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RESEARCH ARTICLE

Effect of adding blood shells powder (Anadara Granosa) on wear rate, impact strength, and hardness test as a motorcycle disc brake pad composite

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Abstract - The automotive industry has always demanded innovation in renewable materials that are environmentally friendly. One of the natural materials that has the potential as a constituent material to make motor vehicle parts is blood clam shell waste (Anadara Granosa) which can be used as a raw material for making brake pads. This study has the purpose to analyze the effect of the addition of blood shell powder on the wear, toughness, and hardness value of epoxy resin matrix composite as a motorcycle brake pad. This study is a type of experimental research by comparing the experimental group with the control group (Honda Genuine Parts brand brake pads). The test results showed that the addition of 30% of blood shells powder got the most optimal results with a wear value of 1.27×10-6 mm2/kg, impact value 2.41×10-3 J/mm2, hardness of 19.98 kgf/mm2. The 30% variation has the closest results to the test value on the brake pads of the Honda Genuine Parts brand motorcycle. With this, it can be concluded that the more volume of blood shells powder, the more the strength of the composite increases. With these results, blood shell powder composite can be recommended as an alternative to brake pad friction material that is more environmentally friendly.

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1. Introduction

The rapid development of the automotive industry also forces us to always follow these developments. These developments must always prioritize a sense of security and comfort. One of them is innovation in the constituent materials of each part of a motor vehicle so that it has ergonomic, strong, and environmentally friendly properties [1] [2]. One of the vehicle parts with a relatively short lifespan is the brake pad. While previous studies have utilized various shell wastes, the specific effects of Anadara granosa (blood cockle) shell powder – with its unique microstructure and high $CaCO_3$ purity from Semarang coastal waste – on the simultaneous tribological (wear rate) and mechanical (impact strength, hardness) properties of disc brake pad composites have not been systematically investigated. There is a paucity of thorough research that links the chemical composition and microstructural properties of Anadara granosa shell powder to the combined evaluation of wear rate, impact strength, and hardness in motorcycle brake pad composites. As a result, the goals of this study are to immediately address this gap through simultaneous tribological and mechanical characterisation.

Due to this problem, innovation is needed in the materials used in friction materials for brake pads to achieve good properties. Innovation in friction materials can use natural materials as the constituent materials. Natural fibers used as reinforcements in brake pad composites are a good alternative because of their environmentally friendly, biodegradable, and renewable properties [3]. Abutu and Adekunle has conducted research aimed at developing brake pads made from shellfish, a material made from various types of shells and does not use a specific type of shell. The results of the research showed good results [4][5]. In this case, blood shells *(Anadara granosa)* are considered to have good potential if used as a constituent material of brake pad composites. At this time, the use of blood shells waste is still very minimal and results in pollution in coastal areas. In addition, blood clam shells have good physical properties when used as friction materials. This is supported by the high content of calcium carbonate ($CaCO_3$) contained in the shell of blood shells. The high calcium carbonate content can increase the strength of composites [6] [7].

The material used in the manufacture of friction materials is aluminum oxide (Al_2O_3) or commonly known as alumina. Alumina is a broad term for corundum-like formations in which oxygen atoms are arranged hexagonally and alumina atoms occupy two-thirds of the octahedral positions in the lattice [8]. Aluminium has lightweight, heat-resistant, corrosion resistance to water (including brine), and oil, as well as many other chemicals. Al_2O_3 can also increase the coefficient of friction under high-speed and heavy-load conditions [9]. Judging from its properties that have good mechanical strength, aluminum oxide is suitable for use as a reinforcing material and abrasive material in brake lining composites. The shape of all the materials that make up the friction material on the brake pad is powder, based on this, the friction material is a composite of particles. Particle composites are a type of composite that has reinforcement in the form of powder or particles that are evenly distributed in the matrix. Small-dimensional particles must be dispersed in order to produce more uniform strength in different directions and can increase the hardness of the material and increase the strength of a composite [10]. The strength of a particle composite is affected by the coherent stress between the matrix phases and the particle showing a good relationship. This is due to the presence of voids decreasing as particle content increases [11].

