

Study on Mechanical Properties of Pineapple Leaf-Glass Fiber Hybrid Composites for Car Body Applications

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ABSTRACT

The purpose of this study was to determine the mechanical properties of glass fiber composites and fiber, orientation, and variations of pineapple with a different composition of the main. Material tests used are glass fiber, pineapple fiber, lye (NaOH), epoxy resin, and hardener. Specimens composites made by the method of hand lay up with variations in the composition of the glass fiber 6%, pineapple fiber 4%, the glass fiber 9%: pineapple fiber 6%, glass fibers 12%: pineapple fiber 8%, glass fibers 15%: pineapple fiber 10% and with random fiber orientation and horizontal. Making the specimens was performed by reference to standard ASTM D 638. This test shows the highest tensile strength in horizontal fiber orientation with the volume fraction of 25%: 143.98 MPa, while the lowest occurred in a random fiber orientation of 10%, amounting to 13.45 MPa. Fault Composite glass fiber and epoxy pineapple fiber average can be classified as a single fracture type.

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1. INTRODUCTION

The development of the composite industry in Indonesia by looking for alternative composite materials must be increased to support the growing demand for composites in Indonesia. The type of composite that has been widely developed is fibre-reinforced composite. So far, the development of composites in Indonesia is still directed at non-renewable natural resource materials derived from earth excavations, such as glass, carbon and aramid. For this reason, it is necessary to develop environmentally friendly composite reinforcing materials, such as natural fibres.

In general, a composite is a material formed from a combination of two or more constituent materials, namely through an inhomogeneous mixture, where the mechanical properties of each constituent material are different. Composite materials generally consist of two elements: fibre as a filler material and a matrix as a fibre-binding material. This mixture will produce a composite material with different mechanical properties

[24]

and characteristics from the constituent material. Statistical analysis of the resulting microstructure and two- and three-dimensional finite element analysis was performed to validate the fibre strength capabilities. Representative volume elements with random fibre distribution are widely used in micromechanics to determine the properties of unidirectional fibre-reinforced composites from their microstructure [1]. The use and utilisation of composite materials is growing, along with the increasing use of these increasingly widespread materials ranging from simple ones such as household appliances to the industrial sector, both small-scale and large-scale industries [2]. Figure 1. shows some of the uses of plastic and polymer composites in automotive components. Polymer composites play an essential role in replacing heavy materials.

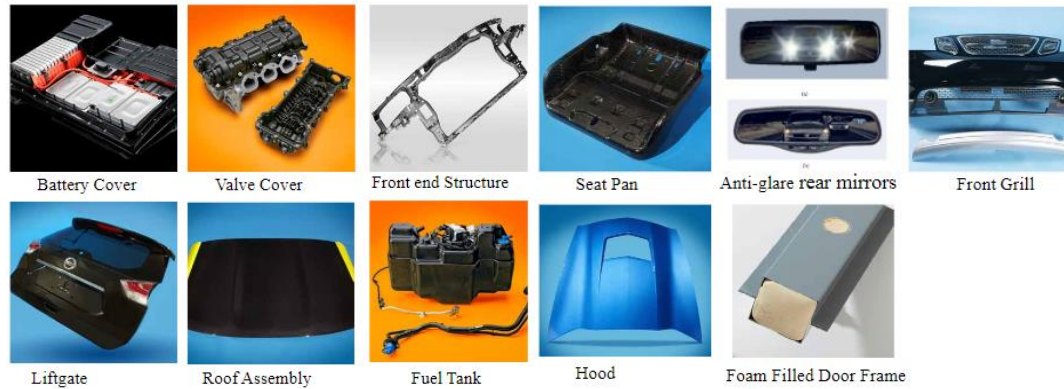


Figure 1. Plastic and polymer composite application [2] [3]

Composite has its advantages compared to other alternative engineering materials such as strong, lightweight, corrosion resistant, economical, etc. The molten glass fibre is drawn into thin fibres with a diameter of about 0.005 mm – 0.01 mm. This fibre can be spun into yarn or woven into cloth, which is then impregnated with resin so that it becomes a strong material, while pineapple fiber is a type of fiber derived from plants (vegetable fiber) obtained from the leaves of the pineapple plant. The use of pineapple leaf fiber as a composite material is an alternative in scientifically making composites, where pineapple leaf fiber is already well known for its strength, where pineapple leaf fiber has good quality with a smooth surface. Random fiber distribution of carbon fiber reinforced plastic with high volume fraction. The novelty is an adaptive fiber shuffling module developed based on Delaunay triangulation and combined with the proposed algorithm [3].

