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Study Of Fracture Of Carbon, Agave, And Rami Fiber-Reinforced Polyester Composites Using Sem And Xrd Methods

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Abstract

The development of composite materials in engineering is very rapid, as composite research results are able to compete with products made from metals or other materials. This study aims to determine the surface structure of fractures and the crystalline phase using SEM and XRD methods. The materials used in this test are carbon fiber reinforced polyester composite, agave fiber, and ramie fiber with three samples and different composition variations, namely with variations in the volume of carbon fiber, agave fiber, ramie fiber and matrix 10:15:15:60, 20:10:10:60, and 30:5:5:60. Mineralogical and crystallographic analysis with X-Ray Diffraction is one of the effective analytical methods to describe rocks and certain chemical compounds in solid form because the preparation process is easy, cheap and fast. Quality control of the preparation results and analysis of the results can be seen from the XRD graph and is carried out by competent lab staff from the Material Characterization Laboratory of HKBP Nommensen University Medan. SEM testing is carried out to determine the structure of the fracture surface found in the material. SEM analysis is carried out in the mineral laboratory of HKBP Nommensen University Medan with a magnification of 0 - 1000x until the desired fracture shape is clearly visible. The test results clearly demonstrate a wide variety of fracture patterns, ranging from brittle and ductile fractures, fiber pull-out, and debonding. XRD analysis revealed that the crystalline phase in the composite material is amorphous due to the presence of hemicellulose, lignin, and impurities still attached to the fibers. The highest intensity value was obtained with a carbon fiber volume fraction of 30% agave, 5% ramie, and 60% matrix.

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Keywords: Surface structure, polyester composite, crystalline phase, SEM, XRD

INTRODUCTION

Natural fiber-reinforced composite materials are more environmentally friendly than synthetic materials. Besides being environmentally friendly, natural fiber-reinforced composites offer several advantages, including low cost, sound dampening, low density, abundance, and high mechanical properties. Composites are generally composed of a binder (*matrix*) and reinforcing material which is also called filler material (*filler).*Composite materials are known for being lightweight, strong, corrosion-resistant, and able to compete with metals, without losing their mechanical characteristics and strength. The industrial world is beginning to develop composites as superior products based on their unique qualities. In addition to the binder (matrix), composites also use reinforcing or filler materials. These binders use fibers. Fibers are typically composed of strong, stiff, and brittle materials.

This aims to ensure that the fibers can withstand external forces. Fibers are basically divided into two, namely natural fibers (*natural fiber*) and artificial fibers (*synthetic fiber*). Natural fiber (*natural fiber*) which are often used in composite materials are hemp, agave, kenaf, rosella fibers and many other natural fibers that can be utilized, while for artificial fibers (*synthetic fiber*) that are often used in composite materials are carbon fiber, nylon, phenol, and many others. Fiber is widely used in the industrial world, especially in Indonesia, such as rope factories, the textile industry, and high-tech industries. Therefore, fiber is very good for application in composite materials. One of these fibers is hemp fiber and agave fiber, which are natural materials.*fibre* An alternative in composite manufacturing. Hemp and agave fibers are being developed for their use because they are readily available and can reduce environmental waste. These composites are capable of addressing environmental issues, are renewable, and are safe for health.

In this research, the main material that will be used is a binding material (*matrix*) use *Thermosetting* which type*resin polyester* because this material has very good chemical resistance and has very high strength, while the filler material (*filler*) using natural fibers and Artificial fibers, namely hemp fiber, agave fiber, and carbon fiber, are used because these three fibers have high strength and good resistance to chemicals. This study was conducted to determine the fracture characteristics of polyester composites with variations in carbon fiber, agave fiber, and hemp fiber.

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RESEARCH DESIGN

Research Flowchart

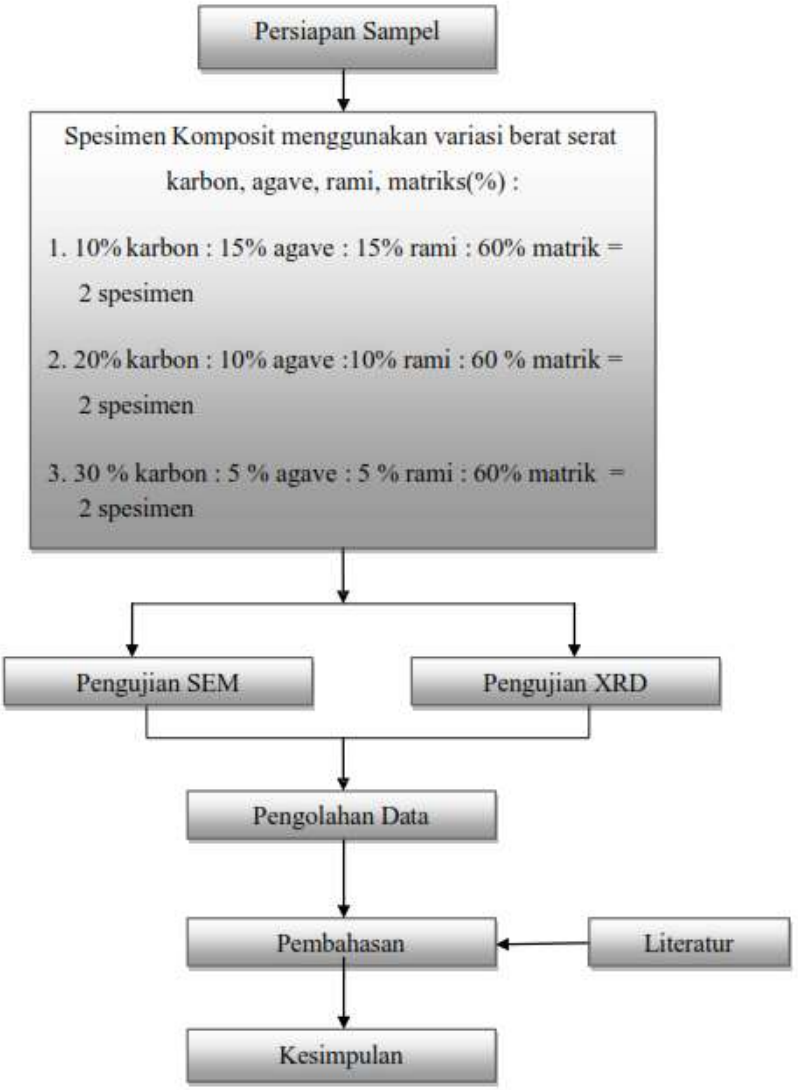


Figure 1. Flowchart

Materials and Specimen Preparation

The materials used in this test are carbon fiber reinforced polyester composite materials, agave fibers, and hemp fibers with a sample size of 3 (three) pieces per test (SEM = 3 specimens, XRD = 3 specimens) with a ratio of fiber volume fraction weight:

