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Development of Brake Camp Material Using Reinforced Polymer Composite by Clamshells/Cardboard Waste/Orange Peel

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ABSTRACT

Brake pads are equipment that uses synthetic friction resistance and is then used on a rotating machine to reduce or stop speed. It is necessary to develop brake pad materials that are more environmentally friendly and can be commercialized. Clamshells containing calcium carbonate ($CaCO_3$), cardboard waste, and orange peel containing cellulose can also be used as alternatives in developing brake pad materials that are more environmentally friendly compared to asbestos brake pads. This research aims to determine the optimal composition for developing reinforcing polymer composites for brake pad materials. The methods used in this research include microscopy test analysis, degree of swelling, and tensile strength. The test results show that variation II shows a clearer surface appearance with a low degree of swelling of 0 – 0.17%, so variation II is appropriate for application as a brake pad material. The tensile strength test results show a maximum tensile strength of 6.521 Mpa.

I. Introduction

Brake pads are an important part of the vehicle braking system. The main function of brake pads is to reduce or stop the vehicle's speed. As the engine develops, the speed of the vehicle will become faster, so it requires reliable brakes [1]. Another important function of the brake is to help the driver park the vehicle so that it is safer from possible collisions. Composite materials are multi-phase in nature and are obtained from a combination of different materials to obtain mechanical properties [2]. Several existing similar studies can be used as references that use variations in the composition of the composite samples, namely between epoxy resin and teak sawdust [3], palm sugar palm powder content [4], and clamshell powder. with banana peel fiber [1]. Recent research also revealed that clamshells containing calcium carbonate ($CaCO_3$) and cardboard waste containing cellulose can also be used as alternatives in developing brake pad materials that are more environmentally friendly compared to asbestos brake pads [5]. The use of calcium carbonate in the development of renewable brake pad materials aims to improve the properties of brake pad polymer materials and cellulose is used because it is light, strong, and has good stiffness so it is suitable for use as a reinforcement for the brake pad material.

Cardboard waste is waste packaging material that is used to protect a product during the process of sending goods from the producer to the consumer. Cardboard is made from raw materials in the form of paper which contains cellulose, the cellulose contained in cardboard is also contained in banana peels [6]. The cellulose content in cardboard is also quite high. Clamshells generally contain large amounts of calcium carbonate ($CaCO_3$) which is one of the organic materials other than plants that contain calcium carbonate. The use of calcium carbonate in clamshells, especially in the development of brake pads in the automotive world, is still not widely developed [1]. Orange peel

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waste generally consists of cellulose, hemicellulose, pectin, lignin, hydrocarbons, and chlorophyll dyes [7]. The content of these organic compounds that make orange peel can be developed as a biomaterial that can potentially be used in a variety of products. Orange peel contains cellulose that is high enough so that it can be used as a filler and reinforcement on brake pads [8].

In this research, the research team plans to use clamshells as reinforcement and filler in the brake pad material because contain high levels of calcium carbonate, and clamshells are also often found in Indonesia [9]. Clamshells can be used as filler and reinforcement in brake pad material because some people who consume green mussels throw away the shells without processing them first, thus potentially disrupting the balance in the environment [10]. Another material that is quite important in the development of renewable brake pad materials is epoxy resin. Epoxy resin is a thermosetting resin that is widely used in the development of composite materials. The manufacture of renewable brake pads is divided into two materials, first, reinforcement and filler consisting of cardboard waste and calcium carbonate which comes from clamshell waste, and second a matrix consisting of epoxy resin. The combination of these materials is a composite. Composite is a material that consists of two or more constituent materials and is formed on a macroscopic scale and then combined [11]. Therefore, the research team is interested in developing composite research related to the development of sustainable brake pads reinforced by cellulose from cardboard waste and calcium carbonate from clamshell and then testing is carried out to determine the Microscopy Test (MT), Degree of Swelling (DS) and tensile strength with Tensile Test (TS).

II. Method

A. Materials

The raw materials for brake pad fabrication include Bisphenol A-epichlorohydrin (R), hardener (H), clamshell (CS), orange peel (OP), and cardboard (CB). A CS, OP, and CB here were sourced locally in Jakarta, Indonesia.