As for the matrix using epoxy resin. Epoxy is different from polyester resin in that the epoxy is cured with a hardener, while polyester uses a catalyst. The hardener, usually an amine, is usually used to cure the epoxy by an additional reaction in which the two materials are subjected to a chemical reaction [5]. The advantages of this epoxy compared to other resins are high mechanical and thermal properties, very water resistance, very low shrinkage, long service life, temperature resistance up to 220 °C, good chemical resistance and dimensional stability, good electrical properties, strong and has good adhesion to glass and metal. Epoxy contains chemical groups, including C = C, O-H and C-H. The presence of O-H groups indicates that the epoxy has the potential to interact with the O-H groups present in pineapple leaf fiber. Composite is a material composed of 2 materials, namely matrix and filler. Natural fibers, especially bamboo fiber and Iron sand, which is waste in Indonesia, has the potential to be developed as a composite engineering material reinforced with natural ingredients. The materials used are bamboo fiber and iron sand as fillers and epoxy resin as the matrix [5] [6] [7].

Interior fibers in yarns of plain oven carbon fiber-reinforced composite are scattered randomly, which further influences the mechanical properties of yarns. To explore the stochastic nature of fibers' supply in yarn and its effect on the chattels of yarn, this study proposes a new perturbation algorithm named Sequential Random Perturbation algorithm to reconstruct the microstructure of randomly distributed fibers, based on which illustrative volume element micromechanical models entailing of three phases to accurately predict the mechanical properties of yarn are established [8]. Materials with a stochastic fiber network as the main physical constituent are broadly encountered in engineering and in ecology. These materials are branded by multiscale heterogeneity and hence their properties evaluated numerically or experimentally are generally dependent on the size of the sample measured. In this work we appraise the size effect on the linear and non-linear powered response of three-dimensional stochastic fiber networks and determine its dependence on material limits and on the degree of affinity of network deformation [9]

The mechanical and physical properties of fiber-reinforced composites depend on several parameters, one of which is the treatment of the fiber, namely alkali (NaOH) treatment. The NaOH treatment on the fiber is carried out with the aim of cleaning the surface of the fiber from dirt and adhering sap so that the bond

between the surfaces between the fiber and the matrix becomes better. In addition to having many advantages, actually natural fiber also has many weaknesses, including low strength, especially against shock loads, low reliability, not resistant to high temperatures, quality varies greatly depending on the season, age, soil conditions, and environment. To overcome these weaknesses, the fiber is treated with alkali (NaOH) [10] [11] [12]. Excessive cavity preparation and root canal treatment leads to a weakened tooth structure with a lower resistance to fracture. Fiber reinforcement is frequently used to reinforce such teeth, and multiple fiber types and possible applications exist. Various methods for utilizing long fibers to internally splint the remaining cavity walls in the case of large mesio-occluso-distal (MOD) cavities have been proposed; however, no summary of their performance has been written up to now. Our study aims to review the available literature to evaluate and compare the mechanical performance of the different materials and methods utilized for horizontal splinting in large MOD cavities [13].

In this study, we will analyze the mechanical properties of the glass fiber and pineapple fiber reinforced composite material with an epoxy resin matrix with different orientations and variations in composition, with the ratio between glass fiber and pineapple fiber as follows: 4% glass fiber: pineapple fiber 6 %, 6% glass fiber: 9% pineapple fiber, 8% glass fiber: 12% pineapple fiber, 10% glass fiber: 15% pineapple fiber. This tensile test aims to get an overview of the properties and conditions of a composite specimen. so that the mechanical properties of the material will be obtained, including: stress, strain, and modulus of elasticity. Natural cellulose fibers have a great potential for the development of new alternative reinforcement materials that are used in several polymer composite applications. In this study, waru tree trunk fiber was extracted and treated with NaOH and Silane. Temporarily, the characteristics of chemical, morphological, mechanical, and fiber surfaces were determined through composition analysis, Fourier transforms infrared (FTIR), scanning electron microscope (SEM), and single fiber test. The results showed that the cellulose content increased with the adding of silane treatment which was supported by the high crystalline index of 63.02% waru bark fiber. Based on this treatment, the tensile strength of the single fiber had the highest value of 243.94 Mpa. Therefore, this fiber has the possible as a new reinforcement development in polymer-based products [14].