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10% carbon : 15% agave : 15% hemp : 60% matrix = 2 specimens
20% carbon : 10% agave :10% hemp : 60% matrix = 2 specimens
30% carbon : 5% agave : 5% hemp : 60% matrix = 2 specimens



Figure 2 Composition of carbon fiber, agave and hemp fiber

SEM test object

SEM test objects were obtained from the results of impact test fractures in previous research



Description: Diameter: 10 mm
Height : 4 mm

Figure 3 SEM test sample and fracture shape 1

The sample size is adjusted to the tool used in the test. Here the test was carried out using an SEM test tool with the inspect-S50 type. Macro image of the impact test fracture surface with a weight ratio of 10% carbon fiber volume fraction: 15% agave: 15% ramie: 60% matrix

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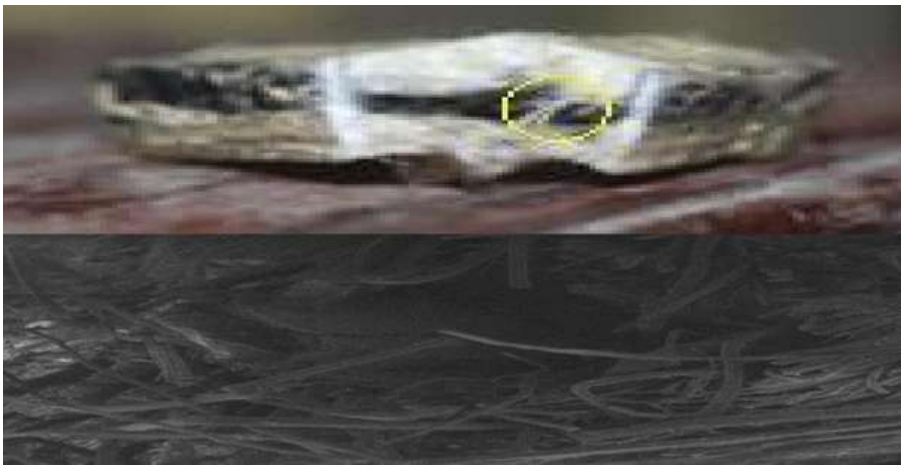


Figure 4 SEM test sample and fracture shape 1 (Source: Personal document)

The fracture that occurs is a mixed fracture. This fracture is a mixture of brittle fracture and ductile fracture. This fracture occurs most often. The strength of the composite will decrease with changes in the angle or weight of the fiber, this is because the weight of the fiber is transverse so it is more easily broken. Macro image of the fracture surface of the impact test with a weight ratio of 20% carbon fiber volume fraction: 10% agave: 10% ramie: 60% matrix.

Macro image of the fracture surface of the impact test with a weight-volume ratio of 30% carbon fiber: 5% agave: 5% ramie: 60% matrix



Figure 5 SEM test sample and fracture shape 3

(Source: Personal document)

Figure 3.5 shows a sample of a fracture caused by the force received by The matrix was then transferred to the carbon, agave, and ramie fibers contained within the specimen. The resulting fracture was a mixed fracture, a combination of brittle and ductile fractures. This type of

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fracture is the most common. The strength of the composite decreases with changes in the angle or weight of the fibers, as the fibers are transversely oriented, making them more prone to fracture.

XRD Test Object



Figure 6 XRD test sample
(Source: Personal document)

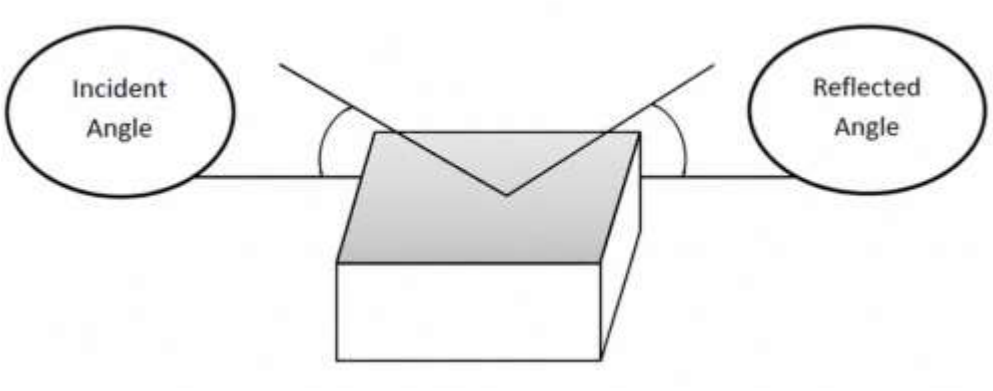


Figure 7 XRD test sample illumination angle
(Source: Wikipedia) Description: Short angle 5^{o}-60^{o}

The illumination angle is adjusted to suit the testing needs. This time, a short illumination angle of 5°C was used.^{o}-60^{o} because it adjusts to the size of the specimen

RESEARCH TOOL

Scanning Electron Microscopy (SEM)

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Figure 8 SEM test equipment

(Source: Mineral Laboratory, HKBP Nommensen University, Medan)

Scanning Electron Microscopy (SEM) was used to determine the surface structure of composite materials reinforced with carbon fiber, agave fiber, and hemp fiber used in this test.

Scanning Electron Microscopy (SEM) Model Specifications : FEI

Type : Inspect-S50 Magnification : 1.000.000X

X-Ray Diffraction (XRD)



Figure 9 X-Ray Diffraction (XRD)

(Source: Material Characterization Laboratory, HKBP Nommensen University, Medan)

X-Ray Diffraction (XRD) was used to determine the crystalline phases found in the carbon fiber, agave fiber, and hemp fiber reinforced composite materials used in this testing.

X-Ray Diffraction (XRD) Brand Specifications : Philip

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Type : Expert Pro

Grinder



Figure 10 Cutting grinder

Cutting grinders are used to cut test specimens according to the size required for each test.

Gloves



Figure 11 Gloves

(Source: Personal document)

Gloves are used to protect hands both when cutting specimens and during testing.

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Vernier Caliper



Figure 12 Vernier caliper

(Source: Personal document)

Vernier calipers are used to measure test specimens to match the required size.

Stationery and so on to record test result data Testing

Test Scanning Electron Mycroscopy (SEM)

Scanning electron microscopy testing can be used to directly explain the surface structure of solid objects. In this study, scanning electron microscopy testing was conducted to determine the fracture surface structure of a polyester composite material reinforced with carbon fiber, agave fiber, and ramie fiber. The fractures tested were the results of composite material testing before the scanning electron microscopy test was carried out.