In the manufacturing process, this composite uses an epoxy resin matrix that functions as an adhesive between the constituent materials [12]. The advantages of this epoxy compared to other resins, namely high mechanical and thermal

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properties, fluidity, bonding properties, impact resistance, and weather resistance in composites will be improved by the addition of epoxy resin [13]. Therefore, in this study, an epoxy resin matrix will be used. This study is specifically intended to examine the potential application of blood cockle shell *(Anadara granosa)* powder as a reinforcing material in motorcycle brake pad composites. In addition, the research aims to analyze the influence of calcium carbonate ($CaCO_3$) content and the micro-structural properties of blood cockle shells on the tribological and mechanical performance of composite brake pads, including wear rate, impact strength, and hardness. The findings of this study are expected to provide an effective approach to utilizing blood cockle shell waste to minimize environmental pollution while simultaneously developing brake pad materials that exhibit high strength, improved wear resistance, and environmentally sustainable characteristics.

2. Materials and Methods

2.1 Blood Shells

Blood shells were collected from fish market waste on the coast of Semarang city. The shell of the blood shells should be clean and dry. The shells used are then ground in a grinder and sifted to 100 mesh (Figure. 1). blood shells are known to contain 98.7% calcium carbonate ($CaCO_3$) shown in Table 1.

(a)

(b)

Figure 1. Blood shells

Table 1. Chemical content of blood shells

Chemical Content	Value (%)
$CaCO_3$	98.70
Na	0.90
P	0.02
Mg	0.05
Fe, Cu, Ni, B, Zn, dan Si	0.20

2.1.2 Aluminium Oxide

Aluminum oxide or aluminum oxide, often known as alumina, is a white oxide which is a chemical compound which is formed as a result of the reaction of aluminum and oxygen. Aluminum Oxide is obtained from a chemical supplier in Semarang, with a mesh size of 100. Judging from its mechanical properties, aluminum oxide has a hardness value of 1500-1800 kgf/mm2 and a density of 3960 kg/m3, as shown in Table 2.

Table 2. Physical and mechanical properties of aluminium oxide [12]

Characteristic	Value
Molecular Weight (g/mol)	101.96
Melting Point (°C)	2072
Gravity Specification	3.5 - 4.0
Density (kg/m^3)	3960
Hardness (kgf/mm^2)	1500 – 1800
Compressive Strength (MPa)	230 - 350
Thermal Conductivity (W/m.K)	20 - 30

2.1.3 Epoxy Resin

The matrix used in this study is Bisphenol A-Epichlorohydrin epoxy resin as a binding agent and Cycloaliphatic Amine type hardener epoxy (Figure 2) obtained from a chemical store in Semarang and using a hardener or catalyst as a hardener.

Epoxy resin has an impact strength value of 30-250 kJ/m^2 and a density value of 1.14-1.18 g/cm^3 as shown in the Table 3.

Figure 2. Bisphenol A-Epichlorohydrin epoxy resin and Cycloaliphatic Amine type hardener epoxy

Table 3. Physical and mechanical properties of epoxy resin [13]

Characteristic	Value
Density (g/cm^3)	1.14 – 1.18
Viscosity at 25°C (MPa×s)	23000 – 29000
Tensile Strength (MPa)	68 – 80
Deformation (%)	5 - 7
Flexural strength (MPa)	110 - 130
Modulus of elasticity (MPa)	2.9 – 3.2
Compressive strength (MPa)	110 - 130
Impact strength (kJ/m^2)	30 - 250

2.2 Method

The research method used in this study was experimental. This research encourages experiments to determine the influence of certain variables. In this design, the experimental group was given treatment while the control group was not. Measurements were taken only once, namely after the treatment was administered to the experimental group. The control group in this study is the brake pads honed from the Honda Genuine Part brand. Throughout the composite testing process, the material was tested under dry, clean conditions. The testing process was carried out at room temperature and repeated three times for each composite variation. After the test results were obtained, the data was processed by verifying its normality value using the Sapphiro-Wilk normality test method [16]. If the data distribution was declared normal (p-value < 0.05), then the test results could be taken as the average value for each variation [17].

This study focuses on the effect of increasing the volume of blood shells powder on composites with aluminum oxide particles and epoxy resin matrices. The particle size of the blood shells and aluminum oxide used is 100 mesh. The composition of blood shells, aluminium oxide, and epoxy resin particles in each variation can be seen in Table 4.

Figures must be self-explanatory and accompanied by concise yet descriptive captions. The journal accepts high-resolution formats, including PNG, EPS, TIFF, JPEG, and BMP. To ensure optimal print and digital quality, grayscale images should have a minimum resolution of 600 dpi, while colour images must be at least 300 dpi. All figures should be numbered sequentially according to their appearance in the text (e.g., Figure 1, Figure 2). For multi-part figures, individual components should be clearly labelled (e.g., Figure 1(a), Figure 1(b)). Captions must be written in sentence case, positioned below the image, centre-aligned, and should not conclude with a period.

