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Effect of Smaller Size Aluminum Particles on Improving the Characteristics of Carbon-Epoxy Wet Lamination

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Abstract:
***Background**: Bio-composite materials are being developed in research to obtain superior mechanical characteristics, this is because more and more industries are realizing the benefits that can be obtained. The aim of this research is to understand the addition of particles and carbon fiber, to increase the strength and strength of bio-composite materials. The material is a bio-composite material from water hyacinth fiber and jute fiber which has been widely used, but only for simple needs. To get maximum strength, the resin used is reduced epoxy resin.*
***Materials and Methods**: The water hyacinth fiber used for this research is made of rope, because it has undergone mechanical work so that the water content has been and becomes stronger.*
***Results**: Burlap sacks and carbon fiber were added to improve their mechanical characteristics (shown from) and rigidity (shown from E↑). Therefore, the fiber packing problem can approach 0.74 and the mechanical characteristics of the material can reach ∼480 [Mpa].*
***Conclusion:** By combining bio-composites and conventional composites and by adding fillers whose diameter is smaller than the resin diameter, the bio-composites become suitable for structural applications.*
Key Word**:**Bio-composite, tensile-test, water hyacinth, jute, carbon

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I. Introduction

Researchers understand government awareness based on new laws of world countries towards greener and environmentally friendly products in every industrial sector including the automotive industry. [1] These requirements have encouraged researchers to be able to develop superior bio products [2] This new provision encourages researchers to focus on applying automotive/other materials that can be recycled. In the incorporation of this filler matrix, it will determine the strength and service life of the composite material. Incorporation of filler into the resin matrix can affect and improve the characteristics of the material, provided that the filler particles are bound to the polymer matrix or vice versa can weaken the resin. [3] Today, about ten percent of the mass of a car is made of plastics and composite materials that, at the end of a vehicle's life, take hundreds to thousands of years to completely decompose. Since, the amount of natural fiber used in a single car increased from 3.5 kg to more than 60 kg and now most car manufacturers use bio-composites for many components of commercial vehicles. The replacement of metal materials that have been used in the automotive industry with plastic materials and composite materials has led to a reduction in vehicle mass. The reduction in the mass of the vehicle has resulted in increased wear mass, increased wear mass, increased absorption of noise and vibration, and insulation between vehicle compartments to absorb shock kinetic energy in the event of an accident. [4] Thus many researchers are trying to find suitable technology that will make the production of spare parts stronger, easier, cheaper, and faster. [5] In the end, environmental concerns and stricter fuel consumption requirements prompted manufacturers to carry out studies on weight and friction reduction. [6] Researchers and engineers have been exploring the possibility of applying a new method in which particulates, as modifiers, are added to molten metal in mass production. It is a subject of current research and has not yet reached a mature and practical level. [6]

II. Material And Methods

This prospective study is to find a material or a combination thereof to replace the metal material in the vehicle structure. This is based on the fact that in the future the vehicle used is an electric vehicle (EV).

Study Design: Prospective Composite Material that is ideal for use in future mass vehicles

Study Location: This study was conducted at the Bandung State Polytechnic laboratory scale.

Study Duration: April 2022 to November 2023.

Sample size calculation: In this research, tensile test, impact test and fatigue test were carried out with several samples

Subjects & selection method: Subject in this research is to have mechanical characteristic material (bio-composite) to build the student race car. In this regard, the first step is to test the combined bio-composite material, which is reinforced with a conventional composite (carbon fiber). In this literature, the results of the tensile test material are presented.

Procedure methodology

Composite testing is carried out to determine material properties, reliability, and damage tolerance. Structural variables such as fiber orientation, fiber volume fraction, laminate thickness, and core density, lay up processing variables, curing temperature and pressure, can have a dramatic influence on the mechanical properties of composite materials. Mechanical and process tests are required to understand the effect of these variables on the finished material or component.

