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Composite Manufacturing of Coir Fiber-Reinforced Polyester as a Motorcycle Helmet Material

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Kata kunci:

Helm, komposit, serat sabut kelapa, poliester

ABSTRAK

Berdasarkan standar SNI 1811-2007 helm di Indonesia terbuat dari bahan polimer ABS (Acrylonitrile Butadiene Styrene) yang harganya relatif mahal. Oleh karena itu, dibutuhkan alternatif pengganti dengan pemanfaatan limbah serat alam sebagai bahan pembuatan komposit. Tujuan penelitian ini yaitu menganalisis pengaruh komposisi material, ketahanan impak, dan kekuatan bending material helm dari serat sabut kelapa dan resin poliester dengan perbandingan 20%:80%, 40%:60% dan 60%:40%. Ukuran panjang serat yang digunakan adalah 50 mm dengan perlakuan kimia pada serat menggunakan larutan NaOH 5% selama 2 jam. Komposit dibuat dengan metode *compression molding*. Penelitian ini menggunakan metode pengujian berupa uji impak ASTM D6110, uji tekuk ASTM D790-03, uji mikrostruktur, dan uji SEM. Didapatkan hasil data dengan nilai tenaga patah optimum sebesar 55,542 J dan nilai kekuatan impak optimum sebesar 0,408 J/mm^2 pada spesimen B. Hasil uji *bending* didapatkan nilai kekuatan tekuk optimum sebesar 52,785 MPa dan nilai modulus elastisitas optimum sebesar 13,064 GPa pada spesimen A. Standar uji kekuatan impak menurut SNI 1811-2007 adalah 29000 J/mm, sedangkan nilai kekuatan impak spesimen ini sebesar 0,408 J/mm^2 sehingga masih belum mencukupi untuk dijadikan bahan alternatif helm.

Keyword:

Helmet, composite, coir fiber, polyester

ABSTRACT

Based on the SNI 1811-2007 standard, helmets in Indonesia are made of ABS (Acrylonitrile Butadiene Styrene) polymer material which is relatively expensive. Therefore, an alternative is needed by utilizing natural fiber waste reinforced as a composite material. The purpose of the study was to analyze the effect of material composition, impact resistance, and bending strength of helmet material from coconut fiber and polyester resin with a ratio of 20%: 80%, 40%: 60%, and 60%: 40%. The fiber length used is 50 mm, with chemical treatment on the fiber using 5% NaOH solution for 2 hours. Composites were made by the compression molding method. In this study, testing was used in the form of impact test ASTM D6110, bending test ASTM D790-03, microstructure test, and SEM test. The data was obtained with the optimum fracture strength value of 55.542 J and the optimum impact strength value of 0.408 J/mm^2 on specimen B. In the bending test, the data was obtained with the optimum bending strength value of 52.785 MPa and the optimum elastic modulus value of 13,064 GPa at specimen A. The impact strength test standard according to SNI 1811-2007 is 29000 J/mm, while the impact strength value of this specimen is 0.408 J/mm^2. Thus, it is still not sufficient to be used as an alternative helmet material.

1. INTRODUCTION

Science and technology are currently experiencing developments in every field, such as the field of vehicle construction, building construction, industry, and the field material engineering, especially composites. The development of technology in the automotive industry is currently very fast, and the need for automotive material products is of course also getting bigger with the increasing variety of types, brands, and the number of motorized vehicles in Indonesia. This development is inseparable from the increasing need and scarcity of materials available in nature. The use of materials for the industry today still relies heavily on non-renewable metal materials, therefore an alternative is needed to make automotive material products that are economical and of good quality [1].

Composite materials are a good choice to produce new materials with better properties. Composites are a few multi-phase systems with combined properties, namely between a matrix or a binder with a reinforcement [2]. Fiber-reinforced composite materials consist of high-strength and modulus fibers embedded in or bonded to a matrix with distinct boundaries (interfaces) between them. The strength of fiber composites when compared to powder reinforcement composites has a higher strength value [3]. Extracted fiber from residues such as woodland, and vegetable biomass is rich in cellulose, hemicellulose, and lignin [4].