B. Brake Pad Step

Before fabricating the brake pads, CS, OP, and CB were prepared to form a powder. A CS, OP, and CB were prepared as dual reinforcement of brake pads. Previously, the CS, OP, and CB were cut into small pieces. Then, the CS, OP, and CB were dried in an oven at a temperature of 100°C. The drying process took approximately 2-6 hours until constant weight for CS, OP, and CB. Each ingredient is weighed in a beaker using an analytical balance according to the composition of each sample. A silicone mold measuring 1×1×1 cm is prepared first by cleaning the surface using a brush before being used to make the composite. After epoxy resin (ER) is weighed and mixed with CS, OP, and CB powder then stirred until evenly distributed. After the sample is evenly distributed, it is poured into a beaker containing the previous mixture, then stirred quickly and poured into a silicone mold. Flatten the surface of the material so that it fits the silicone mold, then let it sit overnight until it hardens. After use, the composite sample is released from the mold weighed, and then tested. Table 1 summarizes the mass composition of the materials used in the fabrication of brake pads.

Table 1. The composition of the raw materials

Specimen	**Composition Percentage (%)**					**Total (%)**
	R	***H***	***CS***	***OP***	***CB***	
OP/CB	30	30	0	20	20	100
CS/OP/CB	30	30	30	5	5	100
CS	30	30	40	0	0	100

C. Physical Characterization

Preparation of each sample to be tested for the microscopy test (MT). Prepare the microscope in a standby position to perform MT testing. Position the lens away from the preparation table and install the preparation glass on the preparation table. The sample being tested is placed on a microscope slide. Magnify the objective lens and lower the position of the lens until it approaches the preparation glass and sample. Spreading material on the sample surface and carrying out photo documentation.

Prepare one sample each to be tested by DS. Weigh the dry mass of each sample using an analytical balance. Prepare as many chemical glasses as there are samples and fill them with 100 mL distilled water, with neutral pH, and at room temperature (25°C). Put the sample into each chemical glass containing distilled water simultaneously. Set the timer for 60 minutes and wait until the timer goes off. After the sound, turn off the timer and remove each sample from the glass. Then weigh the mass of each sample again after soaking for 60 minutes and record the mass. Weigh each sample again with a soaking time of 120 minutes. Calculate DS for each sample using the following formula:

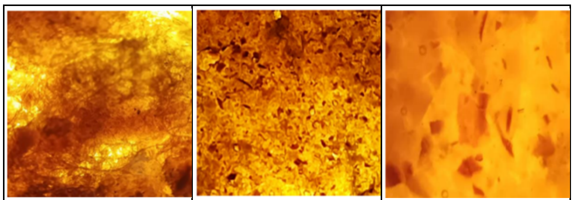
$$DS = \frac{M_W - M_D}{M_D} x100\%$$

Where DS is the level of water absorption (%), M_W is the mass of the wet sample (g) and M_D is the mass of the dry sample (g). Analyzing the DS results obtained, if the DS variation using fiber is <0.3% then the variation is used to make TS test samples. Make a sample from variation 2 by weighing the ingredients 15 times. Combine all ingredients in a plastic cup and stir. Pour the mixed material evenly into a manual forming mold measuring 20 × 20 × 2 cm which has been coated with Teflon paper, and then level it using a metal roller. Wait for the sample to dry for 3-4 days. After drying, the sheet-shaped samples are cut according to standard sizes for tensile strength testing, according to the UTM machine used. UTM in this research refers to the ASTM D638-14 standard.

III. Results and Discussion

A. Morphology Characteristics

Microscopy Test (MT) testing is used to determine the surface appearance of brake pad material samples more closely due to limited observation by the eye. The results of this test are in the form of a collection of images from each variation of samples carried out by MT testing with a magnification of 10 times with the clearest result so that the shape of the surface appearance of the material can be known.



(a) (b) (c)

Fig. 1. Results of microscopy test variation (a) OP/CB, (b) CS/OP/CB, (c) CS

In Figure1 (a), observations on the surface of the OP/CB variation reveal the presence of thread-like strands, which upon closer examination, are identified as fine fibers originating from cardboard waste and orange peel. These fibers are integral constituents of OP/CB brake pads. Additionally, small dark spots scattered across the surface can be identified as lumpy cardboard fibers. This visual analysis provides insights into the composition of the material, highlighting the incorporation of recycled waste materials into the brake pad formulation. Moving to Fig.1 (b), distinct features emerge on the surface of the CS/OP/CB variation. Larger black spots are noticeable, and through further examination, they are identified as shell waste. A comparison with orange peel waste indicates that these spots are slightly larger and have a pointed shape, characteristic of shell waste particles. This observation suggests the utilization of a diverse range of waste materials in the composite, contributing to its structural integrity and performance.

