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Investigation of mechanical properties of *luffa cylindrica* fibre reinforced epoxy hybrid composite

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Abstract

In this present work, the effect of stacking sequence on mechanical properties of untreated *luffa cylindrica* and glass fibre reinforced epoxy hybrid composites has been investigated experimentally. Composite laminates were fabricated by hand lay-up technique. All the composites were made with a total of 4 plies, by varying the number and position of glass layers so as to obtain six different stacking sequences. One group of neat epoxy samples was also fabricated for comparison purpose. Samples were analysed for their mechanical and flexural properties to establish the effect of various stacking sequence. It is found that the optimum properties (tensile and flexural strength) are achieved from hybrid laminate (S5) i.e. by placing two *luffa cylindrica* fibre mats at the middle when supported by two glass fibre mats on either side.

Keywords: Luffa cylindrica-glass hybrid, Tensile strength, Flexural strength, ILSS, SEM

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1. Introduction

In recent years, the use of natural-fiber-reinforced polymeric composite are being popularly used in many applications in view of their easy availability, low cost, light weight, high specific modulus, nontoxity and pollution-free production. Interestingly several types of natural fibers that are abundantly available, such as jute, bagasse, pineapple, sisal, bananas (Rao *et al*, 1985; Sridhar *et al*, 1984; Kumar, 1986; Sha *et al*. 1981; Acharya *et al*, 2008; Luo *et al*, 1999; Bisanda *et al*, 1991; Pothan *et al* 1997) have proved to be good and effective reinforcement in polymer matrix composites. However the major problems associated with the applications of natural fibers in the composite industry are poor wettability, high moisture absorption and susceptibility to environmental degradation (Singh *et al.,* 1995). In these composites, delamination due to moisture absorption weakens the interfacial bond and causes a reduction in the mechanical properties of the composites. It is known that mechanical properties of natural fiber composites are much lower than those of synthetic fiber.

The use of natural fiber alone in polymer matrix is inadequate in satisfactorily tackling all the technical needs of a fiber reinforced composite. It is reported that (Sabeel *et al*, 2008) if natural fiber is combined with a synthetic fiber in the same matrix the properties of natural fiber could be enhanced by taking the advantage of both the fibres. Accordingly, several attempts has been made to combine different natural fibers with synthetic fibers. Abdul Khalil et al (2007) reported the enhancement in the properties of oil palm- polyester composites by incorporating chopped strand mat (CSM) glass fibers with oil palm empty fruit fiber (EFB). Mohan and Kishore *et al* (1983, 1985) reported the enhancement in flexural properties and compressive properties of jute by hybridising with glass fiber. Pavithran *et al*. (1991) evaluated the enhancement in the properties of coir-polyester composites by incorporating glass as intimate mix with coir. Significant improvements in the mechanical properties of pineapple leaf, sisal and jute fiber were reported by different researchers while they hybridised these fiber with synthetic fiber glass (Mishra *et al,* 2001; John *et al,* 2004; Kalaprasad *et al,* 1996; Ahmed *et al*, 2006). The performance of natural fiber depends on their cellulose content. Luffa cylindrica is one such natural fiber whose cellulose content is in order of 63%.The other constituents are hemicelluloses 14.4%, lignin 1.6%, ash 0.9% and others 20.1% (Yoldas *et al.*, 2012). Further this fiber is available abundantly all parts of India and grows to its mature size only in 6 months, whereas wood takes a minimum of 10 years (Xiaoya *et al*, 1998).Thus considerable research and development effects need to be undertaken in finding useful utilisation of this fiber.

Recently Ghali et al (2011) studied the effects of Fibre weight ratio, structure and fiber modification on the Flexural Properties of Luffa-Polyester composites. They observed that the chemical modification of luffa fiber enhanced the flexural strength and the flexural modulus. Boyand et al (2003) studied the effect of alkali treated luffa cylindrica fiber on the flexural properties of the composite. They observed 14% improvement in flexural properties with the treated fiber. Most of the above studies indicate the hybridisation of natural fibers like jute, sisal, coir, pineapple with synthetic fibers. But as per the information of authors no work till now has been done to prepare hybrid composite with *luffa cylindrica* fiber.

Hence, in this present work, an attempt has been made to prepare a hybrid composite with *luffa cylindrica* and glass fiber. The effect of hybridisation of glass and stacking sequence on mechanical properties of the *luffa cylindrica*-glass fiber hybrid composites is studied and reported in this work.

2. Experimental details

2.1 Fiber Material

Luffa cylindrica (LC) is a tropical plant belonging to the family of *Cucurbitaceous*, with a fruit possessing netting like fibrous vascular system. The LC strut are characterized by a micro cellular architecture with continuous hollow microchanels which forms a vascular bundles and yield a multimodal hierarchical pore system (Zampheri *et al*,2006) Figure1 (a) and (b) shows the *luffa cylindrica* plant with fruit and dried luffa fruit with partial removed of outer layer respectively. Figure 1 (c) shows the sponge guard and the hollow micro channels. This specific morphology makes it possible to imagine a specific composition on crystallinity cellulose. In this work *LC fibers* were cut to rectangular mat like after opening the outer core and the micro channel portion as shown in Figure 1(d) and (e) from the sponge guard neglecting the end portion to keep the thickness same for the mat and have been used for manufacturing the layered composite.