At this time, composites with synthetic fiber reinforcing materials have been used in various aspects of life, both in terms of use and technology. Its use is not limited to the automotive sector, but it has now penetrated the household and industrial fields [5]. However, using synthetic fibers as composite reinforcement harms the environment because the waste cannot be decomposed naturally [6]. Therefore, composites with natural fiber reinforcement were found as an alternative solution for innovations due to their biodegradability, relative strength, and low cost for large production [7]. Coconut coir fiber can be used as a new engineered material to produce natural fiber-reinforced composites that are environmentally friendly and support the use of coco fiber in products that have high economic value and technology. Coconut coir fiber has good absorbance properties and has high cellulose and lignin content [8]. In addition, sisal fiber can also be used as a renewable innovation. For example, sisal fiber composites with reinforcement polypropylene exhibit good impact resistance [9].

The results of Obele's research [10] as the volume fraction of the fiber in the composite increases, the resulting impact strength will increase. The increase in the impact strength of the composite is due to good adhesion between the matrix and fiber and the proper absorption and distribution of energy. At 30% fiber volume fraction, the highest impact strength was 26.43 N/mm^2. However, the impact strength obtained is lower than ABS (Acrylonitrile Butadiene Styrene Copolymer) plastic-reinforced composites and hybrids resulting in an impact strength value of 53.06 J/m [11]. Fabricate a military helmet using coir fiber-reinforced epoxy composite. The weight percentage of fiber for different composition is 20, 40, 50, 60, 70, 80, and 85 taken [12]. Based on the description above, a study was conducted on the effect of variations in the volume fraction of coco fiber on polyester-reinforced composites as helmet material, using a variation of the fiber volume fraction of 20%, 40%, and 60% using the method compression molding.

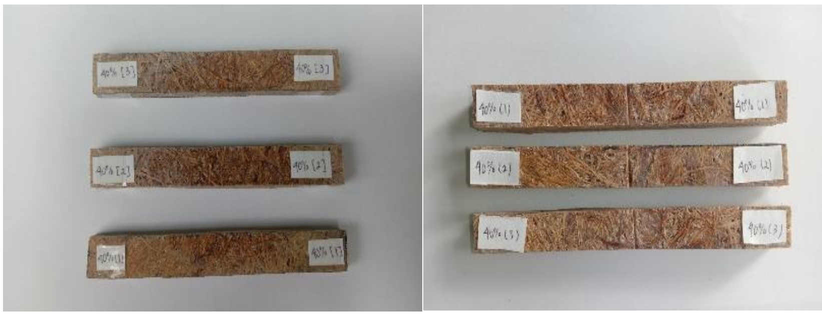
2. MATERIALS AND METHOD

2.1 Material

Coconut coir fiber is a fiber that is formed from coconut coir, which is shown in Figure 1a. The fiber that has been separated from the coconut husk is cut to a length of 50mm. Furthermore, the fiber was given chemical treatment with 5% NaOH solution for 2 hours. Then the coco fiber was rinsed with distilled water and dried in an oven at a temperature of 100˚C for 30 minutes. Dry fiber has a density of 1.28 g/cm^3. The matrix used is unsaturated polyester (UP) type 157 BQTN Yukalac resin with 1% Methyl Ethyl Peroxide (MEKPO) as a catalyst. Specimens were made with fiber volume fractions of 20%, 40%, and 60% using the method of compression molding at a temperature of 100˚C with a pressure of 40bar (4000kN/m^2) for 15 minutes. In addition, specimen molds are also used to print the test sample, which is shown in Figure 1b. Previously, the mold was coated with aluminum foil on the bottom to prevent the liquid matrix from coming out of the sample mold. The test specimens were shaped and tested according to the ASTM D6110 impact test standard using the Charpy method, and the ASTM D790-03 bending test using the three-point bending method, which is shown in Figure 2. The morphology of the specimen was analyzed using the microstructure test and the SEM (*Scanning Electron* Microscopy) test.

(a) (b)

Figure 1. Specimen Preparation (a) Coir Fiber (b) Mold



(a) (b)

Figure 2. Specimen Testing (a) Bending (b) Impact

2.2 Impact Test

Impact testing was carried out using the method Charpy. The impact specimen test standard is ASTM D6110 with a specimen size of 12.7 cm × 1.27 cm × 1.27 cm. Impact testing is carried out to determine the value of the impact strength and fracture strength of the specimen when receiving a shock load. To calculate the value of impact strength and fracture strength, the following equation can be used:

$$E_{serap} = m.g.R.(cos\beta - cos\alpha) \tag{1}$$

$$HI = \frac{E}{A} \tag{2}$$

2.3 Bending Test

The bending test was carried out using the method of three-point bending. The test standard for the bending test specimen is ASTM D790-03 with a test specimen size of 12 cm × 1.5 cm × 0.7 cm. The bending test was carried out to determine the value of the bending strength and modulus of elasticity of the specimen when given a compressive load. To calculate the value of bending strength and modulus of elasticity, the following equation can be used:

$$\sigma_b = \frac{3PL}{2bd^2} \tag{3}$$

$$Eb = \frac{L^3 m}{4bd} \tag{4}$$

2.4 Microstructural Analysis

Microstructural observations in this study used an optical microscope located in the Integrated Laboratory of the Kalimantan Institute of Technology in the Characterization Laboratory. Microstructural observations were made to analyze the morphology of the fiber and matrix interfaces. The specimens observed in this test are specimens from the impact test to see the fracture pattern. In this test, observations were made with a magnification of 10× and 20×.

2.5 SEM (*Scanning Electron Microscopy*)

Scanning electron microscopy in this study was carried out at the Integrated Laboratory of the Kalimantan Institute of Technology in the Characterization Laboratory. This test aims to determine the microstructure and interfacial bonds of fiber and matrix. SEM observations were carried out with a magnification of 320× using the highest impact test specimen. The impact test specimen was then cut to a size of 1cm × 1cm. Scanning electron microscopy (SEM) is one of the most used equipments used in the structural analysis of natural fiber-reinforced polymer composite [13].

4. RESULTS AND DISCUSSION

4.1 Impact Test

Table 1. Mechanical Properties of Composite Coir Fiber Polyester Resin

Specimen	E_{serap} (J)	Impact Strength (J/mm²)	Flexural Strength (MPa)	Modulus of Elasticity (GPa)
20% Coir Fiber 80% Polyester (A)	19,848	0,145	52,785	13,064
40% Coir Fiber 60% Polyester (B)	55,542	0,408	48,127	2,818
60% Coir Fiber 40% Polyester (C)	9,523	0,07	6,520	2,228

In Figure 3, it can be seen the comparison of the fracture strength of the impact test specimens. The average fracture strength of the 20% coconut fiber volume fraction was 19,848 J. In the 40%, coconut fiber volume fraction the fracture strength value was 55,542. J. Then the volume fraction of coco fiber 60% has a fracture strength value of 9.523 J. The higher the effect of the variation of the fiber volume fraction on the composite, the higher the impact strength.

However, if seen from the graph, specimen C has the lowest fracture strength value, because in the 60% variation the fiber is too excessive, and the resin does not spread perfectly. This causes the low value of the resulting fracture strength.

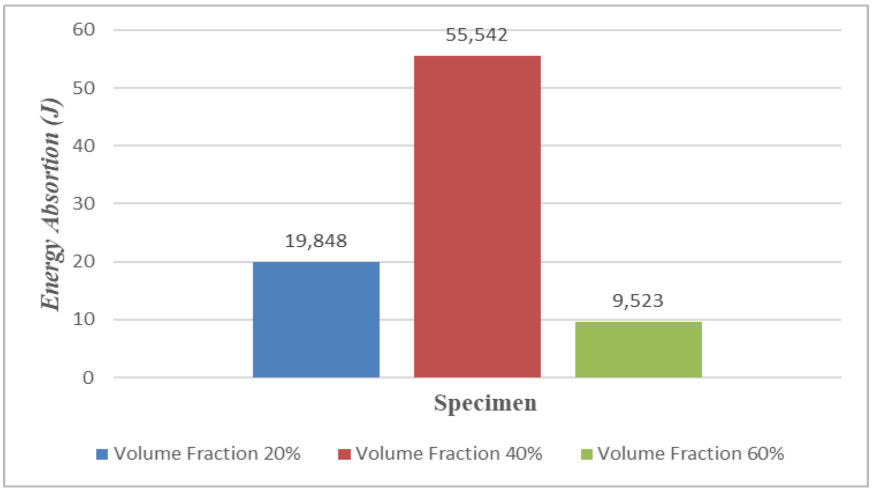


Figure 3. Graph of Composite Fracture Stress Average

In Figure 4, the comparison of the average value of the impact strength produced by the specimen with the 20% fiber volume fraction is 0.145 J/mm². Then the 40% fiber volume fraction has the highest impact strength value of 0.408 J/mm². At 60% fiber volume fraction, the lowest impact strength value is 0.070 J/mm². In the graph, the composition with a fiber volume fraction of 40% produces the highest impact strength value. This is due to the increase in the quality of the bond between the fibers and the polyester matrix [14]. Increasing the percentage of fiber weight to the proper interface between the fiber and the matrix can provide high impact strength [15]. Meanwhile, the decrease in impact strength at 60% fiber volume fraction occurs due to the saturation between the fiber and the polyester matrix, making it difficult to form a bond. The impact strength increases with increasing volume fraction indicating a good bond, but after reaching the maximum point it will decrease. This is because the bond between the fiber and the matrix is not good enough to reduce the impact strength [15]. Composite coir fiber has a higher value when compared to previous studies [16].

