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Research Article

EXPERIMENTAL INVESTIGATION OF A NOVEL FRICTION MODIFIER IN COMPOSITE MATERIALS

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ABSTRACT
In this study, waste banana tree powder was turned into powder and its use in automotive brake lining was investigated. For this purpose, 3 different samples were produced by using powder metallurgy production techniques. Waste banana tree powder (WBTP) was added in different rates (3%, 6% and 9% by weight), keeping the determined content constant. Firstly, homogenous mixtures of the ingredients are provided and then final shapes are given by hot pressing method. The friction, wear, hardness and density analysis of the brake lining samples and the effects of the use of WBTP on the brake lining were evaluated.

Keywords: *Composite Materials, Brake Lining, Friction, Wear*

1. INTRODUCTION

Brake linings are the most important part of the brake system for slowing or stopping of vehicles. Brake linings are made of powdery materials with different content without asbestos. A brake lining is a composite of many different ingredients. Components are classified as fibers, binders, solid lubricants, fillers, abrasives, metallic fillers and friction modifiers (Bijwe *et al.*, 2012; Sugozu, Mutlu, and Sugozu 2018). In generally phenolic or their modified versions are used as binder materials for friction composites. After the prohibition of the use of asbestos in the brake linings, researchers began to create different balata contents (Li *et al.*, 2018; Ikpambese *et al.*, 2016; Kukutschová *et al.*, 2009). The brake linings must be stable and have high coefficient of friction at high temperatures and must be resistant to wear. The brake linings must be noiseless and without vibration during braking.

Today, most of the researchers have focused on the use of industrial and agricultural waste in vehicle brake linings (Sugözü and Kahya, 2018; Ibhadode and Dagwa, 2008; Idris and Aigbodion, 2015). Alternative studies have been made such as hazelnut shell, coconut shell, palm kernel shell for asbestos-free brake linings (Yawas *et al.*, 2016; Akıncıoğlu *et al.*, 2018; Ghazali *et al.*, 2011). The use of waste products on brake linings positively affects economic and environmental impacts.

The aim of this study is to develop a new organic brake lining without asbestos using agricultural waste. The banana tree has a fibrous structure, it is a cheap and easily available waste product. WBTPs were added in different rates (3%, 6% and 9% by weight) and were produced by the powder metallurgy method. The density of specimens was determined and the hardness was determined using the Rockwell hardness tester device (HRL). For friction performance tests, a full-scale brake lining device with grey cast iron disk was used. The specific wear rate was calculated according to the TSE 555 standard (TSE 555, 1992).

2. MATERIALS AND METHODS

In this study, a new automotive brake friction material was obtained by using WBTP. The waste banana tree parts were dried, then it was turned into small particles in the mill. It was powdered using mixer. WBTP was sieved and size analysis was conducted. WBTP in different ratios such as 3%, 6% and 9% was added to the brake lining. Other additive materials were kept constant. Table 1 shows the content of brake lining.

Table 1. The amount of ingredients used for brake lining (weight %)

Type of material	M0	M3	M6	M9
Phenolic resin	20	20	20	20
Steel wool	5	5	5	5
Alumina	8	8	8	8
Brass shavings	5	5	5	5
Graphite	5	5	5	5
Cu particle	8	8	8	8
Cashew	8	8	8	8
WBTP	0	3	6	9
Barite	41	38	35	32

Powder materials forming the contents of the brake lining were mixed in the mixer for 10 minutes then pressed at 80 bar pressure for 2 minutes at ambient temperature. The obtained brake lining samples were left hot pressing at 100 bar pressure for 10 minutes. Detailed conditions for each manufacturing step can be found in the literature (Sugözü *et al.*, 2016). Four different brake lining were produced in an inch diameter. Three experiments were made from a brake lining and the mean of the experiments were taken. Figure 1 shows the brake lining tester used in this study. Detailed information about the test device is described in other studies of the author (Sugözü *et al.*, 2016).

Fig. 1. Brake lining test device used in this study

The wear values of the brake linings are calculated with the equation specified in the TS 555 Turkish standards. Detailed information about the specific wear equation (1) is described in the author's other works (Sugözü *et al.*, 2016).

$$\mathbf{V} = \frac{\mathbf{m_1 - m_2}}{\mathbf{2.\pi.R_d.n.f_m.\rho}} \qquad (\mathbf{1})$$

The density of the brake linings was determined according to the principle of Archimedes. The hardness of the brake linings was determined by using Rockwell hardness tester. During the hardness measurement of the brake linings, 10 kgf preload and 60 kgf full load were applied with a 6.35 mm diameter steel ball. Hardness measurements were taken from the wear surfaces of the brake linings. Performance tests of the brake linings were carried out at 0,5 MPa pressure and 6 m/s speed for 10 minutes.

3. RESULTS

Coefficient of friction and wear are very important when evaluating the performance of the brake linings. The coefficient of friction of the brake linings is high; the wear rate is expected to be low. Figure 2-5 shows the coefficient of friction and temperature performance of the brake lining with WBTP. The coefficient of friction of the brake linings is expected to remain stable depending on the temperature (Kim *et al.*, 2008).

