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Tribological and Thermal Characteristics of Organic Brake Pads Using Rubber Seed Shell and Rubber Fruit Shell as Filler

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ABSTRACT

The *Badan Pusat Statistik* (BPS) data for 2021 shows that the total rubber production in Indonesia reached 2.877,90 tons. The high amount of rubber production will accompany many by-products, such as rubber seed shells and fruit shells. These materials have not been widely used for commercial purposes. This research will use rubber seed shells and fruit shells as brake pad filler. These materials are expected to replace brake pads that still contain asbestos, even though asbestos harms human health. Brake pads are manufactured using the cold press method, which has a composition is 60% epoxy resin, 35% filler, and 5% nylon fiber. The observed characteristics of the organic brake pad are mechanical, tribological, and thermal behavior using rubber seed shell and fruit shell fillers. This research conducted several results. Both friction coefficient values have met the performance values of the standard commercial brake pad material. The rubber seed shell has better wear resistance as filler in brake pad material than fruit shells. The type of wear for rubber seed shells is abrasive wear. The thermal analysis shows that the decomposition temperature of the rubber fruit shell is higher than the rubber seed shell.

Keywords: *Brake pads, Rubber fruit shells s, Rubber seed shell, Wear rate, Thermal stability*

1. INTRODUCTION

Rubber production in Indonesia continues to increase from year to year. According to data from the Central Statistics Agency of Republic Indonesia in 2019, rubber production in Indonesia reached 2.877,90 tons [1]. The main product of this rubber plant (Hevea brasiliensis) is latex. The high amount of rubber production will also be accompanied by by-products, such as rubber fruit shells and seed shells. By-products have not been processed much to become products that have economic value. Along with the current development of science and technology, it is necessary to research the potential use of rubber fruit shells and seed shells as fillers in brake pads.

A brake pad is one of the most critical components in a motor vehicle. In general, brake pads have a lifetime of 30.000 – 45.000 KM. Today, commercial brake pads are still found that contain asbestos elements. Thus, the dust generated from the brake pad can cause mesothelioma cancer.

Mesothelioma is a cancer that develops in the lungs, stomach, or heart [2]. To reduce these adverse effects, we need brake pad materials that are more environmentally friendly.

Several organic materials were previously used as fiber or filler for developing brake pads, including eggshell powder [3], bamboo [4–7], jute [8], coconut [9], kenaf [10], palm kernel [11], bahunia racemose [3], and bagasse [12]. However, this natural material has several weaknesses: lower impact strength, material quality is strongly influenced by weather, not resistant to moisture, shorter service life, not resistant to fire, and hydrophilic [13].

This paper will discuss organic brake pads mechanical, tribologycal, and thermal behaviour using rubber sheed shell and rubber fruit shell.

2. METHODOLOGY

2.1. Sample Preparation

The material used for brake pads consists of 4 types: epoxy resin, rubber fruit shells and seed shells, and nylon fiber. The epoxy resin produced by Goterm Kom Company, USA., is used as a matrix. The nylon fiber is used as reinforcement. Meanwhile, rubber fruit shells and seed shells are used as fillers. These organic materials were obtained from forest products of Lampung Province. Those materials were crushed and sieved with a size of 60 mesh.

The materials composition for the brake pad in this study consisted of 35% filler, 60% epoxy resin, and 5% nylon fiber. The brake pad shape is cylindrical with a diameter of 50 mm. brake pad samples were carried out using the cold press method with a pressure of 30 bar for 90 minutes. The next step is the sintering process, carried out at a temperature of 150 °C with 60 minutes of holding time.

Figure 1. Organic Brake Pads Specimen.

2.2. Wear Rate Test

Wear testing is carried out to determine the specific wear on the specimen. This wear test is carried out with an Ogoshi machine with ASTM G99 standards. The ring rotation speed setting is at 1,97 m/s. The load given to the specimen is 3,16 kg. The sample size has a maximum diameter of 30 mm and a maximum thickness of 10 mm [3].

