Effect of Fabrication Methods on The Density and Impact Strength of Brake Pad Composites for Railway Application

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***Received:** 30 November 2023; **Accepted:** 13 December 2023; **Published:** 15 December 2023*

Abstract: Railway brake pads, which are essential components of braking systems, are commonly manufactured using metallic or composite materials. Nevertheless, these technologies come with disadvantages such as a restricted lifespan and heightened intricacy during installation. The objective of this project was to create composite brake pad materials to minimize the utilization of metal brake pads and reduce the demand for imports. The study entailed fabricating brake pad samples with a composite material. The study produced railway brake pad samples by combining epoxy, hardener, rice husk, aluminium oxide, and iron oxide. The components were blended and subsequently put into a mold, where they were compacted to form compression molding products. The specimens were divided into sections to comply with the density and impact testing requirements set by American Society for Testing and Materials (ASTM). The obtained products were evaluated by a Charpy impact test and an electronic density meter. The study demonstrates that the manufacturing procedure has a substantial effect on the density of composite specimens. The hand layup result exhibits a density of 1.230 g/cm^3, the composite specimen produced using compression molding possesses a density of 1.696 g/cm^3. The compression molding technique results in a 38% increase in density compared to items made using the hand lay-up method. Applying high pressure and temperature during compression hot molding improves the bonding between fibers and the matrix, reduces the presence of empty spaces, and enhances the overall strength of the structure. The impact strength of compression molded items exhibits a 27% enhancement in comparison to hand lay-up products.

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

1. Introduction

PT KAI (Kereta Api Indonesia) is a state-owned enterprise engaged in the transportation sector. It provides services and constructs infrastructure to enable the efficient transportation of both passengers and products. The main goal of PT KAI is to implement and support government policies in the economic sector by providing transportation services. Additionally, the company aims to generate profits by managing a transportation service enterprise that improves the quality of transportation services, including stations and other facilities for handling commodities (Rafli et al., 2023).

Railway brake pads play a crucial role in the functioning of railway braking systems. Their role is to produce friction against the train's wheels, facilitating the deceleration or stop of the railway. Brake pads are primarily composed of several materials that are chosen for their high friction coefficients, excellent thermal stability, and resistance to wear (Hong & Ha, 2023). Railway brake pads are typically fabricated from metallic or composite materials. There are various drawbacks associated with metallic brake pads, such as a limited lifespan, higher cost, increased complexity of installation, and the occurrence of sparks when braking. These disadvantages have led to the abandonment of metallic brake pads in favor of composite brake pads (Fitria Apriliani et al., 2022; Widodo et al., 2023). A composite is a blend of two or more components that creates a new material with enhanced qualities compared to the original material. Composite materials have applications in several engineering fields, including the fabrication of transportation equipment and numerous automobile components. Composite properties are expressed as the sum of the qualities of the constituent materials, taking into account their respective volume fractions. Specifically, the properties of the matrix material are multiplied by its volume fraction, and the properties of the reinforcing material are multiplied by its volume fraction. Nevertheless, the actual interaction between the matrix and the reinforcement is influenced by other interconnected parameters, such as the geometry, size, orientation, and distribution of the reinforcement. These factors also play a crucial role in determining the mechanical properties of a composite material (Primaningtyas et al., 2018, 2019; Yusuf, 2018)

The objective of this study was to develop railway brake pad materials that conform to the established criteria, to substitute or reduce the usage of metal brake pads and to decrease imports of brake pads. This research aimed to investigate the impact of employing hand lay-up and compression hot molding techniques on the density and impact strength of the composite specimens produced. The research involved creating brake pad specimens using a composite material consisting of 20% rice husk, 15% aluminium oxide, 15% iron oxide, and 50% epoxy resin.

