Effects of The Addition of Carbon on Abaca Fiber and PVA Composite Materials Based on Mechanical and Acoustic Properties

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Abstract: Abaca is a kind of banana that grows in Indonesia. Abaca banana product utilized in this research is a fiber that obtained from the midrib of the stem. Henceforth, abaca fiber is processed to be the form of membranes. The purpose of the study is to determine the physical, mechanical, and acoustic properties of abaca fiber composite materials as fillers and polyvinyl acetate (PVA) as a matrix. The ratio of composite materials of abaca fiber and PVA is 1:10. The variations used in producing membranes are the addition of carbon powders by 0, 2, 4, 6 and 8%. The characteristics carried out include testing of density, morphology, tensile strength, and sound absorption coefficient. The results reveal that the highest density is obtained from the sample of 0% carbon, i.e., 1.026 gr/cm^3. Furthermore, the mechanical properties testing shows the highest yield stress value in samples with 4% carbon of 476.8 MPa and the highest Young modulus in samples with 8% carbon is 7905.1 MPa. Therefore, the addition of carbon could improve the mechanical properties of composites materials. Based on the measurement of sound absorption coefficient using an impedance tube with 1 microphone, the highest value can be attained from the sample of 4% carbon, namely 0.211 which shows the sample is more reflective. The material is reflective because the amount of abaca fiber used is less than PVA. The diameter of pores formed between the fiber and PVA are very small which could cause the absorption coefficient value to be lower. Therefore, further research will focus on the addition of abaca fiber content in composite materials. The positive point in this study is that the addition of carbon with 4 and 8% provides optimal mechanical ability.

Keywords: Abaca; Carbon; Membrane; Physical Properties; Mechanical Properties; Acoustic Properties

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I. INTRODUCTION

The membrane is a thin layer that has a structure in the form of porosity. In its application, the membrane can be used as a speaker diaphragm. Speaker diaphragm serves to produce sound caused by vibrations from the magnetic induction that occurs. Materials that are often encountered are paper, plastic, metal, and composites. From the materials mentioned above, the manufacture of speaker diaphragms using composite materials as alternative materials is also often done. The main material that is often found is *carbon fiber*. The characteristics possessed by this *carbon fiber* are that it has good strength and rigidity and is able to increase the electrical conductivity properties [1]. Not only that, but its light weight is also one of the advantages of *carbon fiber*.

A natural material that is often used as reinforcement in composite materials is abaca fiber [2–4]. Banana abaca is a plant native to the Philippines that has a pseudo-stem with a diameter of 15-38 cm with a height of 4-7 meters [5] see Figure 1. The main production of this banana plant is fibers derived from its stems. The utilization and development of abaca banana fiber has been widely researched by the community, one of which is Agnivesh Kumar Sinha (2018) researching the flexibility and tensile strength of abaca composite polymers by using epoxy resin as a matrix with abaca fibers as reinforcement. This test proved that the heavier the mass of the abaca fiber composite produced, the greater the tensile strength [6, 7].

This research made a membrane with abaca fiber composite material and PVC as the matrix. In addition to using abaca as a filler, the addition of carbon was also carried out. The carbon variations used in this study were 0, 2, 4, 6 and 8%. The characterization of this membrane is density testing, morphology, mechanical testing and absorption coefficient value testing. This test is still a basic test related to physical, mechanical and acoustic properties. As a comparison in this research, it will later be compared with the specter membrane in the market that emits carbon fiber.

II. METHOD

The first step in this study is to prepare the ingredients in advance. Slightly dried abaca using an oven for 1 hour at a temperature of 120°C to reduce moisture content. The dried fibers are then cut into pieces between 1-2 mm in length and width between 1-2 mm and 0.1-0.3 mm. Continued with car-

(a)

(b)

FIG. 1: (a) Abaca banana stem, (b) Abaca fiber.

