Experimental Investigation on Mechanical Characteristics of Jute FRP Composites Subjected to Loading

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Abstract— The present investigation deals with Fiber-reinforced polymer composites that played a dominant role for a long time in a variety of applications for their high specific strength and modulus. The fiber which serves as a reinforcement in reinforced plastics may be synthetic or natural. Past studies show that only synthetic fibers such as glass, carbon etc., have been used in fiber-reinforced plastics. Although glass and other synthetic fiber-reinforced plastics possess high specific strength, their fields of application are very limited because of their inherent higher cost of production. In this connection, an investigation has been carried out to make use of jute, a natural fiber abundantly available in India. Natural fibers are not only strong and lightweight but also relatively very cheap. The present work describes the development and characterization of a new set of natural fiber based polymer composites consisting of jute as reinforcement and epoxy resin. The newly developed composites are characterized with respect to their physical and mechanical characteristics. Experiments are carried out to study the effect of fiber loading on physical and mechanical behavior of these epoxy based polymer composites. This work also includes the comparison of elastic properties of composites using micromechanical models with experimental and existing analytical formulations like rule of mixture, Halpin-Tsai, and Lewis and Nielsen models that are used extensively in material modelling.

Key words: FRP Composites, Fibre Reinforced Plastic (FRP)

I. INTRODUCTION

Fibre reinforced plastic (FRP) materials have proven to be very successful in structural applications. They are widely used in the aerospace, automotive and marine industries. Mechanics of composites has developed during the latter part of the 20th century. Many micromechanical analyses based on both analytical and numerical solutions have been presented in the literature for predicting the mechanical and thermal properties of composite materials reinforced with either unidirectional or short fibers or particles. Basic analytical approaches have been reported [194–196] to predict the composite materials properties, such as, strength, stiffness, and thermal conductivity.

Different researchers have performed various experiments to enhance the mechanical properties of natural fibre based polymer composites.

M.A. McCarthy et.al [A], investigated on issues in modelling the contact between the joint parts, which affect the accuracy and efficiency of the model are presented. Experimental measurements of surface strains and joint stiffness are compared with results from a finite element parameter study involving variations in mesh density, element order, boundary conditions, analysis type and material mode issues in modelling the contact between the joint parts, which affect the accuracy and efficiency of the model, are presented. Experimental measurements of surface strains and joint stiffness are compared with results from a finite element parameter study involving variations in mesh density, element order, boundary conditions, analysis type and modelling. The ability of the models to capture three-dimensional effects such as secondary bending and through-thickness variations in stress and strain is evaluated, and the presence of mathematical singularities in such models is highlighted.

O. ESSERSI et.al [B], investigates on the composite assembly’s dynamic behaviour.
In his investigation on the structural rate dependent behaviour of adhesively bounded double lap joints. High rate tests showed ringing in the force/displacement curves. An attempt was made to determine the origins of this phenomenon.

C. Pickthall, M. Heller &L.R.F. Rose[C], Characterisation of the stress reduction compared to the(non-yielding)elastic case, was sought by examining the influences of configurational parameters including plate,adhesive and reinforcement moduli, and adhesive yield stress. Finite element (FE) analyses were conducted for a two-dimensional section through a double-sided (symmetric) lap joint, representative of a typical repair. Stress reductions in the reinforcement of the order of 25% were found. The adhesive yield was shown to be dominated by shear stress, and thus the adhesive behaved essentially one dimensionally. The linear increase in plastic zone length with applied load, as predicted by the Hart-Smith one-dimensional theory, was in good agreement with the FE results. However the observed load transfer length was 6-18% longer than predicted.

Dynamic mechanical behaviour of natural fibres like sisal, pineapple leaf fibre, oil palm empty fruit bunch fibre etc. in various atrices has been studied by Joseph et al. [D]. Luo and Netravali [E] studied the tensile and flexural properties of polymer composites with different pineapple fibre content and compared them with the virgin resin. [F] It was reported that kraft pulped banana fiber composite has good flexural strength. In addition, short banana fiber reinforced polyester composite was studied by Pothan*et al*. Ichazo et al. [G] It found that adding silane treated wood flour to PP produced a sustained increase in the tensile modulus and tensile strength of the composite. Mohanty et al. [H] studied the influence of different surface modifications of jute on the performance of the biocomposites. More than a 40% improvement in the tensile strength occurred as a result of reinforcement with alkali treated jute. Jute fiber content also affected the bio composite performance and about 30% by weight of jute showed optimum properties of the biocomposites.