2. RESEARCH METHOD

The research method was quasi-experimental This composite was made at the Mechanical Engineering Laboratory of Merdeka Madiun University using the hand lay-up method, while the tensile strength test was carried out at the Surakarta Work Training Center Laboratory. Fiberglass is glass fiber or often translated as glass fiber. Glass fiber is molten glass drawn into thin fibers with a diameter of about 0.005mm-0.01mm. This glass fiber is in the form of a finished material that is ready to use. The fiber used in this study was pineapple leaf fiber. This fiber is obtained from the leaves of the pineapple plant. The use of pineapple leaf fiber as a composite material is an alternative in scientifically making composites, where pineapple leaf fiber is already well known for its strength and pineapple leaf fiber has good quality with a smooth surface. Furthermore, the fiber is immersed in a solution of caustic soda, or the so-called alkaline process. The soaking process is about 2 hours. The resin used is Epoxy resin. Epoxy is different from polyester resin in that the epoxy is cured with a hardener, while polyester uses a catalyst. The hardener, usually an amine, is usually used to cure the epoxy by an additional reaction in which the two materials are subjected to a chemical reaction. these two materials usually occur where two epoxy atoms are bonded by an amine atom. This will form a three-dimensional molecular complex structure. Because the amine molecules react with the epoxy molecules in a constant ratio (1:1 or 2:1). Mirror Glaze/Wax, this material is at first glance similar to butter or cheese when it is still in the container. Wax functions as a lubricant at the molding stage using mal/molding, so that the molding and the resulting print do not stick together, so they can be easily removed.

Table 1. Research variable percentage of epoxy resin and fiber

No	Epoxy resin (%)	Glass fiber (%)	Pineapple fiber (%)
1	90	4	6
2	85	6	9
3	80	8	12
4	75	10	15

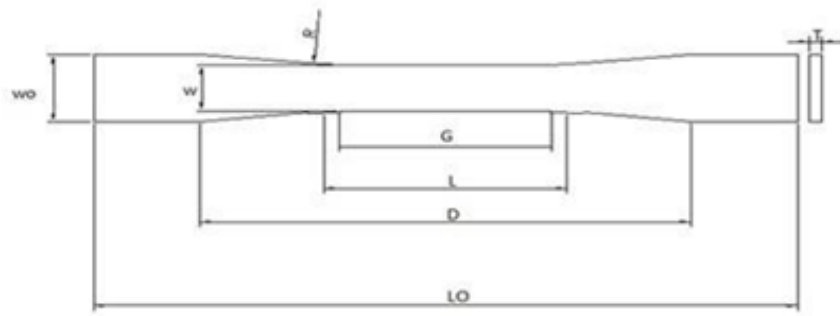


Figure 2. Tensile test specimen according to ASTM D638-01

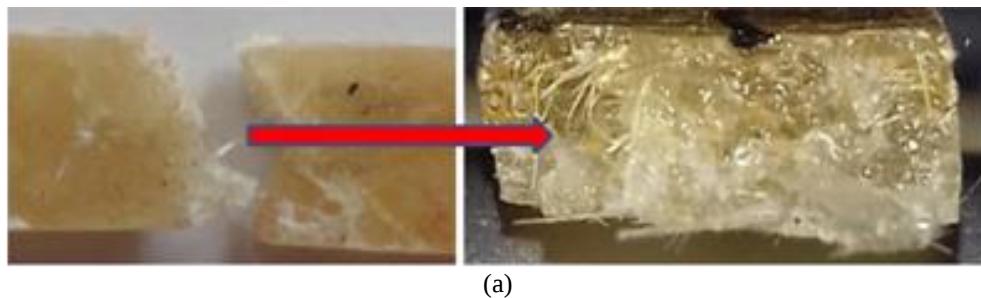
Table 2. Parameter ASTM D638-01

No	Parameter	Value
1	W	Width of narrow section, 13 mm, $\pm 0,5$ mm
2	L	Length of narrow section, 57 mm, $\pm 0,5$ mm
3	WO	Width overall, 19 mm, $\pm 6,4$ mm
4	LO	Length overall, 165 mm
5	G	Gage length, 50 mm, $\pm 0,25$ mm
6	D	Distance between grips, 115 mm, ± 5 mm
7	R	Radius of fillet, 76 mm, ± 1 mm

3. RESULTS AND DISCUSSION

The data from the composite tensile test results have a fairly wide data distribution. This can be caused by several factors, such as the lack of uniform fiber condition and uneven mixture of resin and fiber in the mold, the presence of voids / holes in the composite that cause damage before testing occurs, but also because of the influence of the position of the fibers which are not mutually exclusive, which causes easy cracking of the composite in the matrix. In theory the length of the fiber also affects its strength, short fibers have less strength than long fibers. However, the results of the tensile test are reasonable because the results of research on natural fiber composites by other researchers also have a wide distribution of data.