Table 4. Variations of composite formulations

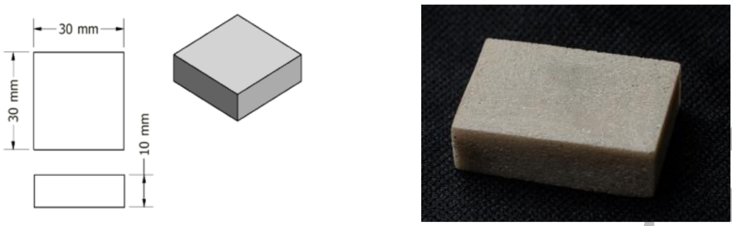
No.	Blood Shells Particles	Aluminium Oxide	Resin
1	10%	20%	70%
2	20%	20%	60%
3	30%	20%	50%

2.3 Fabrication of Particular Composite

The process of preparing the ingredients begins with cleaning the shell of the blood sells from sticking dirt. Next is the process of drying the blood shells by drying them in the sun for 6 hours in 2 days until dry. The shells of the blood shells are then crushed into a 100-mesh powder. The blood shells powder is then mixed with aluminum oxide powder in a container until well mixed. Put in different containers, mix epoxy resin with hardener in a 1:1 ratio and stir with a mixer at 600 rpm for 1 minute. The next step is to mix all the ingredients and stir with a mixer at 600 rpm for 10 minutes [14].

After the mixing process is complete, the dough is poured into the mold and the curing process is carried out for 1 hour until the texture of the mixture is semi-solid. Furthermore, the composite is compaction to obtain a good bond between the particles and reduce the air cavity that occurs during the mixing process. Compaction is carried out at room temperature and pressure of 1500 psi for 10 minutes. After the compaction process is complete, the composite is left to sit for 24 hours to allow the matrix to harden perfectly. After the composite hardens, the sintering process is carried out with the oven for 30 minutes and a temperature of 108 °C [15]. The sintering process is carried out to increase the formation of interlocking bonds between the matrix powder and the reinforcing powder.

The last step before testing is to cut the composite that has been welded to fit the test dimensions. The specimen must be cut precisely and flat on both sides to the standard size. The size of the wear test specimen can refer to the Ogoshi testing machine manual and is shown in Figure 3(a). Meanwhile, in the Vickers hardness test, there is no specific standard regarding specimen dimensions. However, the specimen surface must be flat, perpendicular, and possess a thickness of at least twice the indentation depth. Based on these requirements, the test was conducted using specimen dimensions identical to those used in the wear test specimen. In Figure 3(b), the results of the specimens for the Ogoshi and hardness tests are shown, ready for testing. For impact test specimen sizes, ISO 179-1 is used and is shown in Figure 4(a), Meanwhile, Figure 3(b) shows the results of the specimen for impact testing which is ready to be tested.



3(a) 3(b)

Figure 3. (a) Specimen dimension for Ogoshi wear test and hardness test, (b) Ogoshi wear test and hardness test specimen

4(a) 4(b)

Figure 4. (a) Standard dimension for Impact test (ISO 179-1), (b) Impact test specimen

All specimen fabrication procedures were conducted at the Mechanical Engineering Laboratory, Universitas Negeri Semarang, in accordance with the research procedures and parameters defined in this study. The fabrication process comprised material preparation, specimen shaping, machining, and finishing operations to ensure dimensional consistency and adequate specimen quality before testing.

$$Ws = \frac{B.b^3}{8r.p_0.l_0} \ (mm^2/kg) \quad (1)$$

where:
Ws = Specific Wear Rate (mm2/kg)
B = Revolving Disc Width (mm)
b = Width of Wear on the Test Piece (mm)
r = Radius of Revolving Disc (mm)
p0 = Pressure Force During the Wear Process (kg)
l0 = Mileage in the Wear Process (mm)