Schneider and Karmaker [I] studied the mechanical behaviour of jute and kenaf fibre based polypropylene composites and reported that jute fibre provides better mechanical properties than kenaf fibre.

In this section, various analytical models for evaluation of elastic and thermal properties of composite materials are reviewed. The methods comprise Voigt and Reuss approximations (rule of mixers), Halpin-Tsai model, and Lewis and Nielsen model and are presented.

A. Fiber Material

Jute fiber is generally derived from the stem of a jute plant. Jute is the other natural fiber material that has been used as reinforcement in the present work. Jute is a lingo-cellulosic fiber because its major chemical constituents are lignin and cellulose. Jute fibers used in present investigation are procured from local sources. Figure shows the unidirectional fiber used as reinforcement in the present work.Jute fiber has a density of 1.4 g/cm3 and thermalconductivity of 0.036W/m-K

(a) (b)

II. Composite Fabrication

The fabrication of the epoxy based polymer composites is done by conventional hand lay-up technique followed by light compression moulding. Fiber are taken for the study such as unidirectional. Composites are fabricated with five different fiber loadings (0 wt.%, 10 wt.%, 20 wt.%, 30 wt.%, and 40 wt.%). For epoxy based composites, the epoxy and hardener HY951 are mixed in a ratio of 10:1 by weight as recommended.. Care is taken to avoid the formation of air bubbles during preparation. A moderate pressure of 0.1 MPa is applied from the top and then mold is allowed to cure at room temperature for 48 hrs. After 48 hrs, the samples are taken out of the mould and cut into required size by diamond cutter for physical and mechanical tests.

III. Mechanical Characteristics

After fabrication the test specimens were subjected to various mechanical tests as per ASTM standards. The tensile test and three-point flexural tests of composites were carried out using Instron 1195. The tensile test is generally performed on flat specimens. A uniaxial load is applied through both the ends. The ASTM standard test method for tensile properties of fiber resin composites has the designation D 3039-76. Micro-hardness measurement is done using a Leitz micro-hardness tester. A diamond indenter, in the form of a right pyramid with a square base and an angle 1360 between opposite faces, is forced into the material under a load F.

The two diagonals X and Y of the indentation left on the surface of the material after removal of the load are measured and their arithmetic mean L is calculated. In the present study, the load considered F = 24.54N. Low velocity instrumented impact tests are carried out on composite specimens. The tests are done as per ASTM D 256 using an impact tester. The charpy impact testing machine has been used for measuring impact strength.

A. ILSS

The test is conducted as per ASTM standard D2344-84 using the same universal testing machine Instron 1195. In this test, a short specimen with dimension of 45 mm × 10 mm × 4 mmis submitted to an apparatus at a crosshead speed of 2 mm/min. As the loading cylinder exerts a downward force, the specimen is subjected to normal (bending) and transverse shear stresses

B. Finite Element Modeling

Generation of RVE, for simplicity reasons, most micromechanical models assume a periodic arrangement of fibers for which a RVE or unit cell can be isolated. The RVE has the same elastic constants and fiber volume fraction as the composite. The periodic fiber sequences commonly used are the square array and the hexagonal array.

IV. Boundary conditions for evaluation

Conditions along the 1, 2&3directions of the RVE

1-direction along the faces AEDH and BFCG		2-direction along the faces ABCD and EFGH		3-direction along faces DHGC and AEFB	
U = 0, V and W free	U = K, V and W free	V = 0, U and W free	U, V and W free	W = 0, U and V free	U, V and W free
U = 0, V and W free	U, V and W free	V = 0, U and W free	V = K, U and W free	W = 0, U and V free	U, V and W free

V. Results

The results of various characterization tests are reported. This includes evaluation of tensile strength, flexural strength, impact strength and micro-hardness has been studied. The interpretation of the results and the comparison among composite samples are also presented.

