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Experimental and theoretical investigation of Young's modulus of uni-directional jute/epoxy composite laminates with different fiber volume fraction

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Abstract

Fiber volume percentage greatly effect the mechanical properties and strength of the fiber reinforced laminated composite. In the present paper an experimental and theoretical study was carried out to determine longitudnal Young's modulus of uni-directional laminated composites. Jute/epoxy composites were manufactured to fabricate the specimens as per ASTM standards using hand lay-up technique. A number of experiments were performed to find longitudinal Young's modulus of composite laminates on computerised UTM. Experimental results of laminates were compared with those obtained from mechanics of composites. It was observed that experimental and theoretical results are in a good aggrement with each other. Based on the results percentage of fiber volume could be crucial for desire strength and mechanical properties of composites.

Keywords: composite, fiber volume, jute fiber ,uni-directional, fabricate ,hand lay- up.

INTRODUCTION

Composites have better thermal, electrical and mechanical properties. Hence they are becoming important part of our life these days. They are stiff, more rigid and reliable from their parent fiber. The specific strength and specific stiffness are the mechanical properties which are high in composite structures. The different studies regarding their properties in the field of compressive strength with jute fiber epoxy and stiffness with its different volume ratio.

Impact properties of natural fiber composite like jute fiber has been studied by Pavithran, Mukherjee, Brahmakumar and Damodaran[1]. The dynamic properties of fiber reinforced polymers composite when exposed to hot and wet condition were investigated by Adam and Singh[2]. The effect of water absorption on interlaminar fracture properties of carbon fiber-reinforced polymer laminates were performed by Selzer and Friedrich[3]. A review of the compresive, tensile, shear and flexural properties of hybrid fiber reinforced thermosetting plastics was made by Kretis[4]. Potential of polyetheretherketone (peek) and cabon fiber reinforced peek in medical application has been studied by Williams and Macnmara[5]. The impact of diffusion of water in to epoxy resin and their carbon fiber reinforced composites was made by Wright[6]. The influence of surface treatment of carbon fiber on the mechanical properties of carbon/carbon composites laminates was investigated by Fitzer, Geigl and Huttner[7]. Alkali treatmenmt of jute-fiber and relationship between mechanical properties and structure made by Gassan and Bledzki[8]. Some mechanical and physical properties of untreated jute-fabric reinforced polymer composites were studies by Munikencge and Naidu[9]. A TEM study of carbon fiber reinforced metal matrix composites was performed by Lacin and Marhic[10]. Charecterization of alkali treated jute-fiber for mechanical and physical properties were experimentally observed by Ray and Sarkar[11]. Effect of NaOH treated jute-fiber on composite laminates properties has been studied by Ray and Sarkar[12]. Fiber and resin properties influence on impact and compression after impact (CAI) performance of CFRP was investigated by Cartie and Irving[13]. Interlaminar and flexural shear strenght properties of carbon fiber reinforced polymer composites cured with microwave radiation and thermally were made by Nightinggle and Day[14]. The influence of porosity on physical and mechanical properties of unidirectional natural plant reinforced composites was studied by Madsen and Lilholt[15]. 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).

In this paper the composite of jute fiber with epoxy is prepared with diffrent volume. Experimental and theoretical analysis of Young's modulus for each speciman is calculated and then compared with each other. Their percentage error has been calculated and plotted graphically. The change in volume percentage of fiber effect the mechanical properties and Young's modulus of composite laminates.

MANUFACTURING OF COMPOSITE LAMINATES

The specimen for experiments were made from jute fiber and epoxy resin. For preparation of epoxy resin marix Araldite HY 556 and hardner HY 951 were mixed in the ratio 10:1 by volume. A rigid plywood platform was used for mold fabrication. A plastic release film was used on the plywood mold to prevent the bonding of the mold surface from the lay-up. Subsiquent plyes were placed on one another by simaltanuously applying matrix material with the help of a brush. A hand roller was used to remove the void content

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from the laminates. Laminates were cured at room temprature for 24 hours under high pressure. Finally specimen with fiber volume of 30%, 40%, 50%, 60% and 70% were cut in required dimensions for tensile testing as per ASTM D638. Five specimens of each type that is of different fiber volume of 30%, 40%, 50%, 60% and 70% were prepared to authanticate the experimental results.

