

## Investigation of Usage of Milled Pine Cone in Brake Pads

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### Abstract

Automotive brake pads are polymer composites containing polymer matrix and various fibers and obtained by mixing and pressing different powder materials. Each material added to the content has one or more tasks. Therefore, the properties and quantities of the materials added to the content are very important in terms of braking performance. In this study, the use of milled pinus brutia cone and pinus nigra cone from the pine cone family in the automotive brake pad was investigated experimentally. First of all, cones are ground and powdered. The milled 10% pinus brutia cone and 10% pinus nigra cone were added to the pad component. The performance tests of the pads were carried out on pin on disk type test device. Friction coefficient, wear, density and hardness tests of the pads were done. The test results have been shown to affect the braking performance of milled pine cone.

**Keywords:** Brake pads; Friction; Pine cone; Wear

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### 1. Introduction

One of the important parts of the vehicles is the brake system. The brake system controls the speed of the vehicle. It provides the vehicle to slow down or stop. This is ensured by the pads used in the brake system. The pad controls the speed of the vehicle by rubbing against the disc surface. Pads are formed by combining different powder materials [1]. Materials used in pads are classified as friction modifiers, solid lubricants, abrasives, fillers, reinforcement and binder [2, 3]. These materials are classified by examining their properties such as tribological behavior, vibration and fade resistance at high temperatures [4].

Friction coefficient and wear resistance are the important factors for pads [5-8]. During braking, pads are expected to have high friction coefficient and wear resistance [9]. Due to braking, a decrease in friction coefficient occurs due to the increase in temperature [10]. This reduction is desired to be at the minimum level. Although the increase in temperature, the friction coefficient is expected to take a stable state.

The use of waste products in pads has increased in recent years. Thus, the cost of pad is reduced and waste products are evaluated. In the literature, studies researching the usage of waste products such as banana peel, banana tree, palm beans, walnut shell, nut shell are existing [11-18].

In this study, pine cones were used as waste products. The

effect of pine cones on braking performance was investigated.

### 2. Material and Method

#### 2.1 Sample Preparation

In this study, the effects of pinus brutia and pinus nigra cone powder on braking pads were investigated. Pine cones were dried at ambient temperature and powdered in the grinder. Then, it was subjected to sieving and its dimensions were determined. Material size used in pads was 300 µm.

Table 1. Ingredients of the samples (wt. %)

Sample Code	PC0	PBC	PNC
Phenolic resin	20	20	20
Al <sub>2</sub> O <sub>3</sub>	6	6	6
Steel fibers	6	6	6
Brass particles	6	6	6
Graphite	8	8	8
Cu particles	5	5	5
Cashew	9	9	9
Barite	40	30	30
Pinus brutia cone	0	10	0
Pinus nigra cone	0	0	10

The contents of three pad samples with the same materials except milled pinus brutia and pinus nigra cone are shown in Table 1.

The pad samples were produced by dry mixing method. The nine different ingredients were mixed for 10 minutes in the powder mixing device. After mixing, it was pressed in cold mold at 80 bar pressure for 2 minutes. After cold pressing, pads were pressed at 150 bar pressure and at 180°C temperature for 10 minutes. During the hot-pressing process, pressure was released several times to remove the gases caused by the reaction of the phenolic resin.

## 2.2 Experiments

Performance tests of the produced pads were performed on the test device given in Fig. 1. Detailed information with the test device can be found in other works of the author [19-21].

