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The Effect of Aegle Marmelos Shell Particles Size on The Mechanical Properties of Epoxy Matrix Composites as An Alternative Material For Motorcycle Disc Brake Pad

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Abstract

The particle size can effect the mechanical properties of composite materials. Variations in particle size will form different mechanical properties in the composite. The particle size variations used in this research are 100 mesh, 120 mesh, and 140 mesh. Making composites using a volume fraction of 30% aegle marmelos shell powder, 20% aluminum powder, and 50% epoxy resin using the hand lay-up method. This research design uses true experimental design with posttest-only design type, there is an experimental group (composite) and control group (Indoparts brand brake pads). Mechanical testing carried out is toughness / impact testing, rockwell-b hardness testing and wear testing. The highest toughness value was obtained in the composite with 140 mesh particle size variation of 0.01180 J/mm^2. The highest rockwell-b hardness value was obtained in the 140 mesh particle size variation of 76.9 HRB. The hardness value is closest to the value of the Indoparts brand brake pad. This shows that the smaller the particle size, the hardness value increases. The most optimal wear test results were obtained in the 100 mesh particle size variation with a value of 5.7357×10^{-7} mm^2/kg. This value is the closest value to the value of the Indoparts brand brake pad. So it can be concluded that aegle marmelos shell powder can be recommended as an alternative material for motorcycle brake pad.

Keywords: Particle size, hardness, wear, impact, aegle marmelos, mechanical properties

INTODUCTION

Motorcycle is one of the vehicles that are in great demand by people in Indonesia, this is of course the reason for many manufacturers to continue to develop motorcycle production. The development of innovations on motorcycle aims to provide comfort and safety for its users. One of the many developments made by the industry to provide security for its users is in the braking system. An optimal braking system will make users feel safe and comfortable. The brake system is a system that has a very important function in vehicles, such as slowing down the vehicle speed, stopping the vehicle speed, and allowing the vehicle to park in a downhill place. The component that plays a very important role in slowing down and stopping the vehicle in the brake system is the brake pad. The brake pads bear a load of up to 90% compared to other components, therefore the quality of the brake pad material can affect the safety of the driver. Many brake pads on the market are still made from asbestos, which is an inorganic material that is pressed together with resin, rubber and others to make brake pads. Asbestos brake pads have a relatively low price, but the use of asbestos materials has a risk that is not good for the environment because the content of carcinogenic substances and other substances has the potential to damage the environment. Asbestos materials can also endanger respiratory health because they can

injure the lungs if inhaled. In addition to asbestos brake pads on the market, there are also non-asbestos brake pads made from several types of fiber and can withstand quite high temperatures, but have a higher price compared to asbestos brake pads [1].

The composite materials made from natural fibers and artificial fibers are widely used as research materials to produce alternative materials for making brake pads. Natural fiber is one of the fibers that has good strength and density, relatively low cost, sufficient availability and is more environmentally friendly [2]. Research on natural fibers as composite reinforcing materials has experienced many developments both in terms of industrial applications and fundamental research. This is because its availability is renewable and the cellulose content contained in natural fibers is good to be used as a composite reinforcement material [3].

The most common uses of aegle marmelos are as medicine, organic fertilizer, handicrafts, and so on. Aegle marmelos has many benefits starting from the leaves, until the fruit can be used. Aegle marmelos has a hard skin or can be referred to as a shell. The hard skin of the aegle marmelos eventually gave the idea to be utilized as a filler or reinforcement material in composite materials. Aegle marmelos skin among other lignocellulosic fibers, has a strong level of toughness and hardness [4]. The cellulose content contained in the aegle marmelos peel is what makes it suitable as a composite reinforcement material. Aegle marmelos can be used as a reinforcing material in composites because it has a high tensile strength value [5]. Therefore, this study was conducted to determine the mechanical properties of composites made from fillers, such as aegle marmelos peel or aegle marmelos shell as an alternative material for motorcycle brake pads.

RESEARCH METHODS

The research method used is experimental with the research design is the True Experimental Design category with the Posttest-Only Design type, there are experimental groups and control groups. The experimental group is a composite specimen with a particle size variation of aegle marmelos shell powder, the addition of 320 mesh aluminum powder. While the control group is the Indoparts brand brake pad specimen. The particle size variations of aegle marmelos shell powder used are 100 mesh, 120 mesh, and 140 mesh. The composition of the composite is 30% aegle marmelos shell powder, 20% aluminum powder, and 50% epoxy resin. The composite is made by mixing aegle marmelos shell powder, aluminum powder and epoxy resin in a container that has been prepared according to the weight listed in **Table 1**.

