Study of mechanical properties of composite strengthened mango seed powder (*mangifera indica cultivar manalagi*), brass, and magnesium oxide for brake pads material

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Abstract. The problem of brake pads are too hard cause a short-lived drum or discs. Whereas, if they are too soft, the brake pads life will be short. This study aims to analyze the specific wear and hardness properties of the composite with mango seed powder, brass powder, and magnesium oxide reinforced with epoxy resin matrix. The variable of this study used the mass fraction of mango seed powder: brass powder: magnesium oxide. The wear test used the ogoshi method, while the hardness test used the vickers hardness test tool concerning the ASTM E384-17 standard. The results showed that the specific wear and composite hardness values were close to the mechanical properties of KEV-2700 brake pads, namely composites with a composition of 35% mango seed powder, 35% brass powder, 20% magnesium oxide, and 10% epoxy resin at 3.29 x 10^-7 mm²/kg, and 214.38 N/mm². This composition recommended for manufacture brake pads.

1. Introduction

At present, technology develops rapidly, especially in the automotive field, one of which is the brake pad component. Brake pads function to slow down or stop the movement of the wheels so that it becomes slow [1], [2]. The working principle of the brake system is to convert kinetic Power into heat by rubbing two metals on a rotating object so that the rotation will slow down. Each motor vehicle manufacturer designs a braking system and uses brake pads components under the capabilities of the vehicle [3]. The quality of the brake pads is affected by the hardness of the material. Brake pads that are too hard cause the life of the drum or discs to be short, and if it is too soft the age of the brake pads will be shorter [4]. Disc brakes consist of discs (rotor discs) made of cast iron that rotates with wheels and a disc pad that serves to push and clamp discs. Disc brakes have advantages such as a good heat radiation when exposed to water dries faster, a simple construction, easy to maintain and replace the pad. The working of the disc brake is hydraulic pressure from the master cylinder, then pushes the piston and followed by pressing on the rotor discs. At the same time, hydraulic pressure presses on the side of the pad so that the disc clamps and braking effort occurs. The pad is made of a mixture of metallic fiber and iron powder, which is called a semi-metallic disc pad and is given a gap to indicate the thickness of the allowable pad limit (simplifies inspection). Disc brakes and brake pads can be seen in Figure 1.
There are two types of structure of brake pads, namely asbestos [5] and non-asbestos [6]. Both of them have differences in the resistance to temperatures that occur where the brake pads are still able to work. Asbestos brake pads will not occur or do not work at a braking temperature of 200°C which results in an accident rate will quickly occur, while for non-asbestos brake pads are more heat resistant to braking temperatures of 350°C because of cellulose and other fibers can reduce heat better than asbestos fibers [7]. In making brake pads, the materials used must always be available continuously and will not become extinct. One of them is the mango seed or commonly called a paddle. Mango seed waste in Indonesia reaches 1 million tons per year, while it can be used at least around 200 thousand tons per year. Mango seeds contain crude protein, oil, ash, crude fiber, and carbohydrates [8][9]. Based on the problems above, brake pad needs to be made by utilizing mango seeds as a natural fiber material with a mixture of magnesium oxide and brass. In this study, the research variables were percentage of mango seed powder, brass powder, and magnesium oxide. Testing of brake lining material was with wear test, hardness test, and macro photo test. It is essential to do in order to know the nature of this brake pad material. The purpose of this research is to make a composite for brake pads material with epoxy matrix reinforced with mango seed powder (mangifera indica cultivar manalagi), magnesium oxide powder, and brass powder. The composite was then tested for wear, hardness, microstructure, and then analyzed its mechanical properties.

2. Literature Review
Previous research that is relevant among the effects of the composition of composite materials from epoxy, wood powder, and aluminum for brake pad shows that the value of brake pad of indopart brand has a hardness rate of 22.40 BHN, yamaha brand 22.47 BHN, and a honda brand of 23.6 BHN. Based on these results, the value of hardness approaches the value of hardness in the indopart brake pad (22.40 BHN) is on composite materials with a percentage of 40:40:20 (21.53 BHN) [7]. Moreover, the study of the effect of brass powder size on wear resistance, and the hardness of brake pads with test standards referring to SNI 09-2663-1992 and ASTM E 10-01 show that brass powder size with mesh of 40 has a wear resistance level of 29.44 mm³/hour. The wear resistance is higher than the indopart brake pad, which has a wear value of 32.12 mm³/hour. The hardness value of brake pad with brass mesh powder size of 40 was 20.74 BHN, while the indopart brake pad was 23.53 BHN [3]. Furthermore, research on brake lining material from composite material of cashew husk (phenolic) with aluminum scrap reinforcement was as an alternative material of non-asbestos brake pad. Variations in this research were cashew shells and aluminum scrap powder (70:20; 65:25; 60:30; 55:35; 50:40)%. Tests carried out in the form of pin on disc wear test according to ASTM G99-04, Vickers hardness test regarding ASTM E 384 using a digital microhardness tester HVS-1000Z-CCD. The test results showed the highest hardness value in the composition of 20% aluminum scrap and 70% cashew shells powder at 42.5 BHN. The lowest wear rate in the composition of 20% aluminum scrap, and 70% cashew shells powder was 0.248 mm²/kg [10]. Also, research on the use of palm fiber as a material for motorcycle brake pad shows that the composition of 55% fibers, 15% brass powder, 20% MgO, and 10% resin has a hardness value of 19.5 BHN which is close to indopart brake pad of 18.5 BHN [11]. Brake pad material with a composition

