Comparison of variations of bamboo fiber reinforced epoxy composite with adding powder material for bulletproof application

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Abstract

This study aims to analyze the feasibility of applying bamboo composite material for bulletproof needs using the 70 °C chemical extraction method on bamboo fibers. Composites are made by adding aluminum powder, silicon dioxide powder, fluorocarbon powder which have different variations. From the results obtained using the chemical extraction method at 70 °C on bamboo, it shows that the strength of apus bamboo is 9.68 N/mm^2 (90 minutes), Japan 7.995 N/mm^2 (120 minutes) and Yellow 8.15 N/mm^2 (60 minutes). While the results of the tensile test on the composite material showed 20.375 N/mm^2 (3.2), 1.13% strain (2.3) and 18.98 N/mm^2 (3.2) elasticity. The impact strength is 3.37 Joules (2.1) and the ductility is 1.87 Joules/mm^2 (3.3). The bending test stress showed 92.61 MPa (3.2), 5.32% strain (1.3) and 6755.67 MPa (3.3) bending elasticity. Vicker Hardness Test 2.47052 x 10^{-07} gf/μm^2 (1.3) and water absorption 0.02% (3.2). From several ballistic test results using simulations using ansys 2018 R1 shows that the highest maximum total deformation is found in composite types of Japanese bamboo fiber 4.4461 mm, while the highest equivalent stress is in yellow bamboo 97.596 MPa, and the highest equivalent stress is in yellow bamboo 97.596 MPa, and the main stress was found in yellow bamboo. type of composite with a maximum of 102.39 MPa, while the maximum directional velocity of 258.48 mm/s is found in apus bamboo.

Key words: Bamboo, Composite, Bulletproof, Ansys 2018 R1

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1. Introduction

The development of composite materials is not only in the utilizing of synthetic fibers (fiberglass) [1] but also in the utilization of natural fibers [2][3]. Natural Composite (NACO) is one of the environmentally friendly materials [4], has a light density, is not easy to corrode [5] and has material properties that can be adjusted according to the individual preferences. Natural composite applications have been widely used, such as in lightweight body armor [6] which replaces steel materials with natural fiber materials in order to increase its protective strength.

Bamboo is an environmentally friendly biomass material and is a sustainable renewable material when compared to other materials [7]. In classification, bamboo has around 1600 species [8] which has similar mechanical characteristics to wood and is one of the fast growing plants with a growth rate of about 12 cm/day (Guadua angustifolia). Bamboo is also a perennial plant that can be harvested several times and has a high quality cellulose fiber [9]. According to the list publication, Indonesia is one of the fourth largest bamboo producers in the world after India and 11.5% of the world's bamboo species are found in Indonesia [10]. And thus, bamboo has been used as construction materials and is utilized in various other necessities so that until now, its uses and properties remains to be studied [11].

The development of composites is a material transitional history that shown the evolution from the development of metallic materials to composite materials to hybrid materials [12][13]. However, in relation to the environmental pollution and energy crisis, metal materials are indeed still used in the manufacturing of specific applications such as aluminum which is used in lithium-ion material [14] for rocket fuels, explosives, paint pigments, inks [15] and in hydro thermal manufacturing [16].

Research on natural composite by adding in other materials has actually been done considerably, however, the incorporation by the addition of metal powder can be said to have not been done as much, as was conducted by T. Raj Kumar, et al [17]. In this research, he has conducted a composite research using banana fiber combined with copper powder. From the conclusion, it was found that the resulting composite demonstrated the added strength value of the material, however, there was a fast corrosion rate that occurred due to the use of the copper powder. In addition to this, several other studies also combined bamboo fiber with aluminum oxide (Al2O3) with the results showing that there was an increase in tensile and impact strength up to 70%, but there was a decrease in the effect of 8% bamboo fiber cellulose which caused a decrease in flexural strength [18].