Table 1 The Weight of Each Material

Mechanical Properties	Mass of TBM Powder (gr)	Mass of Al Powder (gr)	Mass of *Epoxy* (gr)
Hardness	3,38	4,67	6,34
Wear	3,38	4,67	6,34

The specimen dimensions of the rockwell-b hardness test and ogoshi wear method were made the same according to the manual book of the testing machine. Rockwell-b hardness testing was carried out at the Mechanical Engineering Laboratory, FT, State University of Semarang, while wear testing was carried out at the Engineering Materials Laboratory, DTMI, Gadjah Mada University. Specimen size can be seen in **Fig. 1.**

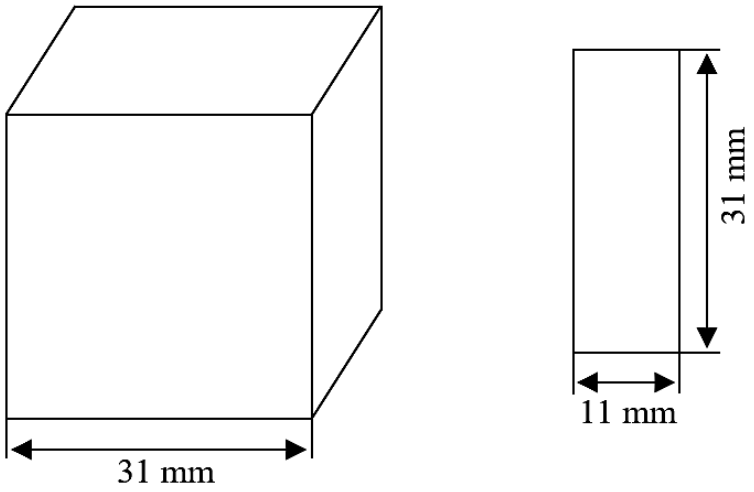

Fig. 1 Size of Hardness and Wear Test Specimens

RESULT AND DISCUSSION

The specimens produced from this study with a composition of 30% aegle marmelos shell powder variation, 20% aluminum powder, and 50% epoxy resin can be seen in **Fig. 2**. Furthermore, the test specimens were tested for hardness and wear three times. The resulting value of each test is taken as the average value of hardness and the average value of wear.

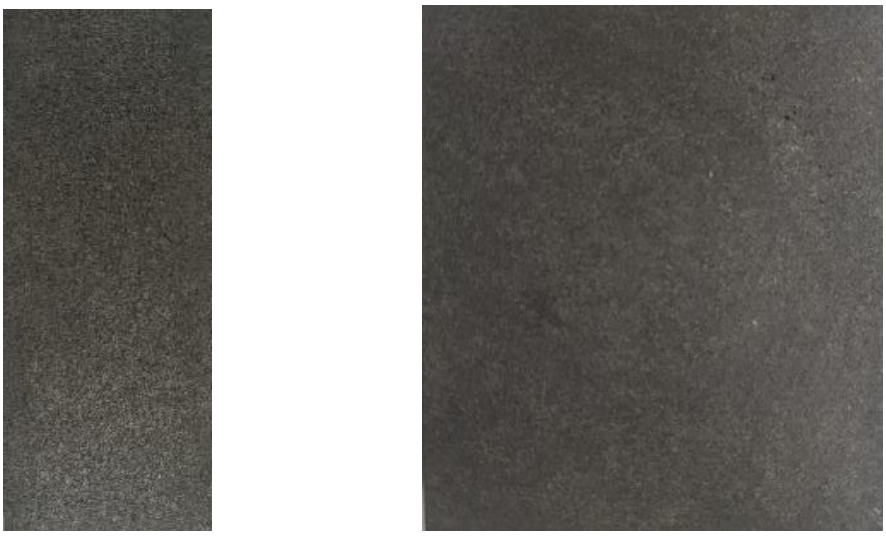

Fig. 2. The Composites of Specimens Test

The Effect of Aegle Marmelos Shell Powder Size Variation on Hardness Value

The rockwell hardness test was conducted to determine the hardness value of the composite material of aegle marmelos shell powder with epoxy matrix. The hardness test on each specimen was carried out taking data five times point, after which the closest 3 points were taken. The results of the rockwell ball hardness test can be seen in **Fig. 3.**

