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INTERNATIONAL ADVANCED RESEARCHES and ENGINEERING JOURNAL

e-ISSN: 2618-575X

Journal homepage: www.dergipark.gov.tr/iarej

International Open Access

Volume 03
Issue 02

August, 2019

*Research Article*

# Experimental investigation of the effect of compression pressure on mechanical properties in glass fiber reinforced organic material-based brake pads production

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ARTICLE INFO

*Article history:*
Received 30 July 2018
Revised 22 December 2018
Accepted 18 April 2019

*Keywords:*
Brake pads
Coefficient of friction
Compression press
Hardness
Juniperus drupacea
Wear ratio

ABSTRACT

In this study, samples which can be used as brake pads are prepared. A mixture of 50% barite by mass, 20% glass fiber, 25% phenolic resin and 5% coke powder was prepared, and 6 samples were prepared by adding juniperus drupacea nut powder (JDNP) at 10%, 25% and 40%. The samples were produced in 3 different mixing times, 2 different compaction times, 3 different compaction temperatures and 3 different compression pressures. The effect of the compression pressure on the wear rate, hardness, density and cold friction coefficient was investigated. The wear rate ranges from $0.093.10^{-7}$ - $4.235.10^{-7} cm^3.N^{-1}.m^{-1}$. The coefficient of cold friction ranges from 0.30 to 0.48. The density is between 1.82-2.17g/$cm^3$. The hardness values are from 85 to 117 according to the Rockwell R scale. Wear rate and cold friction coefficient values are in accordance with TS 555 standard. It has been determined that the compressive pressure is most affected by the hardness and friction coefficient. Generally, rise of pressure reduces hardness and friction coefficient. The effect of density on JDNP ratio is opposite.



## 1. Introduction

People have to complete their needs by either moving or carrying in order to make their lives earlier to get food, beverages, fuel or energy. They use different means of transportation for these needs.

The oldest known wheel remains dates from 3000 to 2500 BC [1]. Although the invention of the wheel goes back 5000 years, the history of motor vehicles is about 130 years.

People acquire the necessary energy from the internal combustion engines that burn different fuels when transporting themselves and the materials they need. This movement of the motor is transmitted by the powertrain to the wheels by adjusting the speed, direction and torque.

The vehicles produce kinetic energy while moving. The brake system turns this energy into heat energy.

The use of frictional forces in the moving bodies to produce a deceleration mechanism and to form between the two sliding bodies in contact with each other has historically been up to the beginning of the first tests of mankind [2].

The performance of the system depends on the friction between the pads that presses against the rotating disk (or drum).

The numerical value of friction is practically always present even if it is too small to be taken into account [3]. Friction should be within certain values between the respective surfaces. A typical example is the fact that the vehicle cannot stop at the desired distance and time due to low friction in the vehicle brakes or that the brakes of the vehicle are blocked due to excessive friction [4].

The most important factor of braking performance is the stopping distance after braking. This is possible by maximum deceleration acceleration. High braking performance is related with high quality braking pads which constitutes a significant portion of the friction surfaces [5].

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DOI: 10.35860/iarej.449089

Abrasion is an inevitable consequence of friction [4]. Wear; temperature, lubrication, working conditions, environment, surface roughness, material pair etc. elements are connected to a system [6]. The contact area of the two friction surfaces is called the mechanical interaction area. This area has a significant effect on wear [7].

Braking systems consist mainly of two rubbing elements fig.1. These are called lining and disc/drum. As we don't have a specific formula for the materials used in these pads, development studies for better pads are still going on [8].

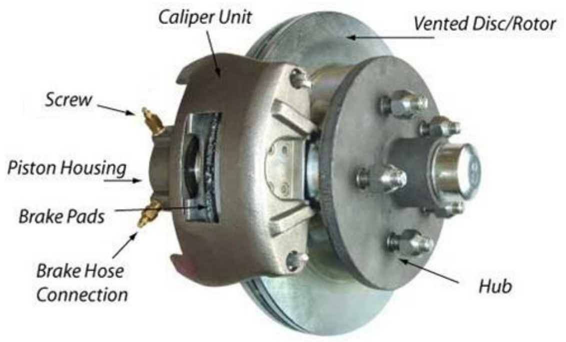



Figure 1. Disc brake unit [9]

The affecting factors to braking pads are components and producing parameters as it surged in studies of braking.

While producing brake pads hundreds of different materials in different rates are tried. Among the parameters affecting the produced brake pads are distinguishing as mixing type, duration of mixing, pressing temperature, pressing pressure, pressing time and sintering time.