The working principle of SEM is starting from*electron beam* produced by a filament on*electron gun*. In general *electron gun* which is used is*tungsten hairpin gun* with filaments in the form of coils*tungsten* which functions as a cathode. Voltage is applied to the coil, causing heating. The anode then forms a force that attracts electrons to move towards the anode. The electron beam is then focused onto a point on the sample surface using two condenser lenses. The second condenser lens (also known as the objective lens) focuses the beam to a very small diameter, approximately 10-20 nm. The scattering of electrons, either Secondary Electrons (SE) or Back Scattered Electrons (BSE) from the sample surface, will be detected by the detector and displayed as an image on the CRT screen..

This testing is expected to support the data from subsequent tests discussed in the discussion, making it more accurate. In this study, the magnification used was between 0 and 1000x, which is expected to identify suitable fracture points and support the research.

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X-Ray Diffraction (XRD) Testing

X-ray diffraction testing can be used to explain the main images of the nuclear structure, namely the core parameters and the type of structure. In addition, it can also determine the different atomic arrangements in crystals, the presence of imperfections in crystal orientation, grains, grain size, size and density of deposits and distension.

In this study, X-ray diffraction testing was conducted to identify the crystalline phase in the material by determining the lattice structure parameters and to obtain the particle size. X-rays are electromagnetic radiation that have high energy around 200 eV to 1 MeV. X-rays are produced by the interaction between an external electron beam and electrons in the atomic shell. The X-ray spectrum has a wavelength of 10^{-10} s/d 5^{-10}nm, with a frequency of 1017-1020 Hz and an energy of 103-106 eV. The wavelength of X-rays is of the same order as the distance between atoms, so they can be used as a source for crystal diffraction.

With this test, it is hoped that it can support the data from the results of subsequent tests in the discussion to be more accurate. In this study, the radiation sources used are in the form of X-ray radiation, electrons, and neutrons. X-rays are photons with high energy that have wavelengths ranging between 0.5 to 2.5 Angstroms. When an X-ray beam interacts with a material, some of the beam is absorbed, some is transmitted, and some is scattered by diffraction. This diffraction is what XRD detects.

RESEARCH RESULTS AND DISCUSSION

Research Result Data

After conducting SEM testing in the mineral laboratory of Malang State University on April 29, 2019, the sample was in the form of a solid with a fibrous surface, the SEM test results were obtained with sample code: AI92, material name: 10% for a variation in the weight of carbon fiber 30%, agave 5%, ramie 5% and matrix 60% which can be seen on page 63 of the attachment. For sample code: A193, material name: 30% is the data result from the variation in the weight of carbon fiber 10%, agave 15%, ramie 15%, and matrix 60% which can be seen on page 65 of the attachment. While for sample code: A194, material name:

: 20% is the data resulting from variations in the weight of carbon fiber 20%, agave 10%, ramie 10% and matrix 60%.

After conducting XRD testing in the material characterization laboratory of Sepuluh November University, Surabaya on May 10, 2019, the XRD test results data were obtained in the form of graphs and peak lists with variations in the weight of carbon fiber (10%), agave (15%),

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ramie (15%), matrix (60%) with Dataset Name: Carbon fiber, ramie, agave 10% which can be seen on page 68 of the appendix. The graph and table of peak variations can be seen on pages 69 and 70 of the appendix. For data on the XRD test results of variations in the weight of carbon fiber (20%), agave (10%), ramie (10%), matrix (60%) with Dataset Name: Carbon fiber, ramie, agave 20% can be seen on page 71 of the appendix. The graph and table of peak variations can be seen on pages 72 and 73 of the appendix. Meanwhile, for the data on the XRD test results of variations in the weight of carbon fiber (30%), agave (5%), ramie (5%), matrix (60%) with Dataset Name Carbon fiber, hemp, and 30% agave can be found on page 74 of the appendix. Graphs and tables of these peak variations can be found on pages 75 and 76 of the appendix.

SEM Test Result Data

Composite made of polyester reinforced with carbon fiber, hemp fiber, agave fiber.From the SEM test data that was conducted in the mineral laboratory of Malang State University on April 29, 2019, it was found that the fracture of the carbon fiber reinforced polyester composite, agave fiber, and ramie fiber with variations in the volume fraction of carbon fiber, agave fiber, ramie fiber and matrix was 10:15:15:60, 20:10:10:60, 30:5:5:60 when viewed from the same magnification, namely 50x magnification, the arrangement of carbon fiber, agave, ramie and matrix that were broken or damaged can be seen in Figures 4.1, 4.2, and 4.3 below. Variation of carbon fiber (30%), agave (5%), hemp (5%), matrix (60%)

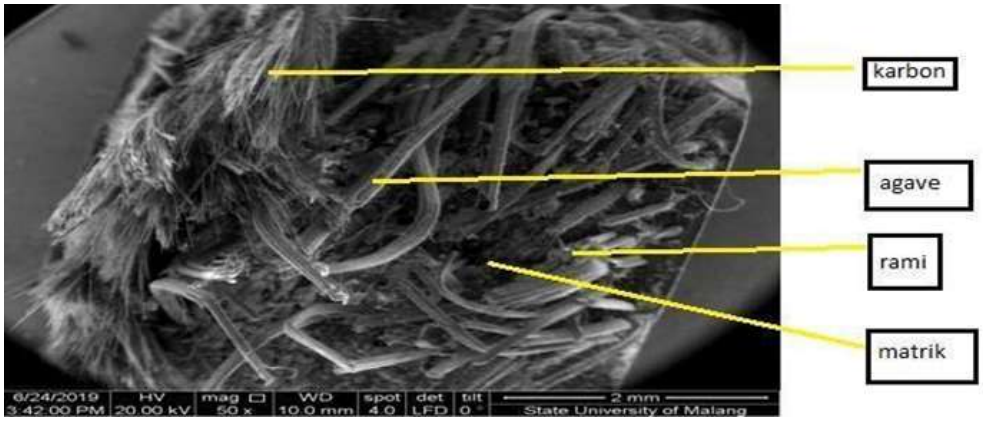


Figure 13 Variation of carbon fiber (30%), agave (5%), hemp (5%), matrix (60%) magnification 50x

(Source: Mineral Laboratory, Malang State University)

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From Figure 4.1, the SEM test results of the weight variation of carbon fiber (30%), agave fiber (5%), ramie fiber (5%) and 60 (%) matrix with a magnification of 50x SEM test can be seen that there is an arrangement of carbon fiber, agave fiber, and ramie fiber. Where the carbon fiber still looks clumped together because the fiber used is in the form of a sheet, but the fiber is damaged at the end due to a fracture. This also applies to agave fiber, ramie fiber, and matrix that are damaged or broken due to the impact test process on the specimen carried out in the previous test Variations of carbon fiber (20%), agave (10%), hemp (10%), matrix (60%)