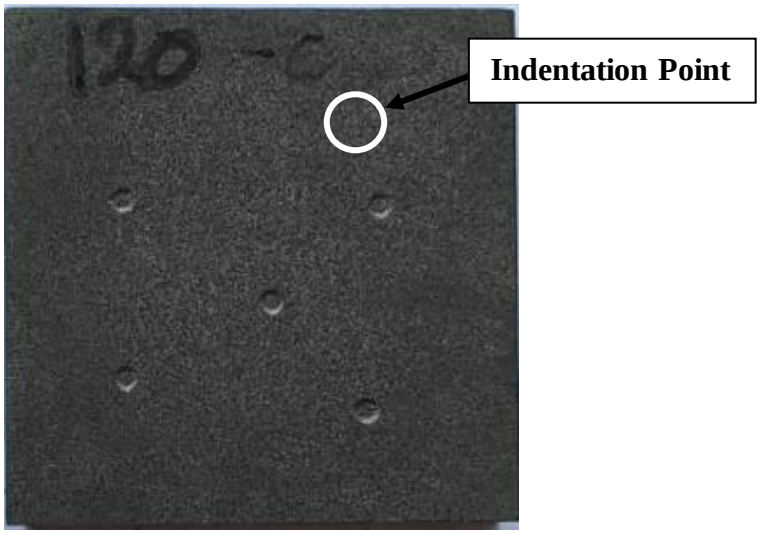

Fig. 3. The Specimen of Result Hardness Test

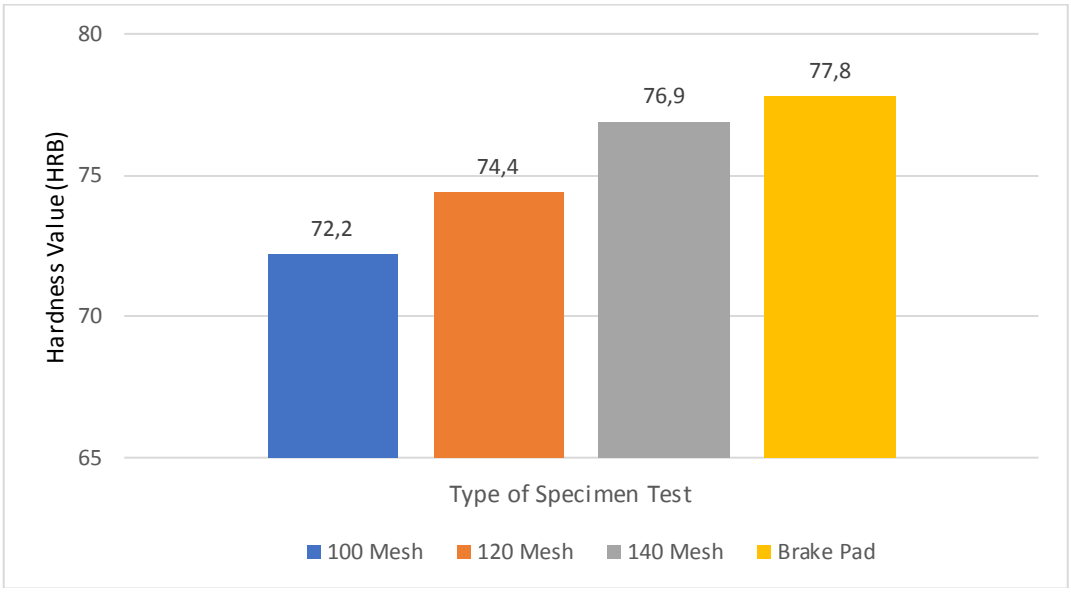

Fig. 4. Graph of Rockwell Hardness Values of Specimens Test

The data obtained from the hardness test shows that the addition of aegle marmelos shell powder with variations in particle size can affect the increase in the hardness value of the composite. The smaller the particle size of aegle marmelos shell powder, the more the hardness value of the composite increases. This is evidenced from the results of the hardness test that has been carried out, the average value of the composite hardness has increased. The percentage increase in the average value of hardness between variation 1 and variation 2 is 3%. While the percentage increase in the average value of hardness between variation 2 and variation 3 is 4%. The increase in the average value of hardness is influenced by variations in the size of aegle marmelos shell powder.