2.3. Thermogravimetry Analysis

The thermal stability of the sample was determined using a thermogravimetric analyzer (TGA) of type NETZSCH TG-209 F1 Libra. Samples weighing 5 - 35 mg were used for thermal analysis. TGA curves were taken by scanning at a heating rate of 20 °C/min and a temperature range of 0-800 °C [14].

2.4. Morphology and EDS testing

The SEM-EDS used in this research is Thermoscientific Quadra 650. the SEM was used to observe the surface morphology, producing more precise and detailed imaging. Sample testing using SEM and EDS working at a voltage of 15 kV and in a vacuum condition. EDS was carried out at 150x magnification to identify the elemental composition contained in the sample.

3. RESULTS AND DISCUSSION

The density, hardness, and porosity of organic brake pads with rubber seed and rubber fruit shell fillers were 1,16 gram/cm3 and 1,09 gram/cm^3, 31,70 and 18,30 BHN, 0,60 and 0,39, respectively.

3.1. Mechanical Properties

Mechanical properties of organic brake pad using rubber seed shell and rubber fruit shell filler had shown in Table 1. These properties observed are density, hardness, and impact strength.

Table 1. Density, hardness, and impact strength of organic brake pad using rubber seed shell and rubber fruit shell filler.

Organic Filler	Density (gram/cm^3)	Hardness (BHN)	Impact Strength (Joule)
Rubber seed shell	1,16	31,7	0,8
Rubber fruit shell	1,09	18,3	0,6

From Table 1, the organic pad material containing rubber seed shell filler has better performance in mechanical properties compared to the organic pad material containing rubber fruit shell filler.

3.2. Wear Characteristics

Environmental exposure affects the tribological performance of brake pad samples. Figure 2 shows that specific wear in both specimens decreased after two years of environmental exposure. The specific wear reduction is insignificant for the composite with rubber seed shell filler. In comparison, brake pads with rubber fruit shells experience a very high reduction in specific wear.

The wear test was carried out at a speed of 1,97 m/s, a load of 3,16 kg with a ring thickness of 3 mm. Figure 2 shows that brake pads with rubber fruit shells as fillers have relatively low wear than rubber seed shell specimens. The wear resistance of composites gets weaker with increasing temperature. Figure 6 shows the occurrence of decomposition when there is an increase in temperature so that the content of organic brake pads is also burned.

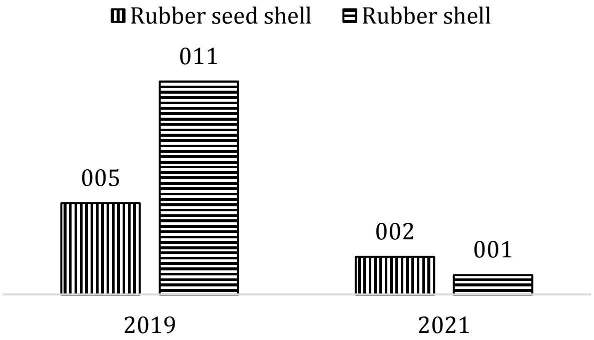

Figure 2. Comparison between composites using rubber seed shells and rubber fruit shells as filler after environmental exposure.

The coefficient of friction affects the effectiveness of braking. The higher the coefficient of friction, the higher the braking effectiveness. When braking occurs, the kinetic energy is converted into frictional heat. This heat will affect the performance of discs and brake pads. The rubber seed shell's friction coefficients are 0,38, higher value than rubber fruit shells friction coefficients which are 0,29, respectively [16]. Meanwhile, the best friction coefficient of is the brake pad with a rubber seed shells as a filler. Both friction coefficient specimens has met the criteria of SNI 09-0143-1987 [15]. Which mean that values meet the performance values of the standard commercial brake pad material.

3.3. Wear surface morphology

Figures 3 and 4 show The results of SEM-EDX in the composite surface morphology before and after friction tests. The rubber seed shell and fruit shell particles were evenly distributed. From the surface morphology of Figures 3a and 4a, fine cracks appear on the surface of the brake pads. Surface defects, cracks, or pores on this surface can reduce mechanical properties, such as strength, hardness, frictional behavior, and wear resistance of composites [18].

