Voids analysis on polyester matrix composites reinforced with a combination of *Bambusa bluemena* fiber and fiber glass from tensile test results

Akhmad Syarief*, Raliannoor, Hajar Isworo, A'yan Sabitah  
Mechanical Engineering Department, Lambung Mangkurat University  
Brigjen H. Hasan Basri, Banjarmasin 70123, Indonesia  
*Email: akhmad.syarief@ulm.ac.id

Abstract. Composites with BQTN 157-EX polyester matrix Yukalac reinforced with bambusablumeanafiber and glass fiber are used to find the right reinforcement composition. For natural fibers that are used to get special treatment, namely the separation of fibers by alkaline immersion process. The mixing process of the 2%, 2.5% and 3% reinforcement volume fraction was used for ASTM D638M-84 tensile testing variations. The maximum tensile strength is obtained in the bamboo powder and glass fiber fraction with a length of 5 mm with a value of 53.581 MPa. Void observations in the form of bubbles were carried out by quantitative metallographic analysis of ASTM E112-10 standards. The result of macroscopic enlargement, most voids in the volume fraction of reinforcement 3% of bamboo fiber haur and glass 5 mm long an average of 9 point grid. The greater the volume volume fraction of the mixed bamboo and fiberglass, increasing the likelihood of voids occurring.

Keywords: composite, natural fiber, glass fiber, macroscopic, ASTM

1. Introduction  
The development of composite materials continues to experience development, along with material demands on the quality of a product. Utilization of composite materials can be an alternative metal and non-metal materials that still need quality improvement. In the automotive industry composites have been widely used both metal and non-metal materials. This process is mostly done to reduce production costs and also preserve the environment.  

Materials used in the manufacture of composites are widely studied in order to obtain strong composites, one of which is by using natural fibers. The combination of natural fibers in composites aims to improve the mechanical properties of environmentally friendly composites. Bamboo fiber has been used in industries including textiles, paper and automotive. Glass fiber is also used in the shipping industry and household appliances.  

The use of polyester and fiber woven as fillers obtained Tensile strength tensile test results of 22.29 MPa and Impact Test with air gun compressor (AGC) maximum impact stress of 6.703 MPa.  

[4] Explore the use of fiber to strengthen meta-kaolin-based geo polymers. The yield of the 3% fiber content has a significant negative effect on the composite tensile strength when compared to
the non-reinforced matrix. Fibers increase tensile strength separately by 100% and 111% respectively, while fibers can increase by 43% and 100% respectively when compared to the strength of non-reinforced matrices. Fiber improves the mechanical properties of meta-kaolin-based geopolymers by using other natural fibers. In the study 5% (by weight) water and fiber and bamboo strips treated with alkali were added to the composite material with tensile strength increased to 45% higher than the initial specimen. The use of natural fibers can increase composite voids and especially in fiber-reinforced composite laminates. Voids can come from bubble gas trapped between layers during the buildup of the specimen layer. Water and dissolved gas species will be adsorbed on the surface of the specimen. Remaining solvents or other volatiles present in resins and voids arising from inadequate drying of fibers.

The printing process using vacuum contributes to compaction of the laminate, disposal of trapped air and evaporation of water vapor or other volatiles. Thus helping provide laminated parts with low voids and optimal mechanical properties. However, it is practically difficult because the fiber is a virtual barrier to void movement. [5,6]

2. Methods
To reduce the occurrence of voids caused by trapped gas on the sides of the fibers, in this study bamboo fibers were made in powder form. This powder-shaped fiber is expected to reduce the formation of voids in composites and still maintain its mechanical properties. This study focuses on observing void formation. Metallographic analysis study of composite bamboo fiber in the form of powder with a mixture of volume fraction of reinforcement weight between 2%, 2.5% and 3%. Based on ASTM E 112 standard to observe failures in composites such as voids and initial bubble movements [16].