Applied pressure value changes from 5 MPa to 4000 MPa in literature. If the pressure is to be applied cold, the pressure value is high, and if it is hot, it is lower.

Some of the applying pressing pressure, pressure heat, sort are given in the table 1 bellow.

Table 1. Compression pressures and temperatures in the literature

| Pressing pressure | Pressing temperature | |
|---|---|---|
| 15MPa | 153°C | [10] |
| 15MPa | 150°C | [11] |
| 8MPa | 150°C | [12] |
| 15MPa | 150°C | [13] |
| 500MPa | cold pressing | [14] |
| 400MPa | room temperature | [15] |
| 1000-400-4000-600 MPa | 150-170°C | [16] |
| 5-7,5-10-12,5 MPa | 125°C | [2] |
| 150-250 bar | 150-180°C | [17] |
| 25Mpa | 150°C | [18] |
| 10, 15, 20 Mpa | 180°C | [19] |
| 100Mpa | 160°C | [20] |
| 100bar | 150°C | [8] |
| 50-100-200-300 Mpa | 150°C | [21] |

In this study the braking pad consists of barite, phenolic resin, glass fiber, coal and juniperus drupacea nut powder (JDNP). The effect of the formed pressures on the hardness, friction coefficient, density and wear rate of different pressing pressures were investigated by changing the pressing pressures to 100, 150 and 200 MPa, which are considered to affect the properties of the starting material.

## 2. Material and Method

While preparing samples used in research 50% barite, 20% glass fiber, 25% phenolic resin, 5% coal powder are used and to this mixture, a mass of 10%, 25%, 40% rate JDNP is added.

### *2.1 The sample inclusion and specifications*

The barite used in this study is 5μm volume and obtained from "Barit Maden Türk AŞ." company. The technical specifications of barite are given in the Table 2.

Table 2. Technical specifications of barite [22]

| | | |
|---|---|---|
| $BaSO_4$ | % | 91-93 |
| Density | g/cm$^3$ | 4,25 (min) |
| Hardness | Moh's | 3-3,5 |
| Humidity / Factory exit | % | 0,1 (max) |
| Oil absorbing value | mL/100g | 15-16 |
| Acidity value (pH) | % | 6-8 |

The resin suitable for ÇK 82790 type disc and drum lining is supplied from Çukurova Kimya Endüstrisi AŞ.

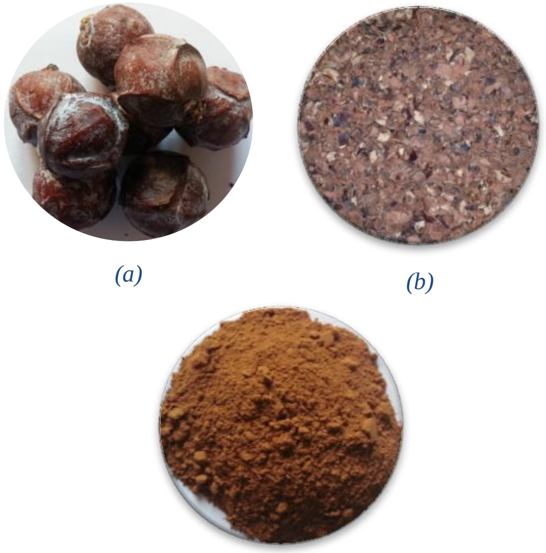
The coke was turned into powder in Selçuk University Mining Engineering Laboratory.

3 mm broken glass fiber bunch (PH2) suitable for the production of phenolic linings is used which was produced by "Cam Elyaf Sanayi AŞ. Gebze/Kocaeli". The product specifications of glass fiber are given in the table 3.

Table 3. Product specifications of glass fiber [23]

| | |
|---|---|
| Glass Type | E |
| Filament Diameter (μ) | Nom. 13 |
| Moisture Content (%) | max. 0,07 |
| Sizing Type | Silane |
| Sizing Content (%) | 0,90 ± 0,15 |
| Flowability | Very good |
| Resin Compatibility | Phenolic |
| Chopped Length (mm) | 3 |

In Figure 2(a) juniperus drupacea nuts (JDN) are collected from nature and dried in the sun light. They were washed to get rid of soil and sand and dried again. The photos of broken nuts are in Figure 2(b). The JDN, which was subjected to dehumidification after being broken, was turned into powder Figure 2(c) at Selçuk University Mining Engineering Laboratory.