The addition of aegle marmelos shell powder with variations in powder particle size in the composite can increase the hardness value of the composite brake pads because aegle marmelos shell has a high cellulose content, the cellulose content can make high tensile strength, high hardness, and high modulus [6]. In this study, the best hardness test data were found in the variation of 140 mesh aegle marmelos shell powder particle size. It can be concluded that the smaller the particle size of aegle marmelos shell powder, the value of composite hardness will increase. This is same as the statement mentioned that the addition of natural powder to the composite will increase its hardness value [7]. The addition of hardwood charcoal to the composite will increase the hardness value of the composite [8]. Therefore, it can be concluded that the addition of 140 mesh aegle marmelos shell powder produces a better bond between the matrix and aegle marmelos shell powder, because the powder can be well distributed. This is in accordance with the statement in the research conducted that the

smaller particle size, the easier it will be evenly distributed throughout the matrix and will form a wider interphase area, so that stress transfer between the matrix and filler can occur properly [9].

Based on the data from the hardness test results in Figure 4, the average value of the composite hardness with a variation of 140 mesh (76.9 HRB) is closest to the average value of the hardness of the Indoparts brand motorcycle brake pads (77.8 HRB). The percentage difference between the brake pad composite and the comparison motorcycle brake pad is 1.2%. These results are also in accordance with the SAE-J661 brake pad hardness standard of 65-101 HRB [11]. Therefore, the composite material with a particle size variation of 140 mesh aegle marmelos shell powder can be recommended as an alternative material for motorcycle brake pads because it meets the standard of brake pad hardness.

The Effect of Aegle Marmelos Shell Powder Size Variation on Wear Value

The wear test is carried out to determine the wear value of a material. This study uses ogoshi wear test equipment with OAT-U type. the results obtained from this test are in the form of wear width of a material or test material which is then taken on average wear width. The width of wear after testing on the test object can be seen in **Fig. 5.**

