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The Effect of Wearing Brake Lining Surface on Braking Performance

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Abstract
After braking, different wear types and micro-macro gaps occur on the brake lining surface. This situation varies depending on the amount of binder, friction modifier, reinforcement, lubricant and filler materials used in the brake lining content and braking conditions. In this study, the effect of brake lining surface morphology, which is worn after braking, on the tribological properties of the brake lining was investigated. In this context, the wearing surfaces of the brake lining after braking were examined. It has been observed that the braking performance increases depending on the rate of wear types seen on the brake lining surface.

1. Introduction

Vehicle brake lining is one of the most important parts of the brake system. Brake linings are produced by combining more than one material and passing through certain production stages. The materials used in the brake lining can protect its properties against temperature increase and are selected from materials with high wear resistance (Elzayady and Elsoeudy, 2021:11).

The brake lining is used to slow down and stop the vehicle by rubbing against the disc surface with the pressure applied on it. As a result of the friction of the brake lining on the disc surface, an increase in temperature occurs. Temperature increase negatively affects braking performance (Xingming et al., 2016:8, Verma et al., 2015:322-323).

It is desired that the wear resistance of the brake lining is high during braking (Rhee et al., 1991:246, Bijwe 1997:18, Jeganmohan et al., 2020:1). Brake linings wear out by rubbing against the disc surface. Micro and macro cavities are formed on the surface of the brake lining, which is worn as a result of friction. In addition, different types of wear occur on the brake lining surface. The wear types on the brake lining surface give information about the brake lining performance. In line

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with this information, material can be added to increase the wear resistance by changing the brake lining material content.

In this study, brake linings with different wear surfaces have been investigated. The effect of the wear surface on the brake lining performance was investigated.

2. Materials and Method

In this study, three different brake lining surfaces were examined and the effect of the wear surface on the brake lining performance was investigated. Three brake linings with the same content were produced. Different wears were created on the brake lining surfaces by changing the friction force. The brake linings are coded as W1, W2 and W3. The materials used in the brake lining and their ratios are given in Table 1.

Table 1. Material ratios in the mixture (% by mass)

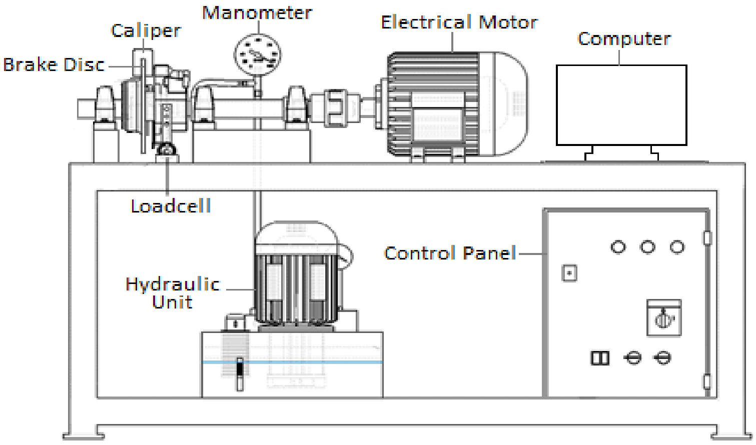
Ingredient	W
Phenolic resin	20
Copper particles	10
Alumina	8
Graphite	5
Brass particles	5
Cashew dust	10
Steel wool	7
Barite	35

In the content of the brake lining; phenolic resin as binder, cashew copper and brass shavings as friction modifier, alumina as abrasive, graphite as solid lubricant, steel wool as reinforcement material, barite as filling material were used.

Before the production process, the powder materials, whose amounts are given in table 1, were determined using a balance with an accuracy of 0.001 g. The weighed materials were transferred to the chamber of the powder mixing device. In order to ensure the homogeneity of the mixture, the sample content was mixed in a specially manufactured powder mixing device at 150 rpm for 10 minutes. The resulting mixture was carefully placed in a 25.4 mm diameter cold press mold and pressed for 2 minutes at room temperature under 80 bar pressure. During the hot pressing phase, the samples were exposed to 100 bar pressure with the help of a hydraulic press for 10 minutes. The hot press molds were heated from the lower and upper tables using electrical energy until a temperature of 150 ºC was obtained.

The experimental set shown in Figure 1 was used to determine the wear and friction coefficient properties of the produced brake lining samples.