Porosity is present in the form of empty voids in the specimen, which are formed due to the presence of air trapped in the composite during the specimen manufacturing process. This porosity appears on the sample before the wear test is carried out. The surface morphology of the rubber fruit shells composite shows much porosity but has fewer fine cracks. This porosity can cause the low hardness and density of rubber fruit shells composites compared to rubber seed shells.

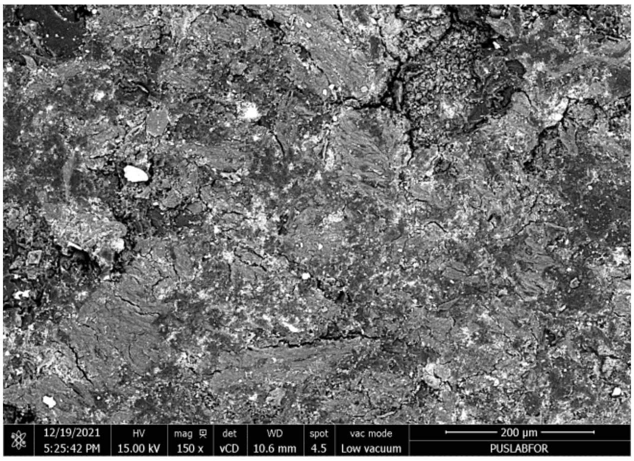

Figure 3a. Surface morphology before wear test on composite rubber seed shell.

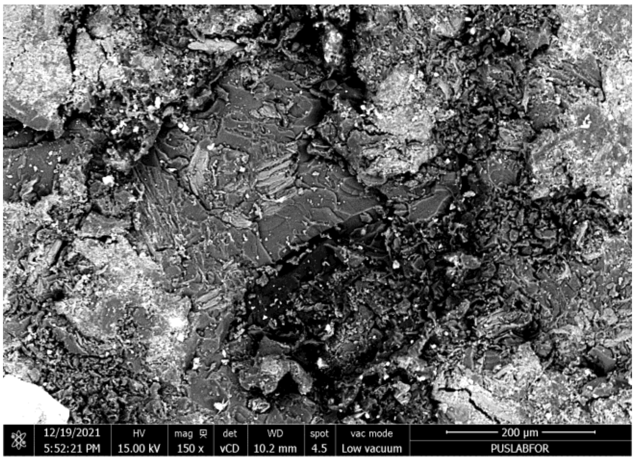

Figure 3b. Surface morphology after wear test on composite rubber seed shell.

The wear mechanism for rubber seed shell composites was found in abrasive mode. This abrasive mode is characterized by gradual surface layer peeling, as shown in Figure 3b. The cracks below the surface indicate the weak interaction between the matrix and the filler. Abrasive wear is usually considered the primary wear mechanism for composite materials [19].

Figure 4 shows the difference in the surface between before and after wear test on the rubber fruit shells as brake pad filler. Cracks and porosity are seen in Figure 4a, although they are small in number. Moreover, The worn surface in Fig. 4b exhibits a plowed shear mark on the friction surface. The damage to the wear surface of the brake pads with a rubber fruit shells as a filler is relatively good compared to the rubber seed shells filler. The wear surface also indicates the occurrence of debonding in the composite material.

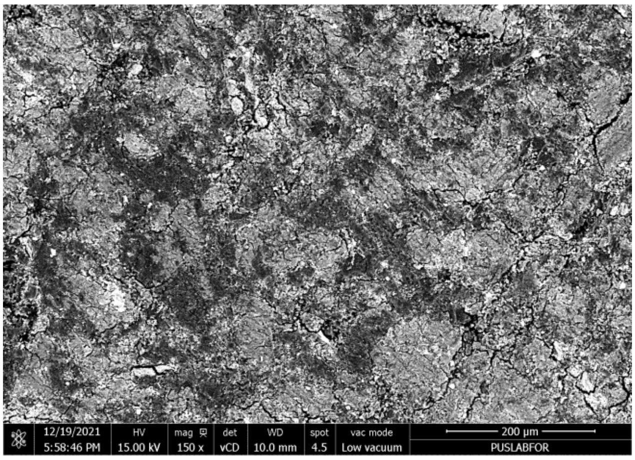

Figure 4a. Surface morphology before wear test on composite rubber fruit shells .

