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The Effect of Orientation Fibres on Flexural and Tensile Properties of Arenga Pinnata Fibres Reinforced Polyester Composites

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Abstract. This paper presents flexural and tensile properties of sugar palm (Arenga pinnata) fibres-reinforced polyester composites study. The fibres were treated by alkaline solution with 5% NaOH solution for 2 hours of soaking time. The composites were prepared with different orientations of fibres (i.e. 0° + 45°, 0° + 90°, 45° + 90°, and 45° + (-45°)), while the ratio between Arenga pinnata fibres and polyester is 30 percent volume. Hand lay-up method was employed to produce the specimens. ASTM D-790 03 and ASTM D-3039 standard were employed to characterize the specimens in good sequent. As the result, the specimen with 45°+90° orientation generated maximum important values both in flexural strength (24.03 MPa) and modulus (4.01 GPa), tensile strength (23.84 MPa) and modulus elasticity (0.97 GPa). This is due to palm fibres as reinforcement that forms an angle of 90 ° or increasingly upright to the load crossing field (load of bending) and tensile load giving the effect of maximum reinforcement compared to other fibres orientations.

1. Introduction

The use of synthetic fibres as a composite reinforcement has a negative impact on the environment due to non-recyclable waste material issue. Therefore, the use of natural fibres is a solution to overcome this problem. Natural fibre composites have other advantages compared to glass fibres because they are more abundant, environmentally friendly because they can degrade naturally and are cheaper than glass fibres [1-11]. One of the widely used natural fibres is palm fibre or locally known as *ijuk* from Arenga pinnata tree.

The use of palm fibre is widely use in household needs and building materials such as brooms, doormat, ropes and roofs. Palm fibre has the advantage of being resistant to seawater and acid, slowing down the weathering of wood and preventing termite attacks [12-13]. Mechanical properties especially the tensile strength of palm fibres, have similarities with the tensile strength of coir, kenaf, bamboo and hemp fibres, which are between 138.7 MPa to 270 MPa [13]. For the tensile strength of single fibres, it is 190.29 MPa, tensile modulus 3.69 GPa, and strain 19.6% [14]. With these advantages, palm fibre is used as one of the reinforcements in potential composite materials. Palm fibre applications as reinforcement in composite materials such as automotive components [2], portable tables, safety helmets, and composite boats [12], [15-16]. In addition to palm fibre has the advantages mentioned

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earlier, it also has drawbacks, namely moisture uptake, quality variations, low thermal stability, and their lack of adequate adhesion between the fibre and the matrix [8], [10], [17-20].

In order to overcome these shortcomings or weaknesses, the researchers used physical fabrication (hybrid fabrication, calendaring, thermal treatment and stretching) and chemical treatments (acetylation, benzoylation, treatment by peroxide, treatment by isocyanate, acidic treatments, coupling agents and grafting, polymeric coating and alkalization) on natural fibres before it were then combined with a matrix or other amplifier [3], [21]. This alkalization process is often used or chosen by the treatment of palm fibres [12], [22-27]. The mechanical properties of the single fibres depend on the chemical compositions, size, shape, orientation and thickness of their cell walls [28].

This study aims to determine the effect of variations of palm fibre fibres orientation on composites structures against bending strength, bending elastic modulus, tensile strength, and tensile modulus of elasticity values. Palm fibre is expected to be used as a material for making hull replacing fibre reinforced plastic (FRP) because it is known as that palm fibre is saltwater resistant and has good mechanical value.