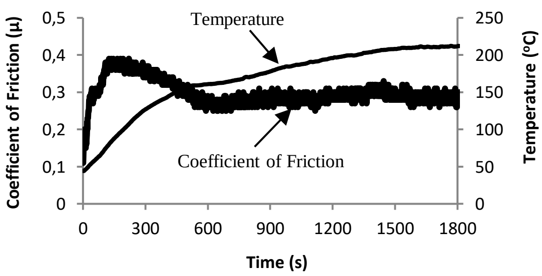

Figure 2. The coefficient of friction-temperature graphs

of the brake lining containing 0% WBTP

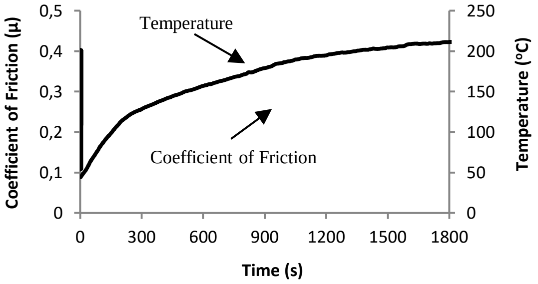

Figure 3. The coefficient of friction-temperature graphs of the brake lining containing 3% WBTP

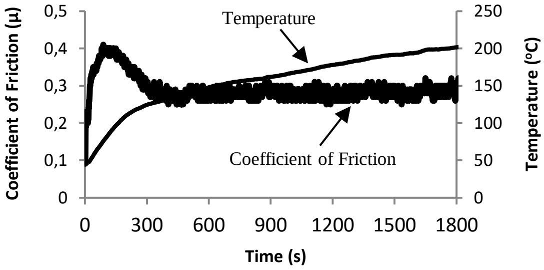

Figure 4. The coefficient of friction-temperature graphs of the brake lining containing 6% WBTP

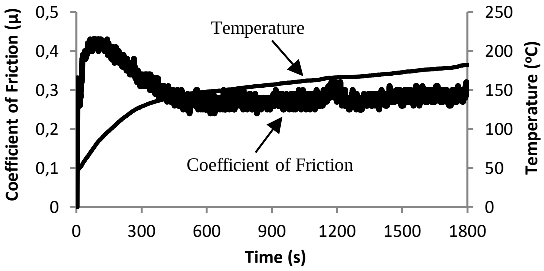

Figure 5. The coefficient of friction-temperature graphs of the brake lining containing 9% WBTP

The mean coefficient of friction of the linings was found at very close values. The mean coefficient of friction of the WBTP unused brake lining sample was 0.297. The coefficient of friction of the brake lining sample, which used 9% WBTP was 0.290. As the ratio of WBTP increased, the friction stability was low. When the shapes are examined, the friction performance were formed after 300 seconds. The highest stable coefficient of friction was 3% WBTP containing the lining sample. Temperature has decreased with increasing WBTP. The highest temperature was found in the brake sample with 3% WBTP content.

When the figures are examined, it is seen that the brake lining tests have become more stable after 300 seconds. The friction stability is known to be an important feature for commercial brake lining. To ensure good friction stability, the components of the brake lining should be selected carefully. The coefficient of friction is in the range of 0.3 industrial standard for the brake lining system (Leonardi *et al.*, 2018). In the literature, it is stated that the coefficient of friction (µ) generally varies between 0.1 and 0.7 depending on the friction force and the temperature of the disc coating interface (Ravikiran and Jahanmir, 2001). The reduction in coefficient of friction at high temperatures seen in the figures results from the thermal decomposition of the phenolic resin used as a binder in the liner, which weakens the adhesion effect between the matrix and the components (Shin *et al.*, 2010).

Zero wear is not expected on brake linings. If very high-resistant materials are used to prevent wear in the lining, this will cause wear on the surface. Therefore, the choice of abrasives is one of the most important aspects of a liner formulation to improve wear resistance (Kahraman and Sugözü, 2019; Sugozu *et al.*, 2018). Table 2 and Table 3 show the specific wear, average coefficient of friction, density, hardness and friction stability of lining samples containing 3% (M3), 6% (M6) and 9% (M9) WBTP and WBTP-free 0% (M0). As the amount of WBTP increased, the amount of wear increased proportionally.

Table 2. Tribological properties of brake lining specimens

Specimen Code	Specific wear rate (cm^3/Nm)	The average coefficient of friction
M0	1.630×10^{-6}	0.297
M3	2.030×10^{-6}	0.295
M6	2.190×10^{-6}	0.293
M9	2.230×10^{-6}	0.290

Table 3. Physical properties of brake lining specimens

Specimen Code	Rockwell hardness (HRL)	Density (g/cm^3)
M0	96	2.35
M3	91	2.15
M6	90	2.14
M9	77	2.06

Table 3 shows that the hardness and density of the specimens are decreased by increasing the amount of WBTP in the composite.

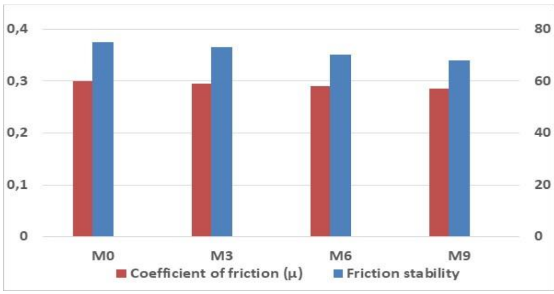

Fig. 6. The coefficient of friction and friction stability graphs of brake lining specimens

Figure 6 shows the friction stability and coefficient of friction of the brake lining samples. Improvements in friction stability were observed as the WBTP ratio decreased. High frictional stability is a sign of high friction performance of the brake lining.

4. CONCLUSION

Composite brake linings with different proportions of WBTP were developed and their mechanical and tribological performances were evaluated according to industrial standards. Based on the experimental results, the following conclusions were drawn:

- The coefficient of friction remained stable as the amount of WBTP increased.
- The coefficient of friction is in the range of 0.3 industrial standard for the brake lining system.
- Depending on the amount of WBTP increased, the density and hardness of the linings decreased.
- The wear resistance of the linings decreased with the increase in the amount of WBTP.
- The lining with 3% WBTP showed a more stable coefficient of friction performance.
- As a result of this experimental study, 3% WBTP could be used as an alternative material in automotive brake lining.

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