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Addition Rice Husk on the Density and Impact Strength of Non-Asbestos Brake Pad Composites Prepared by The Hand Layup Method

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Abstract

In train operations, brakes are an important component that concerns passenger safety and must be replaced periodically according to their useful life. Currently, the most widely used train brake pad material is composite, unfortunately, the majority of train brake pads in Indonesia are imported products. This study aims to manufacture and characterize composite materials for friction material for train brake pads that meet quality standards to substitute imported products. It needs to reduce dependence on imported products while at the same time encouraging the strengthening of the structure of the domestic manufacturing industry. In addition, agricultural waste in rice husks will be used to produce more environmentally friendly products. The composition of the types of composite materials, which include binder, reinforcement, abrasive, and filler materials, will be examined. Making composite materials in this study will use the hand layup method. Material characterization carried out includes impact testing and density. The characterization results show that using rice husk as a filler greatly influences the density of the resulting composite material. Specimen made from epoxy, rice husk, iron filings, and Al_2O_3 (wt.%) at 50%, 20%, 15%, and 15%, respectively, was able to produce a higher density compared to the composite without rice husk and epoxy material. The density test support the results of the impact tests that have been carried out. The higher the rice husk content, the higher the density produced. Adding rice husk can increase the mechanical properties of the resulting composite material.

Keywords: brakes, composite, hand layup, mechanical properties, agricultural waste

INTRODUCTION

Automotive engines have produced enormous power to meet human needs for high-speed transportation facilities. A good braking system is certainly needed to support high engine performance. The consumption of friction material on brake pads ranks second after petroleum and gas fuels. Brake pads are a spare part that slows down or stops vehicles, especially land vehicles. Friction material transforms kinetic energy into thermal energy (Irawan et al., 2022).

During high-speed vehicles, the brake pads get a load of up to 90% of the other components, so the brake pads greatly determine the safety of the driver and passengers. Brake pads are consumables that must be replaced periodically. Therefore, the need for friction material for brake pads is increasing along with the growth of the automotive industry in Indonesia (Irawanirawa.

The friction material is one of the most essential parts of the brake pads. The friction material is made of a material that has good mechanical properties and tribological performance. The friction material is a critical component of brake pads that helps to slow down or stop a moving vehicle. It creates friction between the brake pad and the rotor, which converts the vehicle's kinetic energy into heat energy. This process causes the vehicle to slow down or come to a complete stop. Composite materials for friction materials generally consist of binder, reinforcement, abrasive, and filler materials. The expected mechanical properties of friction materials include hardness, tensile strength, corrosion resistance, and thermal resistance. At the same time, the desired tribological performance includes low wear and a high coefficient of friction, both in dry contact and wet contact (Abutu et al., 2018A; Irawan et al., 2022).

Friction material can make brake pads for motorcycles, cars, trucks, trains, and aeroplanes. Especially for trains, the need for friction material for train operations is very high. It is estimated that hundreds of thousands of brake friction materials are required annually. Initially, the friction material used in the braking system on trains was cast metal. For decades, Small and Medium Industries in Indonesia have been able to meet most of these needs. However, with the development of material technology, composites are now the primary choice of friction material for train braking systems. It is inseparable from the economic value produced, where metallic friction materials have a service life of 14–19 days, while composite materials have a service life of 90–240 days.

PT. Kereta Api Indonesia started substituting friction materials with composites around the beginning of 2010. Local Indonesian producers have not mastered the composite technology for friction materials for train brake pads. As a result, the volume of imports of friction materials for train brake pads is still the majority. In 2018–2019, the import value of friction material for railroads was US$ 86,640,667, or IDR 1,238,961,538,100.00. This value is obtained from imported commodities with HS codes 68138100 and 86072100, according to the data released by Badan Pusat Statistik, 2023. Generally, the composite friction material on the brake pads uses asbestos as reinforcement with certain resins.