2.5 Impact Test

The principle of impact testing is to calculate the energy exerted by the load and calculate the energy absorbed by the specimen [17]. When the load is raised at a certain height, the load has potential energy, then when pounding the specimen the kinetic energy reaches its maximum. The energy absorbed by the specimen will cause the specimen to fail. The form of failure depends on the type of material, whether brittle or ductile fracture. The impact test will be carried out at the Department of Mechanical Engineering laboratory, Faculty of Engineering, Universitas Negeri Semarang using the GOTECH type GT-7045-MD impact testing machine with Charpy impact testing method. Meanwhile, to find the Impact Strength, use the following equation:

$$IS = \frac{E}{A} \quad (2)$$

$$IS = \frac{W \times \ell(\cos\beta - \cos\alpha)}{A} \quad (3)$$

where:
Is = Impact Stength (J/m^2)
E = Absorbed Energy (J)
W = Pendulum weight (N)
α = Starting angle (°)
β = Final angle (°)
A = Cross-sectional area (m^2)

2.6 Hardness Test

Hardness testing is a method for accurately determining a material's hardness using a hardness test tool. Hardness testing will be carried out at the Mechanical Engineering Laboratory, Faculty of Engineering, Universitas Negeri Semarang using the Vickers hardness testing machine. [18] This tool uses a square-shaped diamond peramide indenter to make traces on a material with a load of 5 gf. The magnitude of the hardness value of vickers is calculated by dividing the load value by the area of the compressive surface, or written as follows:

$$VHN = \frac{1{,}854\ P}{d^2}\ (kg/mm^2) \quad (4)$$

where:
VHN = (Vickers Hardness Number) (kg/mm^2)
P = Load Used (kgf)
d = Average Diagonal Penetration (mm)

2.7 Micro Structure

Micro photographs are used to show tissue structure at the micro-nanoscale in composite materials [19]. By knowing the microstructure of the composite, it can be used to determine the effect of the characterization of the composition on a composite. Based on this description, knowing the microstructure of a composite is needed to estimate the mechanical strength to be tested. In this study, microstructure photos were taken using a microscope of type B-510 METROPTIKA ITALY with a magnification of 50 times. This microscope is located in the Mechanical Engineering laboratory, Faculty of Engineering, Universitas Negeri Semarang.

3. Results and Discussion

3.1 Specific Wear Rate

Figure 5 shows the results of the wear test of the Ogoshi method on brake pad composites with variations in the composition of the blood shells. This test showed that there was an effect of each addition of the composition of blood shells powder on the wear test results. In the 10% composition variation, the blood shells powder mixture obtained a wear test result of 2.63×10-6 mm2/kg. After adding the composition of blood shells powder to 20%, the wear value decreased by 39.92% to 1.58×10-6 mm2/kg. With the addition of 30% blood shells powder, the wear value decreased by 51.71% to 1.27×10-6 mm2/kg.

The results obtained from this wear test in Table 5 indicate that the amount of blood shells powder added to the specimen may affect the composite's wear value. The results of the wear test of a material show that the smaller the wear value means the more resistant the material is to the wear that occurs. In this test, it was found that the smallest wear value was obtained in a composite specimen of the brake lining at a variation in the composition of shells powder of 30%. Several factors can affect the wear value in this test, one of which is the selection of the constituent material. It is known from Table 1 that blood shells have a high content of calcium carbonate ($CaCO_3$). This can affect the properties of the composite to be more resistant to wear. Wan Mohammad et al. [20] also explained that the high calcium carbonate content in shells also has properties that bind to other materials so that they can reduce wear values. The decrease in wear value that occurs is in line with research conducted by Adekunle et al., which showed that the wear value decreases with the increase in the content of shell powder [21].

The next factor that can affect the wear value is the use of aluminum oxide as a composite material. The addition of Al_2O_3 as a constituent of a brake lining composite can increase wear resistance [22] [23]. This is also in line with Patel & Dhalana's research, which states that among the commonly used nanofillers, Al_2O_3 powder is one of the well-established nanofillers due to its excellent mechanical, thermal, and tribological properties [24]. Based on the specific wear value graph in Figure 5, the 30% composition variation of the blood shells belt mixture yields the average specific wear value closest to that of the brake pad from Honda Genuine Parts (5.92×10^{-7} mm^2/kg). The difference between the results of the experiment and the comparator was 53.39%, still quite high. One of the factors causing this difference is an insufficiently optimized composite fabrication, resulting in the formation of air cavities in the composite. Rahmawaty and Huo et al. stated that the more cavities there are in a composite, the less it will reduce its strength. The presence of this air cavity reduces bonding between the constituent materials and makes the composite more easily eroded [25]. In addition, the material that makes up the Honda Genuine Part brake pad uses several constituent materials, such as copper, which causes the blood shells powder composite to have a very high wear value.