In Figure 1 (c), the surface characteristics of the material differ significantly from the previous variations. Here, clamshell waste and resin dominate the surface, filling all available space. The absence of fibers from cardboard and orange peel waste indicates a distinct composition, comprising primarily shellfish waste and resin. This observation underscores the versatility of composite formulations, where variations in material composition lead to differences in structural properties and performance characteristics.

B. Physical Characteristics

Based on the data presented in Table 2, it is evident that the variations CS/OP/CB and CS exhibit the lowest swelling values after soaking for 2 hours. Conversely, the OP/CB variation demonstrates the highest Degree of Swelling (DS), reaching 33.76%. This disparity in swelling behavior highlights the influence of different compositions on the water absorption characteristics of the samples. A notable observation is that the CS variation experiences a minimal increase in DS, with only a 0.02% increment after 1 hour of immersion, and no further increase after 2 hours. This suggests that the inclusion of shellfish waste in this variation contributes to the prevention or reduction of water absorption by the epoxy resin and fiber components. This hypothesis is further supported by the behavior of the CS/OP/CB variation, which incorporates a higher proportion of shellfish waste compared to fiber. In this variation, the DS increases by only 0.09% after 2 hours of immersion.

Degree of swelling test results play a crucial role in determining the suitability of materials for various applications, particularly in industries where water resistance is paramount, such as brake pads. In the analysis of DS test results, one particular variation, the CS/OP/CB variation, stands out as the most promising candidate due to its fiber component and low DS value, indicating superior resistance to water absorption compared to other variations tested. Brake pads are vital components in automotive systems, responsible for converting kinetic energy into thermal energy through friction. Thus, they must withstand various environmental conditions, including moisture, to ensure optimal performance and safety. Water absorption in brake pads can lead to reduced friction coefficients, diminished stopping power, and potentially hazardous driving conditions, emphasizing the critical role of water resistance in these components.

The DS test, or degree of swelling, serves as a standard method for evaluating the water absorption characteristics of materials. It involves immersing samples in water and measuring the increase in weight over time due to water absorption. A low DS value indicates minimal water absorption and, consequently, better water resistance, making it a crucial parameter in material selection for applications like brake pads. The CS/OP/CB variation emerges as the most successful candidate based on DS testing outcomes. The presence of a fiber component, coupled with its low DS value, indicates its potential for excellent water resistance, making it well-suited for application in brake pads. The significance of this finding extends beyond the specific application of brake pads, underscoring the broader importance of careful material selection in engineering and manufacturing processes [3]. By identifying materials with optimal performance characteristics through rigorous testing and analysis, researchers can enhance the efficiency, reliability, and safety of various products and systems. Moreover, the success of the CS/OP/CB variation highlights the potential of utilizing natural fibers and agricultural waste products in composite materials [12][13].

The development of composite materials tailored to specific application requirements represents a significant area of research and innovation in materials science and engineering. By understanding the relationship between material composition, structure, and performance properties, researchers can design materials with enhanced functionalities and tailor them to meet the demands of diverse applications.

Table 2. Result of degree of swelling brake pad with variation OP/CB, CS/OP/CB, and CS

Time (min)	**Degree of swelling (DS) (%)**		
	OP/CB	***CS/OP/CB***	***CS***
0	0	0	0
60	33.54	0.08	0.02
120	33.76	0.17	0.02

The tensile strength testing procedure involves the utilization of the Ibertest brand Universal Testing Machine (UTM). Before the commencement of the test, a waiting period of 30 minutes is adhered to, allowing the tool to stabilize and acquire the characteristic properties of the material under tensile loads. This waiting time ensures that the machine reaches a consistent state, thus providing reliable and accurate test results. During the testing phase, only samples of the CS/OP/CB variation are employed. These samples are specifically selected due to their potential suitability for further development as brake pads. The decision to focus solely on this variation is likely based on preliminary assessments or prior knowledge regarding its composition and performance characteristics. Before subjecting the samples to tensile strength (TS) testing, they undergo a preparation process to meet the requirements outlined in the ASTM D638-14 standard. One crucial step in this preparation involves shaping the samples into a dogbone configuration. This particular shape is prescribed by the ASTM standard as it facilitates uniform stress distribution during testing and allows for accurate measurement of tensile properties.