Asbestos was chosen because it has good mechanical strength and is not too expensive. However, brake pads made of asbestos can experience fading at temperatures above 200°C. In addition, based on research conducted by the World Health Organization and International Agency for Research on Cancer, asbestos is carcinogenic, so it can cause lung cancer from the dust it produces. Therefore, the application of this material is prohibited in the automotive industry and other applications. So, it is necessary to develop new materials to replace asbestos as a friction material while still maintaining its mechanical properties (Abutu et al., 2018B; Amirjan, 2019; Arman et al., 2018; Lawal et al., 2019; Singaravelu et al., 2019).

Biomass produced from agricultural activities such as bamboo, palm trees, bagasse, corn stalks, cashew shells, bananas, coconut shells), pineapples, rice straw, grass, and rice husk are materials that are widely used as commercially acceptable and environmentally friendly brake pad reinforcement material (Iman & Widjanarko, 2020; Lawal et al., 2019; Nawangsari et al., 2019). Agricultural waste contains a high concentration of natural fibres for polymer composites to be used as reinforcing material. Agricultural waste has much potential in composites because of its high strength, environmental friendliness, affordability, easy availability, and availability in substantial quantities (Nguyen et al., 2017; Ogah & Timothy, 2018).

This research needs to be carried out to produce friction material used in brake pads on trains that meets the standards so that they can substitute imported commodities in the future. On the other hand, using environmentally friendly materials is also needed to produce safe friction materials for the environment and human health. In previous studies, the research team has successfully utilized various agricultural wastes for composite applications (Cionita et al., 2022; Hadi et al., 2021; Hadi, Tezara, et al., 2021; Rihayat et al., 2021; Tezara et al., 2021). In addition, the research team has also researched the application of agricultural waste for applying friction material to brake pads (Irawan et al., 2022). However, to our knowledge, using epoxy resin, rice husk, Al_2O_3, and Fe_2O_3 in fabricating non-asbestos brake pad composites has yet to be widely explored. Furthermore, in this research, rice husk will be combined with epoxy resin, Al_2O_3, and Fe_2O_3 to produce friction materials that will be used to produce brake pads for trains. This study aims to determine the effect of adding rice husk on the density and impact strength of the Non-Asbestos Brake Pad Composites produced.

METHOD

The materials used in this study were epoxy, hardener, rice husk, iron powder Fe_2O_3, and alumina Al_2O_3. Next, the rice husks were crushed into powder using a crusher machine. The sieving process is carried out with a mesh 100 to produce rice husk powder. Rice husk powder is dried at 80°C for 24 hours before mixed with other ingredients. The materials were mixed using the composition of epoxy, hardener, rice husk, iron powder (Fe_2O_3), and alumina (Al_2O_3) with several variations, as shown in **Table .1**

Table 1. Composite specimen composition

Specimen	Epoxy Resin (wt.%)	Rice husk (wt.%)	Fe_2O_3 (wt.%)	Al_2O_3 (wt.%)
1	100	0	0	0
2	50	0	25	25
3	50	5	22.5	22.5
4	50	10	20	20
5	50	15	17.5	17.5
6	50	20	15	15

The ratio of epoxy and hardener used in this study was 3:1, and then a stirring process was carried out using a magnetic stirrer for 7 minutes. Rice husk, iron, and alumina powders were added according to a predetermined composition and stirred for 5 minutes. The mixture formed was placed in a vacuum oven for 5 minutes to remove air bubbles formed during the mixing process. The mixed material is put into a specimen mould that has been adjusted to an impact specimen according to ASTM D6110. The formed composite was then dried for 24 hours before testing.

The composite material formed was tested for density and impact. The density testing was performed to establish the density of the composite specimens. An electronic density meter (DME 220 series) from Vibra Canada Inc. (Mississauga, ON, USA) was used to conduct density testing following ASTM 792-08. The Charpy impact test was carried out according to the ASTM D6110 standard using the GT-7045-MD IZOD CHARPY Digital Impact Tester manufactured by GOTECH Testing Machines Inc., Taiwan. In this test, the pendulum weight, speed, angle α, and span used were 25 J, 3.46 m/s, 150°, and 101.6 mm, respectively. The test results obtained the absorbed energy value of the brake pad friction material composite specimen. Furthermore, this value is used to find the value of the impact strength by manual calculation.