The result of the wear test is the trace of scratches left on the test specimen as shown in Fig. 6. These traces are derived from friction between the revolving disc and the specimen during testing. On visual observation, the wear that occurs on the test specimen is classified as abrasive wear due to the presence of parallel grooves or lines formed due to friction [26]. Abrasive wear occurs when the surface of objects is lost due to harder materials [27]. Conforms to the way of working on Ogoshi wear testing.

Table 5. Specific wear rate

Specimen Code	Ws (mm^2/kg)	Average Ws (mm^2/kg)	Mean ± SD (mm²/kg)
A1	2.16×10^{-6}	2.63×10^{-6}	$\pm 0.54\times10^{-6}$
A2	2.50×10^{-6}		
A3	3.21×10^{-6}		
B1	1.80×10^{-6}	1.58×10^{-6}	$\pm 0.27\times10^{-6}$
B2	1.67×10^{-6}		
B3	1.28×10^{-6}		
C1	1.13×10^{-6}	1.27×10^{-6}	$\pm 0.16\times10^{-6}$
C2	1.44×10^{-6}		
C3	1.25×10^{-6}		
K1	6.60×10^{-7}	5.92×10^{-7}	$\pm 0.10\times10^{-7}$
K2	6.37×10^{-7}		
K3	4.80×10^{-7}		

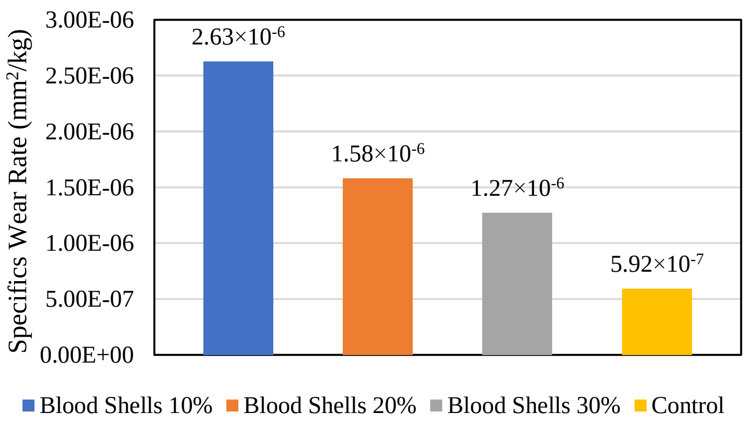


Figure 5. Specific wear rate

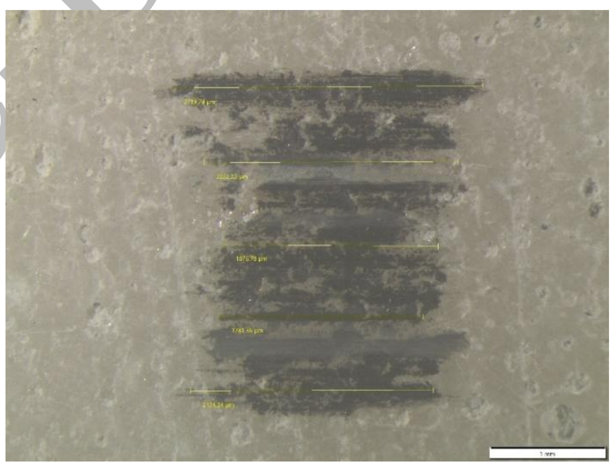


Figure 6. Wear width at 50 times magnification

3.2 Impact Strength

In the impact test, the test specimen will be pounded with a predetermined load. This test is carried out by calculating the energy that can be absorbed (J) per unit cross-sectional area, called the impact force (J/mm^2). The results of the impact tests can be seen in Table 6.

Figure 7 shows the results of impact tests on brake pad composites with variations in the composition of blood shell powder. In this test, it was shown that each additional addition of blood shells powder affected the impact strength. At the 10% composition variation, the blood shells powder mixture obtained an impact value of 1.89×10^{-3} J/mm^2. After adding the composition of blood shells powder to 21.7%, the impact value increased by 18.81% to 2.30×10^{-3} J/mm^2. With the addition of 30% blood shells powder, the impact value increased by 4.8% to 2.41×10^{-2} J/mm^2.

