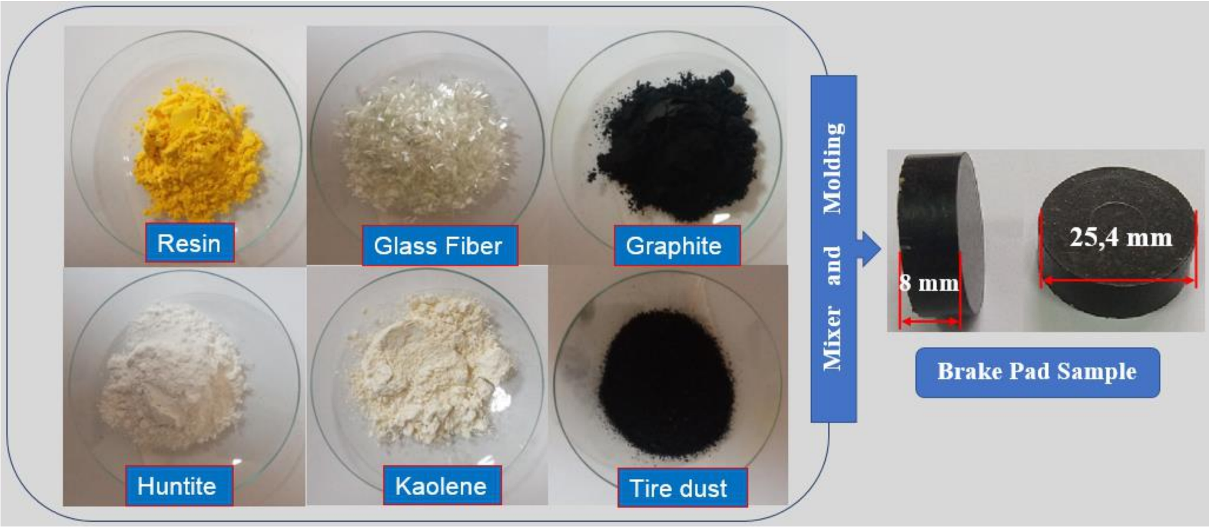

Fig. 1. The materials used in the production of the brake pad sample

Huntite mineral is a calcium magnesium carbonate mineral in the dolomite group under the carbonates class. Its chemical formula is $CaMg_3(CO_3)_4$, and its molecular weight is 353.03 grams (15.88% CaO, 34.25% MgO, and 49.87% CO_2). Huntite is used in industrial sectors such as paint, flame retardant, plastic, polymer, special rubber, and medicine. Studies on flame retardant additive raw materials have come to the fore. Standards for use in other sectors have not yet been clarified. It absorbs heat as a result of endothermic reaction and reduces flame and surface temperatures [64]. Table 1. shows the content ratios of the materials that make up the composite brake pad samples.

Table 1. Sample content and mixing ratios (Weight percent (%))

Material	A05	A10	A15	A20	A25	A30	A35	A40	A45	A50
Glass fiber	20	20	20	20	20	20	20	20	20	20
Resin	22	22	22	22	22	22	22	22	22	22
Tire dust	3	3	3	3	3	3	3	3	3	3
Graphite	5	5	5	5	5	5	5	5	5	5
Kaoline	45	40	35	30	25	20	15	10	5	0
Huntite	5	10	15	20	25	30	35	40	45	50
Total	100	100	100	100	100	100	100	100	100	100

Glass fiber used in the production of composite brake pads was supplied from Sisecam Elyaf Sanayii AS Turkey. Powdered novalak resin was obtained from Cukurova Kimya Endüstrisi AS Turkey. Tire powder was procured from Kahya Rejenere Kauçuk ve Lastik Tozu İmalatı Ltd. Sti. Turkey. Graphite was obtained from Karabacak Madencilik Sanayi ve Dış Ticaret Turizm AS Turkey. Kaolin was procured from Esan Eczacıbaşı Endüstriyel Hammaddeler Sanayi ve Ticaret AS Turkey. Huntite mineral was obtained from the mine in Turkey where the study was carried out by Kuşcu et al. [65], and it was ground and powdered in the laboratory environment.

2.2 Sample preparation conditions

In the studies on brake pad sample production, the materials that make up the samples were mixed for up to 30 minutes in different types of mixing devices. Brake pad samples were produced from the mixed materials at molding temperatures of up to 190 °C, molding pressures of up to 500 MPa, and molding times of up to 20 minutes [66].

For sample production, the materials whose mixing ratio is given in Table 1 were weighed on a precision balance of 0.001 g and mixed for 15 minutes at 190 rpm in I type powder mixing apparatus to form a homogeneous mixture. The mixed materials were placed in a molding capable of producing six samples at the same time with a sample diameter of 25.4 mm and pressed under 40 MPa pressure at 150 °C for 15 minutes. The production process of brake pad samples is shown schematically in Figure 2.