2. Research method

The main material in this study is palm fibre which has been soaked in a 5% NaOH solution for 2 hours. The matrix is the Yukalac BQTN-EX 157 polyester with MEXPO hardener. Percentage of volume between fibres: polyester is 30%:70%. Variations in the orientation of fibre angles used were 0° + 45°, 0° + 90°, 45° + 90° and 45° + (-45°). The bending and tensile test uses a 600kN capacity Servo Hydraulic Universal Testing Machine (UTM) tool. The standard bending test (three-point bending method) uses ASTM D-790 03 [29] with dimensions of specimens 150 mm x 15 mm x 6 mm and standard tensile tests using ASTM D-3039 [30] with dimensions of specimens 250 mm x 125 mm x 6 mm. The equation for calculating bending strength is:

$$\sigma_b = \frac{3\ P\ L}{2\ b\ d^2} \quad (1)$$

Description:
σ_b = Bending strength (MPa)
P = Pressure force (N)
L = Distance between 2 span (mm)
b = Specimen wide (mm)
d = Specimen thickness (mm)

The equation to calculate the modulus of elasticity of bending is:

$$E_b = \frac{L^3 m}{4bd^3} \quad (2)$$

Description:
E_b = Bending modulus of elasticity (GPa)x
m = Initial tangent slope on load deflection curve (N/mm)

The equation for calculating the maximum tensile strength is:

$$\sigma_t = \frac{F^{max}}{A} \quad (3)$$

Description:
σ_t = Maximum tensile strength (MPa)
F_{max} = Maximum tensile force (N)

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A = Cross section area (mm^2)

Modulus of elasticity of attraction can be calculated by equation:

$$E_t = \frac{\Delta\sigma}{\Delta\varepsilon} \tag{4}$$

Description:
E_t = Tensile modulus of elasticity (GPa)
$\Delta\sigma$ = Stress difference (MPa)
$\Delta\epsilon$ = Strain difference

3. **Result and Discussion**

3.1. Flexural strength and bending modulus elasticity

The results of testing of composite samples reinforced palm fibre with variations in fibre orientation to bending strength (flexural strength) are shown in Figure 1.

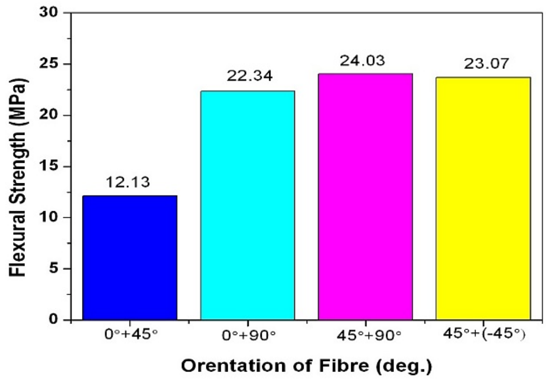

Figure 1. Graph of composites flexural strength.

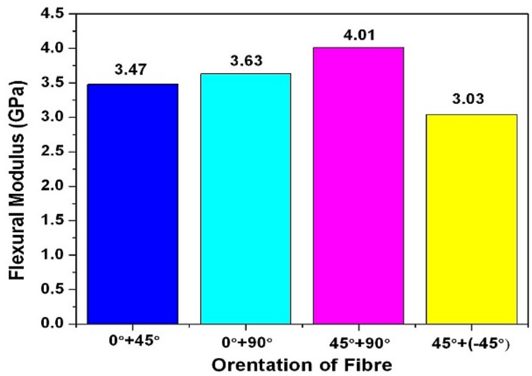

Figure 2. Graph of composites flexural modulus.

Figure 1 shows the relationship between the effect of palm fibre orientation on bending strength, where the orientation of palm fibre fibres 45 ° + 90 ° gets the highest average bending strength value of 24.03 MPa. Figure 2 is a graph that is made based on the results of the calculation of flexural modulus on variations in the fibres.

Based on Figure 2, the maximum flexural modulus value is obtained from the 45° + 90° angle orientation, where the value is 4.01 GPa. The results of the analysis of flexural properties based on Figures 1 and 2 are if the fibres of fibres as reinforcements form an angle of 90° or increasingly perpendicular to the bending load, then the value of strength and bending modulus elasticity will be higher. This is because the load of bending received by the matrix is then forwarded to palm fibre and each fibre of fibres function as a maximum reinforcement, where the load is distributed throughout the fibre [5], [14], [21].