RESULT AND DISCUSSION

The use of rice husk significantly affects the density of the resulting composite material. The composite specimen for density testing is shown in Figure 1. The composite density of the brake pads friction material in specimens 1, 2, 3, 4, 5, and 6 is 1.21 g/cm^3, 1.06 g/cm^3, 1.19 g/cm^3, 1.17 g/cm^3, 1.29 g/cm^3, and 1.33 g/cm^3 are shown in Figure 2. The brake pads friction material composite specimen with the lowest density was found in specimen 2, which was 1.06 g/cm^3. While the highest density in specimen 6 is 1.33 g/cm^3, specimen 2 is a specimen that does not use rice husk. Whereas in specimen 6, the rice husk used was the highest compared to the other specimens, which was 20%wt.

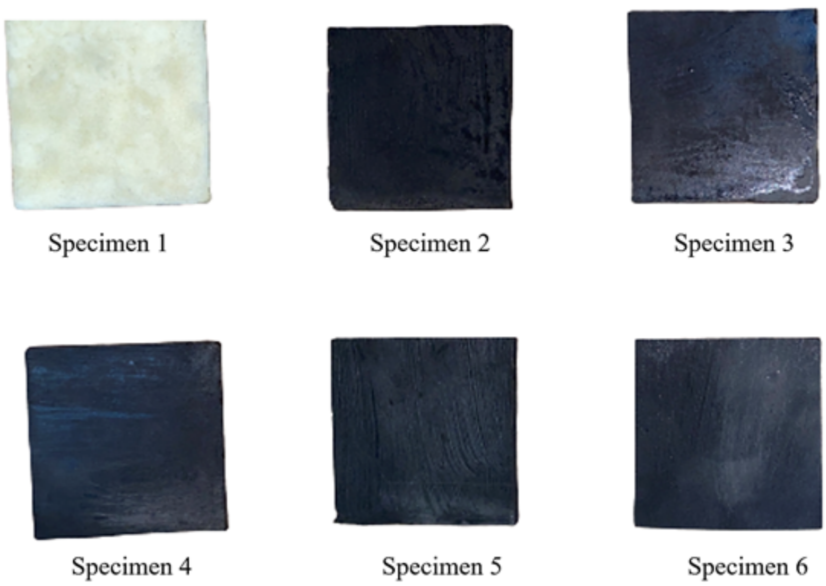

Figure 1. Density test specimens

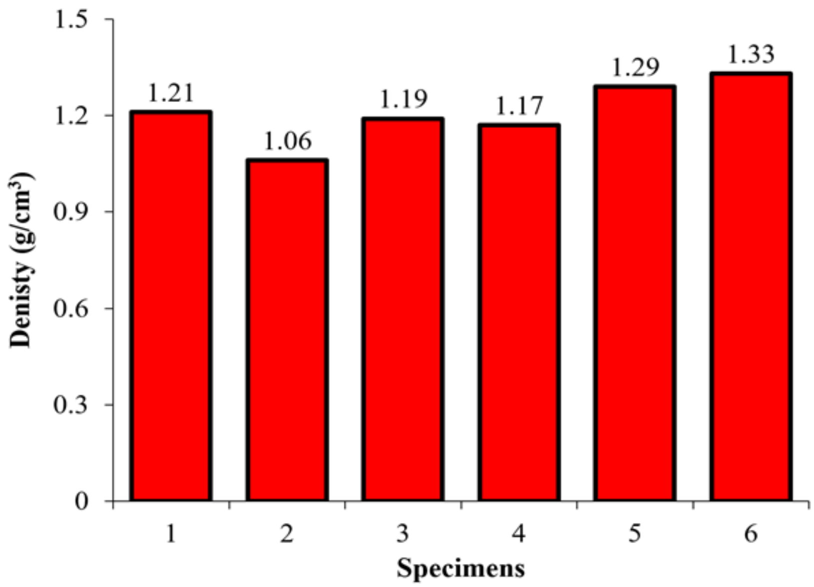

Figure 2. The effect of the composition used on the results of the density test

Rice husk has a high content of amorphous silica, about 95%. Thus, increasing the rice husk used in this study significantly increased the amorphous silica content in the specimens. With a higher volume fraction of rice husk, the silica content contained in the composite specimen also increases. Silica functions as an adsorbent for water vapour by forming bonds between the constituent materials of the composite specimens to combine to form a more optimal unit. Because the low water content can improve the bond density between the constituent materials in the composite specimen of the brake pad friction material, the high water content in composite specimens can interfere with the matrix's primary function as a binder material in the composite (Irawan et al., 2023).

The composites with rice husk reinforcement can be applied to manufacture brake pads. Because rice husk has a high silica content, the composite structure has a good density to form composite specimens of brake pad friction material that can withstand wear and tear and last a long time (Suhot et al., 2021). Other research states that composites with high silica content can increase density due to the increased adhesion between the filler and the matrix, which results in a more compact structure and increased density. A 20% silica concentration with a particle size of 5 μm produced a PTFE/SiO2 composite with a higher density than other specimens. However, the density of the composite decreases if the silica content exceeds 20%, considering that agglomerates can reduce the adhesion between the filler and the matrix (Jiang & Yuan, 2018).