E-glass fibres (360 roving) were utilized in the present work along with luffa fibre. Both the fibres were cut to size 140x100 mm for preparation of composite.

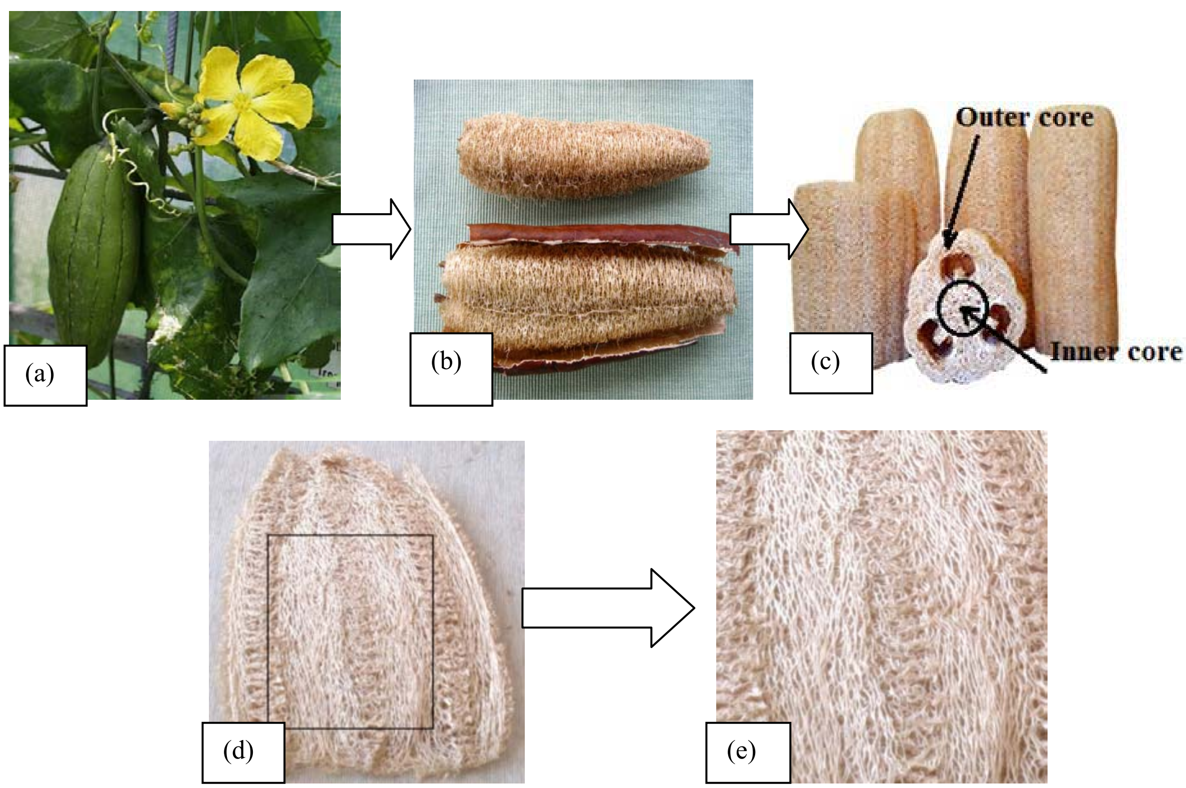

Figure 1. (a) The *luffa cylindrica* fruit (b) Dried *luffa* fruit with partial removed of outer layer (c)Sponge guard with hollow micro channels (d) Outer core open as mat (e) The rectangular portion used for making composite.

2.2 Composite fabrication

In the present investigation the hybrid laminates were fabricated by hand lay-up technique. The epoxy resin (LY 556) and the curing agent hardener (HY 951) were mixed in the ratio 10:1 (v/v). During preparation of the composite stirring at a low rate and degassing of the mixture were carried out. A wooden mold of dimension (140 x 100 x 6) mm was used for casting the composite sheet. Necessary release coat were applied for quick and easy removal of the composite sheet from the mold. Six groups of laminate composite samples with total 4 plies were manufactured by varying stacking sequence of luffa and glass fabrics as shown in Table.1.

Table 1. Laminate stacking sequence.