![Figure 1. Disc brakes and brake pad](image-url)
of 25% fibers, 45% brass powder, 20% MgO, and 10% resin has a wear value of $0.087 \times 10^{-7}$ mm$^2$/kg close to $0.087 \times 10^{-7}$ mm$^2$/kg indopart brake pad. These results show that the addition of fibers is very influential on the wear value and the hardness value of the brake pad [12].

Research on brake pad with a matrix of reopy R-802 type vinyl ester resin and brass composition variation with friction test refers to the CNS (China National Standard) GB5763 test standard. The results of the calculation of the coefficient of friction in the dry friction test and the test of the influence of brake fluid of 6 grams of brass variation of 0.495 and 0.478 show that indopart brands are of 0.496 and 0.486 [13]. Then, a research was done on the influence of sintering temperature variations on the wear resistance brake pad with 50%Al + 30%PET + 10% asbestos + 10% resin composition, sintering with 180°C, 205°C, and 230°C for 40 minutes. It shows the hardness value of brake pad sintering results at a temperature of 180°C at 10,054 kg/mm$^2$, a temperature of 205°C at 8,596 kg/mm$^2$, and a temperature of 230°C at 7,074 kg/mm$^2$, while for comparative brake pad (Aspira) at 8.012 kg/mm$^2$. Likewise, the results of ogoshi wear testing on brake pads obtained sintering wear values with a temperature of 180°C amounted to $1.432 \times 10^{-6}$ mm$^2$/kg, a temperature of 205°C amounted to $1.457 \times 10^{-6}$ mm$^2$/kg, and a temperature of 230°C at $1.66 \times 10^{-6}$ mm$^2$/kg, while for comparison brake pad (ASPIRA) of $1.776 \times 10^{-6}$ mm$^2$/kg. Based on the test results, it shows that the sintering temperature of 230°C is the closest to the wear and hardness value of ASPIRA product brake pad [4].

Wear is defined as the progressive loss of substance from the operating surface of an object due to surface motion relative to other objects [14]. Wear testing can be done with a variety of methods that aim to simulate the actual wear conditions, one of which is the ogoshi method where the specimen gets a friction load from a revolving disc. This friction loading will result in repetitive contact between surfaces which will eventually take up some material on the surface of the test specimen. The large surface footprint of the scraped material is the basis for determining the level of material wear. The greater the wear trace, the higher the volume of material peeled off from the test specimen. Ogoshi wears test equipment and schematic illustration of the surface contact between the revolving disc, and the test specimen is according to Figure 2.

![Figure 2. Ogoshi high-speed universal wear testing machine (OAT-U type)[15]](image)

B is the thickness of the revolving disc (mm), r of the radius of the disc (mm), the width of the abrasive material gap (mm), W is the rotation speed of the disc (rpm), P is the compressive load on the disc (kg), and h is the depth of tread (mm). Specific wear is according to equation 1 [16].

$$W_s = \frac{B.b_o^2}{r.P_0.l_0}$$  \hspace{1cm} (1)

$W_s =$ specific wear (mm$^2$/kg), $B =$ wear plate width (mm), $b_o =$ wear wear width on the test piece (mm), $r =$ wear plate radius (mm), $P_0 =$ compressive load (kg), and $l_0 =$ Mileage (m).