Figure 1. Jute fiber specimen

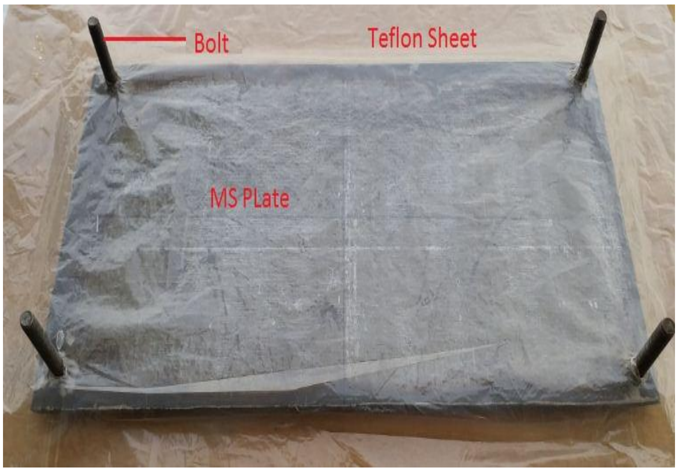

Figure 2. Mold for lamina

TESTING PROCEDURE AND EQUIPMENTS

Tensile test were conducted at room temprature on computerized UTM as per ASTM D-638 standards test method at UIET, MDU Rohtak as shown in figure 3. The composite specimens were clamped in UTM using self tightning jaws. Test were performed at a speed on 1mm/min and with 60 mm span length. Stress vs strain diagrams were plotted during tensile test. Longitudinal Young's moduls of each specimen were calculated by using Hooks law.

Fig. 3. UTM test setup

THEORETICAL ANALYSIS

A theoreitical study was made by using mechanics of composites. In theoretical analysis Young's modulus of each specimen with different volume percentage were calculated by using equation given below:

$$E_C = E_f \times v_f + E_e \times v_e \tag{1}$$

Where

E_c= Young's modulus for composite

E_f = Young`s modulus for jute fiber

v_f = jute fiber volume fraction

E_e = Young`s modulus for epoxy

v_e= epoxy volume fraction

In the above formulation c subscript is for the indication of the composite and f subscript denote the fiber.

In present study Young's modulus of jute fiber E_f is taken 28.43 GPa whereas Young's modulus of epoxy is taken as 3.4 GPa. Values of Young's modulus with different volume percentage of composite laminates were calculated by these values in above equation (1). Uni-directional jute/epoxy composite specimens were prepared with different fiber volume percentage.

RESULTS AND DISCUSSION

General behaviour of composite of specimen of different volume percentage 30%, 40%, 50%, 60% and 70% is obtained from stress-strain diagrams plotted by Universal Testing Machine. From stress-strain diagram Young's modulus of each specimen calculated using Hook's law. Modulus of five specimen with 30% fiber volume percentage are 8.121 GPa, 9.598 GPa, 9.312GPa, 9.406GPa and 9.314GPa. Average value of Young's modulus for 30% fiber volume percentage is 9.149 GPa which is calculated from the values written above. Similarly with 40%, 50%, 60%, and 70% are calculated as 14.550 GPa, 17.24 5Gpa, 16.4842 GPa and 22.2044 GPa respectively. When we compare the values of the Young's modulus for each specimen with different volume percentage it can be seen that values of Young's modulus increase with increase in fiber volume percentage. Figure 4 shows variation of theoritical Young's modulus with fiber volume fraction and from this graph we can see that theoritical Young's modulus increase linearly with increase in fiber volume fraction. On the other hand from figure 5 it is revealed that values of experimental Young's modulus for each specimen increase with increase in fiber volume fraction. Figure 6 shows comparision of experimental vs theoretical value of Young's modulus for each specimen with different volume fraction. From graph it is observed that experimental and theoritical values of Young's modulus are in good co-relation.