*(a)* *(b)*

*(c)*

Figure 2. Pictures of juniperus drupacea nuts (JDN) [24]

All the powders were sieved in ≤1mm. In order to ensure homogeneous distribution of the materials used in the sample production, all of the materials forming the samples were mixed at the mixing times specified in table 4 in the blade mixer.

The contents and parameters used in studies are given in the table 4 below.

Table 4. Sample contents and production parameters

| Sample No | Pressing | | | Mixing time (min) | JDNP (%) |
|---|---|---|---|---|---|
| | Duration (min) | Pressure (MPa) | Temp. (°C) | | |
| 1 | 10 | 100 | 140 | 10 | 10 |
| 2 | 10 | 150 | 160 | 15 | 25 |
| 3 | 10 | 200 | 180 | 20 | 40 |
| 4 | 15 | 200 | 180 | 10 | 25 |
| 5 | 15 | 100 | 140 | 15 | 40 |
| 6 | 15 | 150 | 160 | 20 | 10 |

### *2.2 The experiments*

In order to get the friction coefficient and wear rate of the produced samples, the wear test was carried out with a Turkyus brand abrading device (Figure 3).


Figure 3. Wear tester

Wear rate tests were carried out using a pin-on-disc type tribo-test machine. The pin-on-disc test apparatus with disc made of grey cast iron of hardness value 19 5HB (62.5 kg.f, 5mm ball) and 180mm track diameter was used to investigate the dry sliding wear rate of the brake pad specimens in accordance with ASTM:D792 standard [25].

Load cell located on the device detects the forces axially generated under constant load after the rotation movement starts and transfers the data to the computer program. The wear rate is measured according to the mass loss principle by measuring the masses before and after the wear test; was calculated using equation (1).

$$W_a = \frac{\Delta G}{\rho . M . S}(mm^3 . N^{-1} . m^{-1}) \qquad (1)$$

The hardnesses of the samples were measured on the rockwell R scale (1/2" ball 10kgf preload, 60kgf total load) in the Digirock® brand hardness tester produced by Bulut Makine Sanayi ve Ticaret Ltd.Şti (Figure 4).

Figure 4. Hardness Tester

For the calculation of sample densities, sample masses were weighed with a 1mg precision scales, sample diameters and heights were measured with digital calipers with a sensitivity of 0.01mm in three different axes and calculated with equation (2).

$$\rho = \frac{m}{\frac{\pi . D^2 . h}{4}}(g . cm^{-3}) \qquad (2)$$

In order to calculate the friction coefficient, during the wear test, the load cell data stored in the wear device were recorded on the computer momentarily. The mean cold friction coefficient was calculated by taking the average of the recorded data during the wear test.

### *2.3 The results of the experiments*

It was found that the most wear on the pin-on-disk test to determine the wear rate was at the sample 5. It came out that it was produced 100MPa pressure, the lowest one. Another factor is the reduced sample density, which is high for the proportion of JDNP participating in the sample. Thus, the decrease in density caused the wear rate to increase.

The least wear rate is in the number 2, where the pressing pressure is at the mid-level of 150MPa and the minimum rate of JDNP.

The wear rate values of the samples were given in the Figure 5.

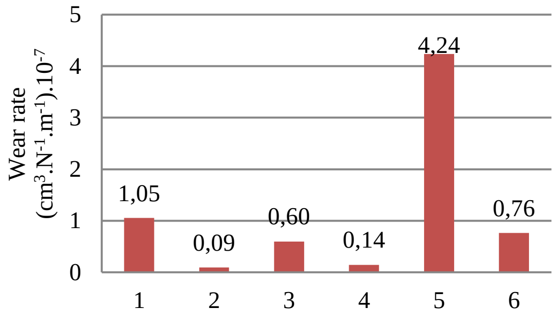



Figure 5. Wear rate graph

When the wear rate graph in fig. 5 and the table 3 are examined together, it is seen that the higher the pressing pressure, the lower the wear rate.

While the wear rate is calculated, the density is also in the denominator. The wear rate is expected to decrease while the density goes up in experiments done in the same conditions. But the density itself isn't the main factor for the wear rate. When we have a look at the graphs in 3 and 4 together, the density of sample 5 is seen low whereas the wear rate is the highest. When the properties of the sample 5, which has the highest wear rate, are examined from table 4, it will be seen that the pressing pressure and pressing temperature is the lowest and the rate of JDNP is the highest. When the wear rates and production parameters of samples 3 and 5 with JDNP at the same rate are examined together, the wear rate of sample 3 is seen to be lower. In order to reduce the wear rate in the use of high-rate JDNP, increasing the pressing pressure and pressing temperature can be a solution.