Table 6. Impact strength

Specimen Code	Impact Strength (Is)	Average Is (J/mm^2)	Mean ± SD (J/mm^2)
A1	1.56×10^{-3}	1.89×10^{-3}	$\pm 0.32\times10^{-3}$
A2	1.92×10^{-3}		
A3	2.19×10^{-3}		
B1	1.08×10^{-3}	2.30×10^{-3}	$\pm 0.29\times10^{-3}$
B2	2.19×10^{-3}		
B3	2.62×10^{-3}		
C1	2.38×10^{-3}	2.41×10^{-3}	$\pm 0.29\times10^{-3}$
C2	2.36×10^{-3}		
C3	2.50×10^{-3}		
K1	2.56×10^{-3}	2.50×10^{-3}	$\pm 0.07\times10^{-3}$
K2	2.53×10^{-3}		
K3	2.39×10^{-3}		

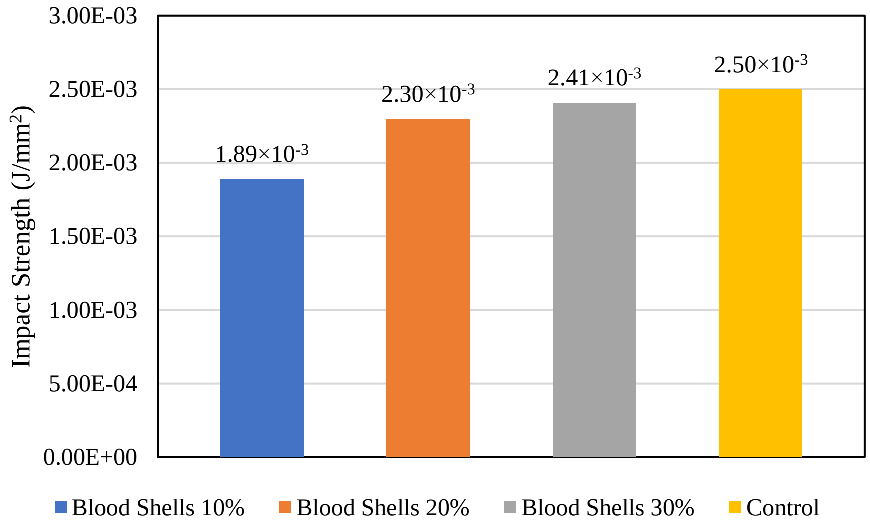


Figure 7. Impact Test Results

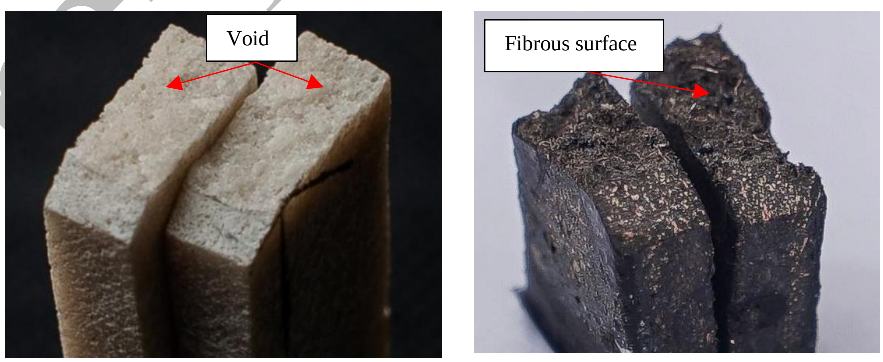


Figure 8. Impact test result on specimens

This phenomenon shows a positive relationship between the impact test results and the composition of blood shells used in the manufacture of composites. This can be caused by the high content of calcium carbonate ($CaCO_3$) in the shell of the blood shells (Table 1). Calcium carbonate has a high ability to improve the mechanical properties and good dispersion of particles in polymer matrices [28].

Another factor affecting impact strength in this study is the use of aluminum oxide powder as the constituent material. Alumina nanoparticles are also widely used as fillers because they can produce composites with greater modulus of elasticity, stronger wear resistance, higher chemical corrosion resistance, strength retention, and stability at higher temperatures [29]. This is in line with research by Bazrgari et al., which reported increased flexural strength and impact resistance in epoxy resin composites with the addition of Al_2O_3 particles [30]. Based on the impact strength graph in Figure 7, the 30% composition variation of the blood shells mixture yields the average impact strength closest to the average value of the brake pad impact force for Honda Genuine Parts (1.38×10^{-2} J/mm^2). The difference between the experimental results and the comparator was 4.55%. This difference can be due to the presence of voids in the experimental composite (Fig. 8). This is because the presence of voids can affect its strength because the bonds between materials cannot occur perfectly [31]. Void is the most common defect found in composite manufacturing processes [32]