From the results of tensile testing of composite specimens reinforced with glass fiber and pineapple fiber with an epoxy matrix, it can be seen how the bond that occurs between the fiber and the matrix by looking at the results of the fractures that occur in the specimen. The following is a picture of the fracture tensile test results for pineapple fiber and glass fiber composites:



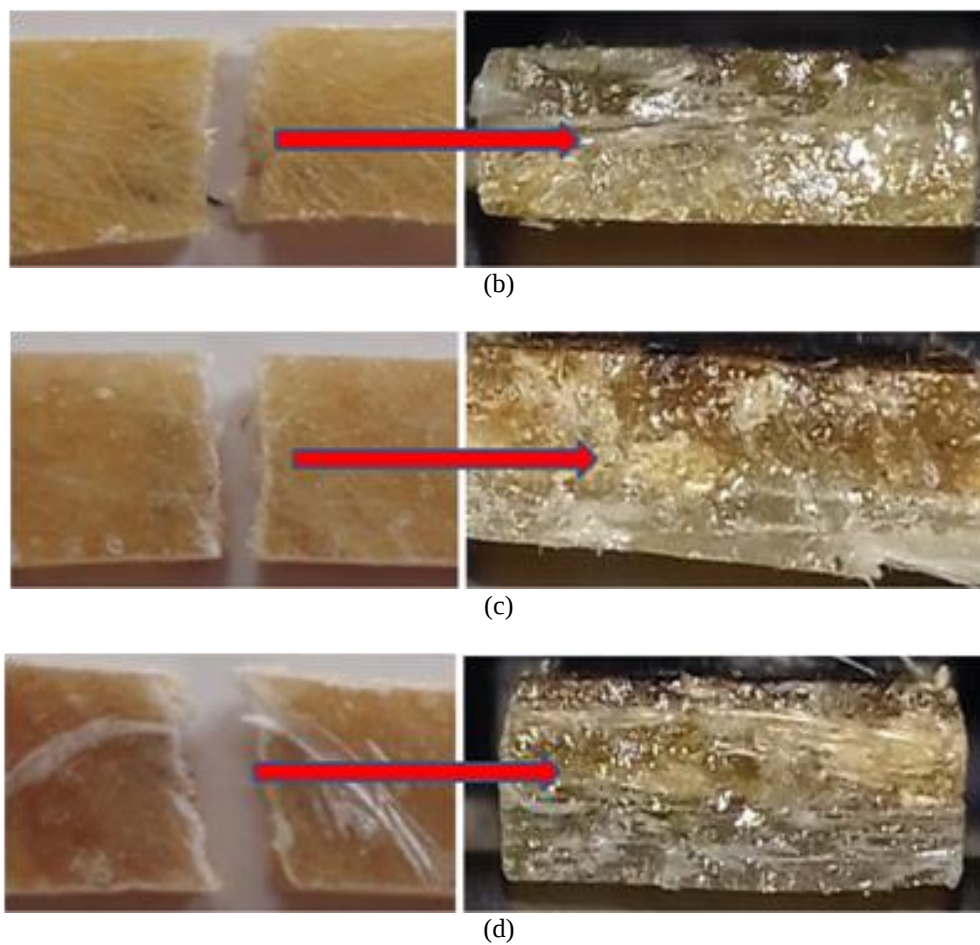
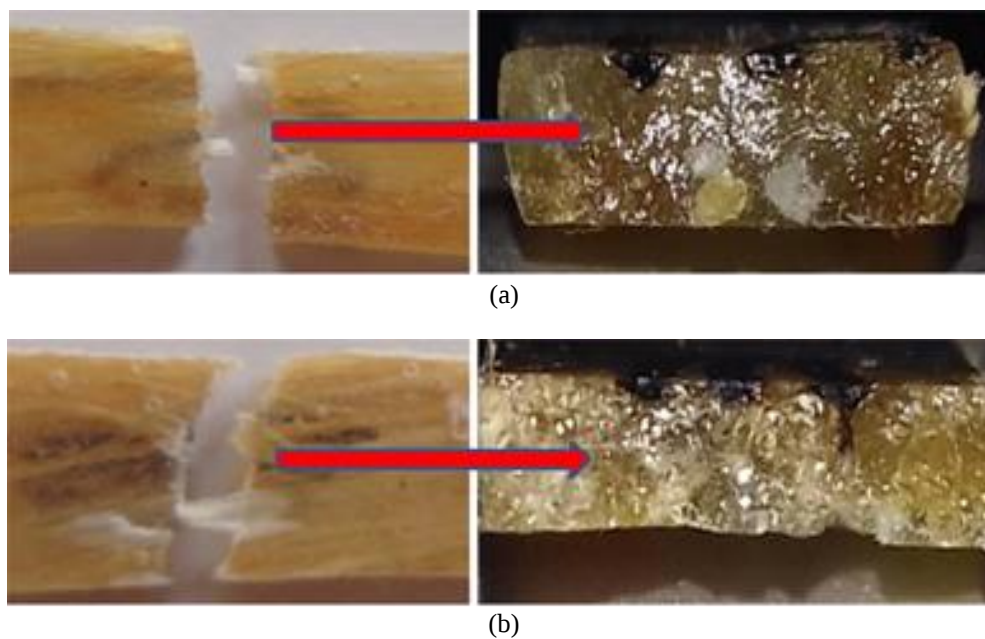