Epoxy composite reinforced with water hyacinth fiber, hemp fiber, carbon fiber and carbon particle with 1650 mesh, which is made into a composite by the hand lay-up method. [7] Stress on composite causes uniform strain on all composite layers. The load acting on the composite can be expressed in terms of Eq. (1) as follows,

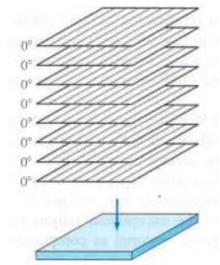


Fig. 1 Uni directional laminte

$$P_c = P_f + P_m \quad \ldots\ldots\ldots \quad (1)$$

Where, P_c is a composite load, P_f is a load supported by fiber and P_m is a load supported by a matrix. Since it is generally known that σ=P/A, then

$$\sigma_c . A_c = \sigma_f A_f + \sigma_m . A_m \quad \ldots\ldots\ldots \quad (2)$$

Since strains equal, so

$$\varepsilon_c = \varepsilon_f = \varepsilon_m \quad \ldots\ldots\ldots \quad (3)$$

Thus the eq. (2) becomes the Rule of mixture of binary composites, as written in the eq. (4)

$$\frac{\sigma_c}{\varepsilon_c} = \frac{\sigma_f . v_f}{\varepsilon_f} + \frac{\sigma_m . v_m}{\varepsilon_m} \quad \ldots\ldots\ldots \quad (4)$$

Such is the iso strain condition that occurs in the composite specimen as a tensile test is carried out with the depiction of the specimen as shown in Fig. 2.

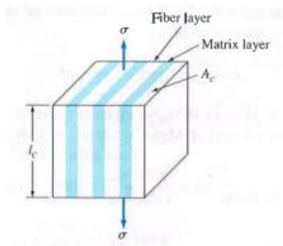


Fig. 2 Composite structure consisting fiber layer and matrix layer

When compared to iso strain and iso stress conditions, it will be obtained as can be observed in the following curve

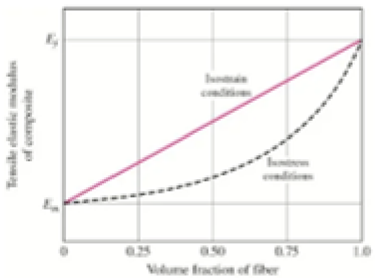


Fig. 3 Komparison of composite iso strain and iso stess condition

However, the test results are very different from the results of the previous calculations, this is because the previous modeling is very regular as can be seen in fig. 4 following.

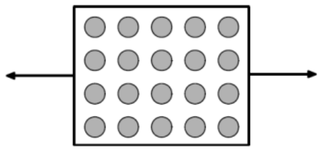


Fig. 4 Theoritis condition of pacing fiber in composite

However, this will not be achieved, so that what will be achieved is in Figure 5, so that the largest fiber volume fraction is 0.74

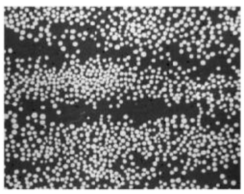


Fig. 5 Real codition of packing fiber in composite

The material used in this study is a material that is predicted to be used as a structure in a student race car and has experience. Seeing this, the specific strength and specific stiffness of the material must be maximized. Specific stiffness and strength values are obtained by comparing with the density as shown in Tables 1, 2 and 3.

Table 1 Mechanical properties of some fibres and metals.