Therefore, in this study, bamboo fiber is used as a reinforcement, adding aluminum powder, silicon dioxide powder, fluorocarbon powder and epoxy hardener as a matrix that has different percentages for the entire material using the transfer molding resin method for its formation. While the manufacture of bamboo fiber will use a chemical extraction method involving 5% NaOH at a temperature of 70 ^{0}C with different times. Fiber production will also be continued using a mechanical extraction method in the form of a rolling mill.

In this research was carried out for the purpose or application of bulletproof which was simulated using the Ansys 2018 R1 application with testing in the form of a ballistic test. However, before the simulation is carried out, of course, experimental material testing will be carried out first to find the value of the properties with several tests.

2. Research Methode

The main ingredients used in this study are String, Yellow, and Japan bamboo fibers as reinforcement, the matrix added that is used as a binder are aluminum powder, silicon dioxide powder (SiO_2), and fluorocarbon powder. Composite material is made by applying different composition to find out which composition is better. The distribution of the composition has been determined as shown in Table 1. The matrices used in this study are epoxy resin (Eposchon A) and hardener (Eposchon B) produced by PT. Justus Kimiaraya.

Table 1. Composition

Specimen	**Fiber Bamboo %**	**Resin *Epoxy* LY556 and *Hardener* HY951 (1:1)**	***Aluminium powder %***	***Silicon dioxide powder %***	***Fluorocarbon powder %***
1	26	60	7	3	4
2	32	55	6	4	3
3	38	50	5	5	2

The following study will be utilizing the 5% NaOH chemical extraction (alkaline) method at a temperature of 70 °C [19] for the extraction of the bamboo fibers. This method involves sodium hydroxide which has been proven in several studies that the strength of the resulting fiber is better when compared to result from the test utilizing no treatment at all [20]. In this study, the thickness of the bamboo stems was determined before the extraction was carried out, namely with a thickness of 1 mm and a length of 20 cm.

For the composite production in this particular study it has been determined that the fiber used was 0.5-1 mm in diameter and the method of forming the composites is by utilizing the lay up method [21]. Furthermore, after manufacturing the composite according to the standard specimen shape, the composite will be tested to determine the characteristics of the composite material. The types of tests and standards that have been determined in this study are the tensile property test standard ISO 527-2, impact strength test ASTM D6110-04, bending test ISO 178 and the hardness vickers test ASTM D785.

3. Result and Discussions

From the manufacturing of bamboo fibers that has been conducted, a parameter ratio has been determined between how much bamboo pulp is extracted in comparison to the 5% NaOH solution. The parameters referred to were defined as 1:20 or 450 gram of bamboo pulp over 9 L of 5% NaOH solution.

Composite material is produced by paying attention to the mixture of materials according to the composition that has been determined in Table 1. Observing from the results that has been obtained in this study, it is shown that when mixing the composite materials, first mix in the epoxy and hardener, then proceed by adding the aluminum powder, silicon dioxide powder and then end it by mixing in the fluorocarbon powder. However, the process of weighing composite materials begins with weighing the aluminum powder, silicon dioxide powder, then the fluorocarbon powder, followed by the epoxy and hardener. The mixing stage process is carried out to avoid the drying speed of the composite materials in question. The weighing process that has been carried out in this study is as shown in Figure 1.

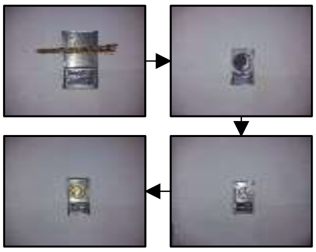


Figure 1. The gradual weighing process of composite materials.

After the weighing process is carried out up to the material mixing process, then the composite pouring process into the mold is conducted. The composite pouring process is carried out by dividing the composite material into 3 parts and first pouring 2 parts into the mold. Then the other 1 portion is poured into the mold to cover any gaps in the specimen. The pouring process conducted in this research can be seen in Figure 2 below.

Figure 2. The process of making bamboo fiber composite materials.

After the pouring process is done, then the closing process is carried out on the cover of the moulding media. This process is carried out by paying attention to the sides of the mold to avoid the spillage of material due to pressure that is occurring.