![Figure 1. Research flow chart](image)

In Figure 1, the bamboo material is obtained from the felling process by paying attention to the age of the bamboo 1 year and above and continued with the fiber separation process. The bamboo
fiber used is powder with a mesh size of 100 and a fiber length of 5 mm. The mixing of bamboo fiber and glass fiber is done by calculating weight of material from filler composition of 2%, 2.5% and 3%. After become specimen, it is checked again for the weight specimen. For tensile testing, the standard is used ASTM D-638M-84. The results tensile test were taken using a digital camera for visual images. To take enlarged photos according to ASTM E 112 standard.

3. Result and discussion

3.1. Tensile test results

In tensile testing the data obtained from the results of tensile testing using the ASTM D638-14 standard consists of the maximum load that can be held and changes in length when loading occurs [16]. Testing with a certain load and tensile speed will produce the maximum strain that is able to be held by the composite. From this stress and strain calculation data will be the basis for the modulus of elasticity calculation.

Graph and table makers in this study aim to make it easier to make data analysis. With the help of graphs and tables, it is expected that analysis and comparison of variations in the volume of composites of 2%, 2.5% and 3% can be more visible.

Figure 2. a) Bamboo and glass fiber composite tensile test specimen p = 5 mm, b) Initial tensile test specimen, c) Specimens after tensile testing

Figure 2a describes the dimensions of the ASTM standard tensile test specimen size. Figure 2 (b) the specimen before testing and 2 (c) the specimen after the tensile test is carried out. Tests are carried out in material testing laboratories, previously specimens were made according to ASTM D638-14 standards [16], which are 165 mm long, 19 to 22 mm outline width, 13mm middle width, and 4 to 6 mm thickness. Specimens were made by molding each specimen tidied and shaped by a grinding machine. Specimens were made as many as 5 samples per test variant.

Tensile strength of materials obtained by manual calculation of standard formulations with reference to the results of tensile load test that can be withstand composite materials until
breaking. The material prepared is tested one by one with the test load results varying according to the readings on the test machine dial.

From the data obtained after the highest maximum tensile testing is the composition of the bamboo powder and glass fiber length of 5 mm with a variation of 3%. Tensile stress 53,581 MPa and modulus of elasticity 87,452 MPa. The approach to the theory of tensile testing conducted by Daniel A.P that presents the maximum tensile stress test data is at a 2.5% weight volume fraction of 38.57 MPa with dimensions of ASTM D-638M-84 M-1 standard test specimens [16].

This test proves that the reinforcement volume fraction by 3% can still increase the tensile stress of haur bamboo fiber composite materials. In previous tests, weight volume fractions above 5% will cause the material’s stress and modulus of elasticity to decrease.

![Figure 3. Tensile stress of volume fractions 2, 2.5 and 3% of haur bamboo fiber and glass fiber p = 5 mm compared to polyoxymethylene type plastic](image)

In Figure 3, the results of composite tensile test show that the power maximum strength in the composition of bamboo fiber and glass fiber with a length of 5 mm is 53,581 MPa approaching value of Polyoxymethylene plastic material that is 54 MPa. The While power minimum composition of bamboo powder and glass fiber with a length of 5 mm is 29.70 MPa. The average value of the composite material composition test results is 39,338 MPa. The strength value of the MPV tensile test specimen is 44.78 MPa.
Figure 4. Modulus of elasticity of tensile fractions of volume 2, 2.5 and 3% of haur bamboo fiber and glass fiber p = 5 mm compared to polyoxymethylene type plastic.

Can be seen in Figure 4 from the comparison value and measurement tensile test specimen dimensions and weight measurements of the test specimen calculation formulation. It is known that the modulus of elasticity of the composite material is the bamboo powder haur and 5 mm long glass fiber filler composition 3% ie 87.452 MPa. For the elastic modulus on the composition of at least 2.5% bamboo fiber length of 5 mm and 5 mm long glass fiber is 31.886 MPa. For Polyoximethilane plastic material elastic modulus value was 94.00 MPa and bumper material MPV is 47.96 MPa. The average value of the modulus of elasticity is 36.644 MPa.

