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Tensile properties of unidirectional glass/epoxy composites at different orientations of fibres

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Abstract
In this work, Diglycidyl Ether of BisphenolA(DGEBA) / TriEthylene Tetra Amine(TETA) system is used as the epoxy matrix and unidirectional glass fabric is used to reinforce with the polymer matrix by hand layup and vacuum bagging process. The glass fibre reinforced composites are prepared with fibre orientations of 0°, 45° and 90°. The specimens, after preparation, are tested for various tensile properties at different angles of the laminate. The tensile properties studied in this case are Tensile Strength, Tensile Modulus, Specific Tensile Strength and Specific Tensile Modulus. The result shave then been tabulated and studied to understand variation in the properties with orientation of fibre in the composite. Experimental procedure is carried out as per ASTM D3039 standards.

I. Introduction

Fiber reinforced composite materials are demanded by the industry because of their high specific strength, especially for applications where weight reduction is critical [1&2]. It is well known that the fibre orientation affects the strength and stiffness of polymer matrix composite structure [3]. The main properties that describe a composite material are the engineering constants and the strength properties of a single unidirectional lamina that make the laminated structure [4]. Greater understanding of the role of variation in tensile properties with orientation of fibres in the laminate was acquired through the experiments [5].

II. Fabrication of specimens

The process of fabrication is carried out by using Diglycidyl Ether of BisphenolA (DGEBA) / TriEthylene Tetra Amine (TETA) as the epoxy matrix, chemically belonging to the 'epoxide' family is used as the matrix materialin the ratio 10:1. The composite specimen is fabricated as per the standard procedure. Unidirectional fabric of E-glass with density 220 gsm is used to reinforce the polymer matrix. The surfaces will be thoroughly cleaned in order to ensure that they were free from oil, dirt etc., before bonding at room temperature and pressure. The laminate will be allowed to cure for about 24 hours.

Figure 1, Manufacture of Glass fibre laminate using Vacuum hand lay – up technique

Vacuum hand lay – up technique (Fig 1) was used to make the laminates. Vacuum bag moulding uses a flexible film to enclose the part and seal it from outside air. A vacuum is then drawn on the vacuum bag and atmospheric pressure compresses the part during the cure. Vacuum bag material is available in a tube shape or a sheet of material [6]. Vacuum level (500 mm of Mercury for 2 hours) was monitored so as to avoid surface undulations and also avoid air pockets at the interface. Vacuum hand lay – up process offers many benefits when compared to conventional hand lay-up techniques. As it is a closed moulding process, it virtually eliminates potentially harmful volatile organic compound (VOC) emissions. The vacuum system also facilitates good resin distribution and consolidation of the laminate. As a result, the mechanical properties of the laminates are likely to be higher than the case with hand laminating.

The laminate will be allowed to cure for about 24 hours at room temperature and then it is cut to obtain test specimens with 3 different orientations of glass fibre (0°, 45° and 90°) as shown in fig. (2)

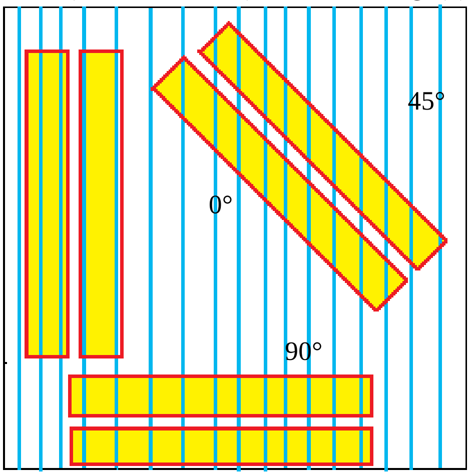

Figure 2, Orientation of Test Specimens in the Laminate

III. Experimental details

Testing for Tensile Strength and Tensile Modulus was carried as per ASTM D-3039 standards [7].

This test method determines the in-plane tensile properties of polymer matrix composite materials reinforced by high-modulus fibers. The specimen is machined from a flat laminate in to the required shape. Fig. 3 shows the testing apparatus.

Density of the specimen was calculated and found to be approximately equal to 58.889 kg/m^3

Specific Tensile Modulus=(Tensile Modulus/Density)
Specific Tensile Strength=(Tensile Strength/Density)

Figure 3, Tensile Testing Apparatus

IV. Results and Discussion

Using the density of the material and the values of tensile strength and tensile modulus obtained experimentally, the values of specific tensile strength and specific tensile modulus were calculated and tabulated as shown in table 1.

Fig.4 shows the fractured specimen and fig. (5a-5f) shows stress-strain curve obtained.

Table 1, Tabulation of Testing Results

Orientation (Degrees)	Specimen Number	Tensile Strength (MPa)	Tensile Modulus (GPa)	Specific Tensile Strength (MPa-m^3/kg)	Specific Tensile Modulus (GPa-m^3/kg)
0	**1**	**324.42**	**10.07**	**5.529**	**0.171**
	2	**326.92**	**10.07**	**5.572**	**0.171**
45	**1**	**47.71**	**2.53**	**0.813**	**0.0431**
	2	**49.40**	**2.53**	**0.842**	**0.0431**
90	**1**	**37.81**	**1.55**	**0.644**	**0.0264**
	2	**22.40**	**2.32**	**0.381**	**0.0395**