Furthermore, after the specimens are completely dry in the moulding media, the next process is to unload the moulding media to retrieve the specimens from the pouring that has been done. The drying process is carried out for 24 hours and some of the results of the composite material in this study are shown in Figure 3.

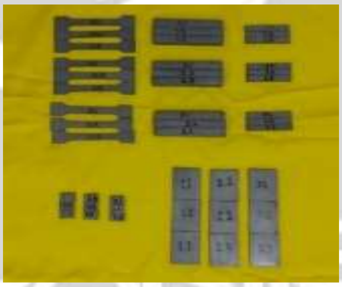


Figure 3. Results of all the composite materials.

Post curing method is a process of maximizing the final result value [22] of the polymerization of the composites. The post curing process is used to alter the resin so that it has a more optimal binding power to the fiber. The post curing process in this study was carried out using an oven machine and the post curing process was carried out by controlling the temperature to 62 °C for 4 hours (temperature increase at the increment of 5 °C/minute).

After the whole process of making the composite material has been carried out and according to the steps that have been planned, then it is followed by the testing of the composite material utilizing several tests. The intended test is to determine the characteristics of the composite material. The results of testing the characteristics of the composite material characteristics in this study are as follows.

a) Tensile Testing Results

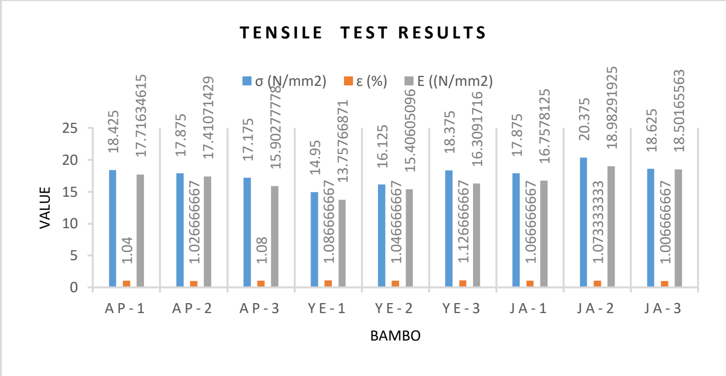


Figure 4. Composite tensile test results.

From the results of the composite stress tensile test, it can be observed that the best value from the three types of time methods that was given and the three types of bamboo is found in the second composition of Japan bamboo (JA-2) with a value of 20.375 N/mm^2. From the results of the three compositions of String bamboo, the best value was 18.425 N/mm^2 and Yellow bamboo, which was 18.375 N/mm^2. For the results of the tensile test strain, it is shown that the values of String and Yellow bamboos are graphically consistent with the equation but the same thing can not be said happened to the Japan bamboo. The highest strain value in tensile testing is found in the third composition of Yellow bamboo with a value of 1.1267%. For the elasticity of the tensile test, the highest value was found in the second composition of Japan bamboo with a value of 18.9829 N/mm^2.

b) Impact Testing Results

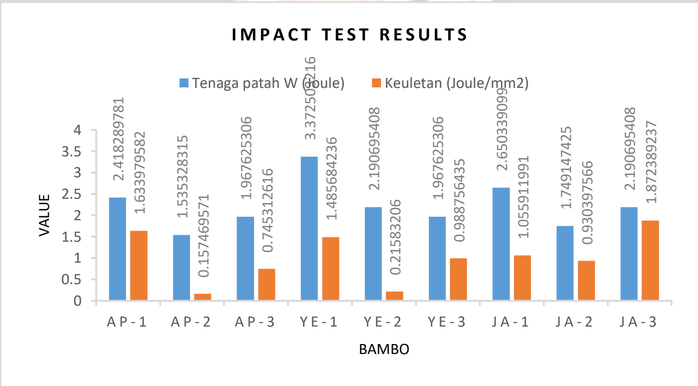


Figure 5. Composite impact test results.

