International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 15 (2018) pp. 12157-12160

Experimental and Numerical Analysis of Tensile Strength of Unidirectional Glass/Epoxy Composite Laminates with Different Fiber Percentage

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Abstract

The present paper deals with the experimental and numerical investigation of tensile strength on unidirectional Glass/epoxy composite laminates with different percentage of glass fiber. Composite laminates with volume fraction percentage of 40%, 50%, 60%, 70% and 80% were prepared using hand layup technique at room temperature. A number of experiments were conducted to obtain tensile strength. Experimental results obtained were compared with the results obtained from numerical methods. A good agreement was found between experimental and numerical results.

Keywords: Volume fraction, Tensile test, Laminated composites, E-glass fiber, Epoxy

INTRODUCTION

Application of composites is increasing day by day due to their superior mechanical, electrical, chemical and thermal properties. Mechanical properties such as specific stiffness and specific strengths are high in composite structures. Various studies have been performed by different researchers to investigate their mechanical properties such as tensile, flexural and compressive strengths at different conditions such as fiber orientation, fiber volume fraction and curing temperature etc.

A study has been made to find the effect of fiber length and their orientation distribution on tensile strength of Glass fiber/epoxy composites by Yub Fu and Lauke [1]. Vallittu [2] determines flexural strength of Acrylic resin epoxy reinforced unidirectional and woven roving glass fibers. Fiber surface treatment effect on bond strength between fiber and matrix of natural fiber embedded composite has been studied by Gonzaliz et al [3]. Fiber treatment effect on the different mechanical properties of unidirectional Sisal fiber/epoxy composites is investigated by Rong, Zhang, Lui, Yang and Zeng [4]. Iglesias, Benito, Aznau, Bravo and Baselga [5] studied the effect of surface treatment of glass fiber on mechanical properties of glass/epoxy composite materials. A comparison of mechanical properties is made by Joseph et al [6] when phenol formaldehyde is reinforced with glass and banana fibers. Mishra, Mohanty, Drzal, Misra, Parija, Nayak and Tripathy [7] performed a study to investigate mechanical performance of glass and bio fiber reinforced polyester composites. Tensile properties of short and long fiber reinforced composites, of natural fiber Vakka, Date and Bamboo have been studied by [8,9]. Rashed, Islam and Rizvi [10] find out the effect of different process parameters on tensile strength of jute reinforced polymer composite. Tensile properties of sugar palm fiber when treated with alkaline is studied by Bachtiar, Sapran and Hamdan [11]. A review of tensile properties of natural fiber composites was made by Ku, Wang, Pattarachaiyakoop and Trada [12]. Kumar, Das and Neckar [13] studied the fiber orientation effect on tensile strength of biocomposites made from poly and nettle fibers. Gai et al [14] experimentally investigated the tensile behavior of unidirectional and woven glass/epoxy laminated composites.

In the present paper tensile strength of unidirectional glass fiber/epoxy composite with different fiber volume percentage is presented. Both numerical and experimental investigations are made and compared with each other.

SPECIMEN PREPARATION

To manufacture laminates a mold was prepared from mild steel plates as shown in figure 2. The diameter of the plates was 250 mm of length × 100 mm of width × 10 mm of thickness. A surface grinder was used to obtain the desired finishing of plates. Four holes each at one corner were made for the nut and bolt assembly. A Teflon sheet was used as a releasing agent on the plates. Epoxy resin LY 556 and Hardener HY951 were mixed in the ratio of 10:1 by volume for the matrix preparation. Laminates were prepared by using hand layup method. Layers of glass fibers were stacked one by one and epoxy resin was applied with the help of brush after placing each layer. A hand roller was used to remove the entrapped air bubbles and distribute the resin properly. The mold and laminate were covered with a Teflon sheet to prevent the bonding of mold and laminates. Laminates were cured at room temperature for 24 hours. The thickness of prepared specimen was 3.5 mm, length 160 mm and width 15 mm as shown in figure 1.

Figure 1. Prepared test specimen

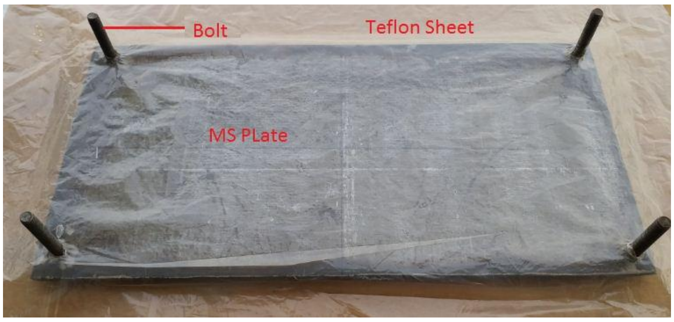


Figure 2. Bottom mold plate with Teflon sheet

EXPERIMENTAL SETUP AND TESTING PROCEDURE

Tensile tests were performed at room temperature with a speed of 2 mm/min and with a span length of 60 mm as per ASTM D638 standard test method on FIE make universal testing machine at UIET, MDU, Rohtak as shown in figure 3. Load vs displacement graphs were plotted during tensile test.