Symbol	Laminate stacking sequence	Total Fibre		Thickness (mm)
		Weight fraction (%)	Volume fraction (%)	
S1	LLLL	18.52	30.86	5.6
S2	LGLG	24.42	28.99	5.12
S3	GLGL	24.52	29.03	5.13
S4	LGGL	17.72	19.12	5.12
S5	GLLG	18.50	19.87	5.13
S6	GGGG	14.27	6.7	5.00
L-Luffa cylindrica layer , G-Glass fiber layer				

Luffa cylindrica and glass fabrics were pre-impregnated with the matrix material consisting of epoxy resin and hardener. Care was taken to avoid formation of air bubbles during pouring. After keeping the luffa and glass fibre sheets in position in the mold, a roller was used to roll the composite so that the resin will be distributed evenly and any air pockets present will be removed. Pressure was then applied from the top and the mold was allowed to cure at room temperature for 72 hrs. After 72 hrs the samples were taken out of the mold and were cut into required size of mechanical tests by a diamond cutter. The neat resin composite plate was also made with the above dimension without any reinforcement. The total fibre volume fraction of fibre is calculated using equation 1.

$$V_f = \frac{(W_l/\rho_l)+(W_g/\rho_g)}{(W_l/\rho_l)+(W_g/\rho_g)+(W_m/\rho_m)} \tag{1}$$

where W_l, *and* Wg and Wm are the known weights of the luffa cylindrica fibre, glass fibre and epoxy resin, respectively, and $\rho_{l,}$ ρ_g *and* ρ_m are the densities of *luffa cylindrica*, glass fibre and epoxy resin. The density of epoxy resin, *luffa cylindrica* and glass fibre is found to be 1.1 g/cm3, 0.56 g/cm3 and 2.55 g/cm^3 respectively.

2.3 Mechanical testing

Density and Void Fraction

The composites under this investigation consists of two components namely matrix and fibre. The theoretical density of composites in terms of weight fraction can easily be obtained as per the following equation:

$$\rho_{ct} = \frac{1}{\frac{w_{fg}}{\rho_g}+\frac{w_{fl}}{\rho_l}+\frac{w_{fm}}{\rho_m}} \tag{2}$$

Where, W_f and ρ represent the weight fraction and density respectively. The suffix g, l, m. and ct stand for the glass fiber, *luffa cylindrica fiber*, matrix, and the composite materials respectively.

The actual density (ρ_{ce}) of the composite, however, can be determined experimentally by simple water-immersion technique. The volume fraction of voids (Vv) in the composites is calculated using the following equation:

$$V_v = \frac{\rho_{ct} - \rho_{ce}}{\rho_{ct}} \tag{3}$$

Micro hardness

Micro-hardness measurement is done using a Lecco Vickers Hardness (LV 700) tester .A diamond indenter, in the form of a right pyramid with a square base and an angle 136º between opposite faces is used with load.

Tensile Strength, Flexural and interlaminar shear strength

The tension test is generally performed on flat specimens. The most commonly used specimen geometries are of dog-bone type and the straight side type with end tabs. The specimen used for the present study is shown in Figure 2.The tensile test was conducted according to the ASTM D 3039-76 standard on a Computerized Universal Testing Machine INSTRON H10KS. The span length of the test specimen used was 42 mm. The tests were performed with a constant strain rate of 2 mm/min.Five specimens for each sample were tested for accuracy. The results were analysed to calculate the tensile strength of the composite samples.

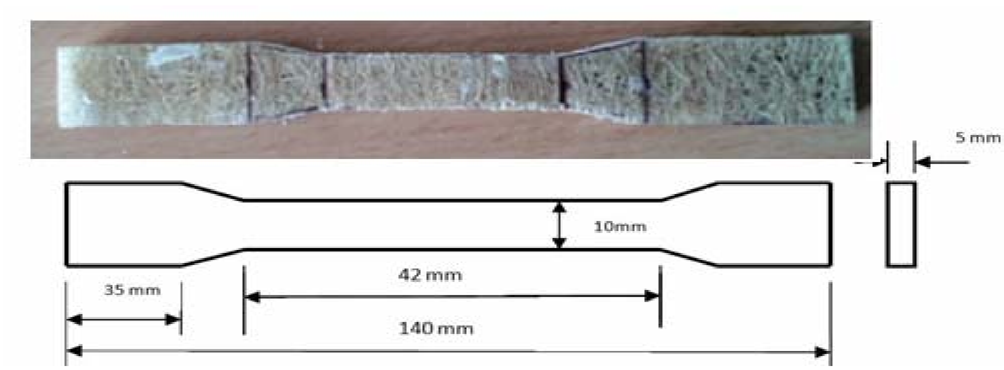

Figure 2. Tensile test configurations.

Flexural test were performed using 3-point bending method according to ASTM D790-03 standard procedure. Specimen of 140 mm length and 15 mm wide were cut and loaded in three point bending with recommended span to depth ratio of 16:1. The same Instron machine is used for this test. The specimens (Figure 3) were tested at a crosshead speed of 2 mm/min. Five specimens for each sample were tested for accuracy. The specimen in loading position for flexural test is shown in Figure 4. The flexural strength can be found out by using the equation

$$\sigma = \frac{3FL}{2bt^2} \tag{4}$$

where F is the maximum load (N), L is the distance between the supports (mm), b and t are the width and thickness (mm) respectively. The data recorded during the 3-point bend test can be used to evaluate the interlaminar shear strength (ILSS) by using equation

$$\text{ILSS} = \frac{3F}{4bt} \tag{5}$$

Where F is the breaking load (N), *b* and *t* are the width and thickness of the specimen (mm)

Figure 3. Flexural test configurations.

Scanning electron microscopy

The surfaces of the specimens are examined directly by scanning electron microscope JEOL JSM-6480 LV.The composite samples are mounted on the stubs with silver paste. To enhance the conductivity of the samples a thin film of platinum is vacuum evaporated on to them before the photomicrographs are taken.