Figure 1. Brake lining test device

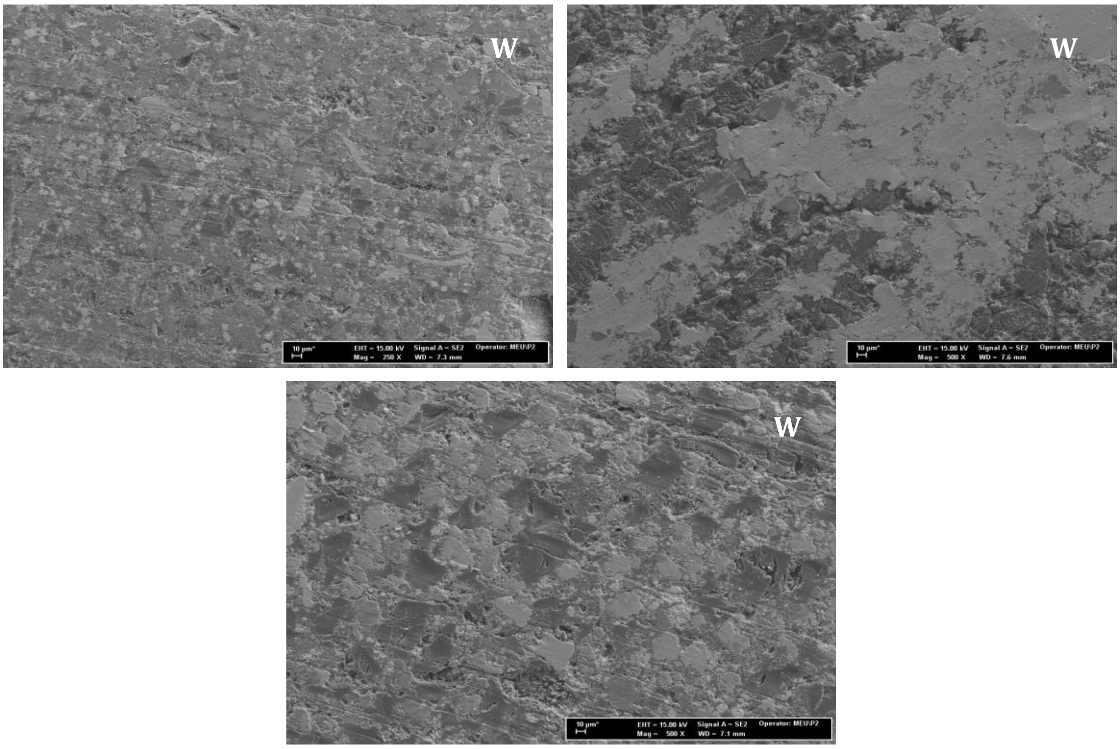


The hardness measurements of the samples were determined with a Rockwell (HRL) hardness measuring device. Hardness measurements were carried out with a 6.35 mm diameter steel ball as the penetrating tip and a 100 N load as a preload and a 600 N load as a full load. Density measurements of the samples were determined using Archimedes' principle in water (Sugözü, 2018:70).

3. Results and Discussion

The friction coefficient of brake friction materials is an important parameter that affects brake performance, and it can be used to understand various braking phenomena such as stopping distance, noise tendency, fade, brake-induced vibration (Hong et al., 2009:7). Figure 2 shows SEM pictures of the wear surfaces of the brake linings.

Figure 2. SEM image of wearing surface of brake lining samples



When SEM pictures are examined, macro and micro voids are seen on the brake lining surfaces (Elzayady and Elsoeudy, 2021:11, Sugözü, 2015:57). In addition, it has been observed that friction layer formation occurs on the surface of the brake lining. When the figure 2 showing the wearing surface of the W1 coded brake lining sample is examined, it is seen that the formation of friction layer occurs in different regions and very little. W1 coded brake lining sample showed the lowest friction coefficient average with 0.32. When the figure 3 showing the wearing surface of the W2 coded brake lining sample is examined, it is seen that many friction layers are formed. This situation affected the brake lining performance positively and caused the friction coefficient to be high. The friction coefficient average of the W2 coded brake lining sample was determined as 0.47. It is seen that the friction layers formed in the W2 coded brake lining sample are very wide and completely cover the brake lining surface. When the wear surface of the W3 coded brake lining sample was examined, it was observed that friction layers were formed from place to place. This has affected the continuity of the friction coefficient (Elzayady and Elsoeudy, 2021:11).