Figure 3. Composite Specimen Tensile Testing with Random Fiber Orientation
(a) 10% fiber, (b) 15% fiber, (c) 20% fiber, (d) 25% fiber



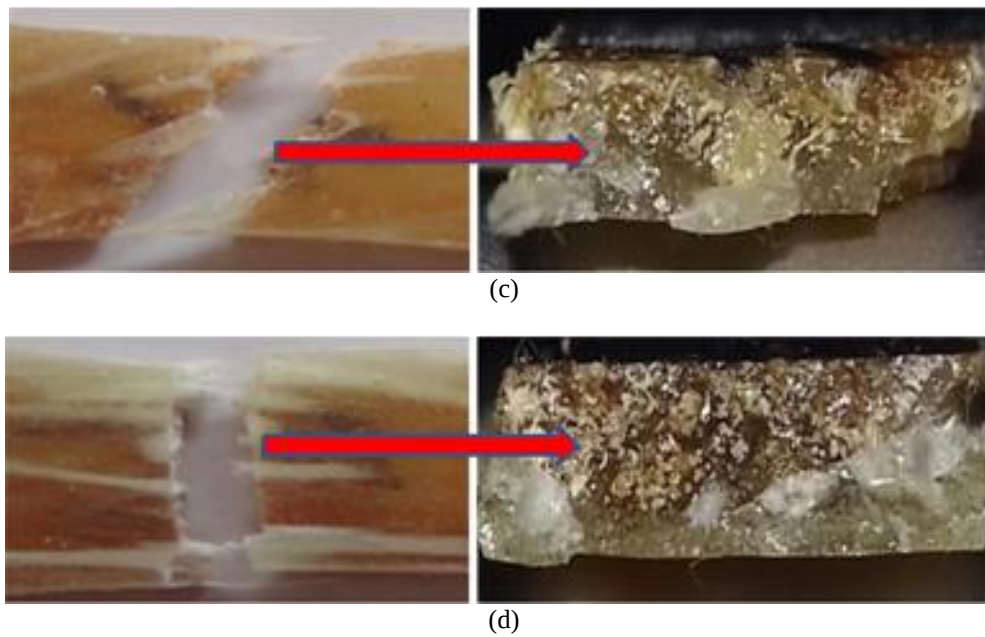


Figure 4. Composite Specimen Tensile Testing with Horizontal Fiber Orientation
(a) 10% fiber, (b) 15% fiber, (c) 20% fiber, (d) 25% fiber

In this test, we can see that in the 10% volume fraction random fiber orientation composite, single debonding fractures occur, while 15%, 20%, 25% single fractures occur and in 20% horizontal fiber orientation composites there are multiple fractures and debonding, while in the fiber orientation composites, multiple fractures occur. horizontally with fiber volume fraction of 10%, 15% and 25%, single fracture and fiber pullout occurred. Fiber pullout occurs in glass fiber, while pineapple fiber has a good bond with the epoxy matrix. This happens because Epoxy contains chemical groups, including C = C, O-H and C-H. The presence of O-H groups indicates that the epoxy has the potential to interact with the O-H groups present in pineapple leaf fiber [12]. The natural fiber is currently widely practical in aerospace applications and the transportation sector. The problem that often arises is the area of failure can be hardly predicted. This condition making it difficult to use fiber in a more composite application. The determination of this study is to examine the fracture area of woven natural fiber composites. Hibiscus tiliaceus bast fibers, as reinforcement, were prepared with alkali treatment using NaOH solution and then were added by the coupling agent. The composite was designed using a woven fiber arrangement with 60:40 fiber-matrices mass relation using a vacuum pressure resin infusion method [7].

