Effect of Rice Husk Addition on The Density and Impact Strength of Epoxy-Matric Composite Materials as Candidates for Eco-Friendly Brake Pads

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Abstract: Automotive industry growth leads to increased demand for friction materials for brake pads. Asbestos is frequently employed because of its robustness and cost-effectiveness. Nevertheless, asbestos is a known carcinogen and has the potential to induce lung cancer. Hence, it is imperative to do research to identify an alternative substance to replace asbestos in brake pads. This study aims to investigate the impact of incorporating rice husk into epoxy-matrix composites on the density and impact strength of the resulting materials, which are being considered as potential environmentally sustainable brake pads. The hand lay-up method was employed in this study to fabricate composite specimens. In this study, rice husk was utilized as a reinforcing agent, comprising 50% of the weight fraction in a composite material with an epoxy matrix. The composite material was combined with epoxy resin and hardener and then dried. It was subsequently divided into sections following the dimensions specified by the American Society for Testing and Materials (ASTM) standard. The sections were then tested to determine their density, hardness, and impact resistance. The study findings indicate that the composite specimen including rice husk exhibits a greater density of 1.35 g/cm^3, in contrast to the epoxy specimen with a 1.21 g/cm^3 density. The augmentation in density holds significant importance in terms of load-bearing capability and resistance against damage. Incorporating rice husk into the composite material enhances its mechanical characteristics by diminishing porosity and augmenting impact resistance. The composite density attained in this investigation is within the spectrum of densities reported in brake pads available in the market.

Keywords: Composites; brake pads; rice husk; epoxy resin

Introduction

A composite is a material formed from a combination of two or more materials that have the purpose of being stronger than the material they form (Paundra et al., 2022). Composite materials are widely used as engineering applications, such as construction and various automotive parts. Along with the increase in vehicles, the need for spare parts also increases. One of the components that a vehicle must have been brake pad.

Brake pad is one of the components in the braking system of a motor vehicle which functions to slow down or stop a motor vehicle. In 2020-2021, the recorded import value of brake pad friction material was 32,484,512 US $ or IDR 454,783,168,000.00 (Statistics Indonesia. Number

of Motor Vehicles by Type (Unit), 2019-2021, 2023). The value was obtained from the Central Bureau of Statistics (BPS) of imported commodities. With this data, the need for friction materials for brake pads is increasing along with the growth of the automotive industry in Indonesia.

In general, brake pad materials use reinforcement from asbestos material with certain resins. Asbestos was chosen because it has good mechanical strength and is not too expensive (Sandip S. Shirsath & R.N. Yerrawar, 2021). According to WHO (World Health Organization) and IARC (International Agency for Reseacrh on Cancer) asbestos is carcinogenic, which can cause lung cancer from the dust produced, so asbestos has a serious effect on the environment and human health. Brake pads made of asbestos work up to a temperature of 200°C, and above that temperature will cause braking failure in a vehicle (Sukrawan et al., 2019). One of the alternatives being developed is to develop new materials to replace asbestos to obtain brake pads that maintain mechanical properties and are not harmful to human health.

A wide variety of agricultural waste is developed as an alternative to composite materials. Agricultural waste has a lot of potential in composites due to its high strength, environmentally friendly, affordable price, easy to find, and available in very large quantities. One of them is the rice plant which is widely found throughout Indonesia. According to data compiled by the Central Bureau of Statistics (BPS), rice production in Indonesia in 2021 reached 54.4 million tons and Java Island produced 28.5 million tons. With this data, the rice husk produced can reach 20% - 25% of the total weight of rice (Sandya et al., 2019). Rice husk consists of organic components, namely 25-35% by weight cellulose, 18-21% by weight hemicellulose, 26-31% by weight lignin and 15-17% by weight silica, with 5-10% moisture content (Wening Kusumawardani et al., 2019). From these components, rice husk is quite attractive because the content of lignin, cellulose, and silica is suitable as an alternative material for making composites whose properties are similar to ceramics. Therefore, in this study, rice husk is used as a reinforcement for brake pad composites with certain treatments. Various studies have been conducted to determine the effect of rice husk addition on the performance of composite brake pads. The volume fraction, particle size, and fermentation treatment of rice husk determine the quality of the resulting composite (Nandiyanto et al., 2021; Primaningtyas et al., 2018, 2019).