Gathered from the results of the tensile fracture from the composite impact test, it can be observed that they provide consistent graphical results as happened in the tensile strain test. The consistency in question is that the ratio of the three compositions has a similarity in ratio, as in AP-1 with YE-1. Both bamboos and the composition have a higher value in common when compared to compositions 2 and 3 or have similarities graphically with the String and Yellow bamboos. The highest value in the comparison of the results on the fracture stress impact test was for YE-1 with a value of 3.3725 Joule and the second highest value was for JA-1 and the third highest value was for AP-1 bamboo with a value of 2.4183 Joule. Then from the results of the tenacity of the impact test, graphically it also has similarities to the String and Yellow bamboos. However, the highest value is for Japan bamboo with a value of 1.8724 Joules/mm^2, while for String bamboo the highest value is in composition 1 with a value of 1.6339 Joules/mm^2 and for Yellow bamboo there is also the highest value in composition 1 with a value of 1.4857 Joule/mm^2.

c) Bending Test Results

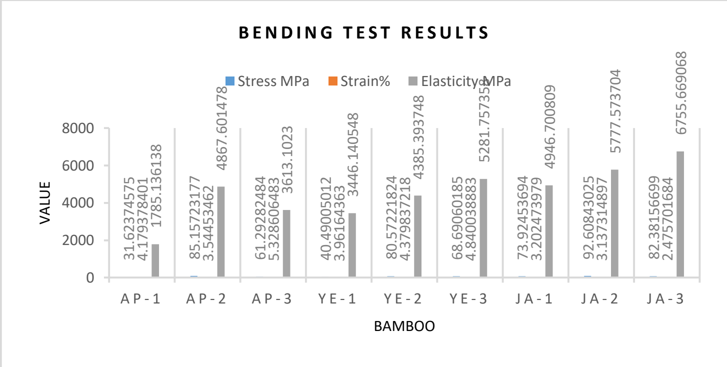


Figure 6. Composite bending test results.

From the results of the tensile bending test, the highest value from the three comparisons is found in Japan bamboo composition 2 (JA-2) at 92.6084 MPa. For String bamboo the highest value was at 85.1572 MPa found in the second composition, while for Yellow bamboo the highest value was at 80.5722 MPa found in the second composition as well. The highest value of the tensile bending test is found in the composition of the 3rd String bamboo (AP-3) with a value of 5.3286%, Yellow bamboo in the 3rd composition (YE-2) with a value of 4.8401% and Japan bamboo in the 2nd composition (JA-2) with a value of 3.2025%. For the elasticity results of the bending test, it can be observed that the highest value of the three bamboos is found in the 3rd composition of the Japan bamboo with a value of 6755.67 Mpa and the highest value in the Apus bamboo is 4867.61 MPa for the 3rd composition, while for the Yellow bamboo the highest value is found in the 2nd composition with a value of 5281.76 MPa.

d) Vicker Hardness Test Results

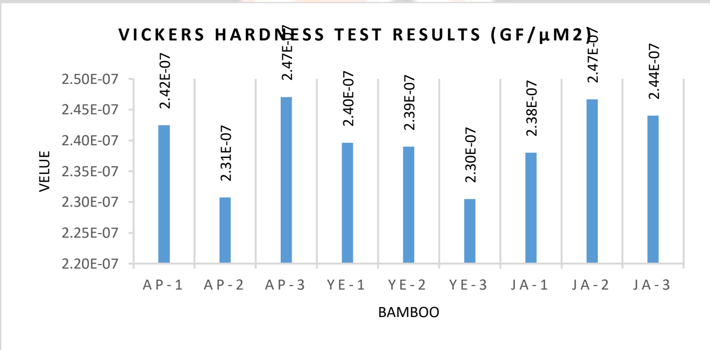
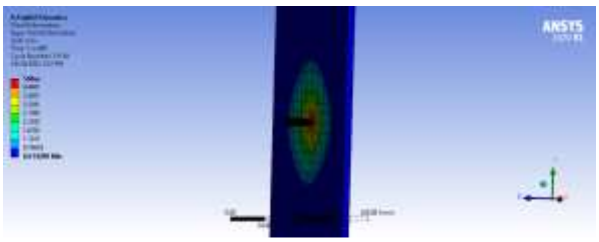


