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Tribological properties of automotive brake pads containing peanut shell powder

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Abstract
In this study, the effect of peanut shell powder content on the tribological properties of automotive brake pads was investigated experimentally. Brake pads are intended to be resistant to environmental conditions such as abrasion, friction, temperature and humidity. Therefore, brake pads are formed by a combination of materials with many different properties. In this study, four brake pad samples containing different amounts of peanut shell powder were designed and produced. The added peanut shell powder is balanced with the filler in the content and the amount of other components was constant. Samples were produced by conventional dry mixing method. A special design brake tester with a gray cast iron disc was used to determine the wear and friction characteristics of the samples. All tests were performed according to appropriate standards. According to the results obtained, the availability of peanut shell powder in brake pads has been evaluated and categorized according to its characteristics.

Keywords: brake pad, friction, wear, powder peanut shell

1. Introduction

Brake pads have been used for many years to meet many requirements in the braking systems of railway and road vehicles. These requirements are; minimum noise, minimum vibration, eco-friendly, economical and maximum braking efficiency. All these requirements are not met by a single material. For this reason, brake pads are composite materials formed by the combination of many materials. Composite materials consist of two main components. These are matrix and fibers. These two components are not sufficient for the brake pads. Therefore, different materials with properties such as abrasives, heat conductors, solid lubricants and fillers are added to the brake pads. The matrix material that holds all components together is usually phenolic resin. Researchers have tried a variety of materials as fiber [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11]. In recent years, studies have been conducted to investigate the usability of organic materials considering that the materials used in friction composites do not harm the environment. In this context, the usability of many organic materials has been investigated [12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24]. In this study, a new brake pad formulation was developed considering the environmental sensitivity and the effect on the braking performance was investigated by adding peanut powder to the content. Necessary tests were performed in accordance with the standards and the results were evaluated for usability.

2. Materials and methods

Literature survey was performed to formulate pads and the properties of the materials were considered. The general content and weight percentages of the developed formulation are shown in Fig.1. Others include abrasive, solid lubricant, thermal conductor, space filler and friction modifier materials.

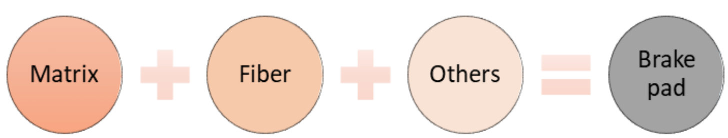

Fig 1: The general contents of developed brake pad

The developed brake pad consists of nine ingredients. Accordingly, phenolic resin as binder, steel fiber as fiber, alumina as abrasive, zinc powder and brass swarf as thermal conductor, graphite as solid lubricant, barite as space filler and, cashew and peanut shell powder as friction modifiers were used. The distribution of materials according to their functions is shown in Fig. 2. The theme is peanut shell powder and barite, and the parent composition is other materials.

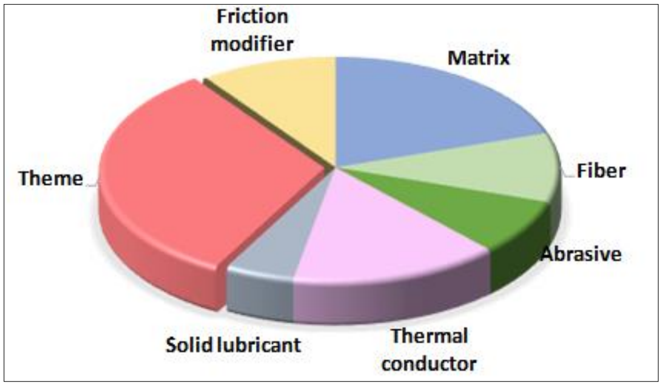

Fig 2: The distribution of materials according to their functions

The weight content of the brake pads is shown in Table 1. The weight ratio of other materials except peanut shell powder and barite is constant for all samples. The change in the ratio of peanut shell powder in the brake pad was balanced with the amount of barite. P0, P3, P6 and P9 are the codes of the samples. "P" represents the peanut shell powder and the number represents the weight percentage of peanut shell powder in brake pad.

Table 1: % Weight content of ingredients in samples

	P0	P3	P6	P9
Peanut shell powder	0	3	6	9
Barite	32	29	26	23
Parent composition	68	68	68	68

All materials are in powder form and conventional powder metallurgy method is used for the production of samples. The general stages of production are shown in Fig. 3. Detailed information about the manufacturing process and parameters can be found in our previous study [20].

