Mode I Fracture Toughness of Jute/Glass Fibre Hybrid Composite – An experimental and Numerical Study

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Abstract *— Mode I fracture behaviour of jute/glass fibre hybrid composite was investigated based on experimental and finite element analysis. Compact tension test was performed to find out the mode I fracture toughness. Fracture toughness was determined for five specimens each with different volume fractions of jute and glass fibre. The results indicated that 100% glass fibre composite gave maximum fracture toughness. Whereas composites with 75% glass & 25% jute fibre and 50% glass and 50% jute fibre also gave nearest values with that of pure glass fibre composite. A similar fracture test was simulated using the finite element analysis software ANSYS and critical stress intensity factor was calculated. The finite element analysis results are found to be close with the experimental results.*

Keywords — *Fracture toughness, Stress intensity factor, Finite element analysis, Compact tension test.*

I. INTRODUCTION (SIZE 10 & BOLD)

Fibre reinforced composites are widely used in many engineering applications. One of the major fields of application of natural fibre is in automotive industry [1]. Glass fibre reinforced composites are mainly used because of their better mechanical properties. But it is a synthetic fibre and cause many environmental problems. On the other hand, natural fibres are environmental friendly, but are poor in mechanical properties. Hence hybrid composites made by mixing a natural fibre and glass fibre will be a suitable alternative which will have better mechanical strength as well as reduced impact on environment. Hybrid composite is one in which two or more fibres are used and one type of fibre compensates the lack of properties of other. The purpose of hybridization is to construct a new material that will retain the advantages of its constituents, but not their disadvantages. In some cases, the properties of natural fibre composites are better than those of glass fibre composites. This suggests that natural fibre composites can be substituted for glass fibre composites in many applications [2]. The main criteria due to which the components fail during operation is fracture [3]. Thus investigation of fracture toughness becomes very important. Investigation on the mechanical properties of jute/glass hybrid composite using different matrix was carried out by a few researchers [4-7]. The fracture toughness investigation of some synthetic fibre composites and very few natural fibre composites has also been done so far [8, 9]. In the present study, mode I fracture toughness of jute/glass hybrid composite at various volume fraction of jute and glass fibre is found out experimentally. Then, finite element analysis is performed using ANSYS software and a comparison between the experimental and experimental results are compared with FE results.

II. MATERIALS AND METHODS

A. Materials

Raw materials used for this experimental work are:

1) Jute fibre: Jute fibre used in this study was procured from Chandraprakash Shah and Company, Rajasthan, India.

2) Glass fibre (E-Glass): Glass fibre was obtained from JRP Enterprises, Kerala, India.

3) Epoxy resin LY556: Epoxy resin was obtained from Sharon resins, Kerala, India.

4) Hardener HY951: Hardener was also obtained from Sharon resins, Kerala, India.

B. Fabrication of composites

Compression moulding was the method used for the fabrication of composite specimens. A cast iron mould of 100*100*3 mm was used for casting. The entire fabrication was done at room temperature and the pressure provided for the moulding was 150 bar. Glass fibre and jute fibre was chopped and stacked layer by layer in the mould and then epoxy resin is poured over the layers. The mould is then closed and pressure was applied for 8 hours. Care was taken to avoid the formation of air bubbles. Five composite specimens, each with different volume fractions of jute and glass fibre were made. For all the samples total fibre volume fraction was maintained as 25%. The composite specimens made by compression moulding are then machined by a counter cutter to dimensions according to ASTM 5045 standard.

Fig. 1 Hybrid composite of 50% glass and 50% jute fibre

C. Mechanical Testing

Compact tension test was performed to calculate the mode I fracture toughness. This test method is used to define the toughness of plastics in terms of critical stress intensity factor. This test method involves loading a specimen that has already cracked by creating a notch. In the compact tension test load is applied on the specimen, to propagate the already created crack. The test was performed according to ASTM 5045 standard [10] using universal testing machine (UTM). Special tensile testing fixtures are used for the test and two 8 mm bolts are inserted in the holes to fix the specimen to these fixtures. Load is applied and the cross head speed is set as 10 mm/min. The load at which the crack propagates is noted from the computer attached to the UTM. This load is used for the fracture toughness calculation.

