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A theoretical and experimental study of young's modulus of bamboo fiber reinforced polymer composite laminates with different fiber volume percentage

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Abstract

Due to superior mechanical properties fiber reinforced polymer composite are used in various applications such as medical, sports, aerospace etc. The percentage of the fiber volume fraction affects the medical properties of uni-directional bamboo/epoxy composite laminates. Present study deals with experimental and theoretical investigations of longitudinal elastic modulus of uni-directional bamboo/epoxy composite with different volume fraction of 30%, 40%, 50%, 60% and 70%. Uni-directional bamboo/epoxy composite laminates were prepared by using hand lay-up technique. A number of experiments were performed to study the longitudinal elastic modulus with different fiber volume fraction in laminates. The experimental observations indicate that longitudinal elastic modulus increase with increase in fiber volume fraction percentage. A good agreement was observed between the experimental and theoretical results.

Keywords: Young's modulus, epoxy, composite, bamboo fiber, polymer, uni-directional, hand lay-up.

INTRODUCTION

Composite plays an important role in day today life in this era. Since composites have better mechanical, electrical and thermal properties than parent fiber, it makes it more practical and useful in various fields like household, industries, labs etc. Many researchers have performed different studies in this field regarding their properties like stiffness, longitudinal and compressive strength with fiber and epoxy with different volume ratio.

Adams and Singh [1] studied the dynamic properties of various fiber reinforced polymer composite expose to steam at hot and wet condition. Mechanical properties such as poison's ratio, modulus and strength of untreated woven jute fiber fabric reinforced polymer composites was investigated by Gowda, Naidu and Chhaya [2] experimentally. Gassan and Bledzki [3] investigated experimentally the mechanical properties of NaOH treated tossa jute fiber and the effect of fiber shrinkage on the fiber structure, tensile strength and modulus. Lancin and Marhic [4] studied transmission electron microscopic of fiber reinforced metal matrix composite and effect of interface and brittle phase on their mechanical properties. Ray and Sarkar [5] performed the characterization of jute fiber for mechanical and physical properties when treated with NaOH solution by weight loss, tenacity, linear density and x-ray measurement. Ray, Sarkar, Rana and Boss also studied the effect of NaOH solution treated jute fibers on composite and mechanical properties. Flexural and laminar shear strength were investigated when carbon fiber re-enforced polymer composites and with Microwave radiation and thermal by Nightingale and Day [7]. An influence of porosity on mechanical and physical properties of uni-directional flax yarns fiber composites were investigated by Madison and Lilhoit [8]. Mishra, Mohanti, Drzal, Panja, Nayak and Tripathy[9] studied experimentally Mechanical performance of glass and bio fiber re-enforced polyester hybrid composite. Jhang and Breidt [10] studied the effect of gaseous oxidation and cryogenic surface treatment on epoxy composite which enhanced the mechanical properties of epoxy composite due to fiber matrix interface bonding. Dhakal, Zhang and Richardson [11] studied effect on mechanical properties of hemp-fiber re-enforced polyester composite subjected to water absorption. Ahmad and Vijayaranjan [12] studied the effects of stacking sequence on flexural, tensile and inter laminar shear properties of jutes fabric and jute glass fabric re-enforced polyester hybrid composite. Ersoy, Garstaka, Potter, Clegs and Stringer[13] developed physical and mechanical properties of carbon fibers re-enforced thermo-setting polymers composites through cure, which are related with residual stresses, and process induced deformation . Effects of fiber surface treatment on mechanical and visco-elastic properties of banana fibers epoxy composite was detected by vankateshwaran, Perumal and Arunsundranayagam[14]. Satish kumar, Raj kumar, Shriniwasan and Uma Pathy[16] determine the role of lignite fly ash on mechanical properties of jute epoxy polymer matrix composite . They find out change in mechanical properties of composite and flu ash was added (2017).Goppx Nath, Kumar. M and Elaya Perumal [15] investigated experimentally mechanical properties of jute fibers reinforced epoxy resin and polyester metrics composites.

In the present study bamboo fiber epoxy composite laminates were prepared using hand lay-up technique with different volume fraction and values of Young's modulus for each composite lamina were investigated experimentally and theoretically.