2. Methodology

The study involved fabricating railway brake pad samples utilizing epoxy, hardener, rice husk, aluminium oxide (Al_2O_3), and iron oxide (Fe_2O_3) (Figure 1). The binder utilized was Bisphenol A-Epichlorohydrin epoxy resin, whereas the epoxy hardener employed was of the Cycloaliphatic Amine kind, sourced from Justus a store in Semarang, Indonesia. The rice husk utilized in this investigation was acquired from a rice mill near campus. Meanwhile, Al_2O_3 and Fe_2O_3 were obtained from PT Merck Tbk, Jakarta, Indonesia. The composition of the materials employed in this investigation consisted of epoxy, rice husk, Al_2O_3, and Fe_2O_3 in weight percentages of 50%, 20%, 15%, and 15%, respectively. The epoxy-to-hardener ratio employed in this study is 3:1. Following the production of a uniform blend of epoxy and hardener, rice husk powder that had been sifted through a 200-mesh sieve, along with pre-mixed Al_2O_3, and Fe_2O_3, was gradually introduced. The mixture was then stirred for 10 minutes using a hand mixer. Subsequently, the concoction was poured into the mold, flattened with a roller, and left to desiccate for 24 hours at ambient temperature. The term used to refer to these specimens is hand layup products. Regarding the compression molding process, the combination of resin, rice husk powder, Al_2O_3 and Fe_2O_3 was left undisturbed for 10 hours. Subsequently, the molding process is carried out at a pressure of 20 MPa for 15 minutes. During the pressing procedure, the specimen mold is heated using a heater, with the temperature adjusted to 100^{o}C. Heating is applied during the pressing process to facilitate the bonding of material particles. Following the heating procedure, the specimens were extracted from the mold while maintaining a temperature of approximately 50^{o}C.

Specimens created by the compression molding technique are commonly known as compression molding products.

Figure 1. Raw materials

The hand layup and compression molding products in this study were sectioned to the specified dimensions defined in the ASTM standards for density and impact testing. An electronic density meter (DME 220 series) produced by Vibra Canada Inc. based in Mississauga, ON, USA was used to conduct a density test. The testing was performed following the guidelines outlined in ASTM D 792-08 (ASTM Standard D 792-08, 2013) (Figure 2a). The Charpy impact test was performed by the ASTM D6110 (ASTM Standard D6110-10, 2010) standard using the GT-7045-MD IZOD CHARPY Digital Impact Tester manufactured by GOTECH Testing Machines, Inc., Taiwan. The specimens for impact testing with the Charpy method are 127 mm x 12.7 mm and have a 45° notch, with a thickness of 3.2 mm Figure 2b. In this study, the density and impact tests were carried out with a repetition of 3 times.

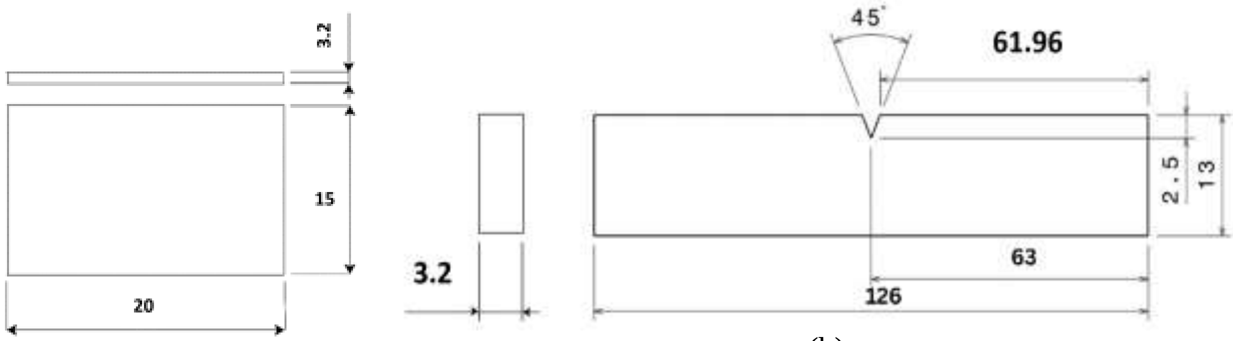

Figure 2. Dimensions of specimens for (a) density, and (b) impact testing

3. Result and Discussion

Figure 3 depicts the influence of the fabrication technique on the density of the composite specimens. The results show that the hand layup product had a density of 1.230

g/cm^3. Furthermore, the composite specimen, which is a product formed through compression molding, possesses a density of 1.696 g/cm^3.