Fig. 2 Compact tension specimen fitted the UTM

Stress intensity factor can be considered as an estimate of fracture toughness. The critical stress intensity factor for mode I is given by the equation, $K_{IC} = (P/BW^{1/2})f(x)$

$f(x) = (2+x)(0.886+4.64x-13.32x^2+14.72x^3-5.6x^4)$ where:

P = Load at which crack propagates in N

B = Specimen thickness in mm

W = Specimen width in mm

a = Crack length in mm

x = a/W

D. Finite element analysis

Finite element analysis was performed using analysis software ANSYS. A three dimensional finite element model was created using ANSYS, Mechanical APDL. The element type used was SOLID 185 and a model of dimension 100*100*3 was created. Five such models were created as there was five different combination of jute-glass hybrid composite. The 3 mm thick model was then divided into 10 layers and each layer was assigned with material property of either glass-epoxy laminate or jute-epoxy laminate according to the volume fraction of the fibres in that particular composite.

The load was applied on the top half hole region and was constrained in all degrees of freedom at the bottom half hole region other than Y direction as shown in Fig 3. Stress intensity factor can be plotted directly from the ANSYS general post processor.

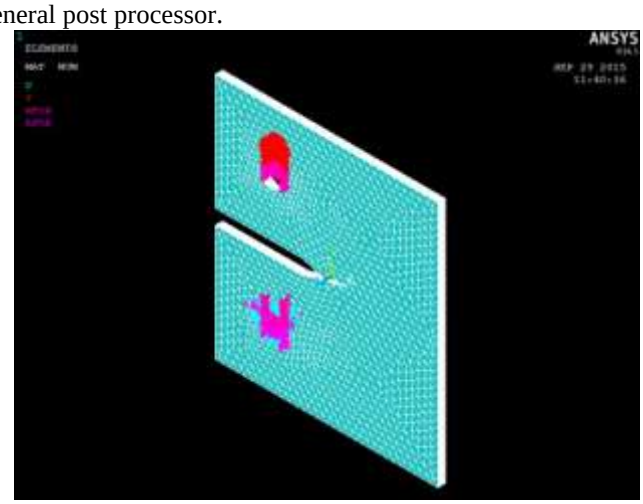

Fig. 3 Meshed specimen with applied boundary condition

III. RESULT AND DISCUSSIONS

Experiments have been performed to study the behaviour of composite material under different loading conditions and with various compositions of the hybrid composite. The analysis and interpretation of the result and comparison among various composite samples is summarized in the following sections.

A. Mode I Fracture Behaviour of Jute/Glass Hybrid Composite

Compact tension test was conducted on five specimens of jute-glass hybrid composite, each specimen with different volume fractions of jute and glass fiber. The experimental results are shown in Table 1.

TABLE 1 EXPERIMENTAL RESULTS OF THE COMPACT TENSION TEST

Volume fraction of glass fibre in %	Volume fraction of jute fibre in %	Load (N)	Stress intensity factor (Mpa.mm$^{1/2}$)
100	0	3255	131.91
75	25	2987	121.05
50	50	2705	109.62
25	75	2173	88.06
0	100	1562	63.30

From the results, it is evident that glass fibre has highest fracture toughness value. But the fracture toughness values of hybrid composites containing 75% glass & 25% jute fibre and 50% glass & 50% jute fibre also has fracture toughness values nearer to that of glass fibre composite. The value of stress

intensity factor at different volume fractions of jute fibre is shown in the Fig 4. From the graph it is clear that jute fibre composite has very low fracture toughness, because it is a pure natural fibre composite. Glass fiber when compared to jute has higher load carrying capacity, thus the resulting strength of composite increases with the increase of glass fiber content. Hence increase of glass fiber content in jute fiber composite will substantially increase the fracture property of the composite.

Glass fiber is a synthetic fiber, so it is very harmful to the environment. The experimental values show that the usage of glass fiber can be reduced by substituting it with jute fiber. The use of natural fiber will reduce the environmental impact of synthetic fiber.

B. Finite Element Analysis of Jute/Glass Hybrid Composite

Finite element analysis was conducted using ANSYS software. The stress intensity factors for mode-I was found out for various compositions of hybrid composite using ANSYS post processor. The magnitudes of stress intensity factor have also been computed experimentally and a comparison of experimental and finite element analysis is shown in the Table 2.

TABLE II COMPARISON BETWEEN EXPERIMENTAL AND FE RESULTS

Volume fraction of fibre in %		Load (N)	K_{IC}(Exp) Mpa.mm$^{1/2}$	K_{IC}(Ansys) Mpa.mm$^{1/2}$	Percentage error
Glass	Jute				
100	0	3255	131.91	137.22	3.86
75	25	2987	121.05	126.75	4.49
50	50	2705	109.62	113.87	3.73
25	75	2173	88.06	95.25	7.54
0	100	1562	63.30	68.640	7.79

From the result in Table 2 it is clear that there exist very less variation between the stress intensity factor values estimated, experimentally by compact tension test and by finite element analysis. It is found that there is only 3% to 7% error in estimation of stress intensity factor. The variation between the estimated values of stress intensity factor by experimental CT test and finite element analysis may be due to the method used for fabrication and different loading conditions during the compact tension test.