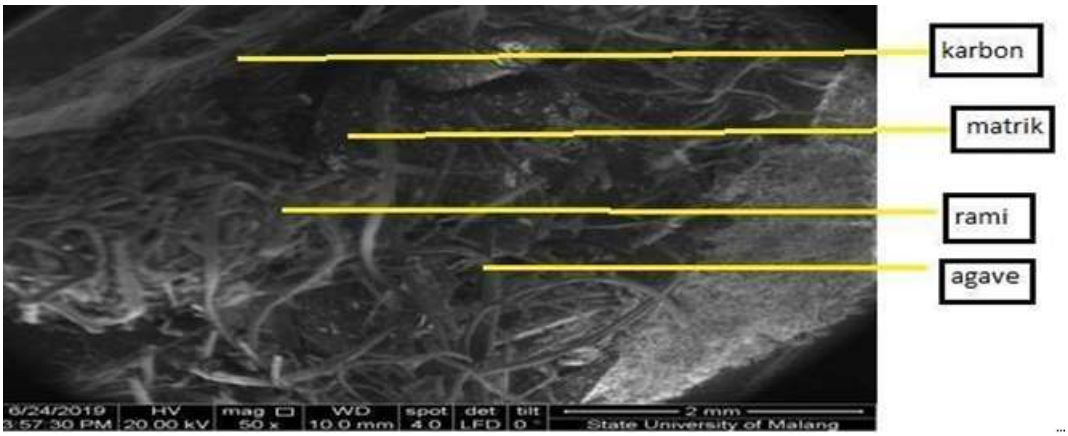


Figure 14 Variation of carbon fiber (20%), agave (10%), hemp (10%), matrix (60%) magnification 50x

(Source: Mineral Laboratory, Malang State University)

From Figure 14, the SEM test results of the variation in the weight of carbon fiber (20%), agave fiber (10%), ramie fiber (10%), and matrix (60%) with a SEM test magnification of 50x, it can be seen that the arrangement of agave fiber and ramie fiber is not homogeneous. This could happen because the process of making this composite uses the hand lay-up method, where this process relies on hand skills in arranging the fibers. So, the ramie fibers look clumped. From Figure 14, it can also be seen where the carbon fibers, agave fibers, ramie fibers, and matrix are damaged or broken due to the impact test process on the specimen in the previous test.

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Variations of carbon fiber(10%), agave(15%), hemp(15%), matrix(60%)

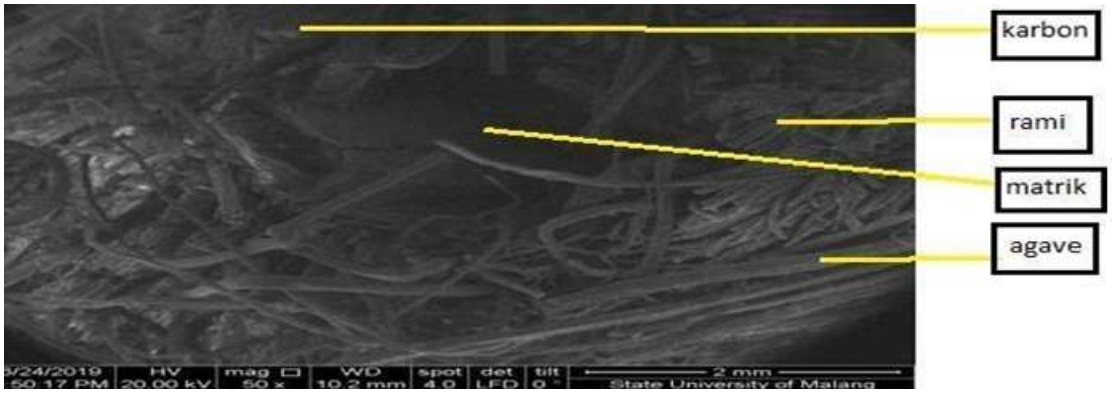


Figure 15 Variation of carbon fiber (10%), agave (15%), hemp (15%), matrix (60%) magnification 50x

(Source: Mineral Laboratory, HKBP Nommesen University, Medan)

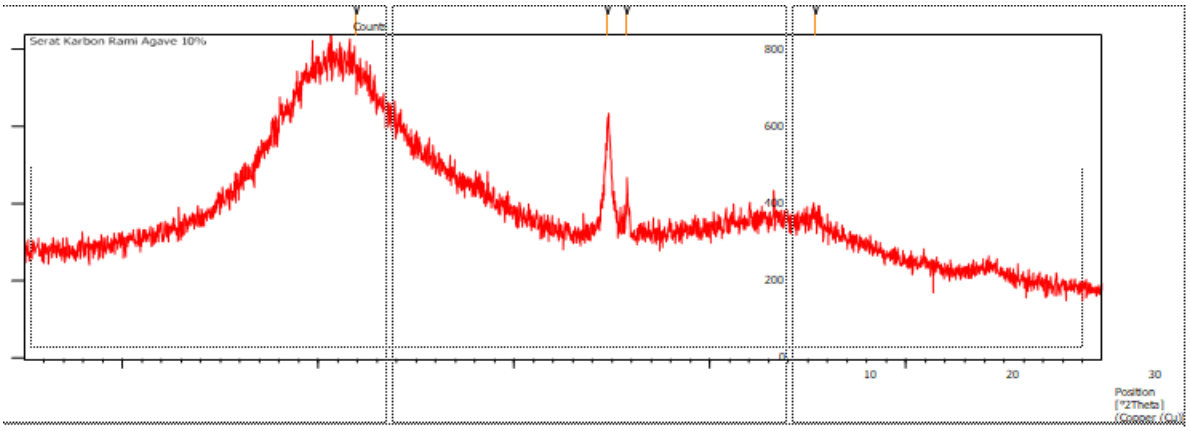
From Figure 15 SEM test results of variations in carbon fiber (10%), agave fiber (15%), ramie fiber (15%), matrix (60%), magnification of 50x can be seen that the composition of carbon fiber, agave fiber, and ramie fiber is not homogeneous. From Figure 4.3 it can also be seen that carbon fiber, agave fiber, ramie fiber, and matrix are damaged or broken due to the impact test process on the specimen in the previous test.