A. Densities and void fraction of different composites

Composite	Density of jute	Density of Epoxy	Weight of jute fiber	Weight of epoxy	Theoretical Density	Experimenta l Density	Void fraction
C1	1.4	1.15	0	1	1.15	1.146	0.347
C2	1.4	1.15	0.1	0.9	1.1709	1.157	1.187
C3	1.4	1.15	0.2	0.8	1.1925	1.165	2.313
C4	1.4	1.15	0.3	0.7	1.2150	1.173	3.464
C5	1.4	1.15	0.4	0.6	1.2389	1.152	4.559

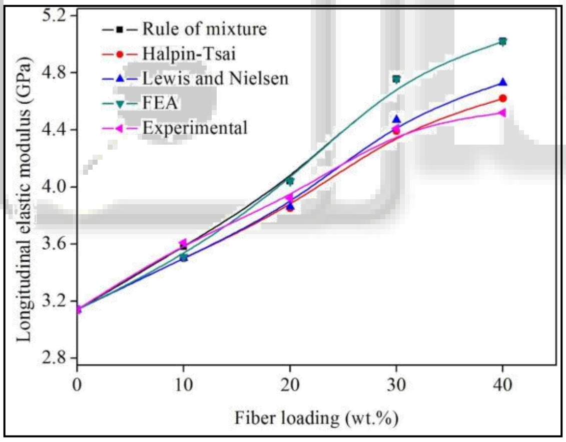
B. *Water Absorption*

Hour	C1	C2	C3	C4	C5
0 Hr	0	0	0	0	0
24Hr	0	0.958646617	1.888404217	2.759139785	3.758538251
48 Hr	0	1.308954204	2.248273355	3.359139785	4.678961749
72 Hr	0	1.609706083	2.569974555	3.879569892	5.519125683
96 Hr	0	1.859193438	2.818974918	4.31827957	6.25025565
120 Hr	0	2.059125085	3.029807343	4.688172043	6.859631148
144 Hr	0	2.228298018	3.178844057	4.969892473	7.378756831
168 Hr	0	2.359876965	3.318793166	5.189247312	7.68954918
192 Hr	0	2.469241285	3.438749546	5.309677419	7.979849727
216 Hr	0	2.508544087	3.518720465	5.378494624	8.078893443
240 Hr	0	2.539302802	3.549618321	5.408602151	8.119877049
264 Hr	0	2.549555707	3.558705925	5.419354839	8.148907104
288 Hr	0.044238	2.549555707	3.558705925	5.419354839	8.159153005

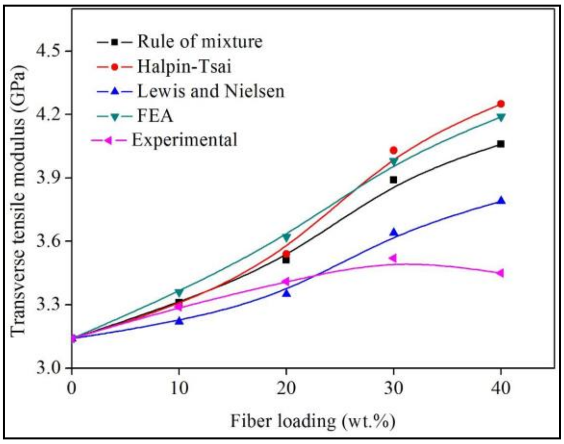
C. *Mechanical Characteristics of Composites*

Composites	Longitudinal Tensile Strength (Mpa)	Transverse Tensile Strength (MPa)	Flexural Strength (MPa)	ILSS	Impact Energy (KJ/m^2)	Hardness (Hv)
C1	32.28	32.28	46.05	54.32	1.015	25.1
C2	49.65	37.21	71.69	69.7	1.756	31.3
C3	38.18	38.18	83.46	78.75	2.181	36.6
C4	65.69	35.69	92.83	84.3	2.498	38.3
C5	27.48	27.48	79.69	80.69	2.905	39.1

D. *Longitudinal tensile modulus Vs fibre loading*



E. *Transverse tensile modulus Vs fibre loading*



VI. CONCLUSIONS

Fabrication of unidirectional jute fiber reinforced epoxy based composites with different fiber loading has been done successfully with hand layup technique.

The micromechanical analysis of composites based on three-dimensional RVE with a square geometry is successfully implemented by using finite element code ANSYS to calculate the elastic properties. The longitudinal and transverse tensile modulus values are found always higher than that of neat polymer. The maximum longitudinal elastic modulus of epoxy based composites at 40 wt. % fiber loading with weight ratio of jute fiber are found to be 4.52GPa. Similarly, the maximum transverse elastic modulus of epoxy based composites at 30 wt. % fiber loading with weight ratio of jute fiber is found to be 3.52GPa.

The density, void content and water absorption coefficients of the unidirectional composites are greatly affected by the type of fiber material, fiber loading, and type of matrix materials. With increase in fiber loading, density, void content and water absorption coefficients increases invariably for both the epoxy based composites.

The mechanical properties of the composites are improved by adding the jute fiber as reinforcement in polymer matrix.

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