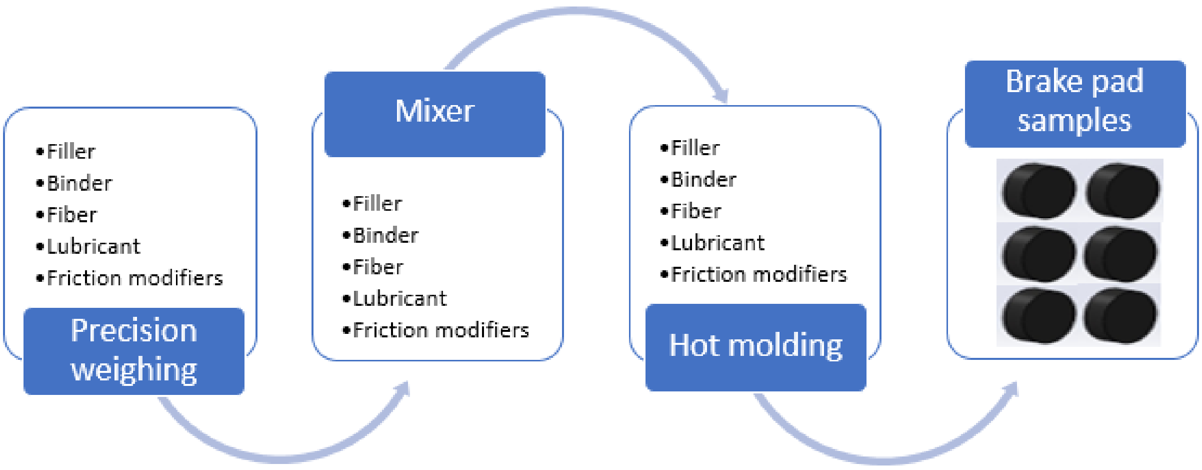

Fig. 2. Brake pad sample production process schematic illustration

2.3 Experimental Studies

2.3.1 Density Values

Density measurements of the test samples were determined according to the Archimedes principle. The average values were taken by measuring the density of three different samples in the same group. Density values were between 1.915 and 2.005 g/cm^3. The minimum density value was measured as 1.915 g/cm^3 in the A05 sample and the maximum density value was 2.005 g/cm^3 in the A30 sample. Density values in A35-A40-A45 samples were similar to each other (Table 2.).

Table 2. Density values of brake pad samples

Sample	A00	A05	A10	A15	A20	A25	A30	A35	A40	A45	A50
Density (g/cm^3)	1,981	1,915	1,978	1,942	1,991	1,985	2,005	1,998	1,997	1,997	1,968

2.3.2 Coefficient of Friction and Wear Rate Values

The friction coefficient and wear rate values are finding from the equations below by processing the data obtained from the brake system lining test device (Figure 3.) measurement results at 6 m/s speed at 1 Mp load and 5000 m test conditions.

Coefficient of friction (COF):

$$\mu = \frac{f}{F} \qquad (1)$$

Where; μ: Coefficient of friction (COF), f: Friction force read on dynamometer [N], F: Compressive force applied to the test specimen [N] means.

Wear rate:

$$W_a = \frac{\Delta G}{S.M.d} \qquad (2)$$

Where; W_a: Wear rate (mm^3/Nm),ΔG: Weight loss (mg), S: Sliding distance (m),M: Loading weight (N), d: Density of wearing material (g/cm^3) means.

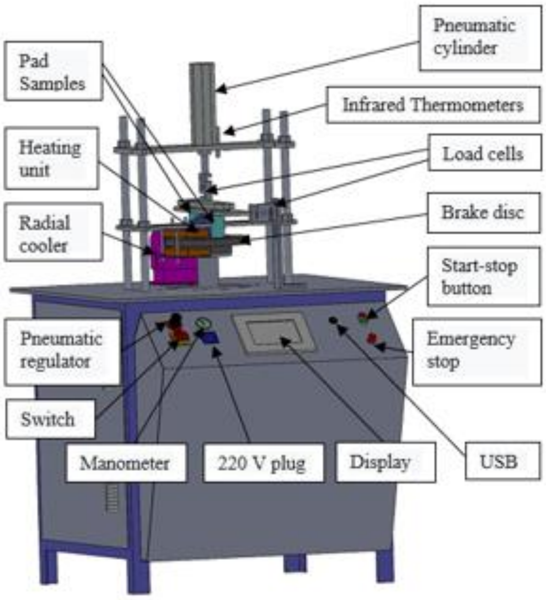

Fig. 3. Brake pad testing machine

The friction coefficient and wear rate values which are among the most important features sought for brake pads are given in Table 3. (The brake pad friction performance tables determined in Turkey and China are taken into account for comparison.) [67- 68]

Table 3. The friction performance standards of brake pads

	Operating temperature (°C)					
	100	150	200	250	300	350
COF	0,25-0,65	0,25-0,70	0,25-0,70	0,25-0,70	0,25-0,70	0,20-0,70
Specified COF	± 0,08	± 0,10	± 0,12	± 0,12	± 0,14	± 0,14
Wear rate (10^{-7}/Nm)	0-0,5	0-0,7	0-1,0	0-1,5	0-2,5*/2**	0-3,5*/2,5**

*Turkey, **China.