Based on this background, this research was conducted to utilize agricultural waste as reinforcement in epoxy-matric composites. In addition, this study was conducted to determine the effect of the addition of rice husk powder on the density, hardness and impact strength of the resulting composite specimens. Moreover, encompassing rice husk in the production of brake pads can yield favourable socio-economic consequences. Rice husk is commonly regarded as a byproduct in the rice milling business and is typically discarded by burning or burying it in landfills. Utilising this waste material as a reinforcement in brake pads decreases the quantity of waste produced and offers an extra source of revenue for rice millers (Moraes et al., 2014).

This research has the potential to make a significant contribution to various Sustainable Development Goals (SDGs), such as SDG 9 which focuses on industry, innovation, and infrastructure, SDG 12 which emphasises responsible consumption and production, and SDG 13 which addresses climate change action. This can be achieved by effectively utilising agricultural wastes. Furthermore, if this research demonstrates the incorporation of agricultural waste into the production of eco-friendly materials, it could also pertain to SDG 15, which specifically addresses terrestrial ecosystems. Therefore, this study can provide a favourable contribution to sustainable development by introducing advancements in the manufacturing of brake materials that are more environmentally friendly.

Methodology

In this study, rice husk is used as reinforcement in composite meterial with epoxy matrix. The rice husk was obtained from a rice mill in Grobogan, Central Java, Indonesia (Figure 1). The rice husk was then cleaned and dried using an oven at 80°C for 24 hours to reduce the moisture content. The rice husk is crushed using a crusher and then sieved with a 200-mesh sieve to produce rice husk powder. This study uses epoxy resin (Bisphenol A-Epichlorohydrin) and epoxy hardener (Cycloaliphatic Amine type) that were purchased at the Justus store in Semarang, Indonesia.

In this study, epoxy resin and hardener were mixed using a hand mixer in a measuring cup for 7 minutes. The ratio of epoxy and hardener used in this study was 3:1. Rice husk with a weight fraction of 50% was poured into the epoxy resin which was then stirred for 10 minutes using a hand mixer. The material was poured into a mold that had previously been coated with a release agent. After pouring into the mold and the mixture of materials is leveled according to the height of the mold using a roller or brush. The formed composite is then dried for 24 hours in the mold at room temperature. After that, the formed specimens were cut to produce specimen dimensions in accordance with ASTM for density, hardness, and impact testing.

Figure 1. Rice husk

The Charpy impact test was conducted following the ASTM D6110 (ASTM Standard D6110-10, 2010) standard utilising the GT-7045-MD IZOD CHARPY Digital Impact Tester made by GOTECH Testing Machines, Inc., Taiwan. The parameters measured in this experiment were as follows: the pendulum weight was 25 J, the speed was 3.46 m/s, the angle α was 150°, and the span employed was 101.6 mm. The test findings yielded the absorbed energy value of the composite specimen of the brake pad friction material. Moreover, this number is employed to determine the impact strength through human computation. Density testing was conducted to determine the density of the composite specimens. A density testing was performed using an electronic density meter (DME 220 series) manufactured by Vibra Canada Inc. located in Mississauga, ON, USA. The testing was conducted in accordance with ASTM 792-08 (ASTM Standard D 792-08, 2013).

Result and Discussion

Figure 2 depicts the impact of including rice husk on the density of epoxy matrix composite products.

The research findings suggest that the epoxy specimen possesses a density of 1.21 g/cm^3. Concurrently, the composite sample strengthened with rice husk exhibits a density of 1.35 g/cm^3. The incorporation of rice husk as reinforcement has a substantial impact on the augmentation of density in composite specimens. The density of a composite material directly impacts its load-bearing capacity and resistance to breaking or damage. The reason for this is that the density value quantifies the amount of mass present in each unit of volume of the specimen. When using brake pads, it is advisable to utilize a composite material with a high load-bearing capacity and appropriate density, which exhibits robust properties as a composite material (Irawan et al., 2022). As the density of a specimen increases, its hardness also increases.