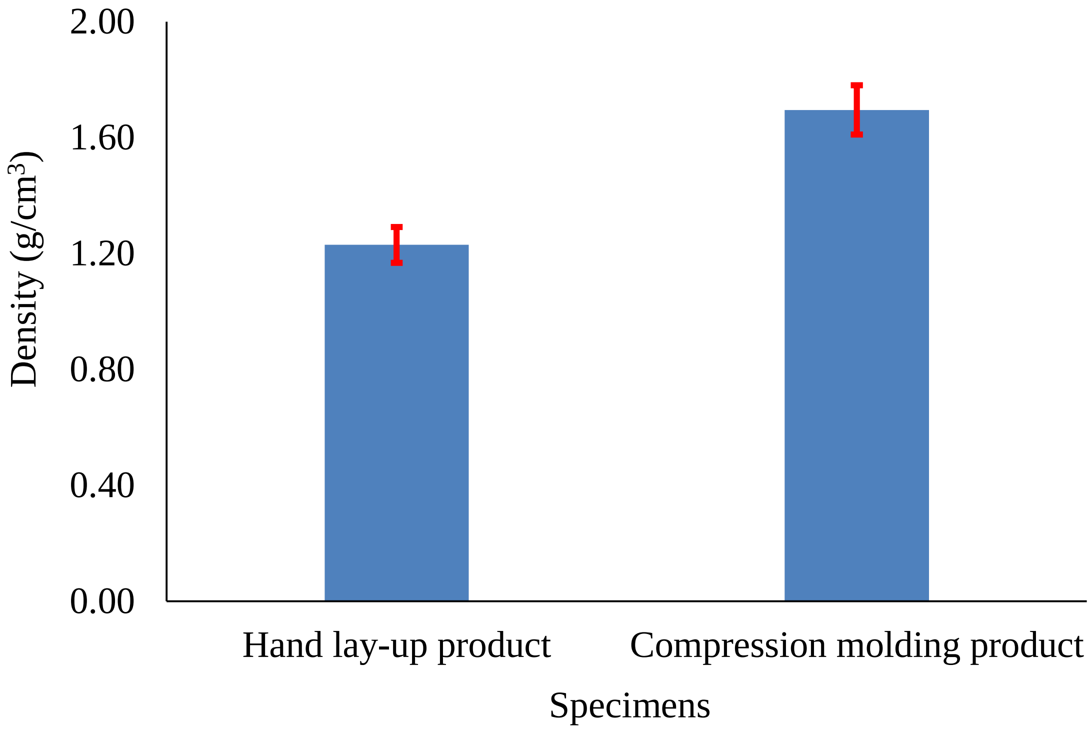

Figure 2. Effect of fabrication methods on composite material density

The selection of the fabrication method significantly affects the density of the composite specimens. The results of this study indicate that compression molding products produce composites with higher density than hand lay-up products. The use of the compression molding method increases the density by 38% compared to hand lay-up products. The hand layup method involves manually placing fibers or composite materials onto an open mold. The presence of several air voids within the composite is more likely in this procedure, as a result of the inconsistent application of pressure (Maiti et al., 2022; Nugraha et al., 2022; Raji et al., 2019; Sałasińska et al., 2022). Compression molding can lead to a higher composite density than this. Alternatively, the compression molding technique involves placing the composite material within a sealed mold and applying significant pressure to shape the composite. The application of high pressure serves to diminish the presence of air voids in the composite material, leading to a more compact structure and consequently a greater density (Nyior & Mgbeahuru, 2018).

The mechanical properties of composites can be modified by a variety of elements, including the kind of fibers, matrix material, curing process, and operator competence. Overall, compression molding offers superior control over the fiber orientation, resin dispersion, and overall quality of the composite, resulting in enhanced mechanical properties (Raji et al., 2019). In general, compression hot molding generates composites with greater mechanical properties than hand lay-up. The application of high pressure and temperature during compression hot molding facilitates enhanced fiber-matrix adhesion, decreased void content, and enhanced overall structural integrity. This can lead to improvements in the composite's density, tensile strength, flexural strength, impact resistance, and other mechanical properties (Almushaikeh et al., 2023). In this study, brake pad samples were produced utilizing the compression molding technique. It was observed that elevating the mold temperature resulted in a reduction in the viscosity of the resin. Consequently, the resin exhibited improved flowability and better impregnation of the reinforcing material. Consequently, the enhanced adhesion between the resin, filler, and reinforcement leads to a higher density of the composite specimen. The reason behind the higher density of compression molded products compared to manual lay-up products is due to the manufacturing process involved (Widodo et al., 2023).

According to the research findings, only the compression molding product achieved the minimum density specified by PT INKA, which was 1.7–2.4 g/cm^3 (PT INKA, 2014; Widodo et al., 2023). Meanwhile, the density of the hand lay-up product nearly satisfied the necessary density requirements.

According to the findings presented in Figure 3, the impact strength of the composite specimen manufactured via compression molding is significantly greater than that of the product assembled by hand. The impact strength of the composite product manufactured by compression molding is 14×10^{-3} J/mm^2, whereas the impact strength of the product manufactured by manual layup is 11×10^{-3} J/mm^2. The test results demonstrate that the use of the compression molding technique greatly improves the impact strength of the composite samples. The impact strength of compression molded products showed a 27% increase in comparison to hand lay-up products. In this investigation, the trend of increasing impact strength is proportional to the trend of the obtained density. The utilization of the hot compression molding method during the creation process of the composite increases the rigidity of the molecular bonds between the composite ingredients. As a result, the impact strength of the specimens is enhanced. Ensuring that resin evenly spreads to the areas of the reinforcing, abrasive, and filler components helps decrease the formation of pores in the composite samples. The reduction in resin viscosity induced by the application of pressure and temperature during the compression molding process leads to adequate and suitable flow. As a result, the rise in mold temperature and pressure enhances the driving force, hence decreasing the formation of gas-induced voids. Consequently, the reduction in porosity enhances the mechanical characteristics of the component, such as its impact strength (Ekuase et al., 2022; Mehdikhani et al., 2019; Widodo et al., 2023; Wu et al., 2018; Xie et al., 2019).