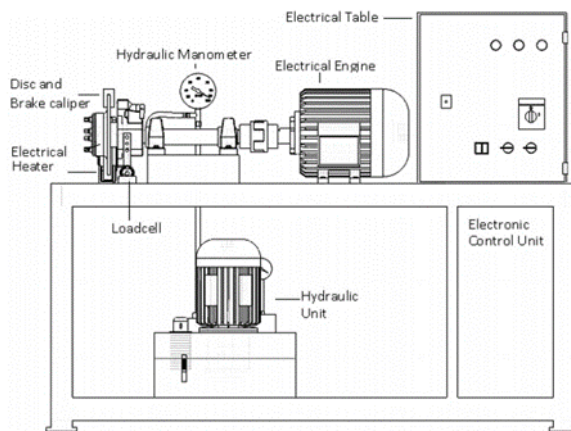


Fig. 1. Schematic view of the brake pad tester

The pads were tested by braking for 5 minutes under 5 bar pressure. The change in friction coefficient was determined depending on the temperature during braking. The pretest was performed to contact the entire surface of the pad with the disc and then performance tests were carried out. Performance tests were repeated 3 times for each pad and the results were evaluated.

The pads are desired to have high wear resistance. The specific wear rate ( $V$ ), which is the important features of the pads, was calculated by the formula given in Equation 1 according to Turkish Standards (TSE 555) and British Standards (BS AU142) [22, 23].

$$V = \frac{m_1 - m_2}{2 \cdot \pi \cdot R_d \cdot n \cdot f_m \cdot \rho} \quad (1)$$

where,  $V$  is the specific wear rate ( $\text{cm}^3/\text{Nm}$ ),  $R_d$  is the distance between centers of the sample and the rotating disc (m),  $m_1$  and  $m_2$  are the average specimen weights before and after the test (g), respectively,  $n$  is the rotating number of disk,  $\rho$  is the density of the brake lining ( $\text{g}/\text{cm}^3$ ) and  $f_m$  is the average frictional force (N). The density of the produced pads was determined by the formula given in Equation 2 according to the Archimedes principle [24]. In the equation;  $\rho$  is

density ( $\text{g}/\text{cm}^3$ ),  $m_h$  is mass of the sample in air (g) and  $m_s$  is mass of the sample in water (g).

$$\rho = \frac{m_h}{m_h - m_s} \quad (2)$$

The pads are requested not to wear the disc surface [25]. For this reason, the hardness of the pads is important for pad and disc usage duration. The hardness of the pads was determined by Brinell test method with 62.5 kg of load and 2.5 mm diameter of indenter steel ball. Hardness measurements were made from the wear surface of the pad and six different points.

The microstructures formed on the wear surface of the pads were examined. Scanning Electron Microscope (SEM) images were taken for microstructure examination of pads.

## 3. Results and Discussion

The friction coefficient-temperature graphs of brake pads produced with pinus brutia cone (PBC), pinus nigra cone (PNC) powders and non-pine cone (PC0) are given in Fig. 2, Fig. 3 and Fig. 4. When the graphs are examined, it is seen that the friction coefficient is shaped after 300 seconds depending on the increase in temperature.

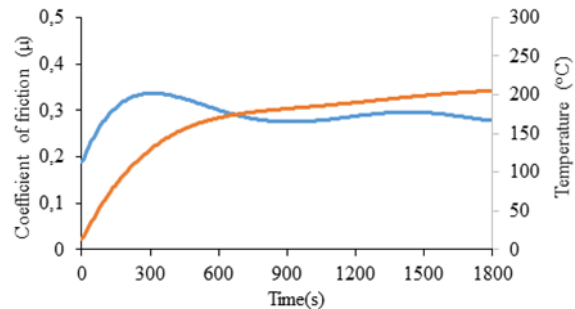


Fig. 2. Friction coefficient-temperature change graph of PC0 pad

When the graphs are examined, it is seen that the friction coefficient of the pad containing PBC shows a more stable performance. The lowest temperature occurred in the pad with PBC content. The pad containing PBC caused an increase in temperature. As the temperature increased, a decrease in friction coefficient was observed. In friction coefficient with increasing temperature to be a slight decline is expected [26]. This situation may be thought to be caused by the high temperature affecting the binding property of the resin. Materials that provide heat conduction such as copper, steel wool and brass shavings in the content of the pad prevent an excessive decrease in friction coefficient. Cashew used in content of the pad causes to remain stable of the friction coefficient during the experiment. When the figures are examined, the friction coefficient continues stably depending on the temperature increase.