Based on the SNI 1811-2007 Standard, the impact strength of the coconut coir fiber composite with a polyester matrix is still not sufficient to be an alternative material for helmets. The results of the impact strength test were produced by the SNI 1811-2007 standard where 29000 J/mm impact strength was produced while the highest was by the coconut coir fiber composite at 0.408 J/mm².

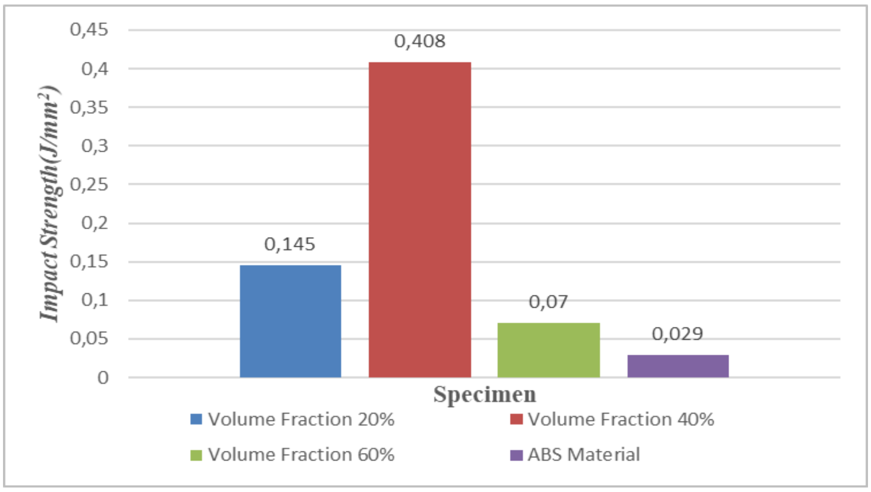


Figure 4. Graph of Composite Impact Strength Average

4.2 Bending Test

In Figure 5, the comparison of the average value of the elastic modulus at the 20% fiber volume fraction has a value of 13,064 GPa. Then the 40% fiber volume fraction has a modulus of elasticity of 2,818 GPa. At 60% fiber volume fraction has the lowest modulus of elasticity of 2,228 GPa. The modulus of elasticity in the bending test experienced a sharp decrease. This is probably due to the uneven distribution of the resin causing the interfacial bond between the fiber and the matrix to be weak

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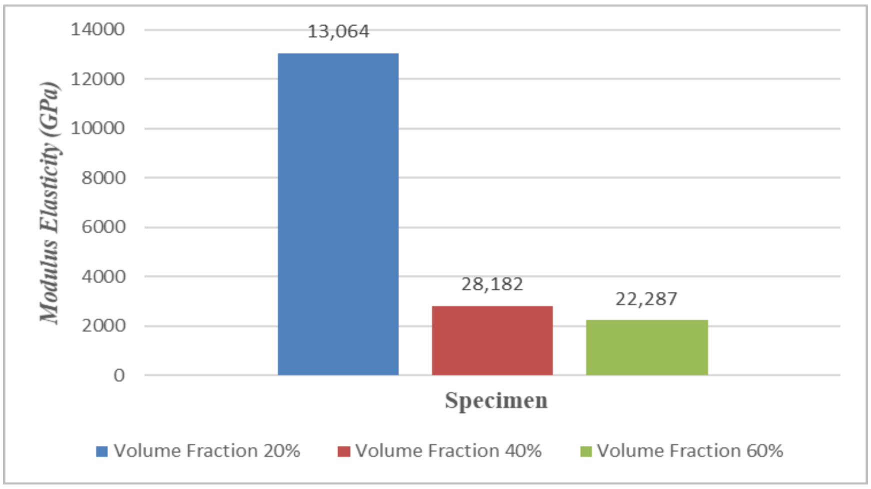


Figure 5. Graph of Composite Flexural Strength Average

The increase in bending strength occurs because the surface of the fiber bonded by the resin is wider so that the bonding becomes better. Otherwise, the decrease in bending strength is caused by too much volume fiber so that the matrix cannot bind all the fiber surface so that the bonding between the matrix and the fiber is not good [17]. Bending test results exceed the result of previous research data [18].