Material	Young's modulus (Gpa)	Shear modulus (Gpa)	Axial Poisson's ratio	Ultimate strength (Mpa) tension	Strain to failure (%)	Density (Kg/m^3)
Carbon fibre HT-T300	230	23	0.23	3530	1.5	1750
Carbon fibre IM-T800	294	23	0.23	5586	1.9	1800
Carbon fibre HM	385	20	0.23	3630	0.4	2170
E-glass fibre glass	72	27.7	0.3	3450	4.7	2580
S-glass fibre	87	33.5	0.3	4710	5.6	2460
Kevlar 49 fibre	124	5	0.3	3850	2.8	1440
Steel	206	81	0.27	648	4	7800
Aluminium	69	25.6	0.35	234	3.5	2600

Table 2 Mechanical properties of some polymeric matrices

Material	Young's modulus (Gpa)	Shear modulus (Gpa)	Axial Poisson's ratio	Ultimate strength (Mpa) tension	Strain to failure (%)	Density (Kg/m^3)
Epoxy	3.1	1.2	0.3	70	4.0	1200
Polyester	3.5	1.4	0.3	70	5.0	1100
Resin RTM 6	2.89	1.08	0.34	75	3.4	1140
Resin RTM 120	2.60	0.96	0.35	77	—	1200

Table 3 Mechanical properties of most used natural fibres compared to E-glass fibres

Mechanical properties	E-glass	Flax	Hemp	Jute	Ramie	Sisal
Density (g/cm^3)	2.55	1.4	1.48	1.46	1.5	1.33
Young's modulus (Gpa)	73	60–80	70	10–30	44	38
Tensile strength (Mpa)	2400	800–1500	550–900	400–800	500	600–700
Elongation at failure (%)	3.0	1.2–1.6	1.6	1.8	2.0	2.0–3.0

Several researchers studied the possibility of replacing conventional fibers with natural (bio) fibers. They investigated the mechanical properties of sisal, hemp, coir, kenaf and jute reinforced polypropylene composites. Tensile strength and modulus increase with increasing fiber volume fraction, and the test results are shown in Tables 1, 2 and 3. The special properties of natural fiber composites are in some cases better than glass. This indicates that natural fiber composites have the potential to replace glass in many applications that do not require very high load bearing capabilities.

III. Result

Theoretical studies need to be carried out to find out the description of the specimen to be tested. For example, a study that conducted tests on ramie obtained a strength of 99.04 ± 2.85 Mpa. The study also stated that the thickness of the layer tends to increase the tensile strength of the composite. [9] For water hyacinth, the same tensile test was carried out with a magnitude of 44.10 [Mpa]. [10] These values were then used as a specimen mixture with a fiber volume fraction of 62%, consisting of

- Water hyacinth fiber = 18 %
- Ramie fiber = 18%
- Carbon fiber ………= 26%

$$\sigma_c = \sigma_e v_e + \sigma_r v_r + \sigma_c v_c + \sigma_m v_m$$

$$\sigma_c = 44.10\ .\ 0{,}18 + 99.04.0.18 + 3630.0.26 + 70.0.38$$

$$\sigma_c \text{ theoritis} = 996{,}1652 \text{ MPa}$$

The tensile test in the field of plain composite laminates is the most common test. Tensile tests are also performed on resin-impregnated fiber bundles ("tows"), through thickness specimens (cut from thick sections of laminate), and sections of sandwich core material. Examples of common standards for tensile testing of laminates are ASTM D 3039, etc. Specimens have parallel sides with bonded tabs to prevent the gripping jaws from damaging the material and causing premature failure. Gripping mechanisms include manual and hydraulic wedge grips. For demanding aerospace testing, hydraulic wedge clamp solutions are generally preferred for their controllability and repeatability.

Composite testing is carried out to determine material properties, reliability, and damage tolerance. Other tests were conducted to study the effect of the variables. Structural variables such as fiber orientation, fiber volume fraction, layer thickness (number of layers), and core density; and processing variables such as layup accuracy, curing temperature and pressure, can have a dramatic influence on the mechanical properties of composite materials. Mechanical and process tests are needed to understand the effect of these variables on materials or components of finished goods. Generally, the specimens of the test specimens are made as shown in Fig. 6.