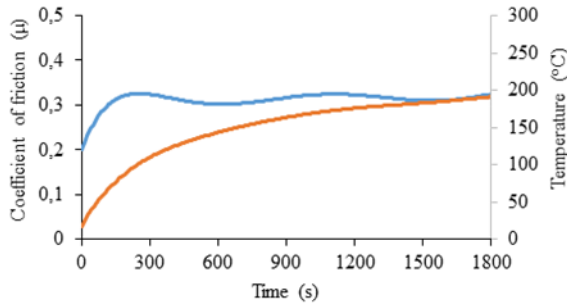


Fig. 3. Friction coefficient-temperature change graph of PBC pad

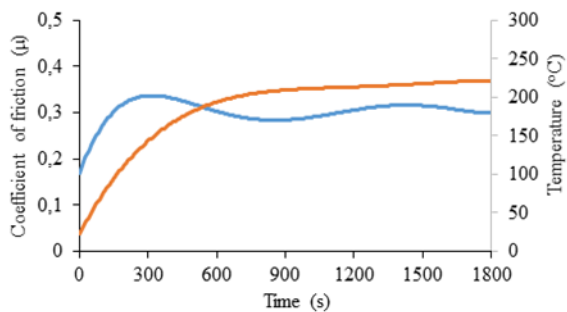


Fig. 4. Friction coefficient-temperature change graph of PNC pad

The average friction coefficient of the pad with PCB content is the highest with 0.36. Using PCB in the pad slowed down the rate of temperature increase. This resulted in the lowest test temperature in the pad samples. The performances of the pad containing PNC and non-pine cone pad have given similar results. Average friction coefficient of PNC and PC0 coded pad samples was determined as 0.30. The use of PBC in the pad increased the friction coefficient. The use of PNC in the pad showed any change in the friction coefficient.

The wear, density, hardness and average friction coefficient values of the produced pads are given in Table 2.

Table 2. Typical characteristics of the PBC, PNC and PC0 brake pads

Sample code	PBC	PNC	PC0
Friction coefficient ( $\mu$ )	0.36	0.30	0.30
Specific wear ( $\text{cm}^3/\text{Nm}$ )	0.39	0.42	0.46
Hardness (HB)	34	30	28
Density ( $\text{g}/\text{cm}^3$ )	2.25	2.12	2.10

When the pad samples were examined, PC0 pad without pine cone powder showed the highest wear value. The highest wear resistance showed PBC pad sample using pinus brutia cone powder. While the wearing value of PNC coded pad

sample with pinus brutia cone content was 0.42, it was determined as 0.39 in PBC coded pad sample and 0.46 in PC0 coded pad sample. PBC pad sample exhibiting low wear rate; It can be interpreted that the rate of pinus brutia cone powder slows the increase of temperature and does not allow the part breaks by preserving the binder characteristic.

Archimedes principle was used in density measurement because of the pad surfaces not being smooth. Thus, density values gave more accurate results. The use of pine cone in the pad increased the density. It is stated in the literature that the increase in density is proportional to the decrease in porosity [27, 28]. Pine cone used in pads reduced the porosity increased binding among the materials.

When Table 2 is examined, it is seen that the hardness of the pad increases with the use of pine cone powder. The pads are not desired to have an excessively hard structure [29, 30]. When the pad is hard, its brittleness increases as pressure is applied during braking. Micro-sized parts that break off the pad during braking will increase the amount of wear. The hardness of the pads affects the pressure applied during production [31]. Applying high pressure during the production phase will increase the hardness of the pad and cause it to become brittle. Therefore, the pad production stage is a very important parameter. Pine cone powder increased the pad hardness. The pad with PBC content had a harder structure than the pad with PNC content. The hardness of the pad without a pine cone was lower. The use of pine cone in pad increased the binding properties of the materials and porosity decreased. The decrease in porosity caused an increase in hardness.