3.2. Tensile strength and tensile modulus elasticity

Tensile testing on composite samples reinforced palm fibre with variations in fibre orientation to tensile strength is shown in Figure 3.

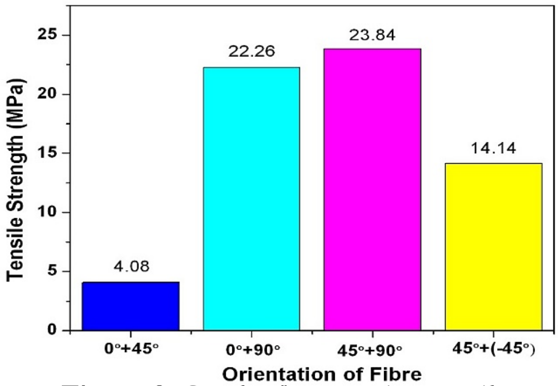

Figure 3. Graph of composites tensile strength.

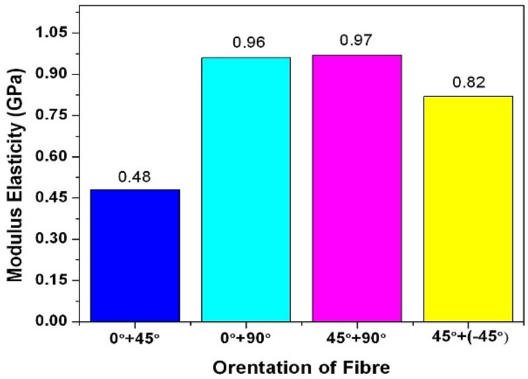

Figure 4. Graph of composites modulus elasticity.

Based on Figure 3 shows that the value of maximum tensile strength occurs at the orientation of fibres 45° + 90° which is 23.84 MPa, while from the results of calculations, the tensile modulus of elasticity is shown in Figure 4.

The calculation of maximum tensile modulus is in the composite with an orientation of fibres of 45° + 90° fibres which is equal to 0.97 GPa. Based on Figures 3 and 4 show that in composites with an orientation of 45° + 90° palm fibre not only has maximum tensile strength but also generates a maximum tensile modulus as well. In composites with fibre orientation upright to the direction of the tensile load, the maximum tensile strength and modulus will be produced. This is because the two composite components, both the matrix and the amplifier, will work together to hold the tensile load given [12].

Conclusions

Based on the conducted research, it can be concluded that:

1. Composite with the orientation of fibres of 45° + 90° fibres with polyester shows the maximum flexural and tensile properties. This is due to palm fibre as reinforcement that forms an angle of 90 ° or increasingly upright to the load crossing field (load of bending) and tensile load giving the effect of maximum reinforcement compared to other fibre orientations.
2. The reinforced composite fibres with polyester-fibre fibres show that the increase in bending and tensile strength is identical to the increase in bending and tensile modulus elasticity.

References

[1] Leman Z, Sapuan S M, Azwan M, Ahmad M M H M and Maleque M A 2008 *J. Polymer-Plastics Technology and Engineering* **47** 606-612

[2] Faris M A O and Sapuan S M 2014 *J. Cleaner Production* **66** 347-354

[3] Ahmad Y A M and Naser A H 2019 *J. Composite Science* **3 27.**

[4] Shahinur S and Hasan M 2019 Reference Module in Materials Science and Materials Engineering 1-9

[5] Begum K and Islam M A 2013 *Res. J. Engineering Sciences* **2** 3 46-53

[6] Sahari J, Sapuan S M, Zainudin E S and Maleque M A 2013 *J. Materials and Design* **49** 285-89

[7] Huzaifah M R M, Sapuan S M, Leman Z and Ishak M R 2019 *J. Fibre and Polymers* **20** 51 1077-84