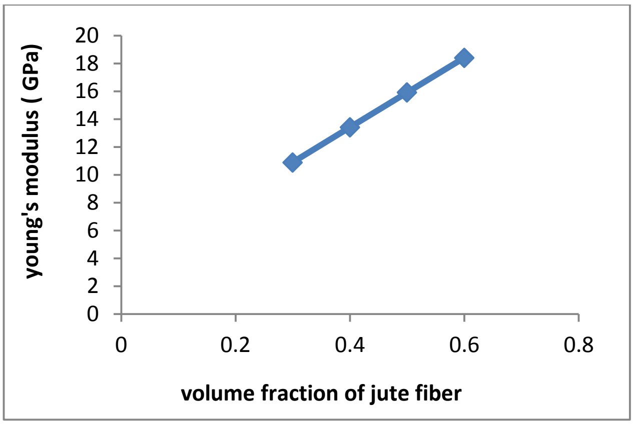

Figure 4.

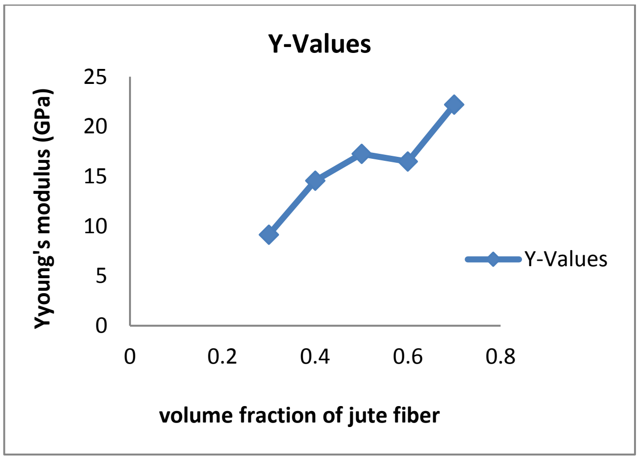

Figure 5.

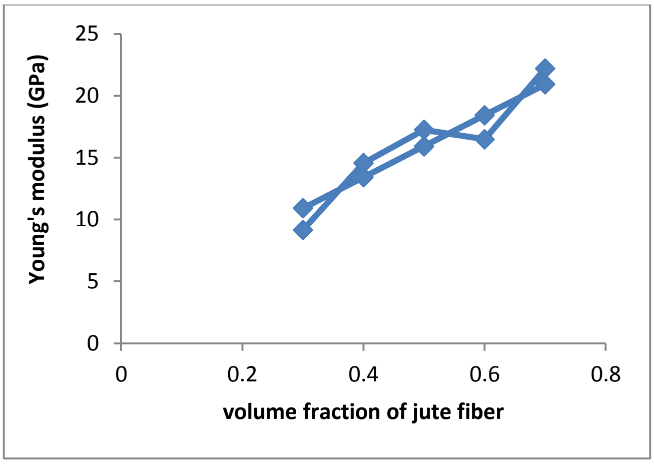

Figure 6.

Table 1.

Specimen	S_1 (GPa)	S_2 (GPa)	S_3 (GPa)	S_4 (GPa)	S_5 (GPa)	Experimental values (GPa)	Theoretical values (GPa)	Error (%)
S(V=30%)	8.121	9.598	9.312	9.406	9.314	9.1498	10.90	-16.056
S(V=40%)	14.121	14.302	14.517	15.102	14.709	14.5502	13.412	8.486
S(V=50%)	17.101	16.901	17.501	16.802	17.919	17.2446	15.915	8.228
S(V=60%)	16.102	17.102	16.502	16.414	16.301	16.4842	18.418	-10.4995
S(V=70%)	21.901	22.402	22.301	22.147	22.001	22.2044	20.921	6.134

CONCLUSION

The results observed above stated following conclusions stated as:

- Stress-strain diagram shows that jute fiber /epoxy composites are brittle in nature.
- Jute fiber percentage influence to a greater extent the strength and stiffness of composite laminates.
- Theoretical observations shows that Young's modulus increase linearly with increase in jute fiber volume fraction in composite laminates.
- Experimentally observed values of Young's modulus for different fiber volume fraction in composite are not exactly linear with increase in volume fraction of fiber but are slightly up-down from theoretical values.

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