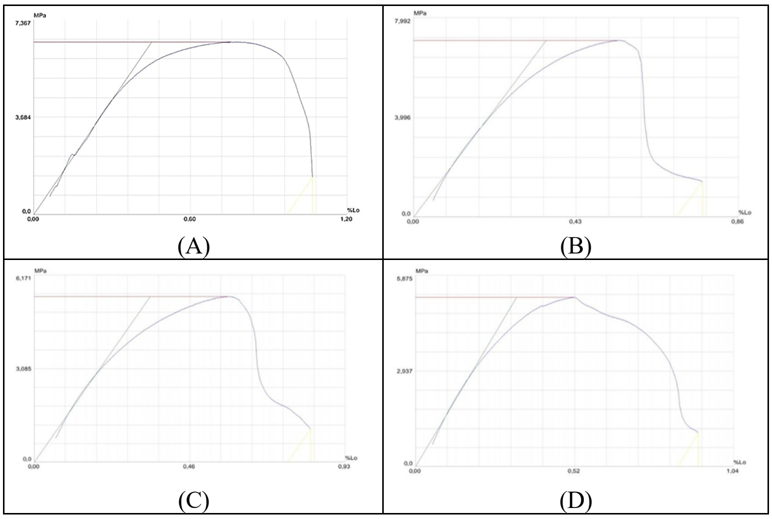


Fig. 2. Results of tensile strength variation CS/OP/CB with samples (A), (B), (C), (D)

From Table 3, it is revealed that in variation A, the maximum tensile strength is found in sample B. This sample stands out because its composition is located in the middle of the material, combining resin, hardener, fiber from cardboard waste, and orange peel. The maximum tensile strength of sample B was recorded at 7.076 MPa. On the other hand, sample D from variation A showed the lowest maximum tensile strength, only reaching 5.202 MPa. In ranking the maximum tensile strength from highest to lowest, sample B occupies the top rank with a value of 7.076 MPa. Followed by sample A with a tensile strength of 6.521 MPa. Then, sample C has a value of 5,463 MPa, and sample D is in the lowest position with 5,202 MPa. However, composite should be noted that these results do not fully represent the true tensile strength of CS/OP/CB variation composites. This is because, during the testing process, the research team experienced difficulty in cutting samples according to ASTM D638-14 standards using type I or type II molds. Therefore, the data obtained does not fully represent the actual tensile strength of the composite material. Tensile testing was only carried out on four samples, namely samples A, B, C, and D. The tensile strength test results were obtained based on reading the graph in Figure 2. In evaluating tensile strength, it is important to consider various factors that can influence the results, including sample cutting method and environmental conditions during the test. In addition, aspects such as material homogeneity and fiber distribution also play an important role in determining the tensile strength of a composite material. Observations of these samples provide an initial picture of the mechanical characteristics of CS/OP/CB composite variations.

Table 3. Result of tensile strength brake pad with variation CS/OP/CB

Variation CS/OP/CB	Tensile Strength
A	6.521
B	7.076
C	5.463
D	5.202

IV. Conclusion

Brake pads are crucial for vehicle safety, reducing speed and aiding parking. Composite materials, like clamshells with calcium carbonate and cellulose from cardboard waste, offer eco-friendly alternatives. Studies explore compositions like epoxy resin with teak sawdust, palm sugar palm powder, and clamshell-banana peel fiber combinations. These composites undergo tests for Microscopy, Degree of Swelling, and tensile strength to ensure performance. The research aims to develop sustainable brake pads with enhanced properties for automotive applications. Microscopy Test (MT) is pivotal for assessing brake pad surface morphology. OP/CB displays fine fibers from cardboard and orange peel, while CS/OP/CB features larger black spots from shell waste. Clamshell waste and resin dominate CS/OP/CB surfaces, indicating compositional differences. Degree of Swelling (DS) testing reveals CS/OP/CB's superior water resistance, crucial for brake pad performance. Tensile strength testing follows ASTM D638-14 standards, with sample B in variation A showing the highest strength. However, challenges in sample preparation may affect data accuracy, necessitating further refinement for reliable results in composite material development.

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