Stacking Sequence Optimization of Sugarcane Bagasse/Glass Laminate Composite Cured with Vacuum Infusion

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Abstract
The rising concern on environmental issues have led to an increased interest in composite field to look for new alternatives replacement of synthetic fiber or at least reduce their volume by filled with natural fibers. Despite of their advantages, poor compatibility between fiber and matrix and the relative high moisture absorption of natural fiber are main issue to be resolved before applying on real structural applications. Therefore, present work are aim focusing to study the optimization properties of hybrid bagasse/glass laminate for three different stacking sequence configuration of [450C/450C/600W/B/600W/450C/450C], [600W/450C/450C/B/450C/450C/600W] and [450C/600C/450C/B/450C/600C/450C]. Short bagasse fiber are prepared and was chemical treated with 4% sodium hydroxide (NaOH) concentration to reduce lignin before dried to form bagasse mat. All laminates with three different stacking sequence then are fabricated using vacuum infusion process and are tested to determine their mechanical and water absorption properties. In addition, the flowbility and formability of hybrid bagasse/glass composite are also observed. Results show hybrid bagasse composite laminate with stacking sequence of [450C/450C/600W/B/600W/450C/450C] gave highest tensile strength values of 13.51 kN. In contrast, laminate with stacking sequence of [600W/450C/450C/B/450C/450C/600W] show highest impact toughness value of 108.5 J. Furthermore, hybrid laminate with stacking sequence of W600/450/450/B/450/450/W600 also show highest water absorption resistance with only 0.53% water intake value for 14 days tested period. This low value moisture resistance percentage give fact hybrid composite bagasse/glass laminate are comparable to those conventional fiberglass composite and able to extend to application to marine structural application.

Keywords: hybrid composite, bagasse fiber, mechanical properties, water absorption.

1.0 Introduction

The use of natural fibers composite is increasing in recent years due to their low density, acceptable specific strength properties, combustible, non-toxic, low cost and biodegradability. In malaysia, composite makers are still using conventional material and fabrication technique in their production whereas synthetic fiber composite material such fiberglass were cured with hand lay-up method remains as their favourite choices. The reason is because materials are ease to find in the market and hand lay-up method process not required complicated equipment with less investment. Although these synthetic fiber show and advantages on durability and their mechanical strength properties, but the natural fibers promise much greater lower density, lower cost, recyclability and biodegradability compare to synthetic fibers. These advantages make natural fibers has potential full or semi replacement for glass fiber in composite material in future especially in marine structural application. Instead of their advantages, high moisture absorption are need to be resolve before applying to marine applications. Therefore, hybridization concept of bagasse/glass fiber are proposed to study

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and determine the bagasse capabilities in replace conventional material for boat hull application.

Many investigations have been made on the potential of the natural fibers such as bamboo, flax, kenaf, coir and jute reinforcements for plastic materials (Sathishkumar, Suresh, Nagamadhu & Krishna, 2017; Corradi, T. Isidori, Corradi & Soleri. 2009). Despite of their advantages, poor compatibility between fiber and matrix and the relative high moisture sorption of natural fiber are main issues need to be resolved. Therefore, chemical treatments including alkaline, silane, acetylation and others are proposed in modifying the fiber surface properties as was reported in previous work (Xue li, 2007; Vilay, Mariatti, Mat Taib, & Todo 2008). Their aimed is to improve the adhesion between the fiber surface and the polymer matrix, reduce water absorption and mechanical properties. Among those natural fiber, bagasse is one of are getting acceptance from many researchers and it can be used as an alternative reinforcement in composite materials. Vilay et a. (2008) was study effect of fiber surface treatment and fiber loading on the properties of bagasse fiber composite. They found that chemical treatment using Sodium Hydroxide and Acrylic Acid lower water absorption properties of bagasse fiber composite compare to those untreated bagasse fiber based composite. In addition, treated bagasse fiber also show an higher tensile strength value compare to untreated fiber composite.