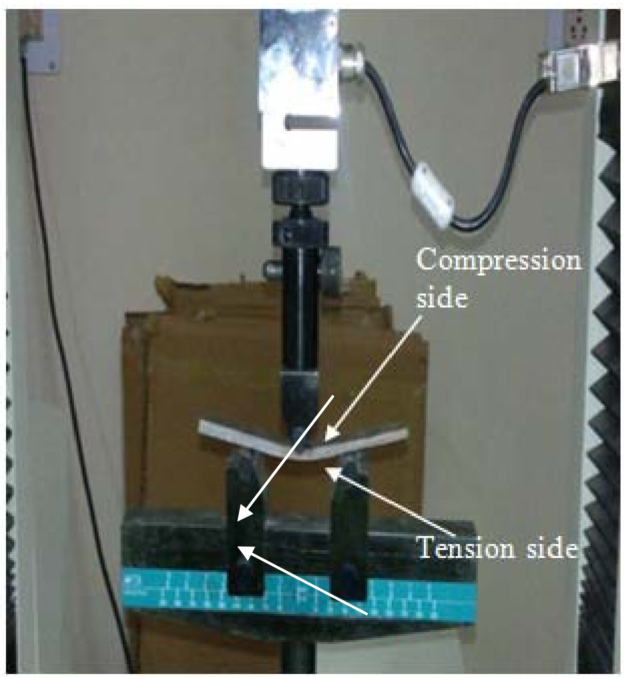

Figure 4. Three-point bending test with the specimen in loading position.

3. Results and discussion

Density and Void fraction

Density is one of the primary factors that determine the properties of the composite. Often it is found that the theoretical values of the density will not match with the experimentally measured values. This is primarily due to presence of voids or air bubbles in the composite .This have a greater contribution to affect the mechanical properties and the performance of the composite in the actual work place. Higher void contents usually mean lower fatigue resistance, greater susceptibility to water penetration, and weathering (Agarwal *et al*, 1990). Thus the knowledge of void content is desirable for estimation of the quality of the composites. It is understandable that a good composite should have fewer voids. However, the presence of void is unavoidable in composite making particularly through hand-lay-up technique.

The theoretical and measured densities of the composites along with the corresponding volume fraction of voids for the present case are presented in Table 2. As shown in table in all laminate stacking sequences, the volume fractions of voids are found to be reasonably small i.e. <1.5%

Table -2. Measured and theoretical densities of the composites.

Stacking sequence	Theoretical density (g/cm^3)	Measured density (g/cm^3)	Volume fraction of voids (%)
Neat epoxy	1.2	1.18	1.66
S1	1.01	1.009	1.2
S2	1.18	1.178	.89
S3	1.18	1.178	.89
S4	1.187	1.177	.878
S5	1.188	1.179	.78
S6	1.305	1.297	.65

Micro hardness

Figure 5 shows the micro-hardness of the composite for different stacking sequences. The micro hardness value is different for different stacking sequences. The maximum value is found for sequence S4.

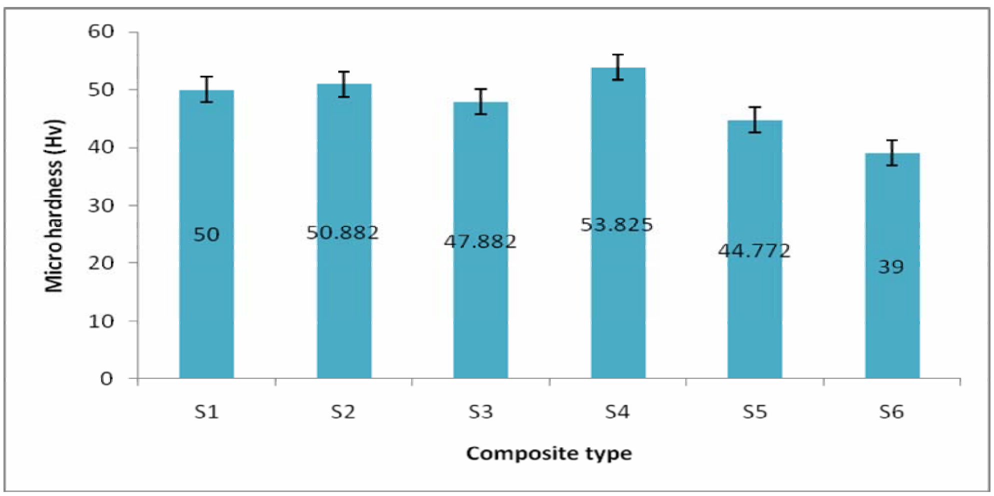

Figure 5. Micro hardness of the laminates

Tensile strength

It is well known that fibre strength is mainly responsible for strength properties of the composite. Therefore variation in tensile strength of the composite with various fibres loading is obvious .The variation of tensile strength for different laminate stacking sequences is shown in Figure 6. It is found that with only *luffa cylindrica* fibre laminates, the tensile strength of the composite is 17.628Mpa.With different sequence of *luffa* fibre with glass fibre the tensile strength varies between 25.87 and 35.34 Mpa.It is found to be maximum for the sequence S5 (i.e.) by placing two *luffa cylindrica* fibre mats at the middle when supported by two glass fibre mats on either side.. It is interesting to note that by incorporating glass fibre with *luffa cylindrica* fibre the tensile strength increases to about 46.6, 47, 82 and 100.4% for the sequences S2,S3,S4 and S5 in comparisons to sequence S1 (i.e.) only *luffa cylindrica* fibre.