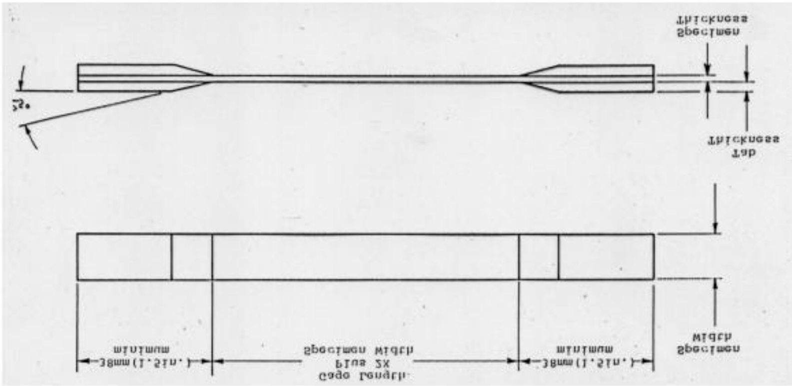
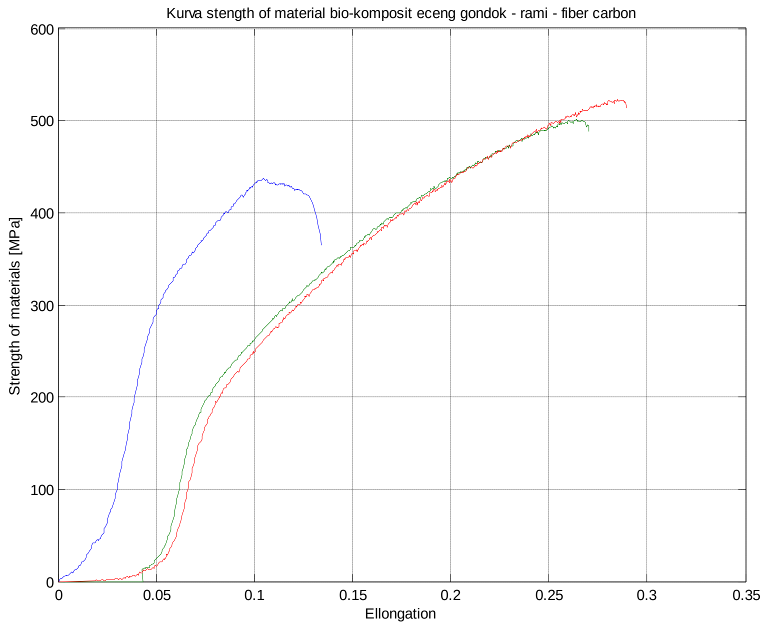


Fig. 6 Spesimen uji tarik komposit

IV. Discussion

Bio and green composites are gradually finding applications in several branches of industry. Among the natural fibers extracted from plants, hemp, sisal, banana fiber, kenaf, jute, and water are the most commonly used fibers. [12] Recent studies have shown that some automotive components are made from natural composites because they are relatively easy to decompose, resistant to vibration, environmentally friendly, and inexpensive. In their quest for more fuel efficient vehicles, designers in the automotive sector are always looking for the highest structural efficiency with the lowest possible weight.

Bio-compatibility is an issue that must be taken into account before development, especially many researchers are very concerned about the water content. If the fiber is taken from the water hyacinth rope, it has undergone mechanical work so that the results will be high. Similarly, the results of tensile testing on the specimens that have been produced are as follows:



The test results above show that the tensile test results are about ~480 [Mpa].

V. Conclusion

From research conducted experimentally, it is known that aluminum particles with a diameter smaller than the length of the resin do not have a negative impact and even strengthen the material by ± 15%, the modulus of elasticity of the material has been changed by adding flexible resin by 8%. The addition of these materials has given a level of flexibility to the material.

By performing a tensile test, it is known that the tensile test results show the results of 480 [Mpa] which gives an error from the theoretical results of 996,1652 – 480 = 516,1642 [Mpa] or about 51.82% error. The error occurred due to improper fiber packing and problems with specimen installation and misalignment of clamps.

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