In figure 1 and figure 2 it is known that a polyester matrix composite with a 5 mm long bamboo fiber reinforcement and a bamboo bamboo powder accompanied by another glass fiber reinforcement blend with a length of 5 mm. The greatest maximum tensile stress in the composition of bamboo powder and fiberglass is 3% variation, which is 53,581 MPa with a modulus of elasticity of 87,452 MPa.

Figure 5. Tensile test results of bamboo fiber, powder and fiberglass 2, 2.5 and 3%.
To figure 5 Tensile maximum of bamboo fiber length of 5 mm with a composition of 2%, ie 51.775 MPa. For bamboo powder maximum tensile stress value is 3% filler composition that is 41.743 MPa. Glass fibers having a maximum tensile stress on the composition of 2%, ie 45.273 MPa and a minimum value at 3% filler composition that is 34.648 MPa. Based on the results of testing of bamboo fiber has a tensile stress on the optimal composition of 2%.

The maximum stress of glass fiber using the weight volume fraction according to Daniel A.P ranges from 2.5%, 40.82 MPa [12]. The difference in the shape of the fibers and the powder makes the density of the volume reinforcement fraction further enhance the quality of the composite. In accordance with the theory made by Dwi.W.N, that for the use of glass fiber as a reinforcement polystyrene if it is to be combined with other amplifiers, it should not exceed 5% of the planned volume fraction. Because it will cause the results of tensile strength not to change significantly according to data from 530 kgf / cm2 to 640 kgf / cm2. Based on testing after 5% phr (per hundred parts of polyester) plus reinforcement variation composition does not cause an increase in tensile strength.

Macro photo aims to determine the type and shape of faults and patterns of failure that occur in composite specimens due to tensile testing. The object taken from the cross section of the broken length is the result of tensile testing. Macro enlargement is done with the Miview Microscope MV13020 model camera with 10x to 200x magnification of 1.3 M Pixels. With a variation of 70x to 150x magnification of the size of the tensile test specimen.

The test standard refers to ASTM E112-10 [17] as macro enlargement and void point determination in the form of bubbles. The Standard Test Methods for Determining Average Grain Size are used with point cointing, which is to count the number of points in a phase area divided by the total number of points.

Specimens are placed on a grading table that has been given a scale meter in millimeters and enlarged to be taken visually. Visual directed to void in the form of bubbles that occur on the composite material in order to know the main cause of the suboptimal results of composite testing. Minimum specimen enlargement is 8 (eight) times magnification. Visuals are taken with a digital camera to capture images.

Analysis of the results of visual photographs of material deformations that undergo deformation is carried out in magnification according to the standards set out in ASTM E 112-10 [17].

3.2. Macro magnification of the fiber tensile test
Data obtained from the macro magnification of the fiber tensile test is known to the amount of voids (bubbles) that occur in the composition of the reinforcement mixture of 3% bamboo fiber length of 5 mm and bamboo powder and fiberglass length of 5 mm by 9 point grid.
4. Conclusion
From the results of the macroscopic enlargement analysis data, the tensile test results obtained from several specimens discuss the evaluation and development of bamboo fiber composite materials and other natural fibers including:

- Addition of reinforcement volume fraction of 2%, 2.5% and 3% based on the volume fraction of the reinforcing fiber results in an increase in the tensile strength of the composite material. The amount of voids that occur in the composite will also increase in number if the amount of filler percentage is added.
- Maximum tensile stress occurs in 3% reinforcing fillers for powder and fiberglass. Most voids are also in the volume strengthening fraction of this composition. Shows that
bamboo fiber is able to increase the tensile strength of the composite even though the amount of voids trapped in the composite is getting bigger.

- For the reading of more specific test results, a further test can be done in the form of SEM test.

5. References

[1] R. Jeyapragash, V. Srinivasan and S. Sathiyamurthy, *Mechanical properties of natural Fiber particulate reinforced epoxy composites – A review of the literature*, Materials Today:Proceedings, https://doi.org/10.1016/j.matpr.2019.12.146

[2] A. Atiqah, M. N. M. Ansari, L. Premkumar. *Impact and hardness properties of honeycomb natural fibre reinforced epoxy composites*

[3] D. Yulianto, Syawaldi and Sarimadoni, “Analisa Pengaruh Variasi Model Komposit pada Sifat Mekanik Bemper Mobil dengan Menggunakan Metode Air Gun Compressor,” Riau, vol.1, pp.1-6, Me, 2015.