Fig 4, Fractured Test Specimens

4.1 Graphs

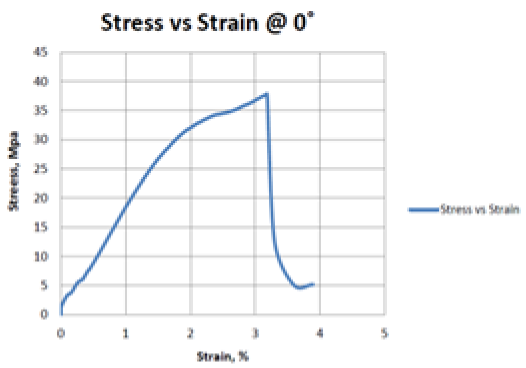

Fig. 5a

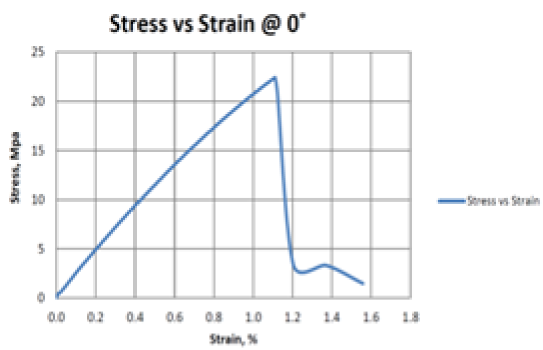

Fig. 5b

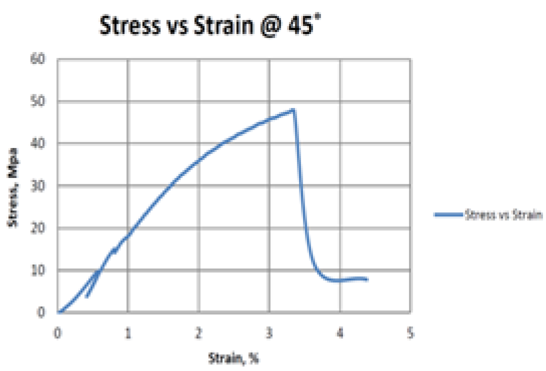

Fig. 5c

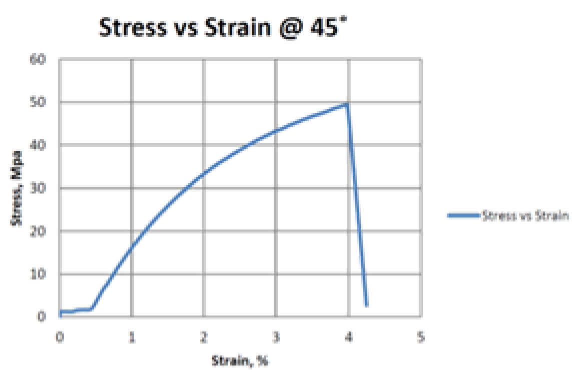

Fig. 5d

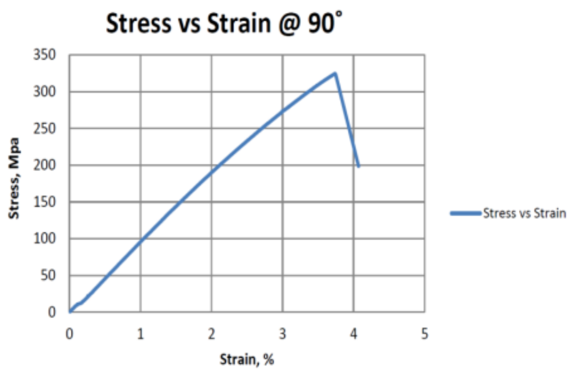

Fig. 5e

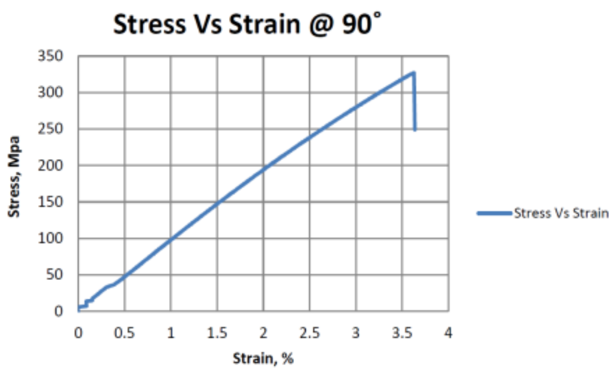

Fig. 5f

From the above results, it can be concluded that the prepared glass/epoxy laminate exhibits various strength and stiffness values at different fibre orientations. Both stiffness and strength are found to be highest in the longitudinal direction and will be least in the transverse direction. Also, the specific strength and specific stiffness are found to be high in the longitudinal direction as compared to the other tested directions. This is because of the dominant properties of the fibres in the longitudinal direction. As fibre orientation changes from 0° to 90°, the properties of the fibres decline and the properties of the matrix dominate. At 45° orientation of fibres, both the fibres and the matrix play a major role in determining the properties of the composite. The difference in these properties may be observed from the obtained results.

V. Conclusion

Over the course of this project, the glass fibre/epoxy laminate has been fabricated and suitable specimens have been created and tested to understand the tensile properties of the composite. The properties studied are tensile strength, tensile modulus, specific tensile strength and specific tensile modulus. The values have been tabulated and additional results for specific tensile strength and specific tensile modulus have been calculated. From the results it is understood that the fibre reinforced polymer laminates exhibit higher strength and stiffness properties in the longitudinal direction as compared to other directions.

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