The finite element simulation of practical problems is found very useful. Results of finite element analysis are reliable as they are found to be close with the experimental results obtained. The valuable time and money can be saved by skipping expensive experimentation processes. Also the failure incidents can be avoided by conducting the finite element analysis prior to actual usage.

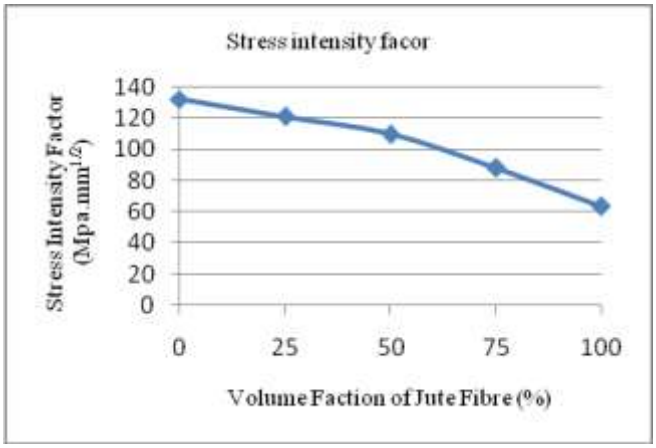

Fig. 4 Stress intensity factor at different volume fractions of jute fibre

IV. CONCLUSIONS

In this study, the effect of fibre volume fraction on the mode I fracture toughness of jute/glass hybrid composite is investigated experimentally by compact tension test and also by finite element analysis using ANSYS software. Compact tension test was performed on five composite specimens with different volume fractions of jute and glass fibre. It is found that hybrid composites with 75% glass & 25% jute and 50% glass and 50% jute shows fracture toughness values close to that of glass fibre composite. Thus environmental impact of synthetic glass fibre can be reduced by substituting it with jute fibre.

The finite element analysis results indicate that there is very less discrepancy between experimental and FE results. Thus valuable time and money can be saved by conducting the finite element analysis instead of experimentation processes. Failure incidents can also be avoided.

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REFERENCES

[1] H. Dieter and Andreas Krobjilowski, "*New Discovery in the Properties of Composites Reinforced with Natural Fibres"*, Journal of Industrial Textiles, 2003, vol.31.

[2] Paul Woumba, Jan Ivens, Ignaas Verpoest, "Natural Fibres: Can They Replace Glass in Fibre Reinforced Plastics", Journal of Composite Science and Technology, vol 63, 2003, p.p.1259-1264.

[3] R.V. Silva, D. Spineli, J.R. Tarpani, "Fracture Toughness of Natural Fibres/Castor Oil Polyurethane Composites", Composite Science and Technology, 2006, vol. 31, pp.1328-1335.

[4] Amit Bindal, Satnam Singh, Rajesh Khanna, "Development of Glass/Jute Fibre Reinforced Polyester Composites, Indian Journal of Material Science, vol 43, p.p.115-119

[5] R. Ravishankar, and K. Chandrashekhara, "Experimental Investigation and Analysis of Mechanical Properties of Jute and Glass Fibre Reinforced Hybrid Polypropylene Composites", International Journal of Mechanical Engineering and Technology, 2013, vol 4, p.p. 197-206.

[6] Raghavendra Ghujjala and Shakunthala Ohja, "Mechanical Properties of Woven Jute-Glass Hybrid Reinforced Epoxy Composites", Journal of Composite Materials, 2013, vol 13, p.p.630-636

[7] Q. Ahshan and S. Tanju, "Mechanical Behavior of Polyester Based Woven Jute/Glass Hybrid Composites", Composite Science and Technology, 2012, vol 43, p.p. 1123-1129

[8] V. Santhanam, M. Chandrasekharan, N. Venkadeshwaran, "Mode I Fracture Toughness of Banana Fibre and Glass Reinforced Composites", Advanced Material Research, 2013, vol 622, p.p.1320-1324

[9] P.S. Sivakumar Gouda, S.K Kudari, S. Prabhuswamy, "Fracture Toughness of Glass-Carbon (0/90) Fibre Reinforced Composite- An Experimental and Numerical Study", 2011, vol 10, p.p. 671-682

[10] ASTM standard D 5045, Standard Test Method for Plain-Strain Fracture Toughness and Strain Energy Release Rate of Plastic Materials.