This study resulted in a friction material specimen with a density that met the requirements for brake friction material applications. Commercial brake friction materials generally have a density of 1,010 to 2,060 g/cm^3 (Irawan et al., 2023). However, the results of this study are not suitable for the application of brake pads on trains. It happens because the brake pads on a train must have a density of 1.7 to 2.4 g/cm^3.

The use of rice husk significantly affects the impact strength of the resulting composite material. The composite specimen for impact strength testing is shown in **Figure 4. Figure 5** shows that the impact strength of the brake pads friction material composite in specimens 1, 2, 3, 4, 5, and 6 was 0.0095 kJ/m^2, 0.0101 kJ/m^2, 0.0104 J/m^2, 0.0101 kJ/m^2, 0.0104 kJ/m^2, and 0.0107 J/m^2. The brake pads friction material composite specimen with the lowest impact strength was found in specimen 1, which was 0.0095kJ/m^2. While the highest impact strength on specimen 6 is 0.0107 kJ/m^2, Specimen 1 is a specimen that uses 100 wt.% epoxy resin. Whereas in specimen 6, the rice husk used was the highest compared to the other specimens, namely 20 wt.%.

The test results show that the presence of rice husk material and additional materials (Al_2O_3 and Fe_2O_3) can influence increasing the impact strength of the brake pad friction material. It was proven by the volume fraction variation in specimens 2 to 6, which showed a higher impact strength than specimen 1. In addition, the addition of rice husk volume fraction in each variation of the friction material composite specimen influenced increasing the impact strength. In general, impact strength is related to the bond between the composite materials. It makes one of the impact strength factors in the brake pads friction material composite specimen have the highest value in specimen 6 with the highest rice husk volume fraction, namely 20% rice husk.