Fig 3: Main production stages

Hardness and density measurements were carried out to determine the effect of physical properties of the samples on brake performance. For the hardness test, the Rockwell hardness tester with a 1/4-inch steel ball tip was used. It was 10 kN as pre-load and 60 kN as full load. Data were obtained from the center of the sample and four different points and the result was written as arithmetic mean. In order to determine the density of the samples, firstly air and then water were weighed according to Archimedes method [25]. Weight loss was determined by measuring the weights of the samples before and after the test. The specific wear rate was calculated according to [25]:

$$W_s = \Delta m/(L \times \rho \times F_n) \qquad (1)$$

where Δ_m is the mass loss, L is the sliding distance, ρ is the density of the composite, and F_n is the applied load. For the brake tests of the composites, a special design device was used in which the gray cast iron disc was used as the counter element. The device is fully computer-controlled and includes data collection software. The partial view of the brake tester is shown in Fig. 4. Brake testing of the samples was carried out as specified in TSE 555 [25] and TSE 9076 [26].

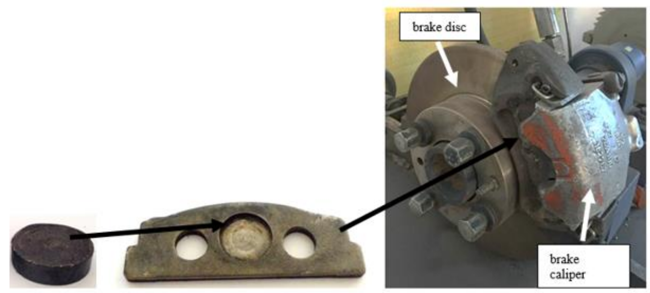

Fig 4: The partial view of the brake tester

1. Results & Discussion

The relationship between the physical properties of the samples and the amount of peanut powder was investigated. The hardness measurement results of the samples are shown in Fig. 5. As can be seen, the hardness of the P0 coded sample without peanut shell powder is higher than the hardness of samples with peanut shell powder. Thus, it can be said that the peanut shell powder softened the composite. In addition, it is observed that the hardness increases with increasing amount of peanut shell powder. In other words, the amount of peanut shell powder in the sample should not be less than 10% in terms of hardness.

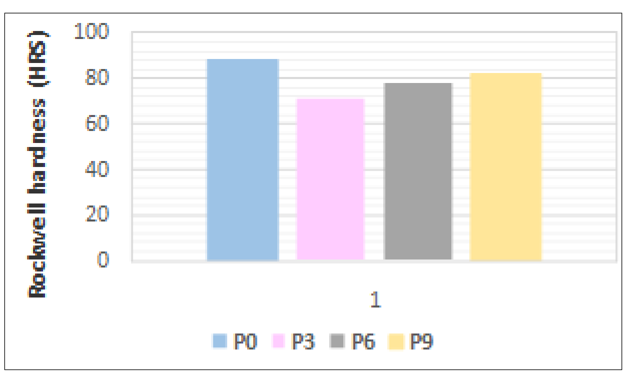

Fig 5: The Rockwell hardness values of the samples

When the density values of the samples in Fig. 6 are examined, it can be said that the increase of peanut shell powder in the content decreases the density of the sample. Considering that the peanut shell powder is balanced with barite in the formulation, the results are consistent because of the peanut shell powder is lighter.

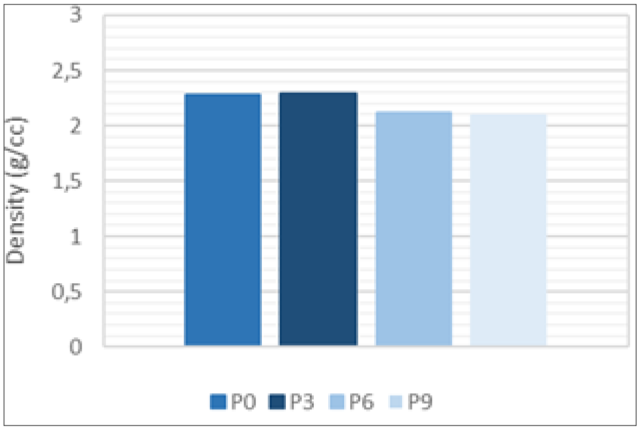

Fig 6: The density values of the samples

Two parameters, friction coefficient and specific wear rate are more important when evaluating brake friction composites. For effective braking performance, it is preferred that the friction coefficient is high and the specific wear rate is low. Fig. 7 shows the recorded average friction coefficient of the samples used in this study. The high friction coefficient is not sufficient by itself, but the change in the friction coefficient during braking must be stable. Fig. 8 shows the disc temperature during the test period. It is seen that the disc temperature does not reach the curing temperature (200°C) of the resin that brings the samples together. When the temperature reaches the curing temperature, the resin loses its binding properties. Such a case did not occur in the tests performed in this study.