SPECIMEN PREPARATION

To manufacture a laminate a mold was being prepared using mild steel plates as illustrated in figure 2. The dimensions of

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mold plates were 280 mm in length, 125 mm in width and of 8 mm thickness. To obtain the required surface finishing of the plates a grinder was used. Four holes were made for the nut and bolts assembly of two plates of mold. A Teflon sheet was used to avoid sticking of specimens to surface of mold plates. Epoxy resin Araldite AY 103 and hardener HY 951 was mixed in the ratio of by volume. Composite lamina was made by using the hand lay-up method. The layers of bamboo fiber were stacked one after another and epoxy resin was being used between layers for proper bonding by using a hand brush. Sometimes there are chances of air trapped between the layers so to avoid this hand roller was used. The composite laminas were cured at room temperature for twenty four hours. A simple bamboo fiber used to make composite lamina is shown in figure 1(a) and figure 1(b) shows the prepared specimen or composite lamina. At last a lamina having thickness 3.5mm, length 180mm and width 12 mm was obtained as per ASTM standards shown in figure 1 (c).

Figure 1 (a) Bamboo fiber

Figure 1(b) Composite lamina

Figure 1 (c) Prepared lamina

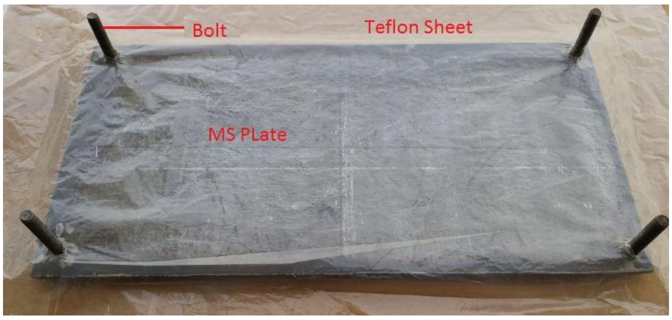

Figure 2. Mold for lamina

EXPERIMENTAL SETUP

Stress-strain diagrams were obtained from tensile tests performed at FIE make computerized Universal Testing Machine. All tests were performed at a speed of 2mm/min and with a span length of 65 mm as per ASTM D638 standards. A total of 25 experiments were performed on the UTM to find the exact value of Young's modulus for each specimen with different fiber volume percentage. All tests were performed in SOM lab at UIET, MDU, Rohtak. From stress –strain diagram values of Young's modulus of each specimen were calculated by using Hook's law.

Figure 3. UTM Test Setup

Theoretical Analysis

Theoretical analysis was done by using mechanics of composites. Here the equation used for theoretical investigation of Young's modulus of specimens with fiber volume percentage of 30%, 40%, 50%, 60% and 70% is calculated from equation given below as:

$$E_C = E_f \times V_f + E_e \times V_e$$

Where

E_c = Young's modulus for composite

E_f = Young's modulus for bamboo fiber

V_f = Volume fraction of bamboo fiber

E_e = Young's modulus for epoxy

V_e = Volume fraction of epoxy

In the above equation the value of Young's modulus for bamboo fiber is taken as 35.45 GPa and Young's modulus for epoxy is taken as 3.4 GPa respectively from literature studied.

RESULTS AND DISCUSSION

The behavior of composite laminates with different bamboo fiber volume fraction is shown in fig (4) where the values of theoretical Young's modulus of each specimen with respective volume fraction are plotted. The values of Young's modulus for specimen with 30% fiber volume is 13.015 GPa and for specimen with 40% fiber volume is calculated as 16.220 GPa. This is 24.62% higher than earlier. Similarly, for specimens with 50%, 60% and 70% the values of Young's modulus calculated were 19.410 GPa, 22.612 GPa and 25.835 GPa respectively.

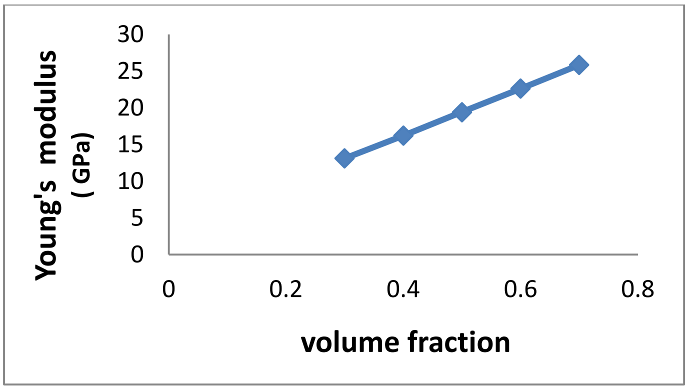

Figure 4

It is revealed from the values of Young's modulus that Young's modulus increase with volume fraction of fiber and this increase is linear in nature. Hence it can be seen that strength of composite laminates increases with increase in bamboo fiber percentage in composite laminate.