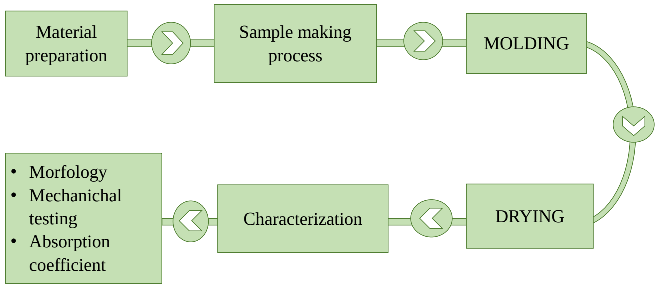

FIG. 2: Methodological scheme.

bon processing by sifting carbon fiber using a sieve measuring 200 mesh. The methodological schema of the study can be seen in Figure 2.

The constituent components in the test sample include three materials, namely abaca banana fiber, carbon, and *polyvinyl acetate*. The three of them are mixed into a saucer to stir evenly. There were 6 samples in this study. Membrane/cone speakers sold generally in the market, abaca fiber composites and PVA with a ratio (1: 10) which is then added with carbon fiber levels of 0, 2, 4, 6 and 8%. The next process is *molding* or printing starting with applying *the original wax paste kit* on top of the ceramic mold. The latter process is the drying of the test sample using room temperature for 1 day until the sample is dry. After drying, the sample is removed from the mold. Samples are measured, cut, and formed according to standards in each test.

Morphology testing uses a digital microscope tool with a CMOS image sensor equipped with a microscope micrometer calibration ruler. It starts with installing software and continues by taking photos of the morphological results of each sample. The focus on the *microscope* is arranged in such a way as to obtain the morphological results of the sample. Tensile strength measurement uses universal testing machine Shimatzu 10 KN RCT-10KN-AF, which has a maximum tensile strength of 10kN. The sample is placed on the specimen shown in Figure 3. The sample is pulled continuously until it breaks. The sampling process is recorded automatically using software on a computer. So that data can be obtained in real time.

Mechanical testing is carried out to determine the amount of yield stress and modulus of elasticity. Related to the elasticity ability of the sample. The sample size tested was (6.9 $\times$ 3 $\times$ 0.01)mm^3. The equipment used to test the absorption coefficient is an impedance tube. The test was carried out at the Acoustics Laboratory, ITS Physics Department. The dimensions of the sample used are 100 mm in diameter with a thickness of 0.01 mm. The microphone that has been prepared is also calibrated according to the original specifications. The sample is laid at the end of the impedance tube. Set the sound frequency on the amplifier with a frequency 1 octave of 125-2000 Hz.

III. RESULTS AND DISCUSSION

A. Morphological Test Results

Morphological testing is carried out to determine the structure and arrangement of particles microscopically. The test was carried out with a *digital microscope* tool by taking photos first for each sample and continued the process of analyzing for each particle. The analysis carried out uses a *calibration ruler* with a scale of 0.5 mm as a reference to determine the size of the fibers, and the distance between the fibers. It can be seen in Figure 4 Morphology of the test sample. Figure 4(a) depicts the morphology of samples are round and regular. This is because the sample is made by fabrication process. Using *digital microscope with CMOS image sensor equipped with a micrometer calibration microscope*. there are fine fibers that are the constituent components of this sample. The fiber size has a length of 0.10 mm and a width of 0.04 mm, while the distance between the fibers of 0.10 mm can be seen in Table 1.

In Figure 4(b)–4(f) the results obtained in the test sample have an inhomogeneous arrangement. This arrangement causes the distance between fibers to be different in each sample. Sample 0% Figure 4(b) obtained a distance between fibers of 0.104 mm. In the 6% carbon sample (Figure 4(e)) with the largest spacing between the fibers among the other samples, namely 0.29 mm. From these results it is known that the more variations of carbon used, the closer the distance between the fibers produced. Inhomogeneous fibers make bonds between polyvinyl acetate, banana abaca fiber and irregular carbon. This results in the appearance of cavities in the sample which will reduce the mechanical strength of the sample.