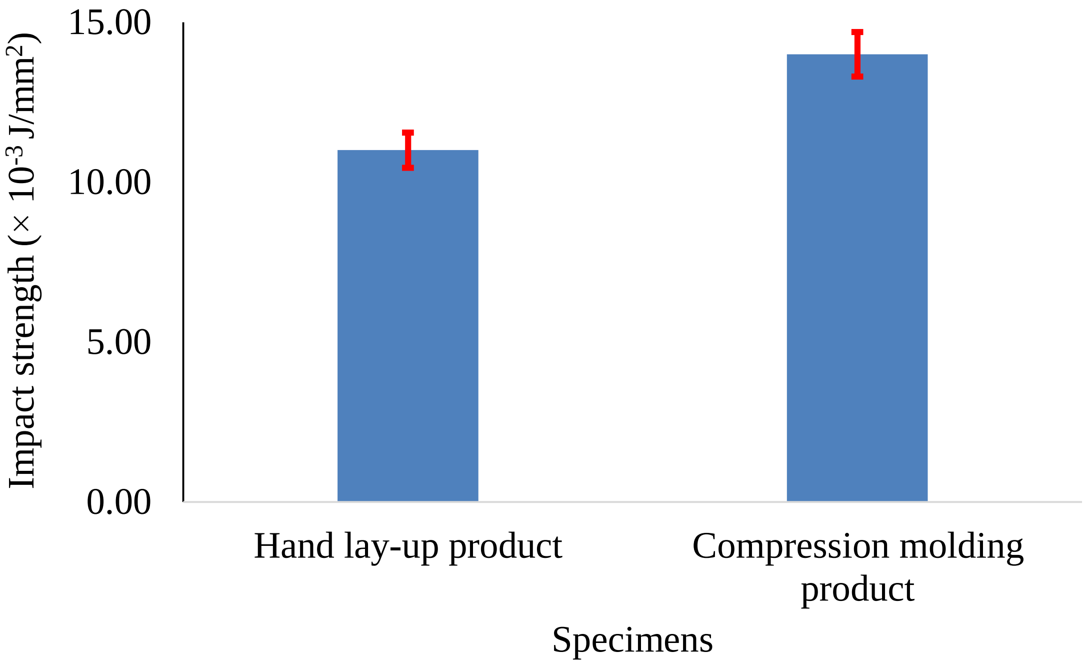

Figure 3. Effect of fabrication methods on composite material impact strength

4. Conclusions

Railway brake pads play a vital role in braking systems and are commonly manufactured using metallic or composite materials. Nevertheless, these materials have disadvantages, which have resulted in the utilization of composite materials. The objective of this project was to create railway brake pad materials that meet specified standards, minimize the reliance on metal brake pads, and reduce the need for imports.

The study entailed creating brake pad samples by combining a composite material composed of 20% rice husk, 15% aluminium oxide, 15% iron oxide, and 50% epoxy resin. The study also examined the influence of hand lay-up and compression hot molding techniques on the density and strength of the composite specimens. The study demonstrates that the manufacturing procedure has a substantial effect on the density of composite specimens. Compression molding results in composites that have a greater density compared to goods made using manual lay-up technique, with a density increase of 38%. The application of high pressure and temperature during compression hot molding improves the adhesion between the fibers and the matrix, reduces the presence of empty spaces, and boosts the overall structural strength. The impact strength of compression molded composites has a 27% superiority over hand lay-up products, resulting in a corresponding 27% augmentation in impact strength. The decrease in resin viscosity throughout the compression molding process results in improved flow and less porosity, hence enhancing the mechanical properties of the component. In general, compression molding provides better manipulation of fiber alignment, distribution of resin, and overall excellence, leading to improved mechanical characteristics.

Acknowledgements

The authors would like to express their gratitude to the Faculty of Engineering, Universitas Negeri Semarang, for providing financing through the Penelitian Kerja Sama Antar Lembaga (FAKULTAS) Grant No.: 11.17.4/UN37/PPK.05/2023.

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