Composite made of polyester reinforced with carbon fiber, hemp fiber, agave fiber, varying weight of carbon fiber (10%), agave fiber (15%), hemp fiber (15%), matrix (60%)

From the weight variations of carbon fiber (10%), agave (15%), hemp (15%), and matrix (60%) with Dataset name: carbon fiber, hemp, agave 10%, the highest intensity peak is obtained at 784 at an angle of 2Θ = 21.9338 which can be seen in graph 1 and table 1 below.

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Graph 1 Results of XRD analysis of weight variations of carbon fiber (10%), agave fiber (15%), hemp fiber (15%), matrix (60%)

(Source: Material Characterization Laboratory, HKBP Nommensen University, Medan)

Table 1 peak list 1

Pos. [°2Th.]	Height [cts]	FWHM Left [°2Th.]	d-spacing [Å]	Rel. Int. [%]
21.9338	157.14	0.0900	4.04906	52.92
34.7831	296.96	0.2342	2.57924	100.00
35.7493	151.11	0.0502	2.51172	50.88
45.3859	34.25	0.4015	1.99832	11.53

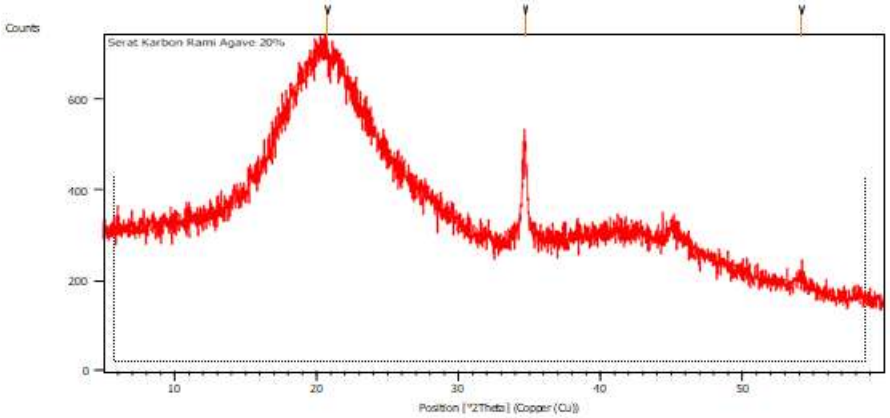
(Source: Material Characterization Laboratory, HKBP Nommensen University, Medan)

Composite made of polyester reinforced with carbon fiber, hemp fiber, agave fiber, varying weight of carbon fiber (20%), agave fiber (10%), hemp fiber (10%), matrix (60%)

From the weight variations of carbon fiber (20%), agave (10%), hemp (10%), and matrix (60%) with Dataset name: carbon fiber, hemp, agave 20%, the highest intensity peak is at 684 at an angle of 2Θ = 20.7295 which can be seen in graph 2 and table 2 below.

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Graph 4.2 Results of XRD analysis of variations in the weight of carbon fiber (20%), agave fiber (10%), hemp fiber (10%), matrix (60%)

(Source: Material Characterization Laboratory, HKBP Nommensen University, Medan)

Tabel 2 peak list 2

Pos. [°2Th.]	Height [cts]	FWHM Left [°2Th.]	d-spacing [Å]	Rel. Int. [%]
20.7295	110.01	0.0900	4.28148	48.33
34.6601	227.64	0.2342	2.58811	100.00
54.1230	24.51	0.6691	1.69457	10.76

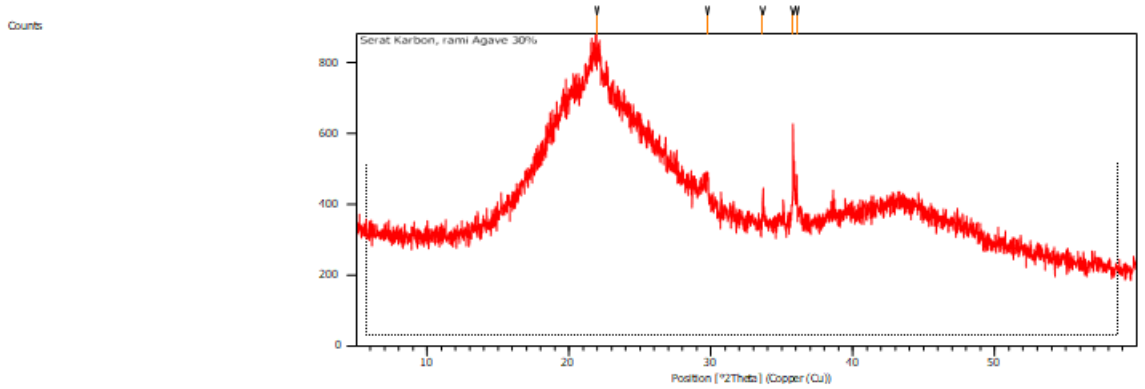
(Source: Material Characterization Laboratory, HKBP Nommensen University, Medan)

Material: Composite made of polyester reinforced with carbon fiber, hemp fiber, agave fiber, varying weights of carbon fiber (30%), agave fiber (5%), hemp fiber (5%), matrix (60%)

The variation in the weight of carbon fiber (30%), agave (5%), hemp (5%), matrix (60%) with Dataset name: carbon fiber, hemp, agave 30% obtained the highest intensity peak at 791 at an angle of 2Θ = 21.9437 which can be seen in graph 1 and table 1 below This

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Graph 3 Results of XRD analysis of weight variations of carbon fiber (30%), agave fiber (5%), hemp fiber (5%), matrix (60%)

(Source: Material Characterization Laboratory, HKBP Nommensen University, Medan)

Tabel 4.3 peak list 3

Pos. [°2Th.]	Height [cts]	FWHM Left [°2Th.]	d-spacing [Å]	Rel. Int. [%]
21.9437	117.20	0.8029	4.05059	41.04
29.6860	70.29	0.2007	3.00946	24.62
33.6180	60.58	0.1338	2.66592	21.21
35.7553	285.54	0.0502	2.51132	100.00
36.0113	141.45	0.0502	2.49405	49.54

(Source: Material Characterization Laboratory, HKBP Nommensen University, Medan)

DISCUSSION

SEM test results

From the results of SEM tests on composites made from carbon fiber reinforced polyester, agave fiber, and ramie fiber with variations in fiber weight (10% carbon: 15% agave: 15% ramie: 60% matrix), (20% carbon: 10% agave: 10% ramie: 60% matrix), and (30% carbon: 5% agave: 5% ramie: 60% matrix) it can be explained that:

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With varying fiber weights (30% carbon: 5% agave: 5% ramie: 60% matrix), the types of fractures that occur are fiber pull-out and debonding. Debonding itself occurs due to imperfect bonds between the fibers and the matrix.)This is reinforced by the results of the SEM test at 500x magnification of the variation in carbon fiber weight in Figure 4.4

where there are holes in the matrix due to fibers being pulled out of the matrix (fiber pull out). Pull-out

is the release of fiber from the matrix which causes holes in the matrix. Pull out has a diameter almost the same as the fiber diameter ([12]).