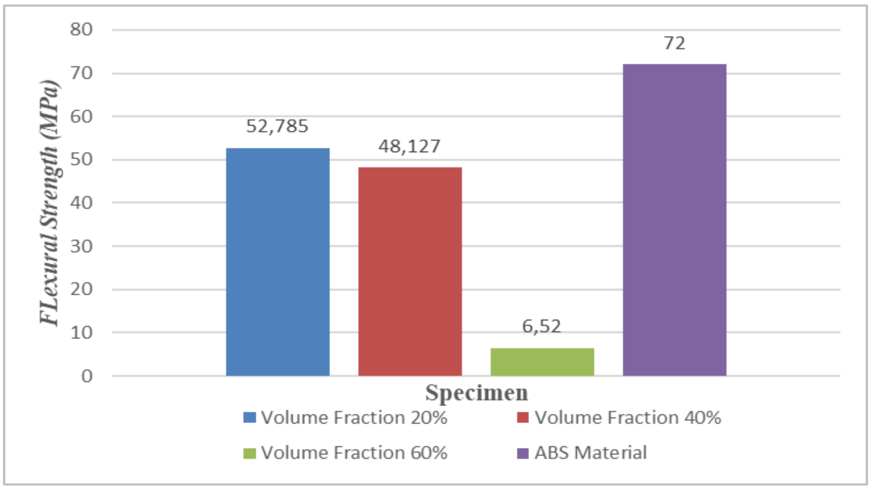
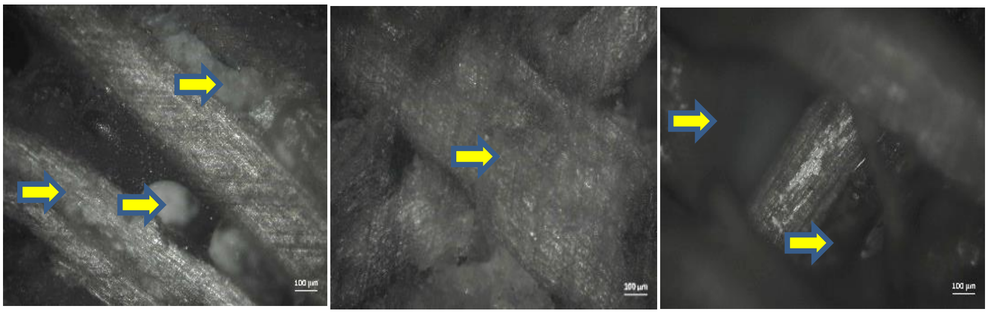


Figure 6. Graph of Composite Modulus Elasticity Average

4.3 Microstructural Analysis

Microstructural observations were made to analyze the morphology of the fiber and matrix interfaces. The specimens observed in this test are specimens from the impact test to see the fracture pattern. In this test, observations were made with a magnification of 10x and 20x.



(a) (b) (c)

Figure 7. Microstructural Observations at (a) 20% Fiber Volume Fraction (b) 40% Fiber Volume Fraction (c) 60% Fiber Volume Fraction

Figure 7a is a morphological appearance of the 20% fiber volume fraction. From the appearance, some cavities cause occurs voids to. This is due to the lack of fiber volume owned so that the fiber and matrix interface bonds that occur are not strong. Figure 7b shows the morphology of the 40% fiber volume fraction. The distribution of fiber in the composite occurs well. Polyester matrix at 40% volume fraction can coat the fiber perfectly. At the time of testing, the fiber has a greater strength value and a better bond. Figure 7c is a morphological appearance of the 60% fiber volume fraction. There are many voids caused when the matrix is poured there is air trapped in the resin. In addition, many fibers in this volume fraction causes the resin to not coat the specimen perfectly.

In Figure 8 there are voids caused by trapped air during the resin pouring process. This can affect the impact strength of the composite. In addition to voids, matrix cracking occurs in this sample. Matrix cracking is caused by the inability of the resin to bind the fibers well so that the matrix cannot withstand impact loads well [19].

