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The Effect of Bamboo Strip on The Impact and Hardness Performances of Unsaturated Polyester Composites

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ABSTRACT

In this study the effects of bamboo strip on the impact and hardness properties were investigated. The bamboo strips with thicknesses of 1.5 mm, 2.0 mm, and 2.5 mm were used. The developed natural composite consist of bamboo strips (BS) reinforced with unsaturated polyester (UP) is produced using a hand lay-up technique. It is found that results on the impact strength of BS 2.5 mm register the highest with 4.2 J/mm2. The hardness found to be 35.7% higher than the inner layer. The Design of experiment (DOE) and Analysis of Variance (ANOVA) were employed to evaluate the effect on BS layer strips on the mechanical properties of the composites.

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INTRODUCTION

In recent years, as a result of growing environmental awareness, the use of mixture between natural fibers and thermoset or thermoplastic for the composite formulations has been increased (Atiqah *et al*. 2014; Jappes and Siva 2011; Lai *et al*. 2005; Monteiroa *et al*. 2008 and Ramesh *et al*. 2013). The natural fiber polymer composites have gained great interest and broader applications to the desirable properties of natural fiber. Among the various fibers, bamboo has a high percentage of lignin (32 %) and its microfibrillar angle is relatively small (2o – 10o) (Liu *et al*. 2012). Bamboo fiber is a good candidate as reinforcement in the natural types of composite because of its available in many countries and one of the fastest growing grasses plants. Moreover, bamboo has excellent specific mechanical properties because its fibers are aligned longitudinally (Rassiah and Ahmad 2013).

There are common polymer matrices used in composites, which is can be classified in thermoplastics, thermosets or elastomers. This polymer is known as Polyester. Polyesters, as the name implies, are polymers that contain *ester* linkages. Unsaturated Polyester has a special interest as a matrix in natural fiber composites for many reasons. The mechanical properties of polyester are most often obtained in the applications of fibers binders, films, engineering resins, and biomedical uses (Eyerer and Gettwert 2010). In addition, the matrix material must be able to be forced around the reinforcement during certain stage in the manufacture of the composite. Therefore, a combination of two materials with natural fibers provides stronger and extra corrosion-resistant improve stiffness, strength and moisture resistant behavior. These factors lead to the attractive features of bamboo specifically due to their high specific strength and modulus.

Based on the above reasons, the aim of this study is to determine the parameters that affect the mechanical properties of laminated BS/ UP composites in term of layer and thickness which are inner, middle and outer and thickness of 1.5 mm, 2.0 mm and 3.0 mm.

Experimental:

Design of Experiment:

The focus of this work is on two parameters, which are type of layer and its thicknesses. Since the levels of each factors used were determined referring to the manufacturing capability and its competency, three levels were chosen for composition of layer and thickness, and the factorial with mixed levels experimental design for design of experiments (DOE) is then used based on outcomes of Design-Expert software.

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Materials:

The internode along bamboo clum is cut according to the desired thickness of 1.5 mm, 2.0 mm, and 2.5 mm. All specimens were washed with water and dried in an oven at 600C for 72 hours to reduce its moisture contents. Unsaturated polyester (UP) type of Reversol P-9509 with the specific gravity at 25°C: 1.12, viscosity: 450-600 cps volumetric shrinkage 8% and acid value, mg KOH/g solid resin 29-34 is mixed with hardener methyl ethyl ketone peroxide (MEKP) then it is used to prepare the laminated composite.

Fabrication of Composites:

The above materials were subjected to the hand lay-up process to produce the mould of sample with 120 mm x 120 mm x 3 mm for its length, width and thickness respectively. UP is mixed with the methyl ethyl ketone peroxide (MEKP) which acted as catalyst with ratio of 100: 2 were stirred until its physical colour changed from light pink to pale yellow. The mixture was poured inside the mould until it closed the lowest surface. Then 10 BS were placed slowly on the top of the lowest surface to wet it. After that, it was poured again on the top surface of the strips and brushed it in one way to ensure it fully closed the strips. The fabricated composites of three different layers are shown in Figure 1a to Figure 1c.

Fig. 1a: Laminated Inner Strip.

Fig. 1b: Laminated Middle Strip.

Fig. 1c: Laminated Outer Strip.

Testing Standard:

The charpy impact tests were performed according to ASTM D6110 using "Pendulum Charpy Tester Model: Eurotech ET-2206" complete with hammer 50 J impact force, with angle of 120° clockwise to specimen position and the operating conditions at 25 ± 2 ° C with 50 % humidity (Figure 1d). The hardness tests are performed according to ASTM D 2240 using Shore D Durometer/ Digital Shore Tester DSAS/DSDS. The test is used to measure the depth of penetration of loaded indenter into the material. The tests were performed at 25±3 °C with 50 % of humidity and average of nine points has been taken from each composition (Figure 1e). The experimental results of each testing have been explained in detail in the earlier work (Rassiah *et al*. 2014).

RESULTS AND DISCUSSION

Table 1a shows the factor and level of layers and thickness variables, while table 1b shows the Anova for impact and hardness strength.

Charpy Impact properties:

In a normal probability plot shown in Figure 2a, the residuals impact strength demonstrated a stable data plot for impact test samples where the R2 value is 0.9953. Based on analysis of variance (Table 1b), all mean values for each group is significantly different (P-value<0.0001). It is proven that each variable gives significant effects towards impact strength performance of the composites.

Figure 1 d : Impact Sample .