[8] Rashid B, Leman Z, Jawaid M, Ghazali M J and Ishak M R 2016 *Intl. J. Precision Engineering and Manufacturing* **17** 8 1001-08

[9] Leman Z, Sastra H Y, Sapuan S M, Hamdan M M and Maleque M A 2005 *Journal of Applied Technology* **3**.1 14-19

[10] Sastra H Y, Siregar J P, Sapuan S M and Hamdan M M 2006 *J. Polymer-Plastics Technology and Engineering* **45** 149-155

[11] Ishak M R, Leman Z, Sapuan, S M, Salleh M Y and Misri S 2009 *International Journal of Mechanical and Materilas Engineering* **4** 3 316-20

[12] Ishak M R, Sapuan S M, Leman Z, Rahman M Z A, Anwar U M K and Siregar J P 2013 *J. Carbohydrate Polymers* **91** 699-710

[13] Norizan M N, Abdan K, Sapuan S M and Mohamed R 2017 *J. Physical Science* **28** 3 115-36

[14] Bachtiar D, Sapuan S M, Zainudin E S, Khaline A and Dahlan K Z M 2010 *IOP Conf. S: Materials Science and Engineering* **11** 012012

[15] Ishak M R, Sapuan S M, Leman Z, Rahman M Z A and Anwar U M K 2012 *J. Thermal Analysis and Calorimetry* **109** 981-989

[16] Misri S, Leman Z, Sapuan S M and Ishak M R 2009 *IOP Conf. Ser.: Materials Science and Enineering* **11** 012015

[17] Leman Z, Sapuan S M, Saifol A M, Maleque, M A and Ahmad M M H M 2008 *J. Material and Design* **29** 1666-70

[18] Pulungan M A, Sutikno and Sani M S M "Analysis of Bulletproof Vest Made from Fiber Carbon Composite and Hollow Glass Microsphere (HGM) in Absorbing Energy due to Projectile Impact" IOP Conf. Ser. Mater. Sci. Eng. 206 012001, 2019

[19] Sani M S M, Abdullah N A Z, Zahari S N, Siregar J P and Rahman M M "Finite element model updating of natural fibre reinforced composite structure in structural dynamics" MATEC Web of Conferences 83 03007, 2016

[20] Yaacob R M, Hashim M A H and Sani M S M "Finite element modeling and updating of the composite plate structure" IOP Conf. Ser. Mater. Sci. Eng. 100 01201, 2019

[21] Sonar T, Patil S, Deshmukh V and Achary R 2015 *IOSR J. Mechanical and Civil Engineering* 142-7

[22] Bledzki A K and Gassan J 1999 *Progressin Polymer Science* **24** 221–274

[23] Bachtiar D 2008 *Mechanical Properties of Alkali-Treated Sugar Palm (Arenga Pinnata) fibre-Reinforced Epoxy Composites*.Thesis. Universiti Putra Malaysia.

[24] Bachtiar D, Sapuan S M and Hamdan M M H M 2008 *J. Materials and Design* **29** 1285–90

[25] Mohammed A A, Bachtiar D, Siregar J P and Rejab M R M 2016 *J. Mechanical Engineering and Sciences* **10** 1 1765-77

[26] Bachtiar D, Sapuan S M and Hamdan M M 2009 *Polymer-Plastics Technology and Engineering* **48** 379–83

[27] Bachtiar D, Sapuan S M, Zainudin E S, Khalina A and Dahlan K Z H M 2011 *J. BioResources* **6** 4815–23

[28] Nurazzi M N, Khalina A, Sapuan S M, Laila D A H A M, Rahman M and Hanafee Z 2017 *Pertanika Journal Science and Technology* **25(4)** 1085-102.

[29] ASTM D 790. Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials West Conshohocken, United States, ASTM International

[30] ASTM D 3039. Tensile Properties of Polymer Matrix Composite Materials West Conshohocken, United States, ASTM International Standard