[4] Meng Wang, Peiwei Zhang, Qingguo Fei, Fei Guo, “Computational evaluation of the effects of void on the transverse tensile strengths of unidirectional composites considering thermal residual stress”, Composite Structures, Volume 227, 1 November 2019, 111287, 111287, https://doi.org/10.1016/j.compstruct.2019.111287

[5] J.R. Wood, M.G. Bader, *Void control for polymer-matrix composites (1): theoretical and experimental methods for determining the growth and collapse of gas bubbles*, Compos. Manuf. 5 (1994) 139–147, http://dx.doi.org/10.1016/0956-7143(94) 90023-X.

[6] Sofyan Arief Setyabudi, Moch. Agus Choiroon, Anindito Purnowidodo, *Effect of angle orientation lay-up on uniaxial tensile test specimen of Fiber carbon composite manufactured by using resin transfer moulding with vacuum bagging*, Materials Science and Engineering 494 (2019) 012020, doi:10.1088/1757-899X/494/1/012020

[7] J.R. Wood, M.G. Bader, *Void control for polymer-matrix composites (2): experimental evaluation of a diffusion model for the growth and collapse of gas bubbles*, Compos. Manuf. 5 (1994) 149–158, http://dx.doi.org/10.1016/0956-7143(94) 90024-8.

[8] L.K. Grunenfelder, S.R. Nutt, *Void formation in composite prepregs - effect of dissolved moisture*, Compos. Sci. Technol. 70 (2010) 2304–2309, http://dx.doi.org/10.1016/j.compscitech.2010.09.009.

[9] J. Kardos, M. Duduković, R. Dave, *Void growth and resin transport during processing of thermosetting - matrix composites - epoxy resins and composites iv - advances in polymer science*, Adv. Polym. Sci. 80 (1986) 101–123, http://dx.doi.org/10.1007/3-540-16423-5_13.

[10] S.S. Tavares, V. Michaud, J.A.E. Månson, *Through thickness air permeability of prepregs during cure*, Compos. Part A Appl. Sci. Manuf. 40 (2009) 1587–1596, http://dx.doi.org/10.1016/j.compositesa.2009.07.004.

[11] S.L. Agius, K.J.C. Magniez, B.L. Fox, *Cure behaviour and void development within rapidly cured out-of-autoclave composites*, Compos. Part B Eng. 47 (2013) 230–237, http://dx.doi.org/10.1016/j.compositesb.2012.11.020.

[12] D.A. Porwanto and L. Johar, M, April 2014, “Karakterisasi Komposit Berpenguat Serat Bambu dan Serat Glass sebagai Alternatif Bahan Baku Industri,” Material teknik industry, vol.1, pp.1-5.

[13] D. Yulianto, Syawaldi and Sarimadoni, Mei 2015 “Analisa Pengaruh Variasi Model Komposit pada Sifat Mekanik Bemper Mobil dengan Menggunakan Metode Air Gun Compressor,” Riau, vol.1, pp.1-6
[14]. Kosjoko, Juni2017, “Pengaruh Perlakuan Alkali Terhadap Kekuatan Tarik dan Bending Bahan Komposit Serat Bambu Tali (Gigantochloa Apus) Bermatriks Polyester”. Fakultas Teknik, Universitas Muhammadiyah Jember, Prosiding SENSEI.
[15]. D.W. Nurhajati, dkk. 2017. “Pengaruh bahan pengisierat kacaterhadapsi fat siks dan kristalinitas poil paduan PC/ABS”. BalaiBesarKulit, Karet, dan Plastik. Yogyakarta. Indonesia.
[16] Annual Book of Standards, 2010, ASTM D-638M-84, “Standard Test Method For Tensile Properties of Plastic”, ASTM
[17] Annual Book of Standards, 2014, ASTM E112-10, “Standard Test Methods for Determining Average Grain Size”, ASTM.