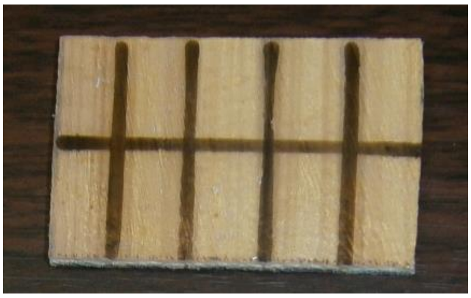

Fig. 1e: hard Sample.

Table 1a: Factor and Level.

Factor	Level 1	Level 2	Level 3
Layer (strip)	Inner	Middle	Outer
Thickness (mm)	1.5	1.5	1.5
	2.0	2.0	2.0
	2.5	2.5	2.5

Table 1b: Anova for Impact and Hardness Strength of different Bamboo Strip.

Source	Sum of Squares		Degree of Freedom		Mean Square		F (Value)		P (Value)	
	Impact	Hardness	Impact	Hardness	Impact	Hardness	Impact	Hardness	Impact	Hardness
A= Layer	3.81	3636.40	2	2	1.91	1818.20	807.17	1398.89	<0.0001	
B= Thickness	3.49	127.06	2	2	1.74	63.53	738.35	48.88	<0.0001	
AB	1.79	289.32	4	4	0.45	72.33	189.13	55.65	<0.0001	
Error	0.042	23.40	18	18	2.360E-003	1.30				
Total	9.12	4076.17	26	26						

Figure 2b shows the interaction plot for impact strength results of layer for different thicknesses. Based on this graph, 2.5 mm middle layer composites show outstanding result as a layer composite. The impact value of the inner and the outer layer is lower than the middle layer. The highest value of impact strength, that is 4.2 J/mm2, occurred at middle layer. For charpy impact test, the 2.5 mm thickness of laminated UP/BS value decreased at outer and inner layer (3.617 J/mm2 and 2.525 J/mm2), which is about 13.9% and 39.9% respectively when compared to highest middle layer. This characteristic is suitable for the inner part of bamboo in order to absorb and dissipate energy under shock. A study conducted by Li *et al*., (2002), found that the double layer reformed bamboo laminate has the largest normalized residual stress. Results for layer types in this research showed dissimilarity of impact strength performance for thickness. Figure 3 shows the samples that fail for mechanism testing.

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Hardness Properties:

Figure 4a demonstrates the normal probability plot for hardness strength, where the R2 value is 0.9943. Not only it declares as a very stable data, but the interactions between each variable, layer types, and thickness gives a significant effect towards the hardness strength performance. Based on analysis of variance, Table 1b shows that all mean values for each group is significantly different (P-value<0.0001). It is proven that each variable gives significant effects towards hardness strength performance of the composites. Meanwhile, the interaction plot of hardness strength resulted from 1.5 mm, 2.0 mm and 2.5 mm thickness respectively for different layers is displayed in Figure 4b. The results exhibited that the outer layer composites with 2.5 mm thickness gave better performance compared to the inner and the middle layer. With the significant differences in the values, it is noted that the thickness of bamboo strip will increase the hardness of the composites when it is laminated with unsaturated polyester. It is suggested that, the thinner bamboo strip for the inner and middle parts are unable to withstand hardness.

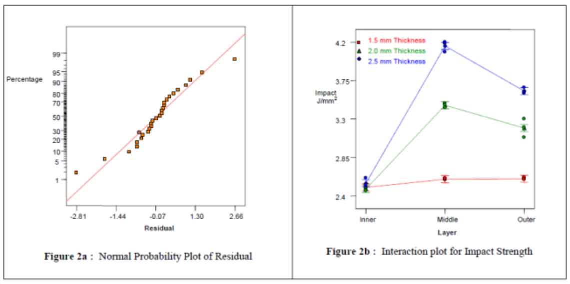

Fig. 2: Probability and Interaction plot for Impact Strength .

Fig. 3: Composite Failure .

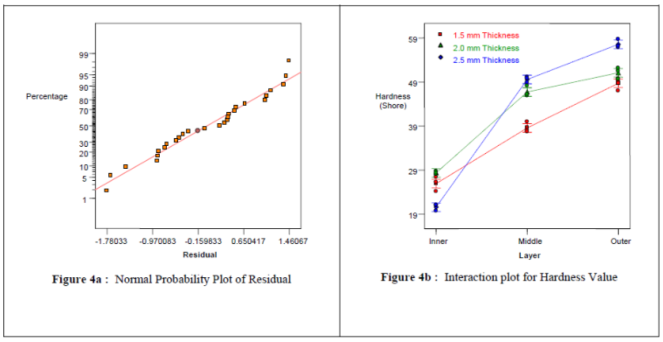

Fig. 4: Probability and Interaction plot for hardness.

Conclusion:

The obtained results are as follows:

1) ANOVA analysis has established that layer types and thicknesses of laminated unsaturated polyester and
bamboo strip give significant effects toward the recital of impact and hardness properties.

2) The middle layer laminate established better results for impact while the outer layer laminate established
better results for hardness.

3) The thicker laminate of unsaturated polyester and bamboo strip composite displays greater impact and hardness strength performance compared to the thinner layer.

4) Larger impact size was pragmatic on the thinner inner and outer laminate of unsaturated polyester and bamboo strip, whereas the thicker middle laminate of unsaturated polyester and bamboo strip structure is proven to have better impact resistance.

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