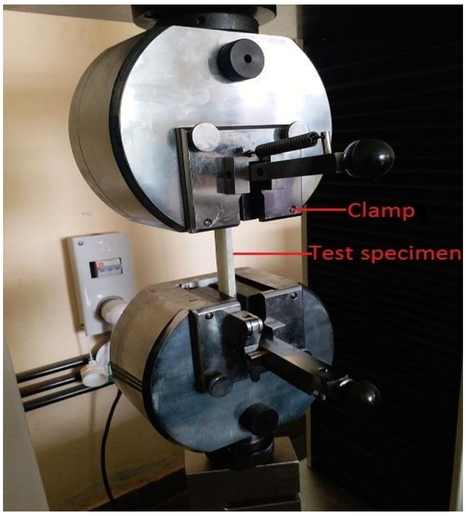


Figure 3. Test Setup

NUMERICAL ANALYSIS

In second part a numerical study was done by using mechanics of composites. The equation used for numerical investigation is given as:

$$\sigma_c = E_f \varepsilon_f V_f + E_m \varepsilon_m V_m$$

Where,

σ_c = Composite strength

E = Young's modulus

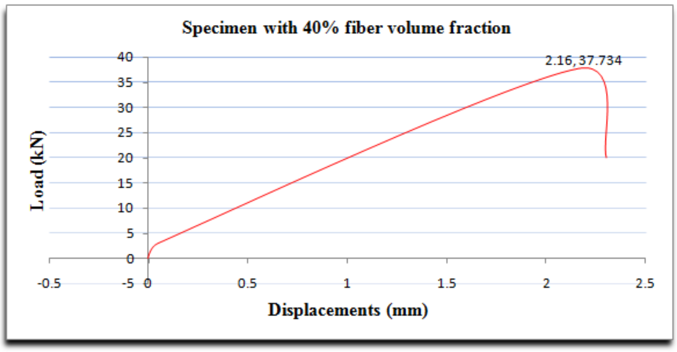
ε = Strain

V = Volume fraction

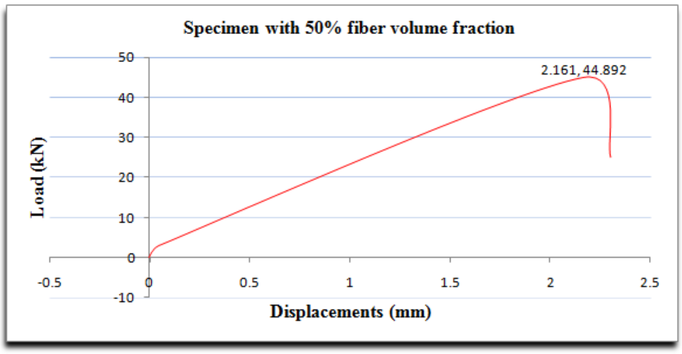
In the above equation 'c' subscript is used for the composite, 'f' subscript is used for the fiber and 'm' subscript is used for the matrix. Young's modulus E_f and E_m for the fiber and matrix are 40 GPa and 3.5 GPa respectively.

RESULTS AND DISCUSSIONS

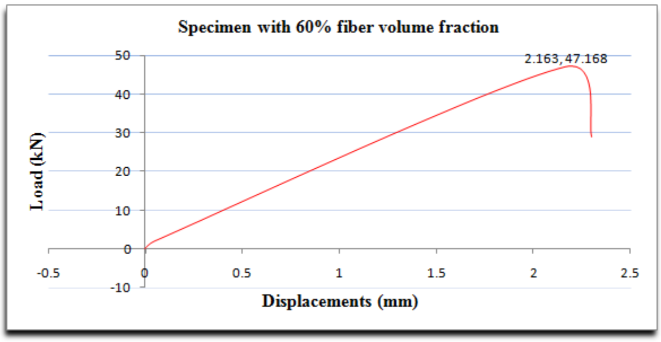
General behavior of composites with different volume fractions of 40%, 50%, 60%, 70% and 80% are obtained from the load vs displacement graphs from computerized universal testing machine. Load vs displacement graphs for different volume fraction specimens are plotted as shown in figure 4.