Since the mechanical properties of natural fibers are lower as well as poor moisture resistance. Therefore, the inclusion of synthetic fibers could improve the performance of natural fiber based composites. The demand for hybrid composites (natural + synthetic fiber) is increasing due to recent advances in construction, automotive components, household, aircraft, marine etc. Although there are many reports about the mechanical properties of various natural fiber through hybridization with sinthetic fiber (M. Idrus et al,2015; H. Bouguessir et al.,2016), to date there are no study focusing on hybrid composite bagasse/glass and their optimization properties. Therefore, the aim of this study is to analyse optimize properties for three different kinds of bagasse/glass laminate stacking configuration on their strentgh, impact and water absorption properties. In this works, vacuum infusion method are selected rather than conventional method to cure the hybrid composite in order to reduce cycle time, reduce air voids, and improve their surface bonding between fiber and the matrice..

2.0 Methodology

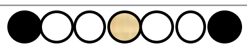
In present work, the sugarcane crops are collected from local market in Bukit Gambir, Muar Johor. Collected sugarcane crops called “bagasse” are clean with water to remove any surface impurities then dry under direct sunlight. After dried, the bagasse fiber then are cutted into length of 2 to 4mm to make it a short fiber. Pulping process then are carried out for chemical treatment with 4% concentration of Sodium Hydroxide (NaOH) about 1 to 1.5 hours to remove lignin. Finally, treated bagasse fibers are washed thoroughly with distilled water before being allowed to dry in form of fiber mat.

2.1 Specimen fabrication

Vacuum Infusion process are used to fabricate the hybrid composite laminate plate. Method are adopted since its offers more benefits than hand lay-up method resulting in stronger and lighter laminate (Saputra & Setyarso, 2017). Three types of hybrid bagasse/glass fiber composite plate with different stacking sequence; [450C/600C/450C/B/450C/600C/450C], [450C/450C/600W/B/600W/450C/450C] and [600W/450C/450C/B/ 450C/450C/600W] are fabricated using vacuum infusion process. In this project, fiberglass and infusion polyester resin was supplied by Chemrex Sdn. Bhd. Fiberglass used in this study are chopped strand 450C, 600C and woven 600W. Fiber glass at first are cut with size of 400mm x 400mm for each plies then were stack as above sequence on steel plate as illustrated in Figure 1(a). In details, Table 1 show configuration of stacking sequence used in this study. Plastic bagging then were setup onto stacked fiber laminate and infusion polyester resin was infuse using 10 CFM vacuum pump (see Fig. 1(b)). Figure 2 shows the fabrication process of composite laminate plate specimen made of hybrid bagasse fiber using vacuum infusion process. The weight of the matrix, hardener and fibres were recorded by using electronic weighing scales before the fabrication process was done. The mixing ratio of the hardener, methyl ethyl ketone peroxide, was 1% from the weight of the polyester.

After plate are cured, the hybrid laminate plate are cut by using a vertical band saw according to ASTM standard procedure. Specimen geometry for specimen plate prepared in this study are 250mm x 25mm x 5mm (lxwxt) according to ASTM D5083 for tensile test; size geometry of 55mm length x 10mm width x 5mm thick with v notch for izod test according to ISO 148 ; and cut off size geometry of 50mm x 50mm x 5mm ((lxwxt)) following ASTM D570 standard for water absorption test. The average thickness of the composites plate are in the range of 5.0 – 5.3mm.

Table 1: Stacking sequence configuration of hybrid bagasse/glass laminate

Symbol	Configuration		Wt% of fibers		thickness (mm)
	Stacking Sequence	designation	Baggasse	Glass	
A	450C/600C/450C/B/450C/600C/450C		20	30	5.1
B	450C/450C/600W/B/600W/450C/450C		20	30	5.3
C	600W/450C/450C/B/450C/450C/600W		20	30	5.2

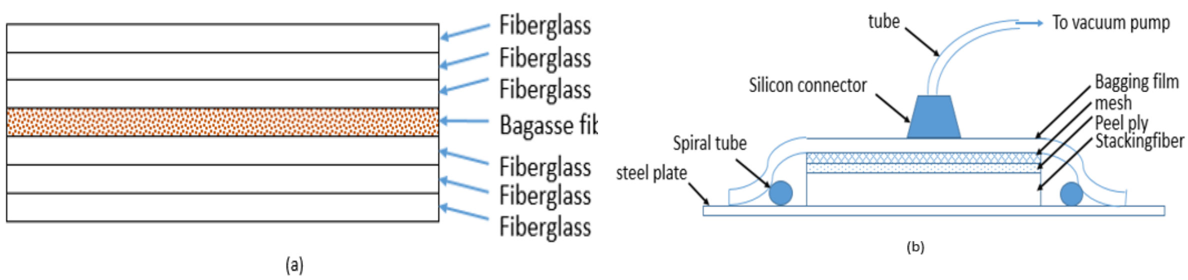


Figure 1: Illustratration of a) specimen plate stacking sequence, b) vacuum bagging setup