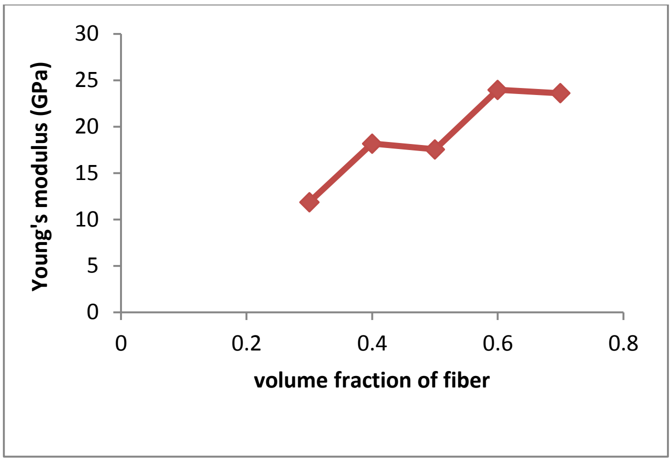

Figure 5.

In fig (5) experimentally observed values of Young's modulus of each specimens with different bamboo percentage are plotted. The experimental observed value of Young's modulus for 30% fiber volume percentage is 11.86 GPa which is 1.155 GPa lower than theoretical value. Similarly experimental values of Young's modulus with 40%, 50%, 60% and 70% fiber volume percentage are observed 18.174 GPa, 17.55 GPa , 23.966 GPa and 23.5979 GPa. Experimental observations also demonstrate that values of Young's modulus increase with increase in fiber volume percentage.

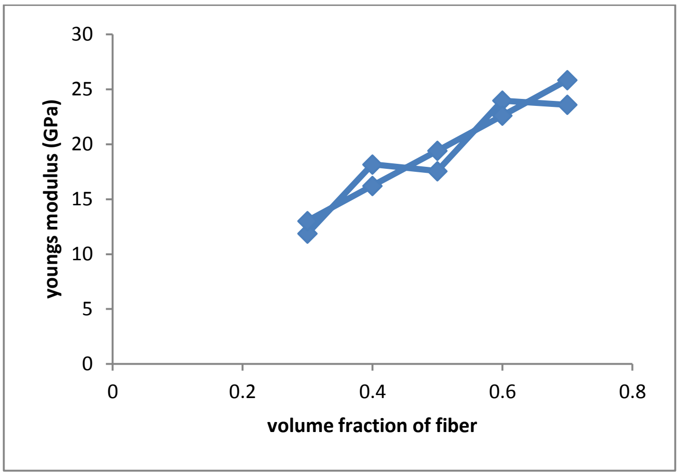

Figure 6.

Figure (6) shows the comparison of experimental and theoretical observations made for each specimen with different volume percentage of bamboo fiber. Theoretical observations shows that Young's modulus varies linearly with fiber volume fraction and increase with increase in volume fraction on the other hand from experimental observations it is evident that values of Young's modulus corresponding to their fiber volume fraction are slightly in variation with those of theoretical values. But as shown in figure (6) experimental values of Young's modulus also increase with increase in volume percentage of bamboo fiber in a composite laminate. Despite being a slight variation in experimental and theoretical observations made a good correlation seems between experimental and theoretical values of Young's modulus.

Table 1.

Specimen	S_1 (GPa)	S_2 (GPa)	S_3 (GPa)	S_4 (GPa)	S_5 (GPa)	Experimental Avg. Value (GPa)	Theoretical Value (GPa)	Error (%)
S(V=30%)	12.135	12.401	11.901	12.789	10.105	11.8662	13.015	-8.826
S(V=40%)	17.198	18.435	17.835	18.501	18.901	18.174	16.220	12.04
S(V=50%)	18.431	17.401	16.901	17.632	17.431	17.5592	19.410	-9.535
S(V=60%)	23.431	24.001	23.532	23.931	24.936	23.9662	22.612	5.988
S(V=70%)	22.431	23.901	23.801	23.839	24.013	23.597	25.835	-8.662

From table (1) it is observed that the lamina with least volume fraction of fiber have minimum value of Young's modulus and hence the minimum strength. The values of experimental Young's modulus for specimen with volume percentage 40% and 60% are slightly higher than their theoretical values. On the other hand these values are lower for specimen with volume percentage of fiber 30%, 50%, and 70%.

CONCLUSION

On the basis of experiment and theoretical analysis for Young's modulus of composite laminates with various volume percentage of fiber following observations are made:

- Stress-strain diagram of each specimen shows that failure of bamboo composite laminate is brittle in nature.
- Values of Young's modulus obtained from theoretical analysis vary linearly with increase in fiber volume fraction.
- A slight variation is observed between experimental and theoretical observation which shows a validation of the model.
- Experimental observations are close to theoretical observations.
- Variation of experimental observation of Young's modulus with increase in fiber volume fraction is not exactly linear but is very close to that.
- Change in strain for laminas with different volume fraction is almost negligible.

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