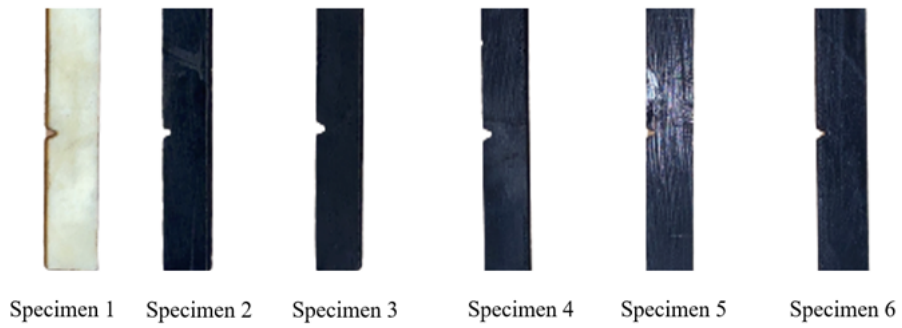

Figure 4. Charpy impact test specimens

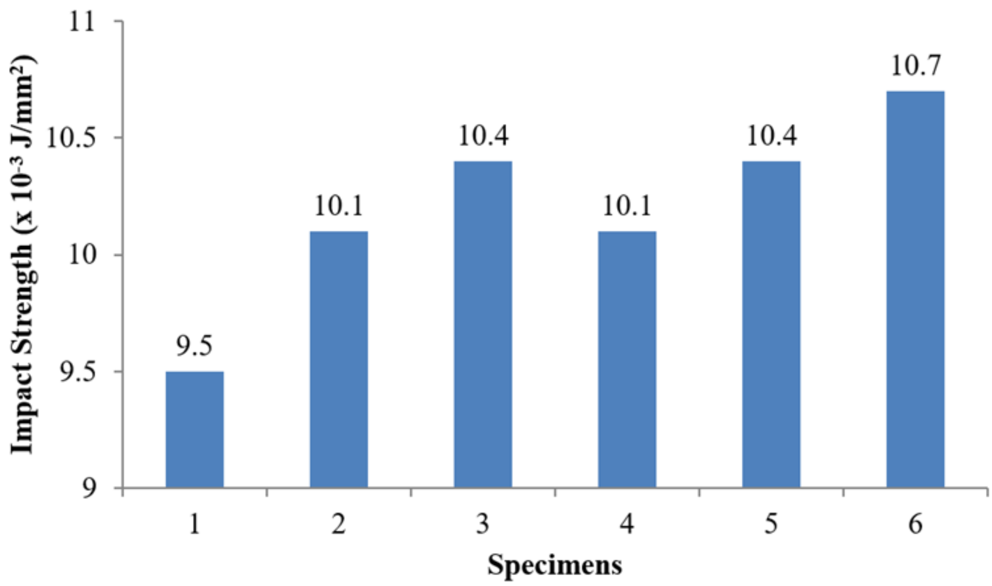

Figure 5. The effect of the composition used on the results of the impact test

The results of the Charpy impact test on specimen six produced in this study were high that acacia wood charcoal with an epoxy matrix as an alternative to non-asbestos brake pads, with the highest impact strength of 0.0080 J/mm^2 (Iman & Widjanarko, 2020). Compared to study that have the best impact test result on the hybrid composite brake lining was 0.000339547 J/mm^2. The hybrid composite brake lining consists of basalt, clamshell, alumina, and resin with a composition of 40%, 10%, 10%, and 40%, respectively. This composite showed a stronger and more complete bond between the matrix and basalt than other hybrid composites, resulting in higher impact strength values (Suriadi & Atmika, 2019).

Wijaya. S et al. (2016) have conducted Charpy impact tests on hybrid composite brake pads made of phenolic resin matrix reinforced with basalt, alumina, and clamshell particles. The results showed that the variation hybrid composite showed the highest impact strength, at 0.000339547 J/mm^2, due to the stronger and more perfect bond between the matrix and basalt particles compared to the other hybrid composite variations. Overall, the Charpy impact test proved effective in evaluating the impact resistance of hybrid composite brake pads (Suma Wijaya et al., 2016).

CONCLUSION

Friction material for railroad brake pads made from composites reinforced with rice husks has been successfully produced. The use of rice husk significantly affects the density of the resulting composite material. Specimen 6, made from epoxy, rice husk, iron powder, and Al_2O_3 of (wt.%) 50%, 20%, 15%, and 15%, produced higher density and impact strength than other specimens. The higher the content of rice husk used, the greater the density and impact strength produced in the specimen.

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