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Figure 2: Vacuum infusion setup for fabrication of plate specimen

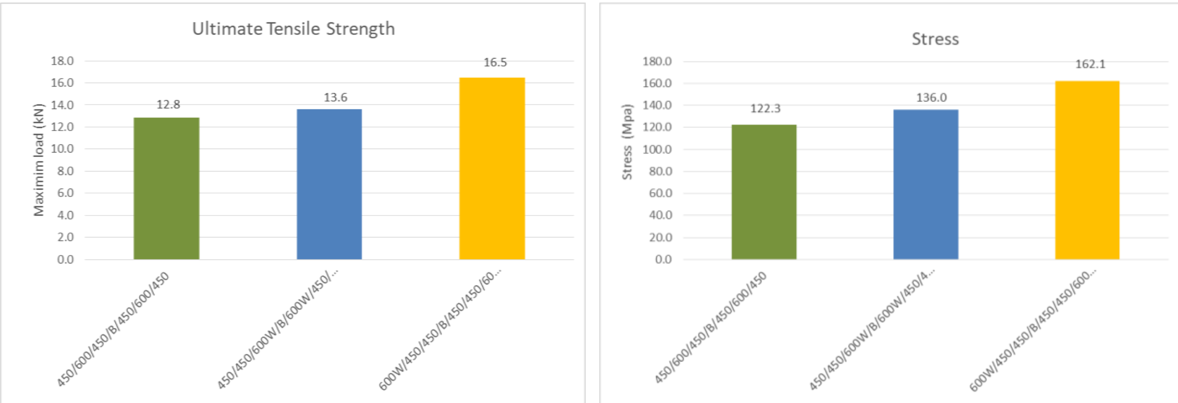
2.2 Experimental

Three kinds of test are conducted to determine the optimize properties of three different stacking configuration laminate plate specimens which are tensile test, charpy test and water absorption test. Tensile tests are carried out using Instron universal testing machine to determine the tensile strength properties of all types stacking sequence with a crosshead speed of 2mm/min. Each specimen are tested by placing it between grips of testing machine and tightened to prevent slippage and not to a point where the specimen will be scratch and A total of three specimens for each types stacking configuration laminates bagasse/glass are tested. Stress-strain curves are obtained and the average values for tensile strength are reported as a result. Next, Izod impact test are carry out to measure the amount of energy absorbed by the specimen during fracture. The Impact test then performed using Monitor impact tester model 43-02-01. The capacity of the hammer used was 5 Joules.

In order to determine the water resistance for hybrid laminate, water absorption test are carried out by immersion laminate specimens in water bath of distilled water at room temperature. At first, all specimens are dried in an oven at 50°C for 12 hours and then were cooled to room temperature. Then, specimen are soaked and immerse in distilled water for 24 hours. After 24 hours, the sample are remove from distilled water and dry using dry cloth. Weight of each specimen using digital scale are recorded. This process are repeated, to weigh the specimens regularly over 14 days of water immersion. At different periods of time, the percentage of weight gain was calculated and it was plotted versus square root of water immersion time. As a result, the average value was reported.

3.0 Results and discussion

Figure 3(a)&(b) shows the average ultimate tensile strength and stress of hybrid composite laminate with woven roving plies was observed to be higher than that hybrid laminate with non woven plies. It can be seen that by replacing two plies with woven instead of non woven, the tensile strength increase between 6.25 to 28.9% than hybrid laminate with non woven plies. This is because woven roving absorbed more matrix than the chopped strand mat thereby impacting more strength to the composite than chopped strand mat. Moreover, the properties are enhanced because plain weave woven ply with 90/0 has higher load bearing to take up high static loads before it fails, and it has good interfacial bonding with the polymer matrix. Furthermore, position of woven plies in laminate also give significant effect on the tensile strength and tensile stress. Result shows that hybrid bagasse/glass laminate with woven at outer plies exhibit higher tensile strength compare to hybrid bagasse/glass laminate with woven plies that place at inner side with values strength of 16.5 kN and 13.6 kN, respectively. This give facts that stacking and correct positioning of woven stacking sequence could increase up to 21% of their strength.