3.3 Hardness Test

In the vickers hardness test, the test specimen was pressed using a diamond indenter with a pressure load of 5 gf. For 15 seconds. To obtain the hardness value, it is necessary to measure the diagonal length of the square formed by the indenter track. The results of the vickers hardness test that has been carried out can be seen in the table. Table 7 shows that the brake pad composite in the 10% blood shells powder variation had a hardness value of 12.39 kgf/mm^2. The brake pad composite in the 20% blood shells variation increased by 26% with a hardness value of 15.61 kgf/mm^2. The brake pad composite in the 30% blood shells variation had a hardness value of 19.98 kgf/mm^2, an increase of 61.26%. Meanwhile, the comparative specimen has a hardness value of 21.63 kgf/mm^2. When compared to the best results of the experiment (30% variation in blood shells powder), the difference in the hardness value of the two was only 8.26%.

Table 7. Hardness Value (VHN)

Specimen Code	Vickers Hardness Number (VHN)	Average Hardness (kgf/mm^2)	Mean ± SD (HV)
A1	12.10	12.39	
A2	12.35		± 0.32
A3	12.73		
B1	15.45	15.61	
B2	15.68		± 0.14
B3	15.70		
C1	19.47	19.98	
C2	19.80		± 0.62
C3	20.68		
K1	20.46	21.63	
K2	21.59		± 1.20
K3	12.10		

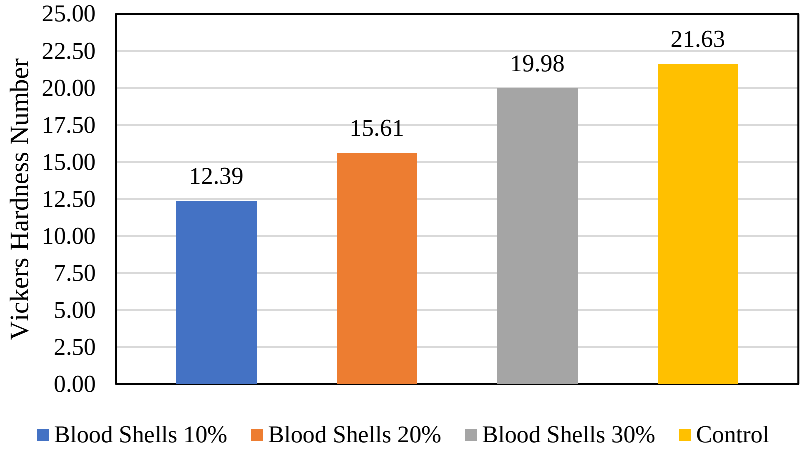


Figure 9. Hardness Value

The results of this test show that, along with the increase in the volume of blood shells powder, the hardness value of the specimen increases. This is also in line with Fombuena et.al research which also shows an increase in hardness ,with increasing volume of shellfish powder in composite manufacturing. [33]. The main component of clam shells is mostly composed of calcium carbonate which makes shells highly resistant to damage, as well as having higher hardness and toughness [34]. Inorganic and organic materials work together to create shells that have remarkable mechanical properties thanks to their micro structure [35].

3.4 Microstructure

In Figure 10. (a) showing the microstructure of the research experiment, it can be seen that the composition variation of 10% shows that the most content in it is a resin that is glossy and slightly dark and looks empty without powder. This can happen because the composition of epoxy resin in this variation reaches 70% of the volume fraction. In Figure 10. (b) and (c) it can be observed that the blank part begins to gradually fill with blood shells powder. This is characterized by the abundance of white powders on the composite although the belt in the experiment showed the same color, which is white as in Figure 10. there is a mark that can distinguish between blood shells powder and aluminum oxide. According to Jamarun et al., blood shells vary in size and have irregular particle shapes [36]. Blood shells powder also has a rough surface morphology due to the calcium carbonate-coated structure. Meanwhile, according to Luo et al. Al_2O_3 powder shows a smooth surface and a more rounded shape than natural powder [37].