This condition can be explained by the hardness graph of fig. 7 and the graph of the mean cold friction coefficient in fig. 8, which show that the coefficient of friction of the sample 5 is the highest and that the hardness is relatively small.

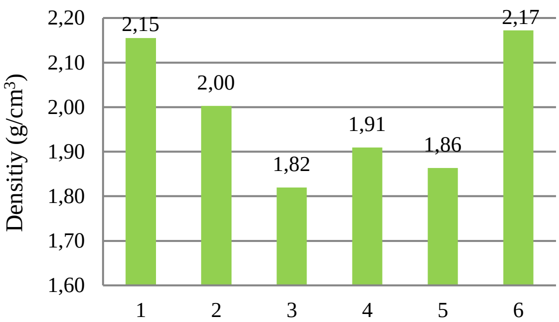



Figure 6. Density graph

High density values were found in samples with low JDNP ratio and low density values were in samples using high JDNP. In other words, the JDNP ratio is increased, the sample density is decreasing.

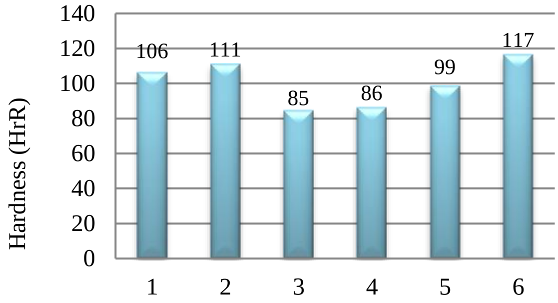



Figure 7. Hardness graph

The pressing pressure alone has not been associated with the hardness value. However, when the samples produced at the same pressing pressure are compared, the hardness of samples with a higher JDNP ratio is lower, while the hardness of samples with a lower JDNP ratio is higher.

As the pressing pressure increases, it is generally seen that the friction coefficient decreases. Figure 8 shows the average cold friction coefficient [26] values of the samples during the wear test.

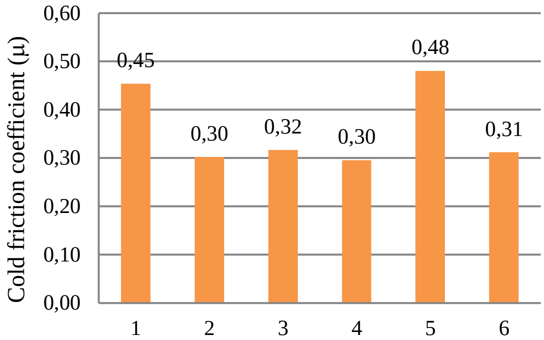



Figure 8. Average cold friction coefficient graph

## 3. Conclusions

The wear rate values change between $0.093.10^{-7}$-$4.235.10^{-7} cm^3.N^{-1}.m^{-1}$. These values are lower than the minimum wear rate specified in TS 555.

The friction coefficient ranges from 0.30 to 0.48. When compared with TS555 values, these values were found to be the E class of 4 samples, the G class friction coefficient of 2 samples, and all the samples were found to conform to the standard [27].

The density changes between 1.82-2.17 $g/cm^3$. The direct effect of pressure to density couldn't be noticed. Density and JDNP rate have reverse effect.

Hardness values range from 85-117 according to the Rockwell R scale.

The hardness values of the samples (2 and 6) produced were higher than the results of the other samples while the pressing pressure was at the medium level (150 MPa). Also, when the pressing pressure is increased to the highest (200 MPa), the produced specimens (3 and 4) are found to fall to the lowest level.

The pressing pressure mostly effected the hardness and friction coefficient. Generally, the excess of pressing force reduces the hardness and friction coefficient.

The wear rate of the samples with low pressing pressure is higher than the wear rate of other samples.

## Acknowledgment

This work was supported by Selçuk University Scientific Research Projects Coordination Unit within the scope of PhD thesis Project 16201089.

We would like to thank Selçuk University Scientific Research Projects Coordination Unit for their support.

## Nomenclature

| | |
|---|---|
| Wa | : wear rate ($mm^3.N^{-1}.m^{-1}$) |
| ΔG | : mass loss (mg) |
| S | : sliding distance (m) |
| M | : loading weight (N), |
| $\rho$ | : sample density ($g/cm^3$) |
| h | : sample height (cm) |
| m | : sample mass (g) |
| D | : sample diameter (cm) |
| JDN | : juniperus drupacea nut |
| JDNP | : juniperus drupacea nut powder |

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