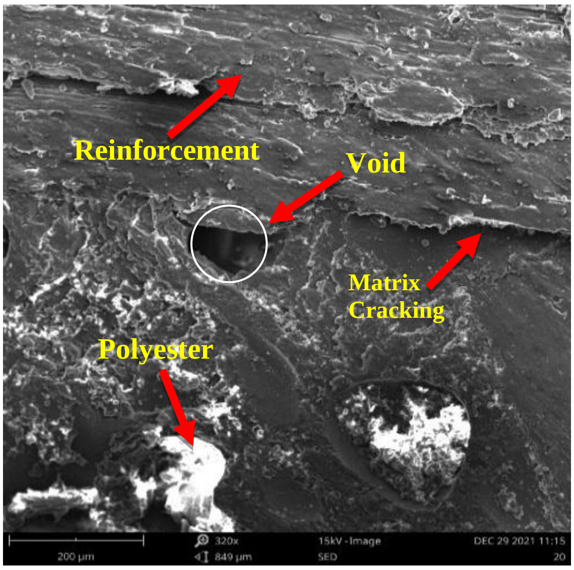


Figure 8. Result of Scanning Electron Microscopy for Fraction Volume Fiber 20% Composite Sample

In Figure 9, there are cracks and voids. Cracks that occur are caused by the specimen receiving a high impact load so that the matrix will crack and then split [20]. The interfacial bond between the fiber and the matrix occurs well, which makes the mechanical properties of the 40% volume fraction increase. The crack that occurs is due to the strong bond between fiber and matrix so the strength increases due to stress concentration under impact loading [21].

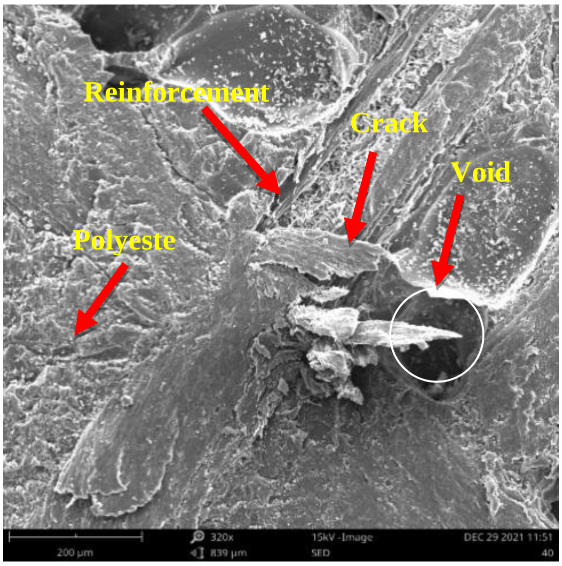


Figure 9. Result of Scanning Electron Microscopy for Fraction Volume Fiber 40% Composite Sample

In Figure 10, the polyester resin does not spread evenly in coating the coconut fiber, and voids were still visible in this composite. Voids that occur can cause a decrease in the value of the impact strength of the specimen. This can be seen from the results of the impact strength data on the fiber volume fraction of 60% resulting in the lowest impact strength value.

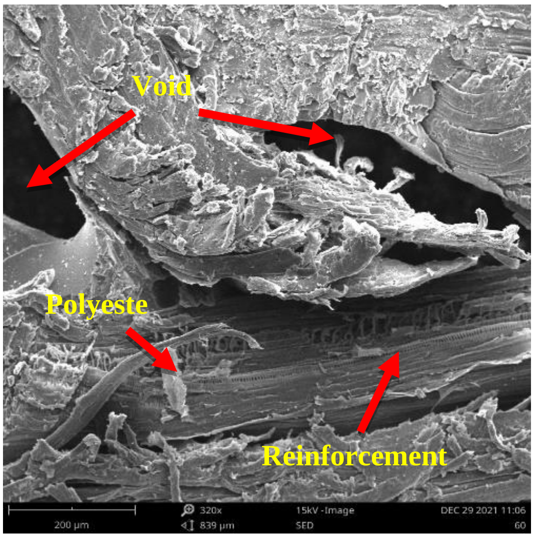


Figure 10. Result of Scanning Electron Microscopy for Fraction Volume Fiber 60% Composite Sample

5. Conclusion

This study found that the distribution of matrix and fiber cannot occur properly, and buildup occurs. This can cause occur voids which can decrease the mechanical properties of the resulting composite. The optimum impact strength was obtained by a 40% fiber volume fraction specimen of 0.408 J/mm^2 with a fracture strength of 55.542 J. Meanwhile, the optimum bending strength was obtained by a 20% fiber volume fraction specimen of 52.785 MPa with the resulting elastic modulus of 13,064 GPa. The impact strength test standard according to SNI 1811-2007 is 29000 J/mm, while the impact strength value of this specimen is 0.408 J/mm^2. Thus, it is still not sufficient to be used as an alternative helmet material.

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