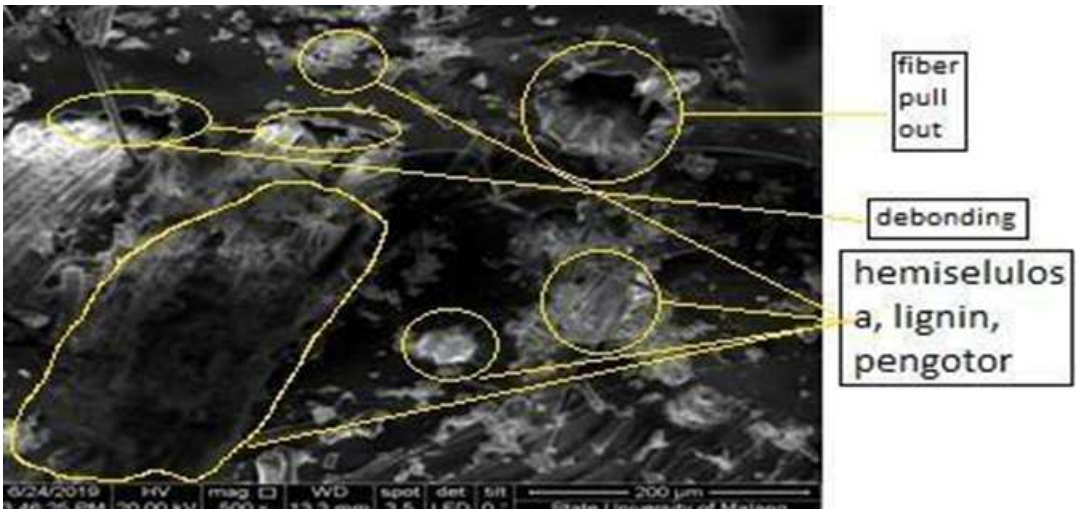


Figure 16 Results of SEM test at 500x magnification for fiber weight variation (30% carbon: 5% agave: 5% ramie: 60% matrix)

(Source: Mineral Laboratory, HKBP Nommensen University, Medan)

With varying fiber weights (20% carbon: 10% agave: 10% ramie: 60% matrix), the fractures that occur are mixed fractures. The fractures that occur are a mixture of brittle and ductile fractures. This type of fracture is the most common. The strength of the composite will decrease with changes in the angle or weight of the fibers. This is because the fibers are transverse in weight, making them more prone to fracture.[1])However, the results of the SEM test of fiber weight variations (20% carbon: 10% agave: 10% ramie: 60% matrix) show that in this variation the fiber arrangement looks less good. Looking at the fiber variations (20% carbon: 10% agave: 10% ramie: 60% matrix) the results of the SEM test at 50x magnification, where the ramie fibers clump together and are not neatly arranged, and the matrix is visible more in one area. This is also

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clarified in the results of the SEM test at 250x magnification of the fiber variation (20% carbon: 10% agave

:10% ramie : 60% matrix) that the fiber arrangement between carbon, agave and ramie fibers is not neatly arranged. Brittle and ductile fractures themselves can occur because the impact load on the brittle part of the matrix is transmitted to the ductile part

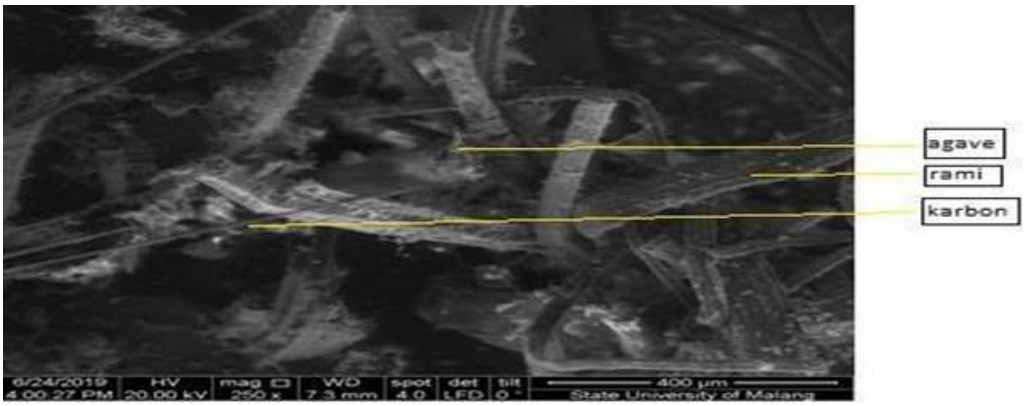


Figure 17 Results of SEM test at 250x magnification for fiber weight variation (20% carbon: 10% agave: 10% ramie: 60% matrix)

(Source: HKBP Nommensen University mineral laboratory Medan).

From the XRD results on the variation of fiber weight (20% carbon: 10% agave: 10% ramie: 60% matrix) shows the lowest intensity, this can be explained by the SEM test results that from the variation of fiber weight (20% carbon: 10% agave: 10% ramie: 60% matrix) agave and ramie fibers found in a plane that has been cut for the XRD test, produce the lowest crystal intensity because the plane is not filled by carbon fibers or agave and ramie fibers neatly/evenly. This is reinforced from Figure 4.6 500x SEM test magnification shows the comparison between carbon fibers, ramie fibers wrapped in impurities with the matrix is very different. Where the matrix looks more than the fibers that make up the composite. Debonding (imperfect bonding between fiber and matrix) is also seen in the variation in fiber weight (20% carbon: 10% agave: 10% ramie: 60% matrix) as shown in Figure 4.6.