Flexural strength

The variation of flexural strength for various laminate- stacking sequences is shown in Figure 7. The flexural strength of the only *luffa cylindrica* reinforced epoxy resin is found to be 39.1 MPa. An increase in the flexural strength of 59,176, 61.4 and 177 % is observed for *luffa*-glass fibre-reinforced hybrid laminate for sequences S2, S3, S4 and S5 composites when compared to that of only *luffa cylindrica* laminate (i.e.) S1.It is interesting to note that when load is applied for the specimen (S3) i.e. from the glass fibre side the flexural strength is found to be 107.93 Mpa. When the load is applied on the *luffa* side (S2) there is a decrease in value of the flexural strength to 62.13 Mpa. It is also found that Flexural strength for the sequences S3 and S5 are maximum (i.e.) when the glass fibre layers are placed at the extreme layer. This can be said for this type of observation that the flexural strength is controlled by the extreme layer of reinforcement. Same type of observation is reported by Munikenche Gouda et al (1999) while they worked with untreated jute fabric-reinforced polyester composites.

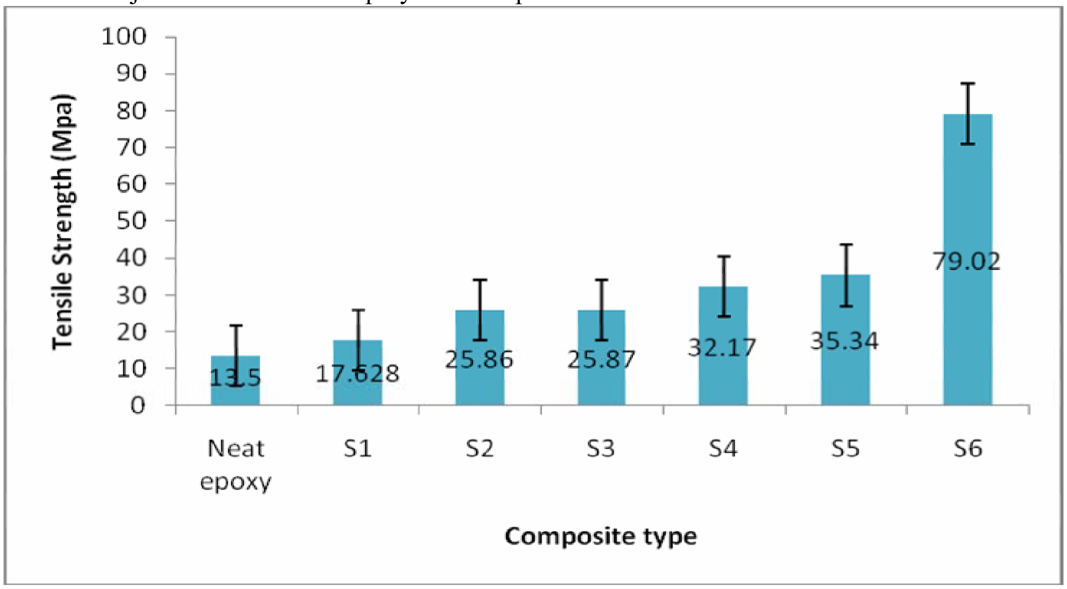

Figure 6. Tensile strength of the laminates.

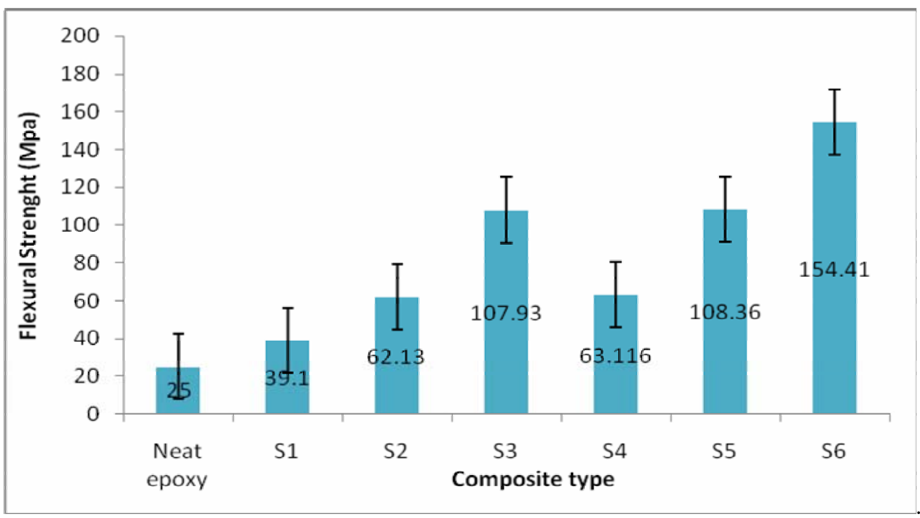

Figure 7. Flexural strength of the laminates.