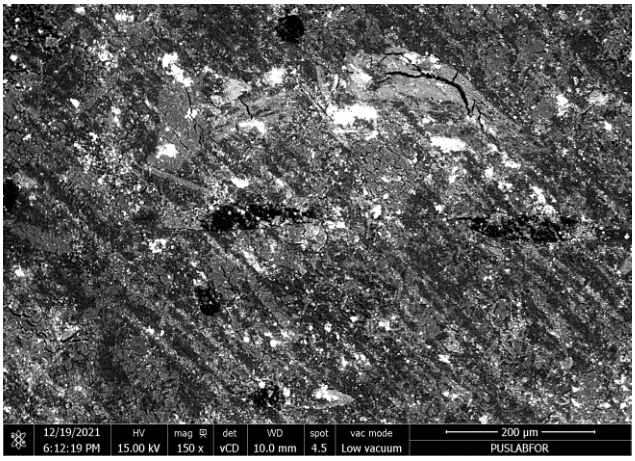

Figure 4b. Surface morphology before wear test on composite rubber shell.

Observations on the worn surface in Figure 4b show that there are micro-pittings due to adhesion between the composite and the friction material. This feature has similarities with the research conducted by Omrani et al. [20].

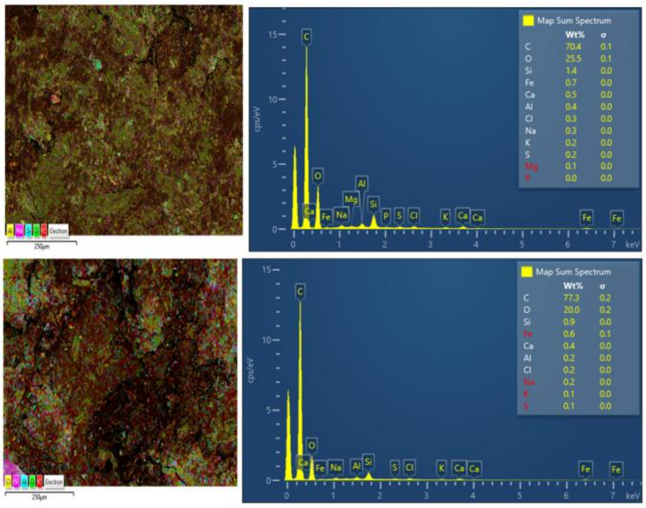

Figure 5a. EDS spectrum rubber seed shell, (upper) before wear test, (below) after wear test.

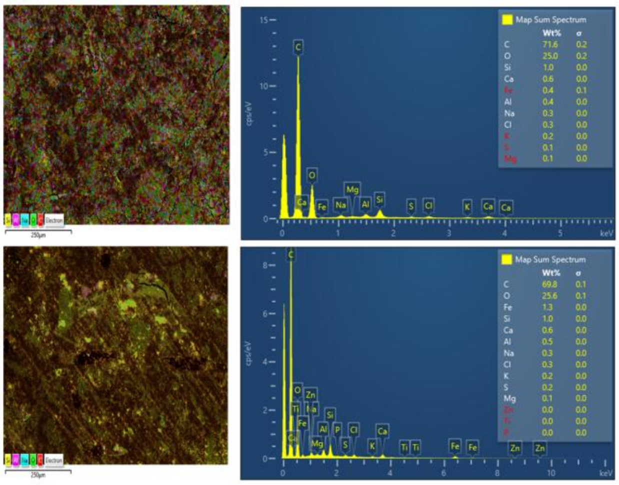

Figure 5b. EDS spectrum rubber fruit shell, (upper) before wear test, (below) after wear test.