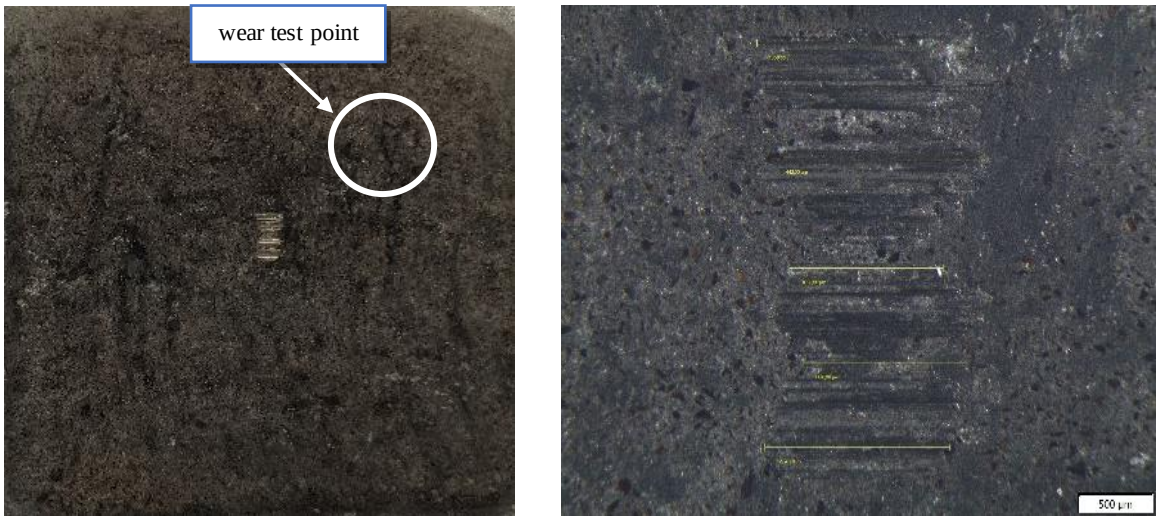

Fig. 5. The Specimen of Result Wear Test

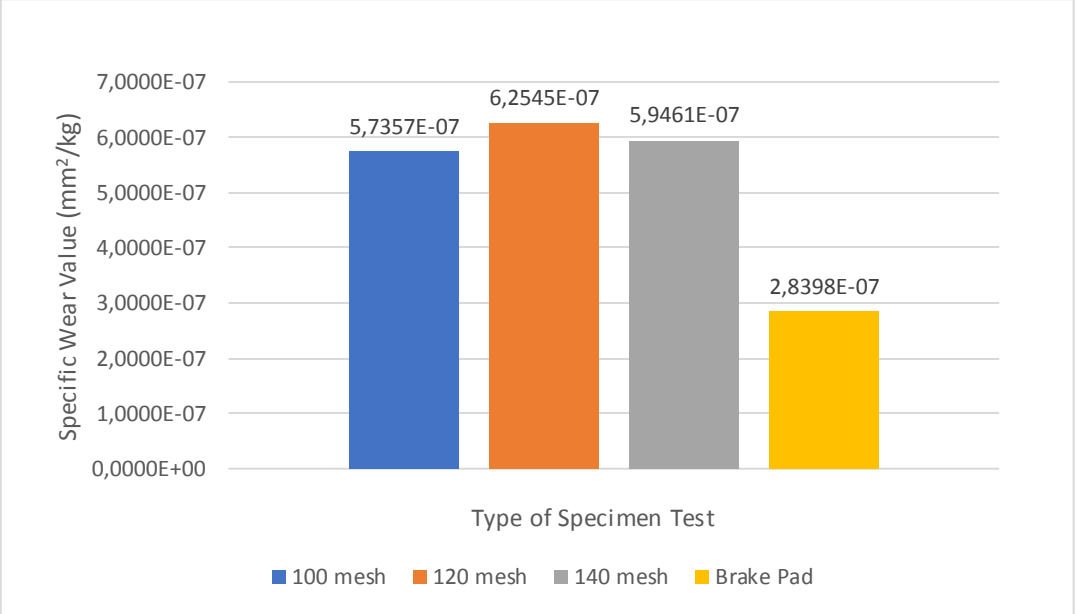

Fig. 6. Graph of Specific Wear Values on Specimens Test

Based on the results of ogoshi wear testing, it can be seen that the average value of the specific wear of the aegle marmelos shell powder composite variation 1 is 5.7357×10^{-7} mm^2/kg, variation 2 is 6.2545×10^{-7} mm^2/kg, and variation 3 is 5.9461×10^{-7} mm^2/kg. The increase in the average value of specific wear in variation

1 to variation 2 is as much as 5%, while the decrease in the average value of specific wear in variation 2 to 3 is 8%. The increase and decrease in the average value of specific wear is influenced by several factors such as the volume fraction of aegle marmelos shell powder, the particle size of aegle marmelos shell powder, the addition of materials to the composite, and also the printing technique of the test specimen.

The specific wear test results show the lowest specific wear value is the particle size variation of 100 mesh aegle marmelo shell powder. The addition of 100 mesh aegle marmelos shell powder is the best composition among other compositions, due to the filler material that is evenly distributed in the matrix and the absence of a heterogeneous mixture. In other words, as small as the particle size, the process of mixing composite materials with each other will be difficult and prone to becoming a heterogeneous mixture or imperfect mixture so that it can affect the specific wear value of the composite. This is in line with research conducted that the lowest wear value of the brake pad is obtained because the filler and matrix are well mixed, thus providing a good frictional bond to the wear rate of the material [10].

The preparation of aegle marmelos shell powder with the size of 100 mesh, 120 mesh and 140 mesh and the roasting of aegle marmelos shell powder can affect the wear value of the composite material. This is in accordance with research conducted that the particle size of natural powder can affect the wear value of the composite [11]. The compaction process carried out in the specimen molding process can also affect the density of the composite. In accordance with research [12], that the wear properties of composites can be influenced by several factors including hardness and porosity of the material

Based on the data from the calculation of the specific wear value in Figure 6 shows the average value of the lowest composite wear with a variation of 100 mesh (5.7357×10^{-7} mm^2/kg) and the average value of Indoparts brand motorcycle brake pad wear (2.8398×10^{-7} mm^2/kg), the percentage difference between the composite and the comparison brake pad is still quite high at 50.5%. The difference can be caused by imperfect mixing of composite materials (heterogeneous mixture) and also in the manufacture of composite materials do not use the sintering process after the compression process. The sintering process can increase the hardness value, so the wear value is also lower. In addition, Indoparts brand motorcycle brake pads also contain other metal materials, such as brass so that the composite material of aegle marmelos shell powder is still higher in wear value. Composite brake pads have wear value requirements in the SAE J661 standard between 5×10^{-4} to 5×10^{-3} mm^2/kg [13]. Therefore, composite materials with a particle size variation of 100 mesh as much as 30%, aluminum powder as much as 20%, and epoxy resin as much as 50% can still be recommended as an alternative material for motorcycle brake pads.

CONCLUSION

The conclusion that can be drawn from this research is that the particle size of aegle marmelos shell powder can affect the hardness value and wear value of the brake pad composite. The mechanical properties (hardness and wear) of the most optimum aegle marmelos shell powder brake pad composite close to commercial products are 140 mesh for a hardness value of 76.9 HRB and 100 mesh for the lowest specific wear value of 5.7357×10^{-7} mm^2/kg. The specific wear value of the composite is still higher than the specific wear value of the Indoparts brand brake pads. This can be caused by the composition of composite brake pads that have not added other metal materials.

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