Interlaminar shear strength

The stresses acting on the interface of the two adjacent laminae in a layered composite are called interlaminar shear stress. These stresses cause relative deformation between the consecutive laminae and if these are sufficiently high they may cause failure along the mid plane between two adjacent laminae. It is therefore almost important to evaluate ILSS through test in which failure of the laminates of the composite initiates in a shear (delamination) mode. In the present case the ILSS of the laminates for different stacking sequences shows similar trend in line with flexural strength as shown in Figure 8. The maximum ILSS of 5.628 Mpa is observed for laminate S3 among all hybrid laminate sequences.

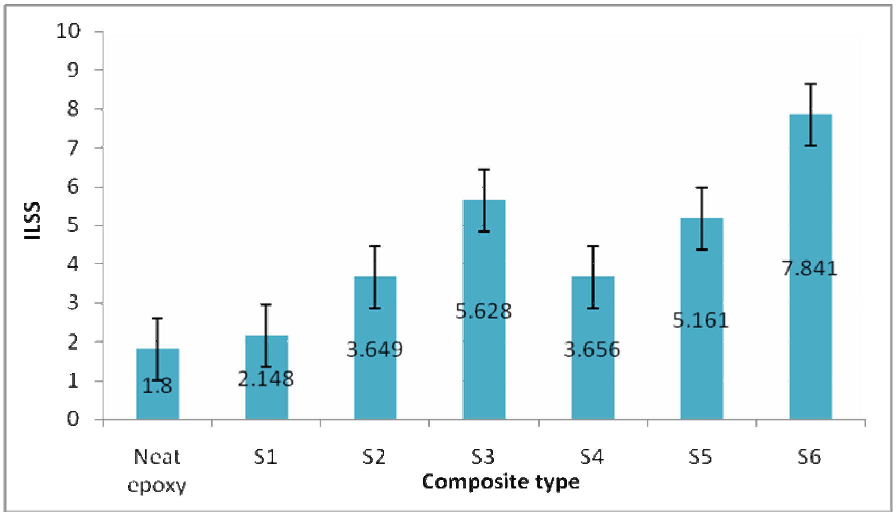

Figure 8. Interlaminar shear strength of the laminates.

Surface morphology of Laminates

Figure 9 (a) shows the SEM image of fractured surface of only *luffa cylnidrica* reinforced epoxy composite i.e. for sequence S1 under tensile load .The fiber breakage and pull out of fiber along loading direction from the matrix is clearly visible. The formation of voids due to fibre pull out is also noticed because of poor resin compatibility with natural fibres. Figure 9 (b) shows the tensile failure of *luffa cyilndrica*-glass fiber hybrid laminate (S5).The stretching and elongation and bending of glass fibre are visible due to the applied tensile load. Also breakage of Luffa fibre without any stretching is clearly visible. The stretching of glass fibre indicates that the strength of the composite increased due to the incorporation of glass fibre, and this supplement to the results shown in Figure 6.

Figure 10 (a) shows the SEM micrograph of flexural specimen for tensile side as indicated in fig.4 of the laminate S1 under flexural load.Debonding of fiber with the matrix is clearly visible. Enlargement of fiber tissue due to flexural load probably reduced the strength of laminate S1. Figure 10 (b) shows the SEM micrograph of hybrid laminate S5 representing the failure on the tension side of the specimen under flexural load. Greater extensibility of the glass fibres leading to fibre pull out and matrix failure is clearly visible. No delamination between the *luffa cylindrica* and glass plies is noticed for flexural specimens. This probably is the main reason for increased flexural strength for hybrid laminates S5. Similar observations are reported by K. Sabeel Ahmeda etal (1999) while they worked for jute-glass hybrid laminates.