B. Mechanical Properties

Mechanical properties can be observed by mechanical testing on composites. This result reveals Young's modulus, yield stress, Max stress, and break stress. Youngs modulus is meaningful only in the range in which the stress is proportional to the strain, and the material returns to its original dimensions

TABLE I: Sample mechanical test results

Properties of Samples	Mechanical test result of membrane					
	Standard	0% Carbon	2% Carbon	4% Carbon	6% Carbon	8% Carbon
Length fiber (mm)	0.11	1.06	1.14	1.22	1.25	1.04
Width fiber (mm)	0.04	0.17	0.19	0.11	0.13	0.14
Distance fiber (mm)	0.10	0.10	0.20	0.28	0.29	0.23
Young Modulus (MPa)	4576.7	3478.3	2805.1	6689.0	3623.2	7905.1
Yield Stress (MPa)	463.8	459.4	466.7	476.8	466.7	297.1
Max stress (MPa)	656.5	539.1	587.0	637.7	466.7	291.7
Break stress (MPa)	172.5	191.3	208.7	297.1	243.5	107.2

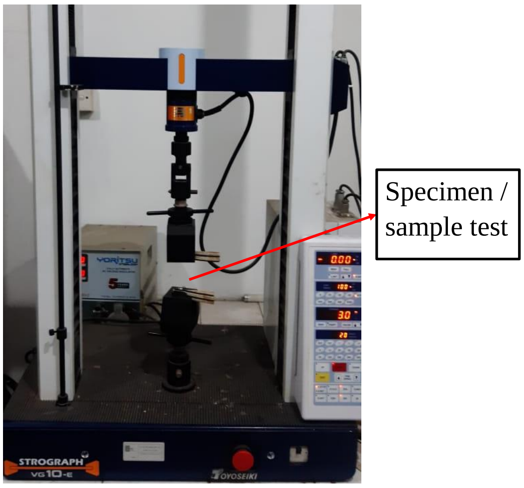

FIG. 3: RCT-10KN-AF.

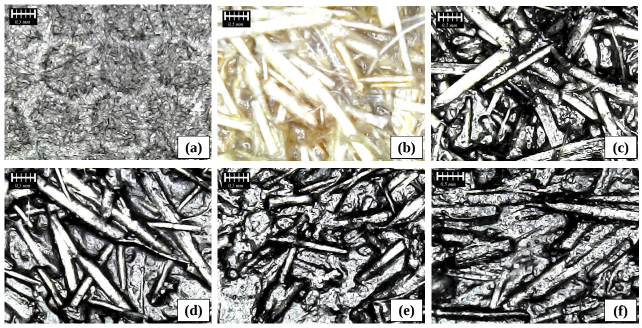

FIG. 4: Sample morphological test (a) standard membrane, (b) composite with 0% carbon, (c) composite with 2% carbon, (d) composite with 4% carbon, (e) composites with 6% carbon, (f) composite with 8% carbon

when the external force is removed. Yield stress defines the point at which an object changes from experiencing elastic deformation to plastic deformation. Breaking stress is the maximum force that can be applied on a cross sectional area of a material in such a way that the material is unable to withstand any additional amount of stress before breaking.

The results shown in Table I are obtained in the form of 4 parameters for mechanical properties. The yield stress parameter has almost the same value, which is >450 MPa but inversely proportional to the sample of 8% carbon. The yield stress value of the sample is 8% carbon which has the smallest value of 297.1 MPa while the young modulus has the highest value reaching 7905.1 this shows that the addition of 8% carbon makes the sample more rigid. The highest max stress is 656.5 MPa. The value of such tensile strength can be influenced by various factors, one of which is the diameter of the fibers. The diameter of this fiber can also be said to be the width of the fiber. In general, the smaller the diameter of the fiber, the higher the tensile strength [8]. This is appropriate when observed in Table I where the standard sample has the smallest fiber width compared to other samples.

The addition of carbon is obtained from the value of both yield stress, Max stress and break stress have increasing values ranging from the addition of 2% carbon and 4% carbon. This suggests that the application of carbon improves its mechanical properties [9]. However, this is different When the addition of 6% carbon and 8% carbon is more likely to decrease, one of the causes is that the composite material formed is still not homogeneous, there are voids or cracks in the sample. This can be seen in Fig. 4, the fiber and the inhomogeneous PVA distance between the fibers is also quite large.