The friction coefficient values obtained in the experimental study were given in Figure 4. In the literature, it is state that the friction coefficient should be at high values [66]. The highest value of the maximum coefficient of friction was measured in the sample coded A05, and the highest value of the minimum coefficient of friction was measured in the sample A50. The highest average friction coefficient value was obtained in the A45 sample as 0.30. According to the brake pad standard specified in Table 3. the friction coefficient values of the brake pads were inside the limits.

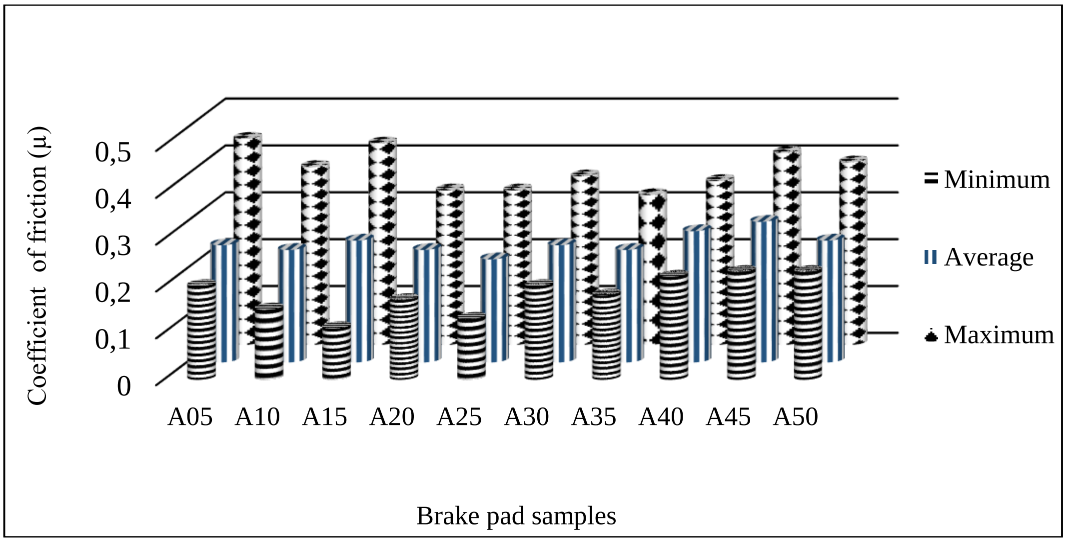

Fig. 4. Friction coefficient maximum, minimum and average values

The wear rate values were determined in the brake system pad tester at 5000 m, 6 m/s speed, and 1 Mp load (Figure 5.). While the highest wear rate was obtained in the A05 coded-sample, the lowest value was obtained in the A10 coded sample with a value of 0.058 x 10^{-7}. Wear rate values were in accordance with the standards specified in Table 3. for all the brake pad samples.