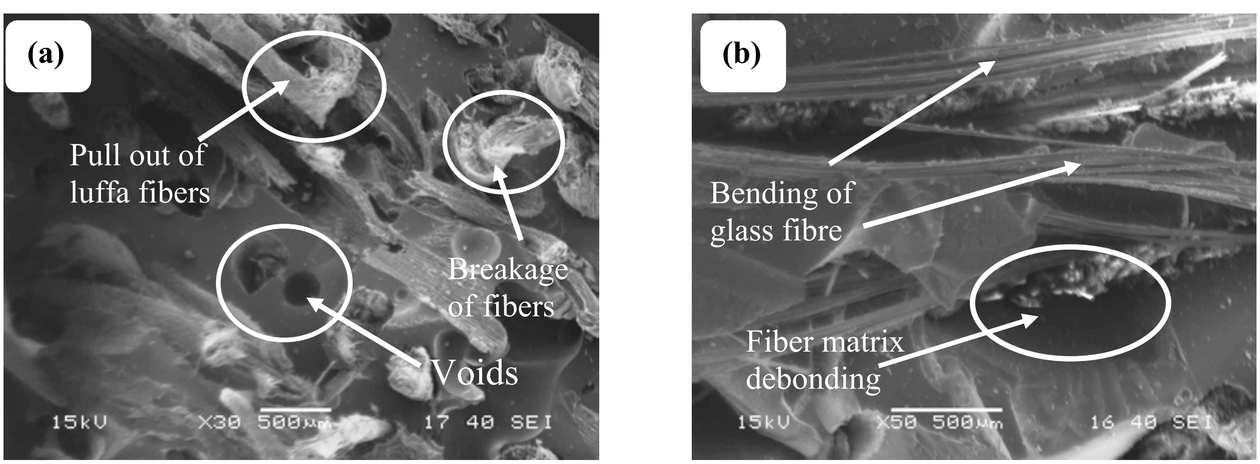

Figure 9. SEM image of fractured surface of laminates (a) S1 and (b) S5 under tensile load.

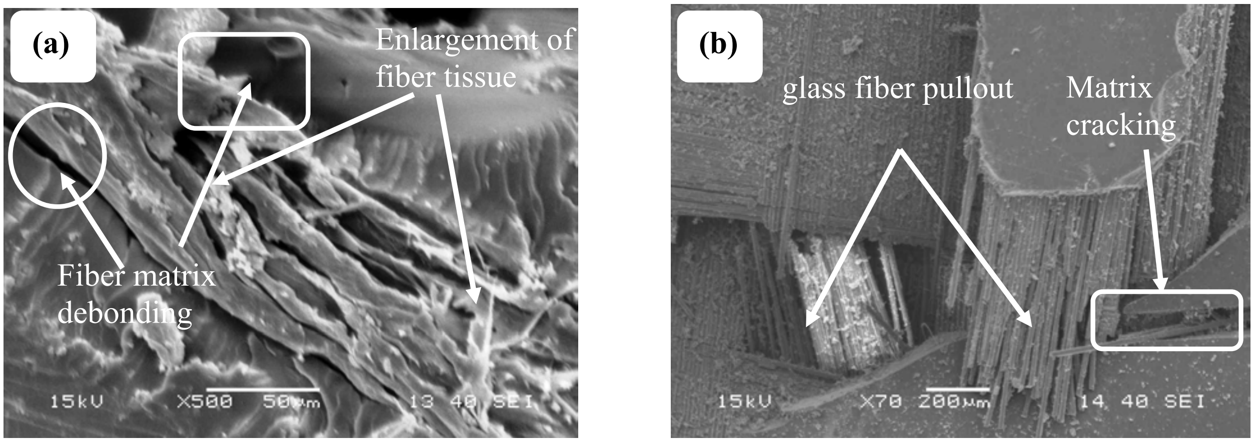

Figure 10. SEM image of tensile fractured surface of laminates (a) S1 and (b) S5 under flexural load.

4. Conclusion

The following conclusions are drawn from this study.

1. A new type of *luffa cylindrica*-glass fibre hybrid composite laminates has been fabricated successfully.
2. The tensile strength of *luffa* -glass fibre-reinforced hybrid composite is found to be maximum for the stacking sequence (S5) among all hybrid laminates which is about 100.4% higher than the strength of only *luffa cylindrica* reinforced fibres i.e. sequence S1.
3. The flexural strength is also found to be 108.36Mpa for stacking sequence S5 which is about 177% higher than the only *luffa cylindrica* reinforced fibres (i.e.) is from sequence S1.
4. The maximum ILSS of 5.628 Mpa is observed for laminate S3 among all hybrid laminates.
5. Comparing the properties of the designed hybrid laminates, it is found that the optimum properties (Tensile and Flexural strength) are achieved from hybrid laminate (S5) i.e. by placing two *luffa cylindrica* fibre mats at the middle when supported by two glass fibre mats on either side.
6. Scanning electron micrographs showed that failure of composite mainly due to pull out of the fibres for both *luffa cylindrica* and glass fibre.

References

Abdul Khalil H. P. S., Hanida S. and Kang C. W. 2007. Agro-hybrid composite: The effects on mechanical and physical properties of oil palm fiber (EFB)/glass hybrid reinforced polyester composites, *Journal of Reinforced Plastics and Composites*, Vol. 26, p. 203.

Acharya S. K. , Mishra P., Meher S. K. and Dikshit V. 2008. Weathering behavior of bagasse fibers reinforced polymer composite. *Journal of Reinforced Plastics and Composites,* Vol. 27, p. 1839.

Agarwal B. D. and Broutman L. J. 1990. Analysis and Performance of Fibre Composites, 2nd edn, *John Wiley and Sons*, Inc, New York.

Ahmed KS, Vijayarangan S and Rajput C. 2006. Mechanical behaviour of isothalic polyester-based untreated woven jute and glass fabric hybrid composites. *Journal of Reinforced Plastics and Composites*, Vol. 25, p. 1549.

Boynard C. A., Monteiro S. N., and D'Almeida J. R. M. 2003. Aspects of alkali treatment of sponge gourd (*luffa cylindrica*) fibers on the flexural properties of polyester matrix composites, *Journal of Applied Polymer Science*, Vol. 87, No. 12, pp. 1927-1932.