(a) (b)

Figure 3 : Strength properties of hybrid laminate on a) tensile strength, b) stress

The stacking sequence effect of hybrid bagasse/glass composites laminate on resistance energy to impact are illustrated in figure 4. It can be observed that impact strength in laminate with stacking sequence of [450C/450C/600W/B/600W/450C/450C] show highest absorbed energy values of 12.7 J followed by hybrid laminate [600W/450C/450C/B/450C/450C/600W] and [450C/600C/450C/B/450C/600C/450C] with value of 10.9 J and 4.2 J, respectively. Figure 5 show water absorption properties of three different types stacking laminate. Results show after 14 days of distilled water immersion, specimen with configuration [450W/450W/600W/B/600W/450C/405C] give the maximum percentage weight gain about 1.13% followed by specimen [450C/600C/450C/B/450C/600C/450C] and [600W/450C/450C/B/450C/450C/600W] with percentage gain values of 0.96% and 0.53%, respectively. This slight difference can be explained due to the presence and position of woven plies in laminate. From the results, positioning the woven at the outer plies exhibit significant higher water resistance to the laminate compare to laminate where woven place near side to side of bagasse ply. In contrast, woven place near to bagasse fiber was found not efficient to prevent water from transporting through fiber matrice interface and show weaker bonding between woven and bagasse.

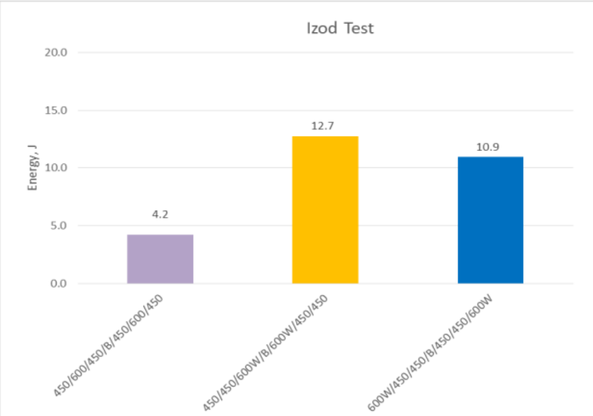


Figure 4 : Izod impact test

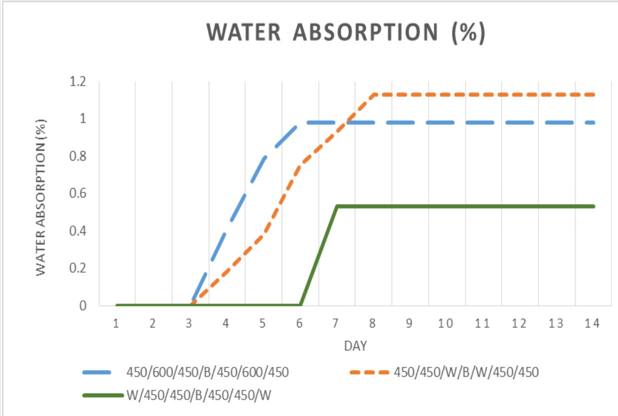


Figure 5 : Water absorption

4.0 Conclusion

All the numerous experimental tests gathered important information about the hybrid bagasse/glass composites and the best optimum stacking configuration that can be considered when applying to certain specific applications. Following conclusions can be drawn from above study:

a. Stacking sequence, and appearance of woven and non woven plies give significant effect to strength properties of hybrid laminate. Correct positioning of woven plies increase up to 21% of the laminate strength properties.
b. Bagasse fiber offer a possible alternative reinforcement to glass and comparable moisture resistance through hybridization. In addition, stacking sequence give significant effect to the water intake values where placing woven at outer ply improve more water resistance to hybrid composite plate.
c. Bagasse fiber and synthethic fiberglass show good bonding between fiber and matrix through vacuum infusion without no void are found.

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