Figure 3. Friction coefficient-time graph of brake lining samples

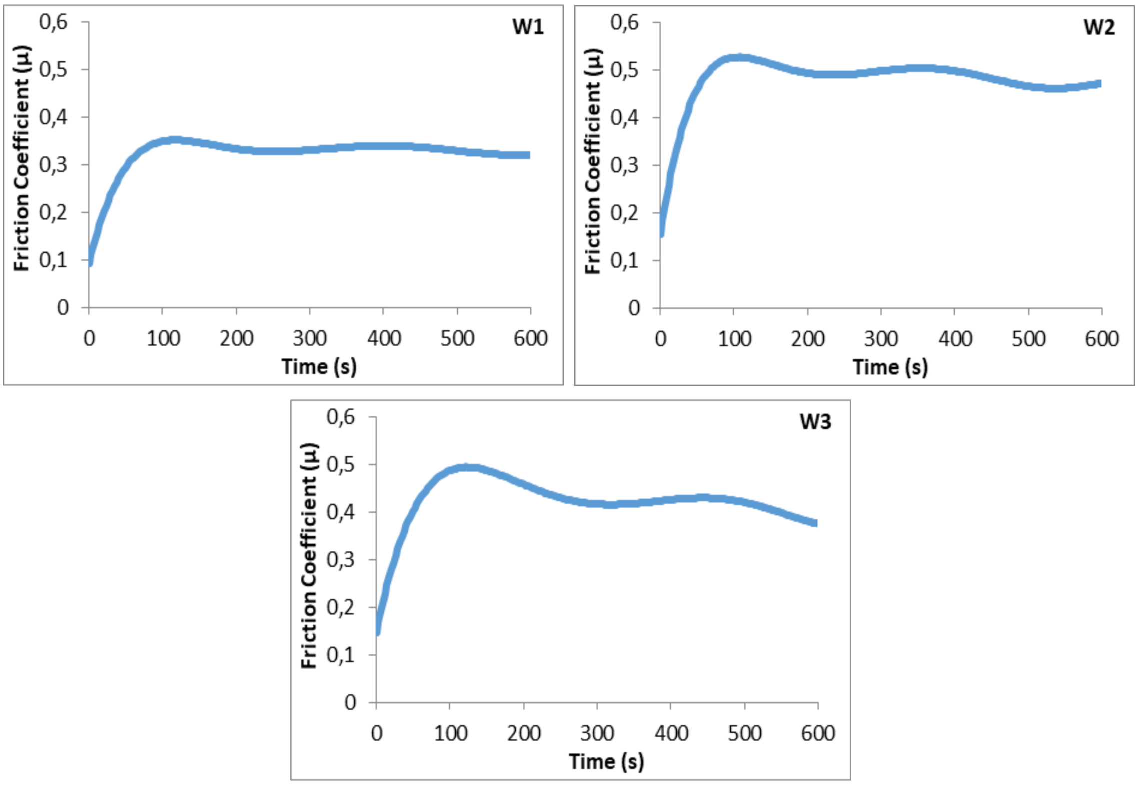


Figure 3 shows the friction coefficient changes over time. When the friction coefficient time graph of the W1 coded brake lining, which does not form a friction layer on the brake lining surface, is examined, it is seen that the friction coefficient starts to decrease after the 100th second. Since friction layer did not form on the surface of W1 coded brake lining sample, the friction coefficient was found to be low. When the friction coefficient-time graph of W2 coded brake lining sample is examined, it is seen that it exhibits a high friction coefficient performance (Figure 6). When the SEM image of W2 coded brake lining sample is examined, it is seen that friction layers covering the brake lining surface are formed. This resulted in a high friction coefficient (Figure 7). When the SEM image of the W3 coded brake lining sample is examined, it is seen that non-continuous friction layers are formed on the brake lining surface. This caused an unstable friction coefficient performance and lowered the average friction coefficient (Severin and Dorsch, 2001:9).

Table 2 shows the hardness, density, specific wear rate and average friction coefficient values of the brake lining sample.

Table 2. Experimental data of brake lining samples

Sample	Hardness (HRL)	Density (g/cm^3)	Average friction coefficient (μort)	Specific wear rate (cm^3/Nm)
W1			0,32	$1,7x10^{-6}$
W2	80	1,95	0,47	$2,8x10^{-6}$
W3			0,41	$2,1x10^{-6}$

Friction coefficient and specific wear rate of brake friction materials are important parameters that affect brake performance. In terms of braking performance, it is desirable to have a high friction coefficient and a low specific wear rate (Severin and Dorsch, 2001:9). It was observed that the wear rate increased as the friction coefficient increased. The specific wear rate may vary according to material content and production parameters. The highest wear occurred in the W2 brake lining sample, which exhibited the highest friction coefficient performance.

4. Conclusions

In this study, the braking performance of the brake linings with different worn surfaces was investigated. Obtained results are given below;

- Micro-macro gaps and friction layers have formed on the surfaces of the worn brake linings. Macro voids were observed in the brake lining sample with low friction force. This situation negatively affected the friction coefficient.
- Due to the fact that the brake lining surface is in contact with the disc surface more in the brake lining with micro gaps, the friction force has increased and the friction coefficient is high.
- The friction layers formed on the brake lining surface increased the adhesion between the disc and the brake lining, increasing the friction coefficient and reducing the braking distance.
- The specific wear rate increased in direct proportion to the friction coefficient.
- The friction layers formed on the brake lining surface caused an increase in the friction coefficient.

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