Bisanda E. T. N. and Ansell M. P. 1991.The effect of saline treatment on the mechanical and physical properties of sisal–epoxy composites. *Composite Science and Technology*, Vol. 41, pp. 165-178.

John K and Naidu S.V. 2004. Tensile properties of unsaturated polyester-based sisal fiber–glass fiber hybrid composites. *Journal of Reinforced Plastics and Composites*, Vol. 23, pp. 1815.

Kalaprasad G., Thomas S., Pavithran C., Neelakantan N. R., Balakrishnan S., 1996. Hybrid effect in the mechanical properties of short sisal/glass hybrid fiber reinforced low density polyethylene composites. *Journal of Reinforced Plastics and Composites,* Vol. 15, No. 1, pp. 48-73.

Kishore M.R. 1983. Compressive strength of jute-glass hybrid fiber composites. *Journal of Material Science Letters*, Vol. 2, 99-102.

Kishore M.R. 1985. Jute-glass sandwich composites. *Journal of Reinforced Plastics and Composites*. Vol. 4, pp. 186-194.

Kumar P. 1986.Mechanical behaviour of jute fiber and their composites*, Indian Journal of Technology,* Vol. 24, pp. 29-32

Luo S. and Netravali A.N.1999. Interfacial and mechanical properties of environment- friendly 'Green' composites made from pineapple fibers and poly (Hydyoxybutyrate-co valerate) resin. *Journal of Material Science and Engineering,* Vol. 34, pp. 3709-3719.

Ghali L., Msahli S., Zidi M., Sakli F. 2011. Effects of fiber weight ratio, structure and fiber modification onto flexural properties of *luffa*-polyester composites. *Advances in Materials Physics and Chemistry*, Vol. 1, pp. 78-85

Mishra S, Mishra M, Tripathy SS, et al. 2001. Potentiality of pineapple leaf fiber as reinforcement in PALF-polyester composite: surface modification and mechanical performance. *Journal of Reinforced Plastics and Composites*, Vol. 20, pp. 321–334.

Munikenche Gowda, T., Naidu, A.C.B., Chhaya, Rajput, 1999. Some mechanical properties of untreated jute fabric-reinforced polyester composites. *Composites: Part. A,* Vol. 30, pp. 277–284.

Pavithran C., Mukherjee P.C., Brahma Kumar M. 1991a. Coir-glass intermingled fiber hybrid composites. *Journal of Reinforced Plastics and Composites*, Vol. 10, pp. 91–101.

Pothan L. A., Thomas S. and Neelakantan N. R. 1997. Short banana fiber-reinforced polyester composites: Mechanical, failure and aging characteristics. *Journal of Reinforced Plastics*, Vol. 16, pp. 744-765.

Roe P. J. and Ansell M. P. 1985. Jute-reinforced polyester composites. *Material Science*, Vol. 20, pp. 4015–4020.

Sabeel Ahmeda K. Vijayarangan S. 2008. Tensile, flexural and interlaminar shear properties of woven jute and jute-glass fabric reinforced polyester composites. *Journal of Materials Processing Technology*, Vol. 207, pp. 330-335.

Sha A. N. and Lakkad S.C. 1981.Mechanical properties of jute reinforced plastic. *Fibre Science and Technology,* Vol. 15, pp. 41-46.

Singh B., Manorama Gupta and Anchal Verma. 1995. Mechanical behaviour of particulate hybrid composite laminates as potential building material. *Construction and Building Materials*, Vol 9, No 1, pp 39-44.

Sridhar M. K., Basavarappa G., Kasturi S. G., and Balasubramaniam N. 1984. Mechanical properties of jute/ polyester composites. *Indian J. Tech,* Vol. 22, pp. 213-215.

Xiaoya C,Qipeng G and Yongli M, 1998. Bamboo fiber-reinforced polypropylene composites: A study of the mechanical properties. *Journal of Applied Polymer Science*, Vol. 69, No. 10, pp. 1891-1899.

Yoldas S., Kutlay S., Seckin E., Mehmet S., Gokdeniz ,Neser, Cicek O..2012. Characterization of *luffa cylindrica* fibers and the effect of water aging on the mechanical properties of its composite with polyester. *Journal of Applied Polymer Scienc*e, Vol. 123, pp. 2330–2337.

Zampheri, A., Mabande G.T.P., Selvam, T., Schwieger W., Rudulph A., Hermann R., Sieber H., and Greil P. 2006. Biotemplating of *luffa cylindrical* sponges to self supporting hierarchical zeolite macrostructures for bio-inspired structured catalytic reactors. *Material Science and Engineering:* C, Vol. 26, No. 1, pp. 130-135.

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Dr. S.K Acharya is a Professor in the Department of Mechanical Engineering, National Institute of Technology Rourkela, India. He has more than 26 years of experience in teaching and research. His current area of research includes tribology, composite materials and nano-technology. He has published more than thirty papers in referred national and international journals. He has also presented more than seventy five research articles in national and international conferences.

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