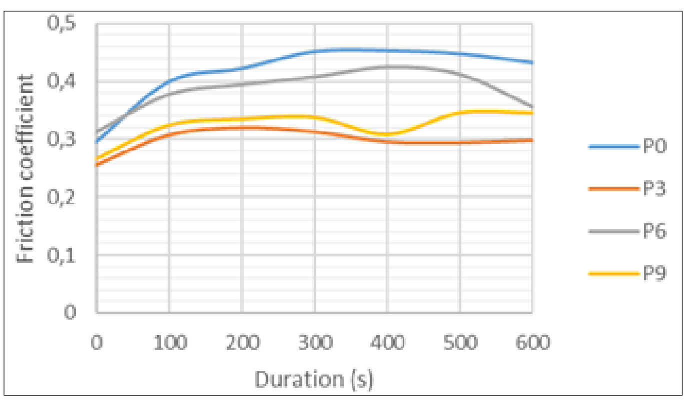

Fig 7: The mean change of friction coefficient of samples during the test period

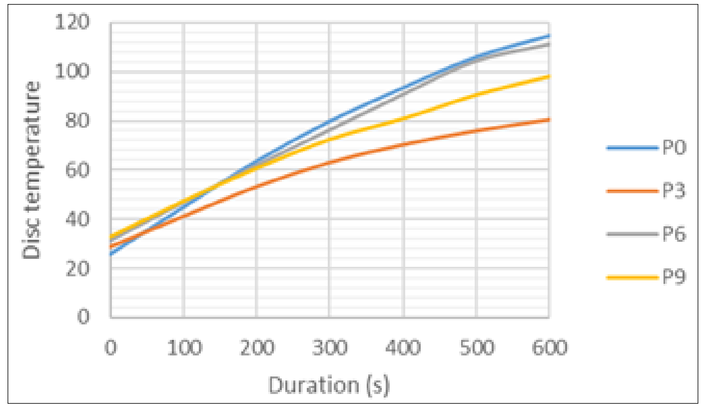

Fig 8: The mean disc temperature during the test period

The structure friction coefficient shows the formation of friction layers. The friction layers are formed by debris, which breaks down from the composite, by gathering around parts having relatively high hardness near the surface and re-bonding with the effect of temperature. The primary or secondary plates formed in this way provide a better adhesion between the disc and the composite and increase the friction coefficient. Too much fluctuation in friction coefficient graphs is undesirable. Fluctuations indicate low friction stability. In theory, friction stability is calculated by the ratio of the average friction coefficient to the maximum friction coefficient obtained during the test. The percent friction stability of the samples and maximum disc temperature are shown in Fig. 9. When the figure is examined, it is seen that the friction stability of the sample without peanut shell powder is higher. However, there is no striking difference in samples containing peanut shell powder. Maximum disc temperature was not directly related to the peanut shell powder content.

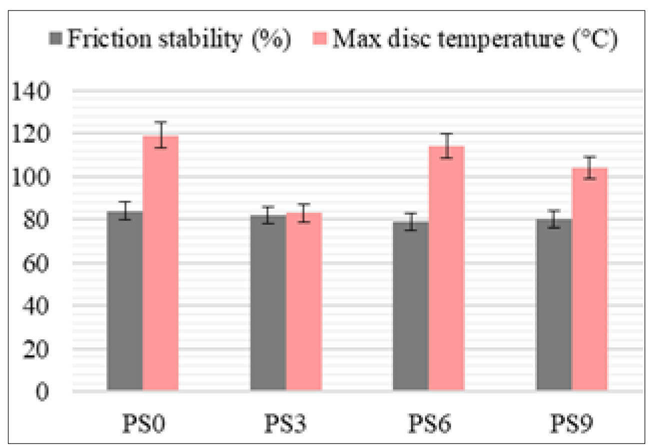

Fig 9: The friction stabilities of the samples and maximum disc temperature

The wear properties of the samples are shown in Table 2. When the friction characteristics of the samples are examined, the average friction coefficient value of the sample with P0 code without peanut shell powder is higher than the others. When the specific wear rate values and weigh losses are considered, it is concluded that there is not a trend that is proportional to the amount of peanut shell powder.