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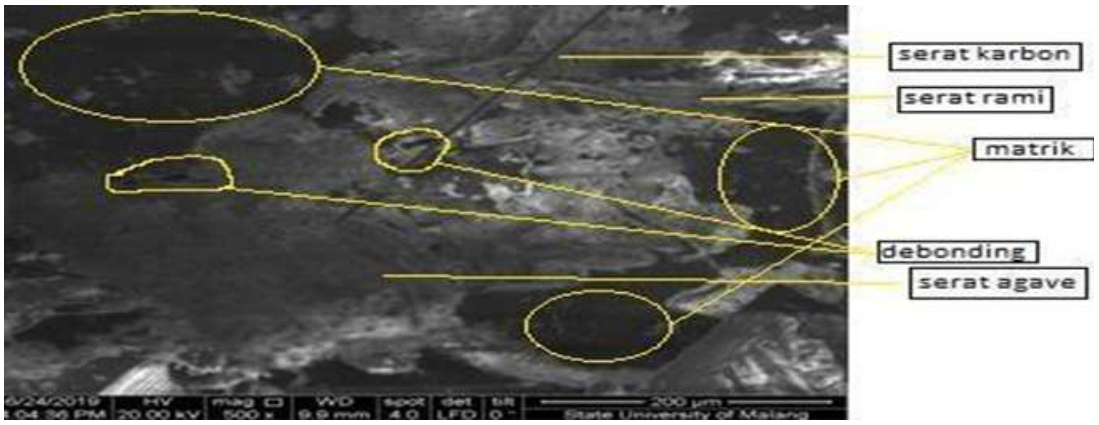


Figure 18 Results of SEM test at 500x magnification for fiber weight variation (20% carbon: 10% agave: 10% ramie: 60% matrix)

(Source: Mineral Laboratory, HKBP Nommensen University, Medan)

With varying fiber weights (10% carbon: 15% agave: 15% ramie: 60% matrix), the fractures that occur are mixed fractures. The fractures that occur are a mixture of brittle and ductile fractures. This fracture is the most common. The strength of the composite will decrease with changes in the angle or weight of the fibers. This is because the transverse weight of the fibers makes them more prone to fracture.1 Brittle and ductile fractures themselves can occur because the impact load on the brittle part of the matrix is transmitted to the ductile part.

In this case, the intended meaning is natural fibers (agave and ramie) and carbon fibers. From this variation, it can be seen that the arrangement of agave and ramie fibers is so dense that in this variation the specimen has a ductile fracture. This is shown by the results of the SEM test at 50x magnification of fiber weight variations (10% carbon: 15% agave: 15% ramie: 60% matrix). In this specimen, there is also debonding (imperfect bonding between fibers and the matrix) because it can be caused by agave and ramie fibers still being affected by hemicellulose, lignin and other visible impurities. Uneven fiber distribution can also be seen in this specimen. The evenness or unevenness of the fiber distribution to the polypropylene matrix causes the matrix bond to be hindered by agglomerated fibers, thereby reducing mechanical strength.[6]). The inhomogeneous fiber distribution can also be seen from the results of the SEM test at 200× magnification of fiber weight variations (10% carbon: 15% agave: 15% ramie: 60% matrix)

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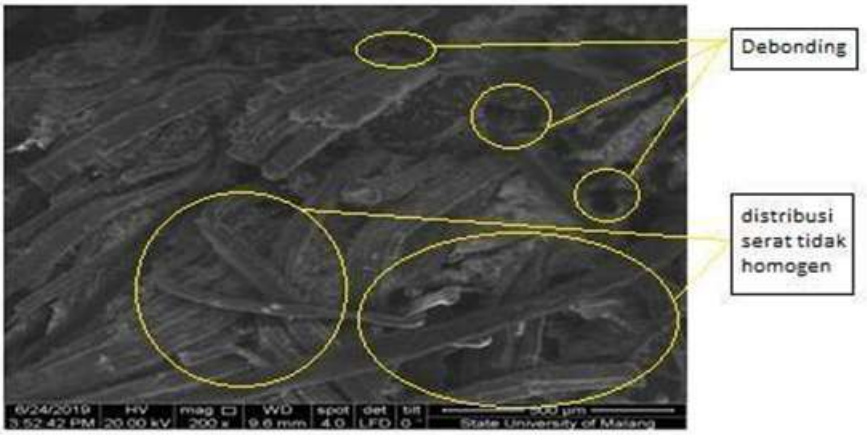


Figure 19 Results of SEM test at 200x magnification for fiber weight variation (10% carbon : 15% agave : 15% hemp : 60% matrix)
(Source: Mineral Laboratory, HKBP Nommensen University, Medan)

From the variation of fiber weight (10% carbon: 15% agave: 15% ramie: 60% matrix) and (20% carbon: 10% agave: 10% ramie: 60% matrix), have the same fracture, namely a mixed type fracture. The fracture that occurs is a mixture of brittle fracture and

clay fracture. In the variation (30% carbon: 5% agave: 5% ramie: 60% matrix) there is a fiber pull out fracture (fiber pulled out from the matrix). And seen from the results of the SEM test, the three variations of fiber weight have debonding which can be caused because the fibers used (agave and ramie) still contain elements of hemicellulose, lignin and other impurities that are still attached to the fiber. So the matrix cannot bind perfectly to the fibers.

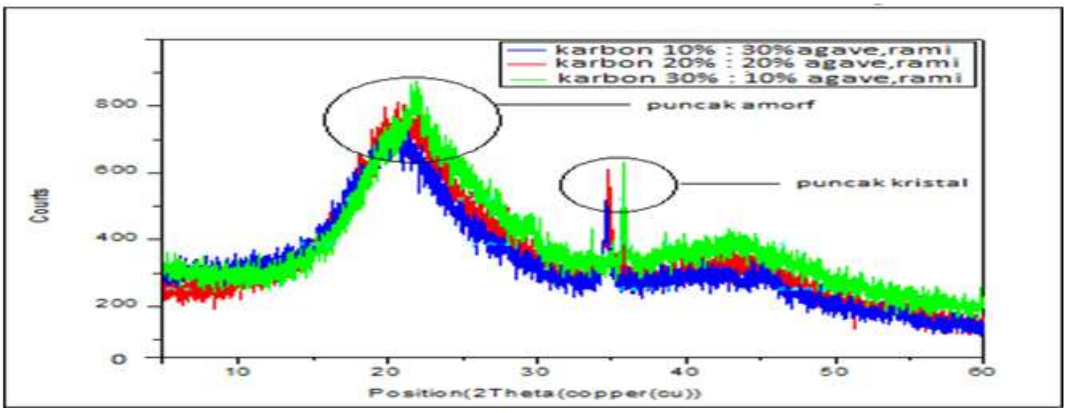
From the results of SEM testing of carbon fiber, ramie, and agave composites, it shows that the data for a composite does not have the same properties.*homogenery* at every point, this is upheld by opinion (*Matthews* et al. 1994) which states that a composite is a material formed from a combination of two or more forming materials through a non-homogeneous mixture, where the mechanical properties of each forming material are different. From the results of tensile testing of carbon fiber, ramie, and agave composites, it shows that the data on a composite does not have the same properties.*homogenery* at every point[1]).