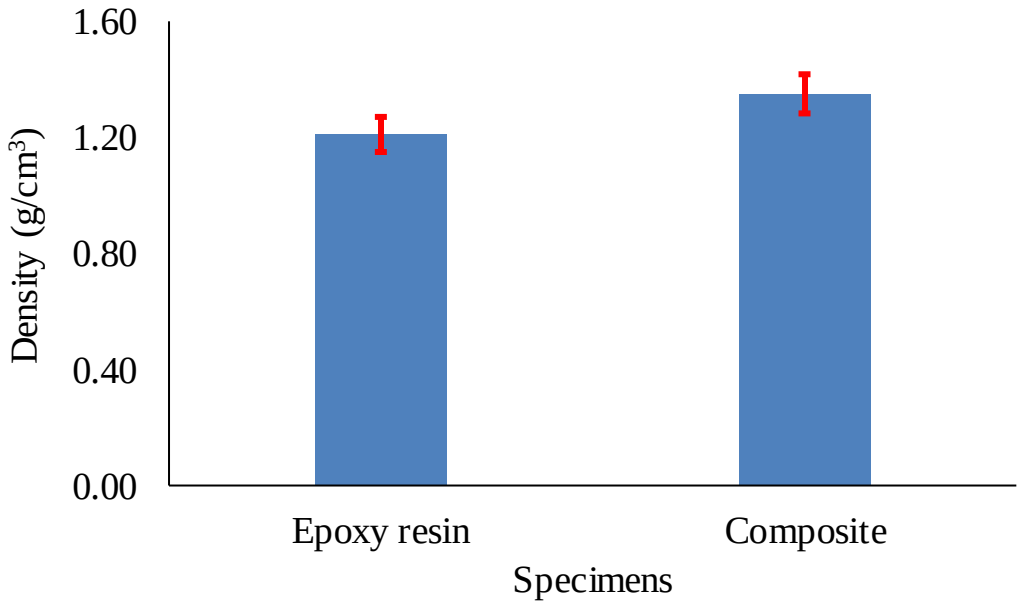

Figure 2. Effect of rice husk addition on composite material density

The study conducted by Suhot et al. (2021) suggests that brake pads can be manufactured using composites reinforced with rice husk. The reason for this is that rice husk possesses a significant quantity of silica, which enables the composite structure to exhibit favourable density. Consequently, it can create a composite sample for brake pad friction material that exhibits enhanced durability and extended lifespan. Incorporating rice husk into the epoxy matrix results in an elevated silica concentration within the composite specimen. This process occurs due to the high concentration of silica present in rice husks, making up about 98% of their makeup. The addition of silica to the composite specimen enhances its ability to absorb water vapour and facilitates efficient bonding between the constituent elements. The decreased moisture content enhances the density of the component components in the composite samples. The presence of excessive moisture in composite specimens can impede the primary function of the matrix as a bonding agent in the composite. A greater density in the composite specimen signifies a reduced level of porosity, leading to enhanced mechanical characteristics. Materials with low density generally exhibit limited porosity, which may result in susceptibility to cracking or fracture during loading or testing scenarios (Patria Putra, 2022). This pertains to the density of the bonding between the constituent materials that are formed in the specimen of friction composite brake pads. As the particle size decreases, the density between the constituent materials of the composite increases. The dimensions of rice husk particles have an impact on the spacing between particles, the cohesion between particles, and the ability to withstand heat. Decreasing particle size can lead to reduced mass loss by reducing the number of pores (Nandiyanto, et al., 2021). The composite density achieved in this investigation is within the range of densities observed in commercial brake pads, which typically range from 1.010 to 2.060 g/cm^3 (Irawan et al., 2023).