Table 2: The wear properties of the samples

	P0	P3	P6	P9
Average friction coefficient (μ_{avg})	0.41	0.31	0.38	0.32
Specific wear ratio (cc^3/Nm)	$1.37x10^{-6}$	$1.58x10^{-6}$	$2.73\ x10^{-6}$	$1.95\ x10^{-6}$
Weight loss (g)	0.073	0.061	0.125	0.074
Friction stability (%)	84	82	79	80

The surface roughness values of the samples after friction testing are given in Fig. 10. Three different points were taken from the sample surface for the test and the mean was presented. The surface roughness of the sample containing 3% peanut shell powder is lower than the other samples. However, no significant relationship was found between peanut shell powder and surface roughness.

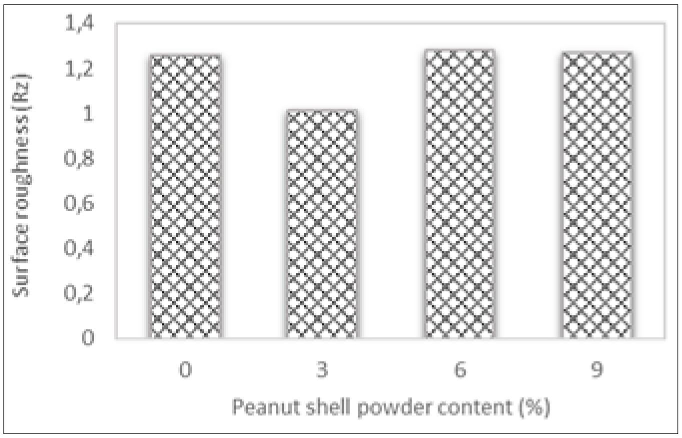

Fig 10: The surface roughness of the samples

When the optical microscope pictures in Fig. 11 of the wear surfaces of the samples are examined, it is seen that friction layers are formed. Since the primary and secondary friction layers increase the adhesion between the disc and the sample, it has a positive effect on the friction performance. However, micro-cracks and gaps were formed by the effect of friction, as anticipated.

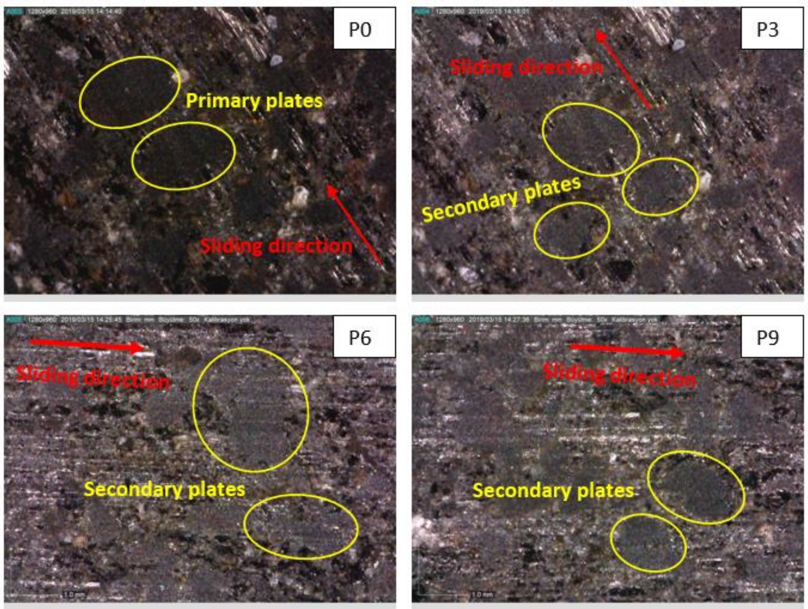

Fig 11: The optical microscope photographs of worn surfaces of samples

4. Conclusions

The usability of peanut shell powder in brake pads was investigated and the necessary tests were performed. According to the test results, all samples are compatible with the literature, applicable in industry and comply with TS 555 standard. When all parameters are evaluated together, the brake lining sample containing 6% peanut shell powder is better than the other samples. However, in terms of surface roughness and weight loss, the brake pad sample containing 3% peanut shell powder is more ideal. There was no direct correlation between the physical properties and friction characteristics of the brake pads. The friction stability of the samples containing peanut shell powder is lower than that of peanut shell powder-free sample.

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