Thus, in Figure 10(a), (b), and (c), it can be observed that the differences in the materials that make up the composite can be microscopically based on the existing physical characteristics. In the image, it can also be observed that the increase in the volume of blood shells powder causes a change in the structure of the composite. In the observation of microstructures, the highest variation was found in the sample with the highest amount of blood shell powder, at 30%. While in Figure 10(d) which is a control specimen, it shows a different image from the others. The image shows copper powder (Cu) measuring more than 100 mesh. In addition, there are other materials in the form of fibers in it. By observing these microstructures, it can be known that the morphological differences between the control specimens and the experiments can be seen. Figure 10's microstructural observations offer concrete proof of the patterns in hardness, impact strength, and wear rate. Enhancing interfacial adhesion between the filler and matrix and improving particle dispersion inside the epoxy matrix are two benefits of increasing the blood shell powder content from 10% to 30%. This enhanced bonding diminishes particle pull-out during frictional contact and lessens void formation, which accounts for the wear rate drop at higher shell powder compositions.

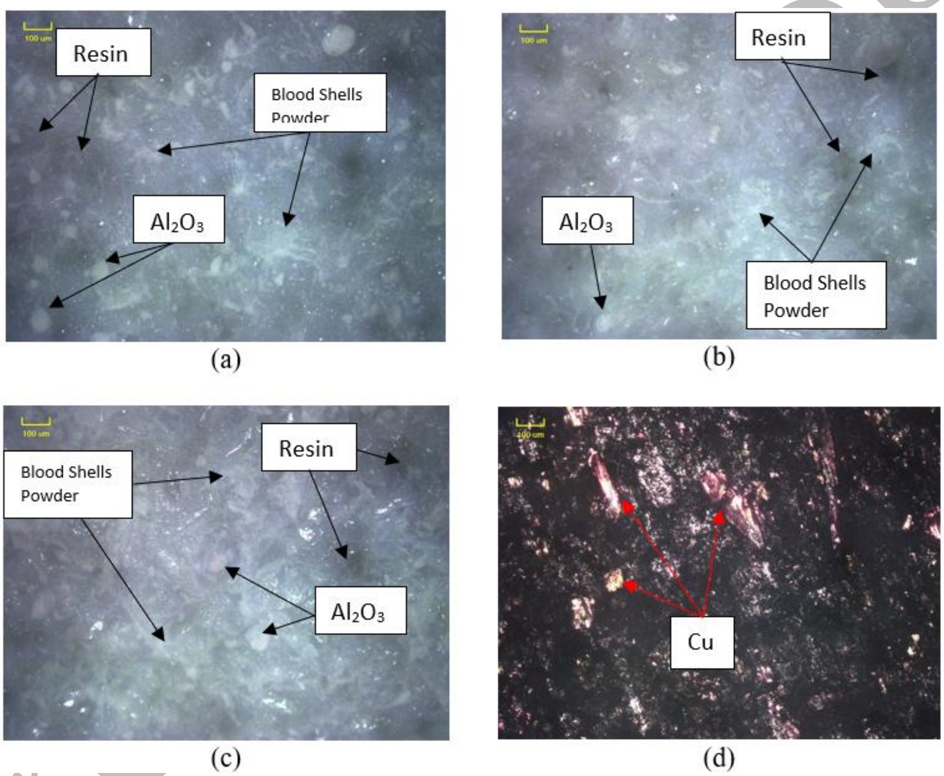


Figure 10. Microstructure (a) 10%, (b) 20%, (c) 30%, (d) Honda genuine parts

Additionally, the increased impact strength is a result of improved stress transmission between the matrix and the scattered particles. In addition to increasing resistance to indentation, the removal of voids and more uniform particle distribution also raises hardness levels. Thus, there is a direct correlation between the microstructural properties and the generated brake pad composites' mechanical and tribological performance.

4. Conclusions

Based on the results of the analysis carried out, the addition of blood shell powder *(Anadara Granosa*) as a constituent material in brake pad composites can affect the specific wear rate, impact strength, and hardness. The results of the hardness and impact tests are inversely proportional to the wear rate, where the harder the brake pad composite, the impact test value will increase, and the wear level will decrease. The test value that showed the best results was found in the variation in the composition of blood shell powder at 30%. The variation is nearly equal to that of commercial brake pad products used for comparison. This study shows that blood shell powder has the potential to be used as a composite material for more natural motorcycle brake pads. Some suggestions for future research include optimizing the composite manufacturing process so that the air bubbles formed can be completely eliminated. In addition, add natural fibers and other metal materials that can improve the mechanical and physical properties of the brake pad composite. Then perform tests on other mechanical and physical properties, such as friction coefficient, compressive strength, tensile strength, density, porosity, etc.

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Declaration of Competing Interest
The author declares no conflicts of interest.

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