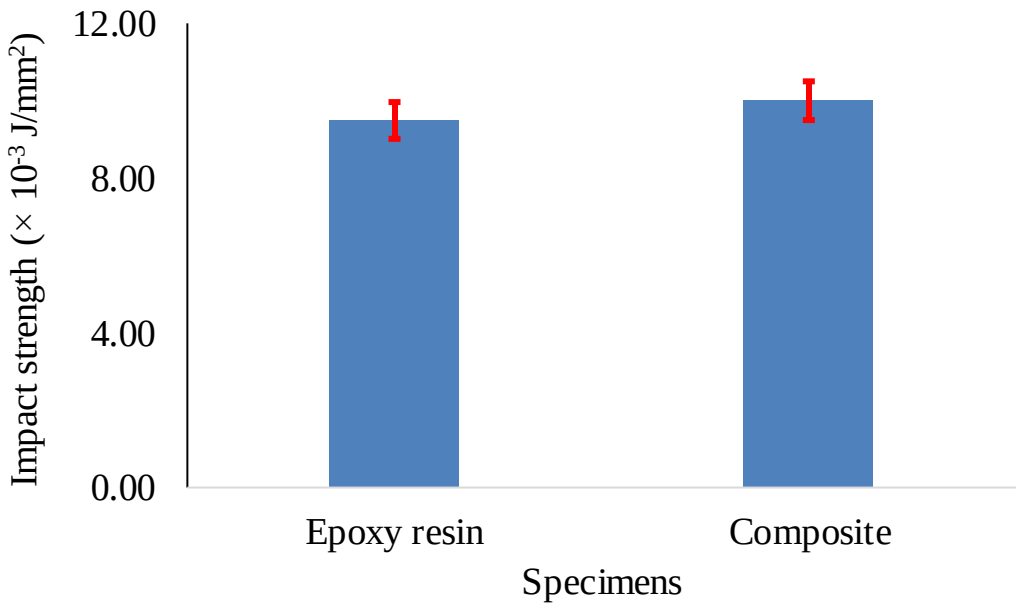

Figure 3. Effect of rice husk addition on composite material impact strength

Figure 3 illustrates that the composite specimen, which is reinforced with rice husk, exhibits a superior impact strength in comparison to the epoxy matrix. The composite has an impact strength of 10×10^{-3} J/mm^2, while the epoxy resin has an impact strength of 9×10^{-3} J/mm^2. The test findings demonstrate that the use of rice husk material substantially improves the impact strength of the composite specimens. The impact strength of a composite is determined by the intermolecular bonding between its constituents. The mechanical properties of a material increase in direct proportion to its density value when applied. The rationale behind this is that elevated mechanical strength values result from the increased density of the bonds between the constituent materials. Increasing the density of material results in a higher degree of particle packing and improved binding, hence augmenting the impact strength of the composite material.

The investigation involves conducting impact testing on composite specimens by applying rapid stress at a single central point. The test results suggest that the composite specimen underwent brittle fracture under compression, with the specimen fracturing directly without any deformation. An increase in the density of a composite generally leads to a corresponding increase in its impact strength. This phenomenon might arise as a consequence of a rise in density, leading to a more compact and robust configuration, hence augmenting the composite's capacity to endure stresses and absorb impact energy. The enhancement in impact strength is attributed to the establishment of robust cross-links between the matrix and other components, effectively impeding crack propagation inside the specimen. This can also be attributed to the enhanced durability of composite materials. The study's findings suggest that including rice husk powder results in a notable enhancement in the impact strength of the composite material. Alshahrani et al. (2022) found that including natural particles enhances the flexibility of the matrix and fills any empty spaces, hence mitigating the formation of flaws or cracks when subjected to external forces. Incorporating a certain proportion of rice husk into the composite specimen results in an enhancement of the impact strength value.

Conclusions

Rice husk, a residual product of rice milling, can be used as a cost-effective substitute for conventional reinforcing materials in the production of brake pads. This decreases the manufacturing expenses of brake pads and encourages the effective utilization of agricultural waste.

The research findings indicate that incorporating rice husk into composite materials with an epoxy matrix leads to a substantial increase in the composite specimens' density and impact strength. The results show that the composite specimen with rice husk has a higher density of 1.35 g/cm^3, compared to the epoxy specimen with 1.21 g/cm^3. This increase in density is very important for load-bearing capacity and damage resistance. The addition of rice husk to the composite material also improves its mechanical properties, as it reduces porosity and increases impact strength. The composite density achieved in this study is within the typical density observed in commercial brake pads. The impact strength of the composite is determined by its intermolecular bonds, and its mechanical properties increase in proportion to its density. Using rice husk as a reinforcement in brake pads reduces carbon emissions. Traditional brake pads frequently consist of significant quantities of synthetic fibers from fossil fuels and potentially harmful additives like asbestos. The manufacturing process of brake pads using these materials results in the emission of greenhouse gases, hence contributing to environmental pollution. Substituting these parts with rice husk, an environmentally friendly and sustainable resource, will significantly reduce the carbon emissions linked to the manufacturing of brake pads.

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