SEM pictures of the test samples are shown in Fig. 5-7. When the figures are examined, it is seen that there are some adhering parts on the friction surfaces of the PBC containing pad with high friction coefficient. It is stated as abrasive wear in the literature [32-34]. This situation caused an increase in friction coefficient.

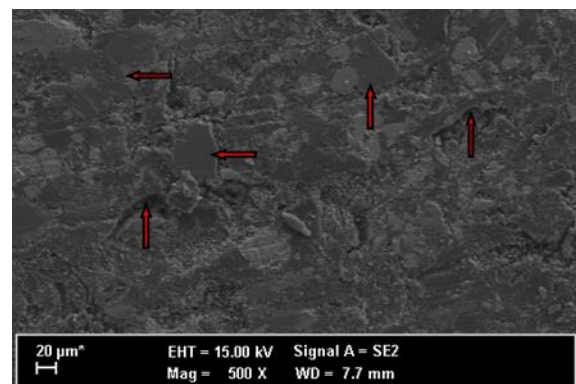


Fig. 5. SEM micrograph of PC0 pad

The traces seen as rupture and adhesion due to friction on the wearing surfaces of the pads showed positive results in the friction coefficient. Micro and macro gaps can be seen on

the pad surfaces. These gaps affect the hardness and density values of the pad. The SEM images of the pad containing PBC which showed the highest friction coefficient average were found to have more adhesion due to rupture.

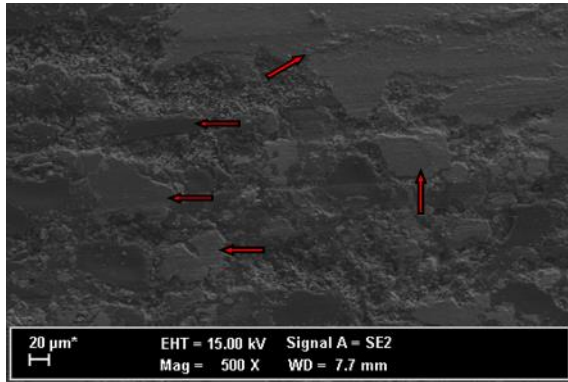


Fig. 6. SEM micrograph of PBC pad

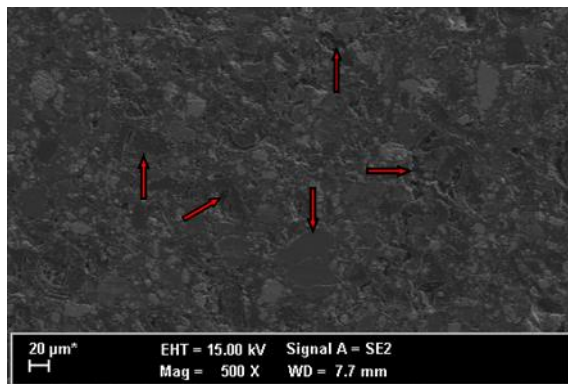


Fig. 7. SEM micrograph of PNC pad

According to TSE 555 standard, pads are classified according to the friction coefficient. The friction coefficient is 0.25-0.34 (E), 0.35-0.44 (F), 0.45-0.54 (G), 0.55 and above (H). The test results obtained in this study showed that the PBC coded pad is F class and the others are E class pads.

#### 4. Conclusions

As a result of the tests with the pads containing pinus brutia cone (PBC) and pinus nigra cone (PNC) powder;

- Pinus nigra cone powder slowed the temperature rise velocity of the pad.
- The low temperature in the pad containing pinus nigra cone increased the friction coefficient.
- Since the temperature increase rate of the pinus brutia cone (PBC) containing pad is slow, the resin has not lost its binding feature.
- Pine cone powder increased the wear resistance of the pad.

- Pine cone powder increased the density of the pad.
- Pine cone powder increased the hardness of the pad.
- The results obtained from friction-wear tests showed that the pads with pine cones have the standard values.

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