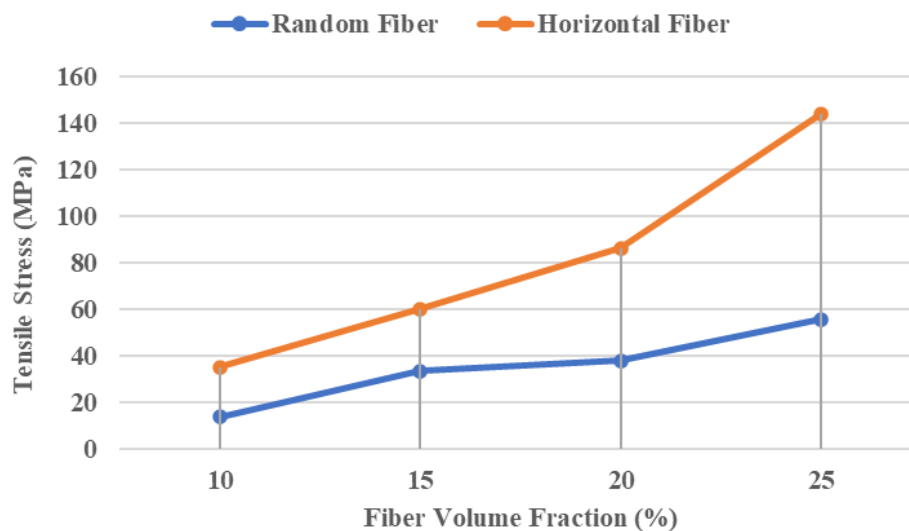


Figure 5. Graph of Tensile Stress - Fiber Volume Fraction
[29]

In the tensile test of glass fiber and pineapple fiber reinforced composites with epoxy resin, a graph of the relationship between tensile stress and fiber volume fraction was obtained as shown above. In the graph above, it can be seen that the composite with a horizontal fiber orientation with a volume fraction of 10% is 34.83 MPa, a volume fraction of 15% is 59.92 MPa, a volume fraction of 20% is 86.20 MPa and a volume fraction of 25% is 144.04 MPa. While the random fiber orientation at 10% volume fraction is 13.45 Mpa, 15% volume fraction is 33.26 Mpa, 20% volume fraction is 37.69 Mpa, and at 25% volume fraction is 55.51 Mpa. Thus, it is known that the higher the percentage of fiber, the higher the stress will be, and conversely, the smaller the percentage of fiber, the smaller the stress will be. This is due to the increase in the mass of the fiber fraction which has strong properties. Meanwhile, the largest tensile stress is in the 25% volume fraction composite with a horizontal orientation compared to the 25% volume fraction composite with a random orientation, this is because in the random orientation the fiber direction is irregular, so during the tensile test the results will be better for the composite with a horizontal fiber orientation. parallel to the tensile test.

This tensile strength study is the same as that conducted by Hariyanto (2009) on the effect of volume fraction of kenaf and rayon fiber composites arranged in a straight line with a polyester matrix on the tensile and impact strength. The tensile strength of polyester matrix kenaf fiber at 10% volume fraction is 22.04 MPa, 15% volume fraction is 28.35 MPa and 20% volume fraction is 38.32 MPa. The highest value is in the volume fraction of 20% and the lowest is in the volume fraction of 10%. Biocomposite is an innovation of renewable material in engineering made from the bark fiber of waru (*Hibiscus tiliaceus*, the bark is ecologically friendly and has the potential to be developed. The purpose of this study is to modify biocomposite by adding methacryloxypropyltrimethoxysilane-coupling mediator on waru bark fiber (*Hibiscus tiliaceus*) as an effort to improve tensile properties. Waru bast fibers, as fortification, were prepared by alkali process using 6% NaOH resolution for 120 minutes and then added 0.75% coupling agent and ordered using continuous fibers with 0/0, 0/90 and 45/45 orientation [16]. From the results of tensile testing of composites of pineapple fiber and glass fiber with an epoxy resin matrix, the tensile strain data are obtained as follows:

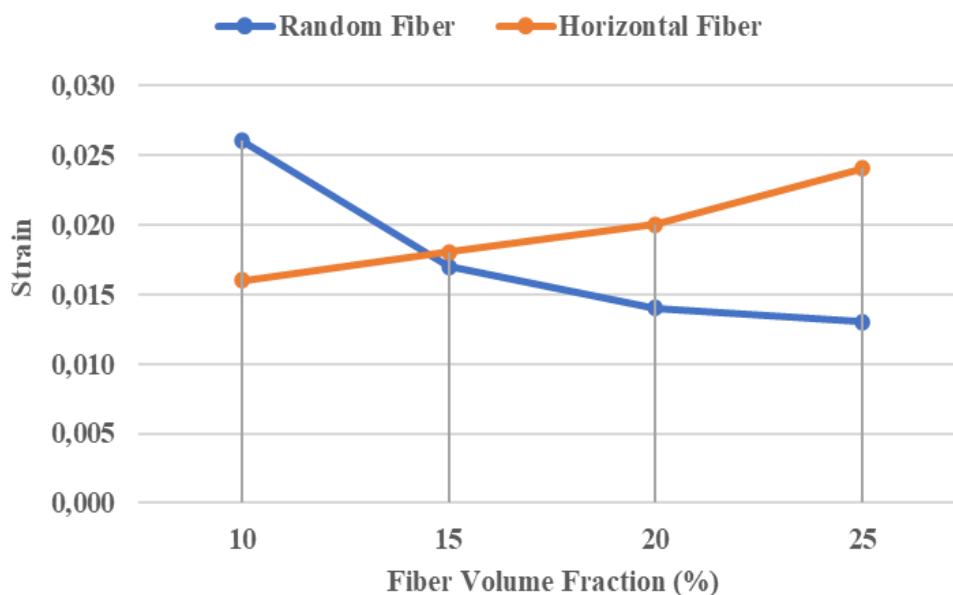


Figure 6. Graph of Strain - Fiber Volume Fraction

Figure 6. the graph of the relationship between strain and fiber volume fraction shows that the strain in the tensile test of the glass fiber composite specimen and the epoxy matrix pineapple fiber with random orientation at the volume fraction of 10% has the highest tensile strain, which is 0.026 mm/mm. while the lowest was in the volume fraction of 20% and 25%, namely 0.014 mm/mm. Meanwhile, in the horizontal fiber orientation, the highest strain was in the 25% volume fraction, which was 0.024 mm/mm and the lowest was in the 10% and 15% volume fractions with the same average amount of 0.016. Thus, it can be concluded that the tensile strain in random fiber orientation has fewer volume fractions, the higher the tensile strain, this happens because in the 25% volume fraction the mass of the fiber is large but in an irregular direction so it will become more brittle than the 10% volume fraction. whereas in horizontal fiber orientation, the higher the fiber volume fraction, the higher the tensile strain, this is due to the small number of matrices and the strong and

flexible nature of the fiber. From the results of tensile testing of composites of pineapple fiber and glass fiber with an epoxy resin matrix, the modulus of elasticity data is obtained as follows:

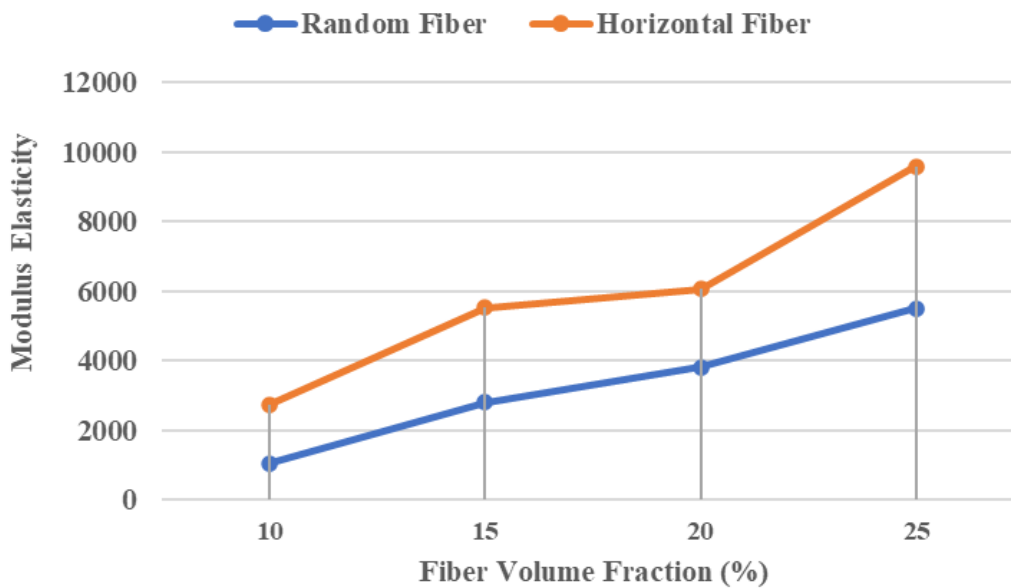


Figure 7. Graph of Elasticity Modulus Relationship and Fiber Volume Fraction

According to the graph of the relationship between the modulus of elasticity and the volume fraction of the fiber above, it shows that the composite with a random orientation with a volume fraction of 10% is 1041.55 Mpa, a volume fraction of 15% is 2803.65 Mpa, a volume fraction of 20% is 3806.28 Mpa, a volume fraction of 25 % of 5501.94 MPa. In the composite variation with horizontal fiber orientation, the volume fraction of 10% is 2744.18 Mpa, the 15% volume fraction is 5528.13 Mpa, the 20% volume fraction is 6065.34 Mpa, and the 25% volume fraction is 9580.39 Mpa. This is because by reducing the matrix mass it will increase the elasticity of a material, if given a mass fraction above 25%, the elasticity of a composite material will be higher, and vice versa if there is a fraction below 25% the elasticity will decrease.

The results of this study are the same as what has been done by Hariyanto (2009) regarding the effect of volume fraction of kenaf and rayon fiber composites arranged in a straight line with a polyester matrix on the tensile and impact strength [20]. The modulus produced in the tests carried out by Hariyanto (2009) is the largest in rayon fiber composites with a volume fraction = 20% polyester matrix of 286.37 MPa, next with a volume fraction = 15% polyester matrix which is 267.63 MPa, and the smallest is at volume fraction = 10% polyester matrix of 173.52 MPa. Meanwhile, the modulus of elasticity in the polyester matrix kenaf composite also increased along with the increase in the volume fraction of fiber = 10% by 179.26 MPa, volume fraction = 15% by 221.62 MPa, and volume fraction = 20% by 251.14 MPa.