The mechanical property of the latter is the modulus of elasticity. The modulus of elasticity is a measure of the rigidity of a material. From Table I, the highest to lowest modulus values of elasticity were 7905.1 MPa in samples 8%; 6689 MPa in samples of 4% carbon; 4576.7 MPa in standard samples; 3623.2 MPa in samples of 6% carbon; 3478.3 MPa in samples of 0% carbon; and 2805.1 MPa in samples of 2% carbon. The value indicates in the sample with the addition of the most carbon variations resulting in a high modulus value of elasticity. This is due to the rigid nature of carbon, which increases the toughness of the sample [9].

C. Acoustic Properties

One of the determinations of acoustic properties is by measuring the value of the sound absorption coefficient (α) in the sample. This test was carried out at the Acoustic Physics Laboratory of the ITS Physics Department using the impedance tube method. The impedance tube method uses one micro-

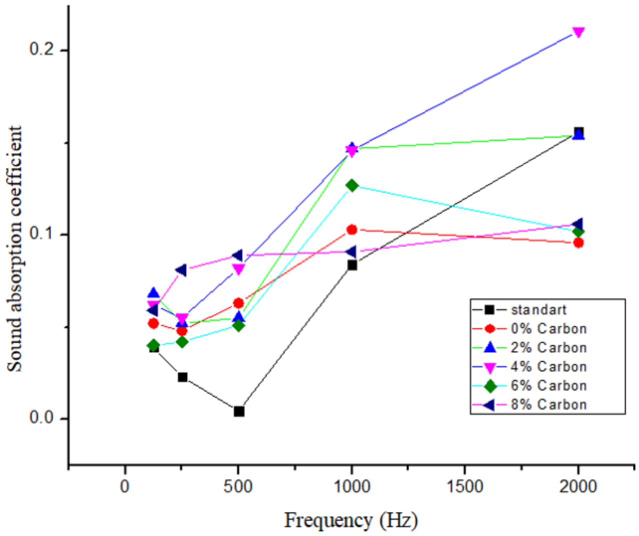

FIG. 5: Sample absorption coefficient value.

phone using the principle of standing wave ratio. The data obtained from the test results can be seen in Figure 5.

Figure 5 shows the relationship between frequency and the value of the absorption coefficient in each sample. It is noticed that a sample of 4% carbon at a frequency of 2000 Hz has the highest coefficient value of 0.211. This is based on the morphological results obtained in Figure 4(d) where a 4% carbon sample has the smallest fiber width or diameter when compared to other samples when carbon variation is added. Likewise, in a sample of 0% carbon which has the largest fiber width or diameter, which is 0.44 mm, has the lowest absorption coefficient value at a frequency of 2000 Hz. So, from these results it can be said that the smaller the width or diameter of the fiber, the higher the value of the absorption coefficient.

In the sample 0% carbon, 2% carbon and 6% carbon have a similar graph. It is said to be similar because it has the same trend. A significant increase in the value of the coefficient of absorption at a frequency of 1000 Hz indicates that these three samples can absorb the same sound at a frequency of 1000 Hz. The value of the α obtained is very small, being in order 0.2 which indicates that the sample is a reflector material. The material is reflective because the amount of abaca fiber used is less than PVA. The pore diameter formed between the fiber and PVA is very small so that it can cause the absorption coefficient value to be lower. Therefore, future research will focus on adding abaca fiber content to composite materials. The positive thing from this research is the addition of 4 and 8% carbon provides optimal mechanical performance.

IV. CONCLUSION

According to morphological testing, the fiber size of samples is still not homogeneous, i.e.., diameter and length of fiber vary. In addition, the size of the fiber is still quite large, a cutting tool is needed that can chop the fibers into finer ones. In mechanical properties testing, the highest tensile strength value is obtained in the sample of 656.5 MPa, and the highest modulus of elasticity in the sample of 8% of 7905.1 MPa. Value of sound absorption coefficient obtained the highest value of 0.211 in the sample with the addition of a 4% carbon variation. The value is a category of reflector material. The material is reflective because the samples are very thin, and the number of abaca fibers used is less than PVA.

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