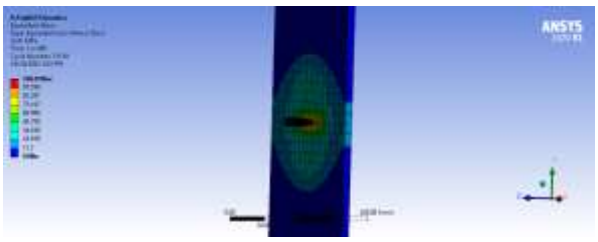
Figure 7. Composite vicker hardness test results.

In vicker hardness testing, it can be observed that the results of the three comparisons of bamboo composites are not graphically consistent. From the results of the three compositions and the three types of bamboo, the highest value was found in String bamboo composition 3 (AP-3) with a value of 2.47052x10^{-07} gf/µm^2. For Yellow bamboo the highest value was found in composition 1 with a value of 2.39602z10^{-07} gf/µm^2, while for Japan bamboo, the highest value was in the second composition at 2.4669x10^{-07} gf/µm^2.

e) Ballistic simulation



(a)



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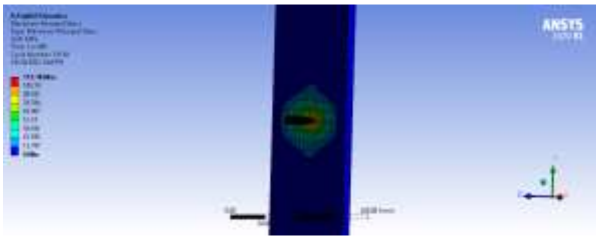
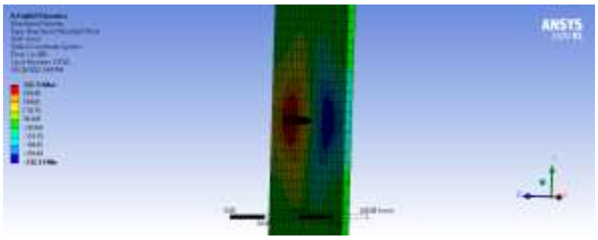


(c)



(d)

Figure 8. Ballistic simulation results (a) total deformasi, (b) equevalent stress, (c) maximum principal stress, and (d) directional velocity.

Table 2. Maximum yield of ballistic simulation

Bamboo Type	Total Deformasi (mm)	Equevalent Stress (MPa)	Maximum Principal Stress (MPa)	Directional Velocity (mm/s)
Apus	4.4459	88.285	93.04	252.03
Yellow	4.4458	97.596	102.39	258.48
Japan	4.4461	85.48	90.194	250.16

The results of the ballistic simulation show that the highest maximum total deformation is found in the Japanese bamboo fiber composite type, which is 4.4461 mm, while the highest equivalent stress is bamboo Yellow 97.596 MPa, and the maximum principal stress is found in the yellow bamboo composite type with a maximum of 102.39 MPa, while the maximum directional velocity 258.48 mm/s is found in Apus bamboo.

4. Conclusion

From the results of the three types of bamboo fibers applied as composite materials, it can be concluded that the best type of bamboo fiber material is Japanese bamboo, where the value in the tensile test for the composite type of Japanese fiber is 20.375 N/mm^2, impact is 2.6503 Joule and 1.8724 joule.mm^2, bending 92.61 MPa and Hardness 2.4669x10^{-09} gf/µm^2. Meanwhile, from the results of the ballistic test simulation conducted, the composite material using bamboo fiber and the addition of powder material did not meet the standards to be applied. In addition, of the three types of apus fiber, yellow and Japanese the best is bamboo apus. This is a question that requires continuous research from the open method of making composites to the closed process method.

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