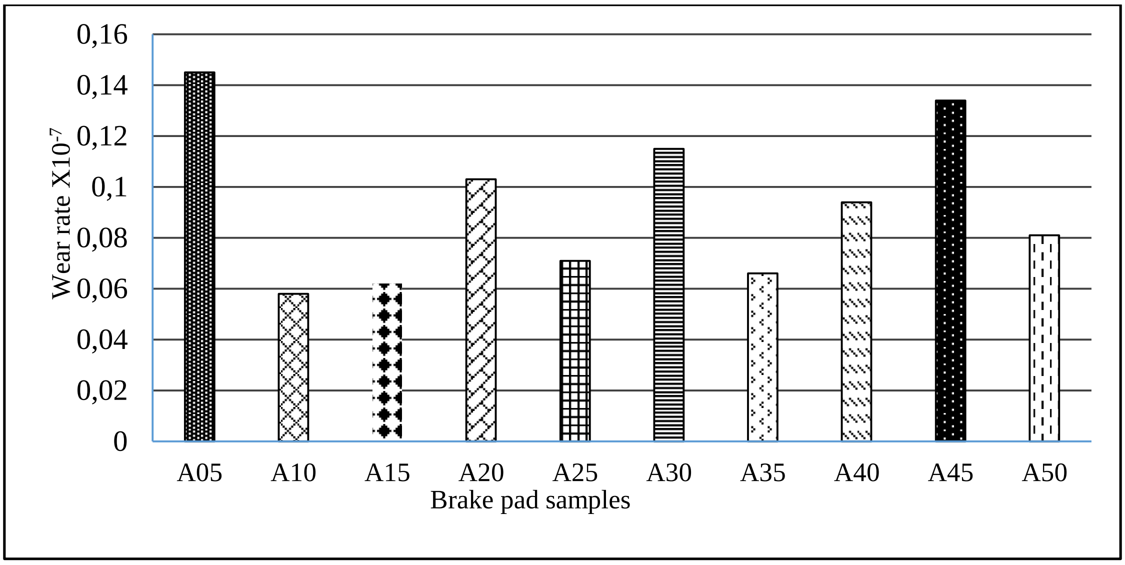

Fig. 5. Wear rates (x10^{-7} cm^3/Nm)

2.3.3 Disc roughness values

Ra roughness values from three 3 fixed points (Figure 6.) determined on the disc were measured before the experiment started and after the experiment was finished. The values were showed in Figure 7. by taking the average of the measured values.

Due to the abrasive effect of the brake pad samples, the disc roughness values increased after the test compared to the pre-test. The Ra roughness changed at a minimum value of 0.031 µm in the A25 sample.

Fig. 6. Disc roughness measuring points

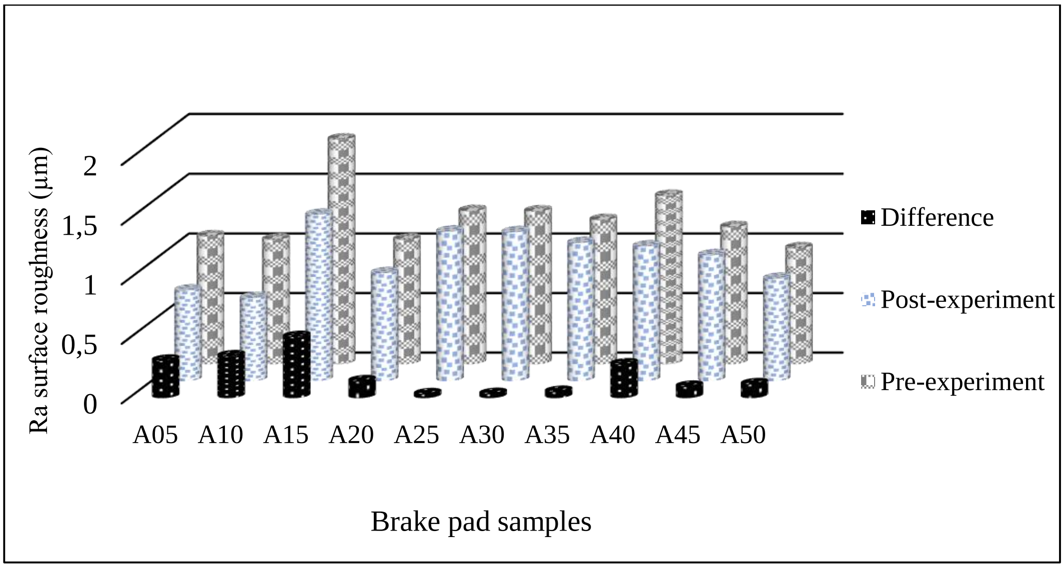

Fig. 7. Ra Disc Roughness

3. Conclusions and future perspectives

An experimental study was carried out to determine the use of huntite mineral which is used in different areas in the industry for brake pad composites. The materials used for the production of composite brake pads were mixed in an I-type mixer to form a homogeneous mixture. The samples were produced from the mixed materials by hot pressing method in a 6-cavity molding.

The densities of the samples were determined according to the Archimedes principle, and then the friction coefficient and wear rate values were experimentally examined in the brake pad testing device for the samples.

Density values were between 1.915-2.005 g/cm^3 and showed similarity to the studies in the literature [66, 69].

Friction coefficient average values were taken into account. The average friction coefficient value was obtained at most in the A45 coded sample. The friction coefficient values of all samples were inside the standard limits.

Minimum wear rate is required for wear rate values. The minimum wear rate was measured on sample coded A10 and all pad samples were inside brake pad standards.

Disc roughness is an important consideration for the lifetime of the disc, and disc roughness values changed little in the A25-A30 and A35 samples. Disc wear will be less in working with these samples.

As a result, the friction coefficient and wear rate values which are the most important features sought for the pads were in accordance with the brake pad standards in the produced samples. Huntite mineral can be used in brake linings for all mixing ratios made in the study.

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Conflict of Interest Statement

The authors declare that there is no conflict of interest in the study.

CRediT Author Statement

Hicri Yavuz: Conceptualization, Investigation, Methodology, Resources, Software, Writing - original draft

Hüseyin Bayrakçeken: Investigation, Project administration, Supervision, Validation, Writing- review & editing

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