The rubber seed and fruit shell reinforced composite have similar main compositions. Based on Figure 5a, the rubber seed shell composites contain C, O, Si, Fe, and Ca. After wear testing, there is a change in the weight of the composition contained in the composite material. The same condition is also found in organic brake pads that use rubber fruit shells as a filler (Figure 5b). The organic brake pad from The Rubber seed shell has a higher hardness value than the Rubber fruit shell. Therefore, the Si content of The Rubber seed shell is higher than the Rubber fruit shell.

As observed from the wear marks, the surface of the composite material with rubber fruit shell filler shows cracks and micro pitting. An exciting finding from the EDS analysis is an increase in Fe content after wear testing. The increased Fe content may have been caused by friction between the brake pad material and the friction material during the wear test. This phenomenon was also identified by Salem et al. [21].

3.4. Thermal Analysis

The heat generated by friction can cause the thermal decomposition of organic elements in the brake pads during braking. Thermal decomposition at high temperatures will weaken the structure of the brake pad materials [22]. Thermal testing is carried out using thermogravimetric analysis to determine the weight loss in the material when the sample gets thermal exposure at a high temperature.

Figure 6 shows a graphic plot of TGA describing the peak temperature at which the decomposition occurs. The rubber seed shell has four decomposition peaks at 26,10 °C - 91,60 °C. The first peak indicates the loss of water content in the sample so that the mass is reduced by 1,96 %. The second peak shows the decomposition of hemicellulose content at 149,40 °C - 223,50 °C and a decrease in mass of 3,60 %. At the third peak of 223,50 °C - 568,90 °C, the decomposition process occurs in the epoxy resin. The fourth peak shows the thermal stability of the rubber seed shell. There is a decomposition of the lignin content in a temperature range of 668,80 °C - 792,20 °C.

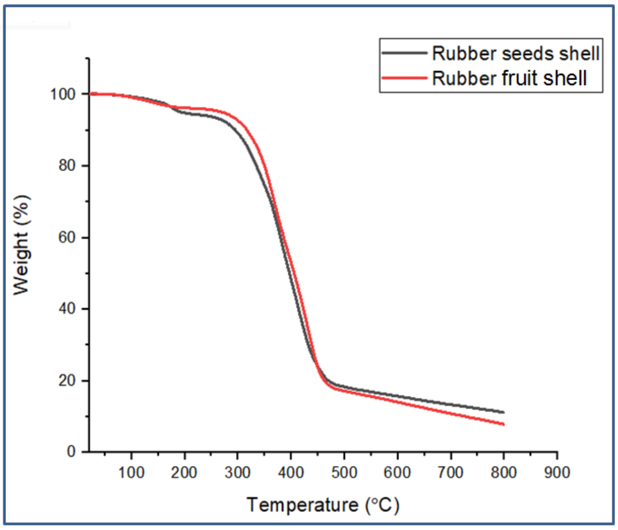

Figure 6. Thermogravimetry analysis of composites with rubber seed shell and rubber fruit shell as filler.

In rubber fruit shells as filler, the sample experienced four peaks either. The first peak in the temperature range of 23,20 °C - 208,60 °C is moisture loss in the sample. At the second peak of 209,10 °C - 393 °C, cellulose decomposition occurred in the specimen. At the third peak of 393 °C - 528,60 °C, decomposition occurs in the rubber fruit shell. Finally, the lignin content decomposes gradually at a temperature of 645,70 °C - 792,20 °C. El-Sayed and Mostafa showed that lignin loss occurs slowly over an extensive temperature range from 180 °C - 900 °C [23].

4. CONCLUSION

The research conducted several conclusions. The rubber seed shell has better wear resistance as filler in brake pad material than fruit shells. The type of wear for rubber seed shells is abrasive wear, i.e., material peels off when friction occurs. The thermal analysis shows that the rubber fruit shell has a higher decomposition temperature than the rubber seed shell.

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