XRD Test Results

To make it easier to analyze and see the differences in the XRD test data graphs above shown in, here I use the Origin application to combine the three graphs. To make it clearer, I

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changed the color of each graph to different colors. From the original red color, for the variation of fiber weight (10% carbon: 15% agave: 15% ramie: 60% matrix) here I use blue. The red color is for the variation of fiber weight (20% carbon: 10% agave: 10% ramie: 60% matrix), and the green color is for the variation of fiber weight (30% carbon: 15% agave: 15% ramie: 60% matrix). : 5% agave : 5% hemp : 60% matrix)



Graph 4.4 Results of XRD analysis of polyester composites with variations in fiber weight (10% carbon: 15% agave: 15% ramie: 60% matrix), (20% carbon: 10% agave: 10% ramie: 60% matrix), (30 % carbon: 5% agave: 5% hemp: 60% matrix) (source: personal document)

From the graph of carbon fiber reinforced polyester, agave fiber, ramie fiber, fiber weight variations (10% carbon: 15% agave: 15% ramie: 60% matrix), (20% carbon: 10% agave :10% ramie : 60% matrix), (30% carbon : 5% agave : 5% ramie : 60% matrix) shown in graphs 4.1, 4.2 and 4.3, the vertical axis shows the intensity of x-rays in units of counts per second, while the horizontal axis shows the scattering angle 2Θ which is the angle of movement of the counter detector.

For graph 4.4 is the result of the three XRD test graphs of fiber weight variations (10% carbon: 15% agave: 15% ramie: 60% matrix), (20% carbon: 10% agave: 10% ramie: 60% matrix), (30% carbon: 5% agave: 5% ramie: 60% matrix) which have been combined, the resulting pattern is almost the same, where in each graph there is a maximum peak but cannot be categorized as a crystal peak because the peak is still a diffraction hump-shaped pattern or irregular background intensity. According to the diffraction peak analysis by Nurun Nayiroh, M.Si (2014) said that, "the presence of a crystal phase can be immediately seen from the presence of diffraction peaks, while amorphous materials provide a diffraction hump-shaped pattern or irregular background intensity". This irregular pattern can also be called an amorphous phase (hemicellulose and lignin).

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Li Lui's Researchet *al.*(2009) states that "cellulose is crystalline while hemicellulose and lignin are amorphous. The content of amorphous substances in the sample can affect the size of the crystallinity of the fiber."

From the graph it can be seen that the variation in fiber weight (10% carbon: 15% agave) : 15% ramie : 60% matrix) there is an amorphous peak at an angle of 2θ = 21.9338 with an intensity value obtained at number = 784, and a crystal peak value at an angle of 2θ = 34.7831 with an intensity value at number = 579. In the variation of fiber weight (20% carbon : 10% agave : 10% ramie : 60% matrix) there is an amorphous peak at an angle of 2θ = 20.7295 with an intensity value at number = 684, and a crystal peak value at an angle of 2θ = 34.6601 with an intensity value obtained at number = 491. In the variation of fiber weight (30% carbon : 5% agave : 5% ramie : 60% matrix) there is an amorphous peak at an angle of 2θ = 21.9437 with an intensity value at number = 791, and a crystalline peak value at an angle of 2θ = 35.7553 with an intensity value obtained at number = 649.

The peak with the highest intensity is found in the fiber weight variation (30% carbon: 5% agave: 5% ramie: 60% matrix) where there is an amorphous peak at an angle of 2Θ = 21.9437 with an intensity value at number = 791, and a crystalline peak value at angle 2Θ = 35.7553 with the intensity value obtained at number = 649. This explains the research conducted by Agustinus Vilemon Ola Mangu that the greatest mechanical strength of the impact test is in the variation of fiber weight (30% carbon: 5% agave: 5% ramie: 60% matrix) with impact energy and impact value found in the variation of fiber weight (30% carbon: 5% agave: 5% ramie: 60% matrix) namely: 1.223*joule* with an impact price of 0.0152*joule/mm*^{2}. The impact test table can be seen in the appendix page. Carbon plays an important role in increasing the intensity value because carbon fiber does not contain amorphous hemicellulose or lignin as found in agave and hemp fibers, carbon atoms are bound together in crystals that are more or less parallel to the long axis of the fiber, because the alignment of the crystals provides a ratio of strength to fiber volume (wikipedia).

The results of the XRD test in the form of a spectrum indicate the relationship between the scattering angle 2Θ and the intensity of the spectrum peak. If the material being tested is crystalline, the XRD graph will show many peaks, but if the peak in question is not present, then it can be ascertained that the material is amorphous[16]). This explains that the carbon, agave, and ramie fiber reinforced polyester specimens with variations in fiber weight (10% carbon: 15% agave: 15% ramie: 60% matrix), (20% carbon: 10% agave :10% ramie : 60% matrix), (30% carbon : 5% agave : 5% ramie : 60% matrix) is a material with an amorphous phase.

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Strengthened by the results of the previous SEM test analysis, this polyester composite material uses natural agave and ramie fibers. In these natural fibers there is cellulose content that produces peaks for crystal peaks. However, these natural agave and ramie fibers do not only contain cellulose. But also contain hemicellulose, lignin and other impurities that are still attached to these natural fibers (agave and ramie). These elements dominate in each test specimen and are evident from each SEM photo result. It is from these elements that cause the graphic data of the XRD test results to have the highest peaks owned by the amorphous phase, which causes this specimen to be classified as an amorphous material.

The results of all three graphs show almost the same XRD pattern because the material content comes from the same source, namely carbon fiber reinforced polyester, agave fiber, and hemp fiber

CONCLUSION

From the results of SEM testing, it can be concluded that the fracture surface structure of carbon, agave, and ramie fiber reinforced polyester experiences mixed fracture (brittle and ductile) at fiber weight variations (10% carbon: 15% agave: 15% ramie: 60% matrix) and (20% carbon: 10% agave: 10% ramie: 60% matrix). In the surface structure of fiber weight variations (30% carbon: 5% agave: 5% ramie: 60% matrix) there is fiber pull out (fiber pulled out from the matrix). From the three variations there is also debonding which can be caused by the fibers used (agave and ramie) still containing elements of hemicellulose, lignin, and other impurities that are still attached to the fibers. So the matrix cannot bind perfectly to the fibers. The distribution of fibers is not homogeneous.

From the results of the XRD test, it can be concluded that the crystalline phase formed in the polyester composite reinforced with carbon fiber, agave fiber and hemp fiber is amorphous or irregular in shape with the highest intensity value at a fiber weight variation of 30% carbon : 5 % agave : 5 % hemp : 60% matrix

From the relationship between the SEM test results and the XRD test, it can be concluded that from the XRD test results, the crystalline phase formed in the carbon, agave, and hemp fiber reinforced polyester composite is amorphous. This is proven by the results of the SEM photo test where all results show the presence of hemicellulose, lignin, and other impurities that are still attached to the fibers which results in the XRD graph being amorphous

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