The use of natural fibers as an alternative material in transportation applications offers a number of advantages, especially in terms of good mechanical properties. (1) High Tension Strength : Natural fibers have a high tension strength. This strength allows natural fibers to withstand significant mechanical loads, which is very important in transportation applications. Vehicles, bridges, and other structures made from natural fibers can maintain their strength and structural integrity under a wide range of environmental and mechanical conditions. (2) Lightweight : One of the main advantages of natural fibers is their low weight compared to conventional materials such as steel. The lightness of natural fibers contributes to the reduction of vehicle weight, which in turn improves fuel efficiency in vehicles. It can also reduce structural loads on bridges and roads, extending the service life of transportation infrastructure. (3) Resistant to Vibration : The vibration-damping properties of natural fibers make them ideal for applications that require vibration isolation. In vehicles, natural fibers can be used in springs or bearings to dampen vibration, improve passenger comfort and reduce component wear. (4) Environmentally Friendly : One of the most important aspects of using natural fibers is their positive impact on the environment. Natural fibers are usually obtained from renewable natural resources such as plants and have a lower carbon footprint compared to traditional fibers.

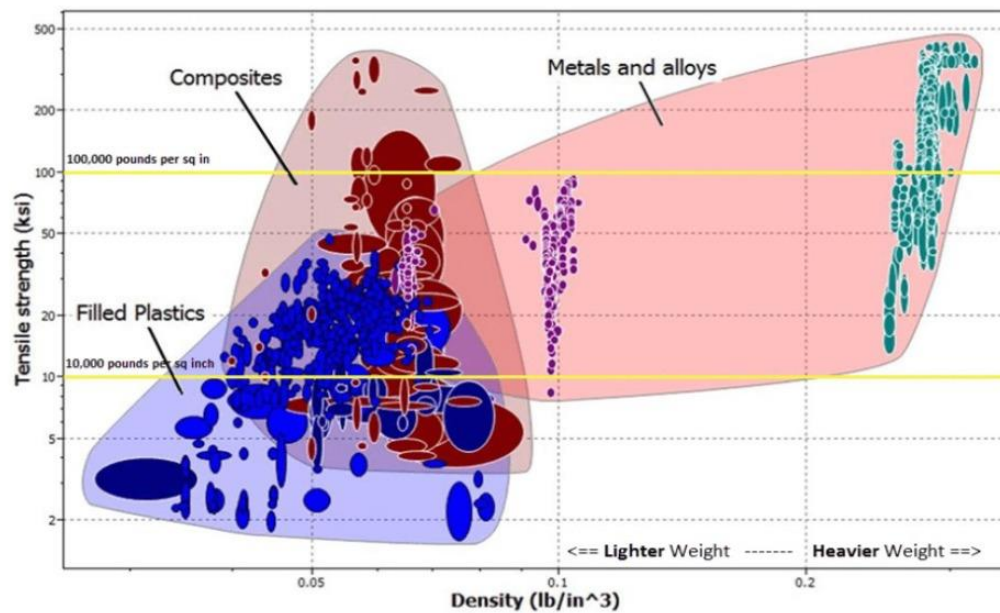


Figure 8. Automotive materials tensile strength vs density [3] [21]

With good mechanical properties, this research can provide an alternative to using natural fibers that are more environmentally friendly for various transportation applications. Figure 8 is a graph of material tensile strength vs density. The diagram shows that metals, plastics and composites have equivalent mechanical properties. The strength-to-weight ratio of composites enables transportation manufacturers to provide lightweight cars.

4. CONCLUSION

Based on the results of testing and discussion, the following conclusions can be drawn: The tensile stress of the composite horizontally increased in tensile strength with the addition of fiber volume fractions of 10% , 15%, 20%, and 25% with tensile strength values 34.83 MPa, 59.92 MPa, 86.20 MPa, and 144.04 MPa this was due to the strong and flexible nature of the fiber. The strain of the horizontally oriented composite specimen increased with the addition of the volume fraction, on the contrary, the random fiber orientation decreased with the addition of fiber; this is because in the horizontal fiber orientation the fiber direction is in the same direction as the tensile test. The modulus of elasticity in both composites with random and horizontal fiber orientations increased with increasing fiber volume fraction. The composite fracture of glass fiber and pineapple fiber reinforced with epoxy matrix can be classified as a single fracture type. These results can be recommended in the use of automotive material applications.

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