Material hardness is the ability of a material to withstand the penetration or penetrating force of another harder object. Hardness is the mechanical property of a material which is largely influenced by its alloying elements [17]. Vickers hardness can be calculated according to equation 2 [18][19].

$$VHN = 1.854 \times \frac{P}{d^2}$$  \hspace{1cm} (2)

$VHN =$ Vickers hardness number (kg/mm$^2$), $P =$ pressure load (kg), and $d =$length of diagonal indentation (mm$^2$).
3. Method
The first steps in this research as preparing the materials and tools. After preparation of materials and tools, mango seed powder and brass powder were filtered with a mesh 40 of the sieve. It was weighing the total mass of each sample according to its composition. The process of mixing the material was by using a blender for 60 seconds so that the results of homogeneous mixing with variations in the composition of manalagi mango seed powder \((mangifera indica cultivar manalagi)\), brass powder, magnesium oxide, and epoxy resins 45%: 25%: 20%: 10%, 35%: 35%: 20%: 10%, and 25%: 45%: 20%: 10%. After all the dry ingredients have been mixed, then they were mixed with epoxy resin and catalyst in a ratio of 1: 1. The next step was pressing with a load of 9 MPa for 60 minutes, and then the brake pad was released from the mold, then it was sintered at a temperature of 135°C for 30 minutes. Then, the last step was the wear testing, hardness, and microphotos.

4. Result and Discussion

4.1 Mechanical Properties of Brake Pad Material
Each composition was made of five specimens to be tested for wear and hardness test, then the average values of specific wear and vickers hardness were taken from each variation of manalagi mango seed powder \((mangifera indica cultivar manalagi)\), brass powder, magnesium oxide, and epoxy resins respectively turquoise of 25%: 45%: 20%: 10%, 35%: 35%: 20%: 10%, and 45%: 25%: 20%: 10%. The results were then presented in the form of graph of specific wear and average hardness of the brake pad according to Figure 3 and Figure 4.

![Figure 3. Specific wear of brake pad](image)

Figure 3 shows the lowest to highest wear values starting from the composition of 25%: 45%: 20%: 10% at 2.52 x 10^{-7} \text{mm}^2/\text{kg}, then the composition of 35%: 35%: 20%: 10% of 3.1 x 10^{-7} \text{mm}^2/\text{kg} and the highest wear is 45%: 25%: 20%: 10% composition of 3.46 x 10^{-7} \text{mm}^2/\text{kg}. The specific wear value of the comparator brake pad (KEV-2700) is 3.29 x 10^{-7} \text{mm}^2/\text{kg}. Specimens are close to comparative brake wear values with a composition of 35%: 35%: 20%: 10%. The lowest to the highest hardness
value starts from the composition of 45%: 25%: 20%: 10% at 181.07 kg/mm$^2$, then the composition of 35%: 35%: 20%: 10% at 214.38 kg/mm$^2$ and the highest hardness is the composition of 25%: 45%: 20%: 10% of 253.84 kg/mm$^2$. The comparative brake pad hardness value (KEV-2700) is 223.26 kg/mm$^2$, the most optimal specimen that approaches the comparative brake pad hardness value is the composition of 35%: 35%: 20%: 10%. The results of the brake pad research showed that the greater the increase (percentage) of mango seed powder and the reduction (percentage) of brass powder, the smaller the value of hardness and the greater the specific wear rate. It is relevant to the results of previous studies which said that the hard the material is, the smaller the rate of wear and the better the microstructure [20]. The most dominant cause of brake pad is brass powder. It is because brass powder has a greater hardness value than mango seed powder.

4.2. Microstructure of Brake Pad
Taking microphotographs of brake pad specimens used a metallurgical microscope to determine the surface microstructure of the brake pad. Microstructure of brake pads with the composition of 25%: 45%: 20%: 10%; 35%: 35%: 20%: 10%; 45%: 25%: 20%: 10% can be seen in Figures 5a, 5b, and 5c.

![Microstructure of brake pads](image)

**Figure 5.** Microstructure of brake pads with the composition of a. 25%: 45%: 20%: 10%; b. 35%: 35%: 20%: 10%; c. 45%: 25%: 20%: 10%

The composition of 45% mango seed powder, 25% brass powder, 20% MgO and 10% epoxy resin showed mango seed powder on all parts of the specimen, and brass powder seen slightly in the material mixture. The composition of 35% mango seed powder, 35% brass powder, 20% MgO, and 10% epoxy resin looks brass powder is increasing, and mango seed powder is decreasing. In the composition of 25% mango seed powder, 45% brass powder, 20% MgO, and 10% epoxy resin showed increasing brass powder and lower mango seed powder. Therefore, based on microstructure analysis, it is also consistent with the results of research which show that along with the reduction in the composition of mango seed powder and the increase in brass, the hardness is increasing and the rate of specific wear decreases.

5. Conclusion
Based on the research results of brake pads, the optimal composition for making brake pads with a composition of 35% mango seed powder, 35% brass powder, 20% MgO, and 10% epoxy resin with specific wear values of $3.1 \times 10^{-7}$ mm$^2$/kg and hardness values of vickers 214, 38 kg/mm$^2$. It is close to the mechanical value of the KEV-2700 type brake pad. This composition recommended for manufacture brake pads.
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