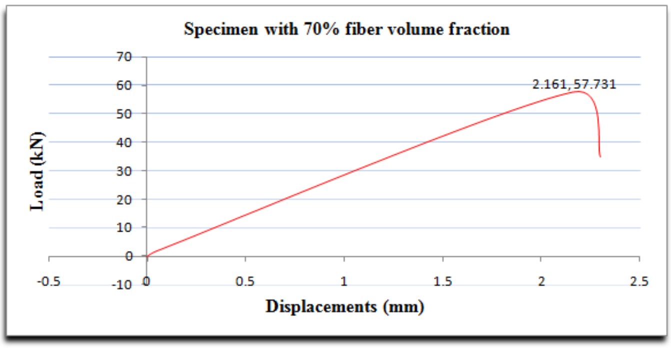
(a)



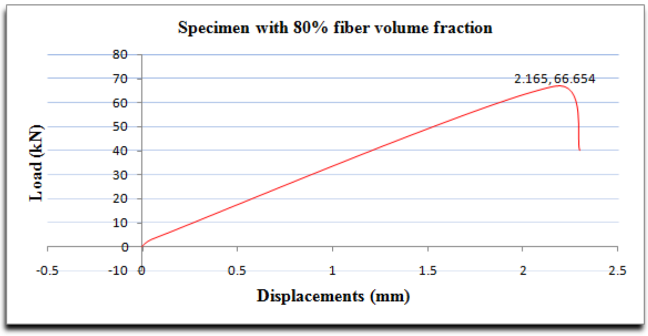
(b)



(c)



(d)



(e)

Figure 4. a,b,c,d and e represents the load vs displacement graphs of specimens with different volume fractions

It is observed from the load vs displacement graphs that the composite laminate shows brittle behavior. Results obtained from load vs displacement graphs with various volume fractions and numerical analysis are shown in table 1

Table 1.

Specimen	Strain	Strengths (MPa)		Error (%)
		Experimental	Numerical	
S (V_f = 40%)	0.036	37.734	34.209	9.341
S (V_f = 50%)	0.036	44.892	41.107	8.431
S (V_f = 60%)	0.037	47.168	49.339	-2.307
S (V_f = 70%)	0.037	57.731	56.429	2.255
S (V_f = 80%)	0.038	66.654	65.236	2.127

- It is observed from that specimen with least volume fraction of glass fiber fails at lowest load in comparison to that of the laminates with higher volume fractions of fibers.
- It is also observed that the contribution of epoxy resin in tensile strength is negligible in comparison to the Glass fiber, which shows that the main function of epoxy resin is to hold the glass fiber in composites.

Tensile strength of the specimen with fiber of 80% volume fraction has the tensile strength of 1242.6 Mpa, tensile strength of laminate with a volume fraction of 40% fiber is 651.6 Mpa which is 47.561% lower than the laminate with fiber of 80% volume fraction.

Least error is observed between experimental and numerical a result which shows a good agreement between experimental and numerical results.

CONCLUSIONS

Based on the results obtained from experimental and numerical study the broad conclusion that can be made are as follows:

- Load vs displacement graphs of E-glass epoxy composite shows brittle behavior
- Tensile strength increases with increase volume fraction of glass fiber in glass fiber/epoxy laminates
- Glass fiber dominates in tensile strength in comparison of matrix material i.e., epoxy resin.
- Change in volume fraction of glass fiber has almost negligible effect on the strain produced in laminates.

REFERENCES

[1] Yun Fu S, Lauke B. Effects of fiber length and fiber orientation distribution on the tensile strength of short-fiber-reinforced polymers. Compos Sci and Tech 1996;56:1179-1190/

[2] Pekka K, Vallittu. Flexural properties of acrylic resin polymers reinforced with unidirectional and woven glass fibers. The jour of Pros Dent 1999;81:318-326.

[3] Gonzalez AV, Cervantes JM, Olayo R, Franco PJH. Effect of fiber surface treatment on the fiber-matrix bond strength of natural fiber reinforced composites. Compos Part B 1999;30:309-320.

[4] Rong MZ, Zhang MQ, Liu Y, Yang GC, Zeng HM. The effect of fiber treatment on the mechanical properties of unidirectional sisal-reinforced epoxy composites. Compos Sci and Tech 2001;61:1437-1447.

[5] Iglesias JG, Benito JG, Aznar AJ, Bravo J, Baselga J. Effect of glass fiber surface treatments on mechanical strength of epoxy based composite materials. Jou of Collo and Inter Sci 2002;250:251-260

[6] Joseph S, Sreekala MS, Oommen Z, Koshy P, Thomas S. A comparison of the mechanical properties of phenol formaldehyde composite reinforced with banana fibers and glass fibers. Compos Sci and Tech 2002;62:1857-1868.

[7] Mishra S, Mohanty AK, Drzai LT, Misra M, Parija S, Nayak SK, Tripathy SS. Studies on mechanical performance of biofiber/glass reinforced polyester hybrid composites. Compos Sci and Tech 2003;63:1377-1385.

[8] Hassan A, Yahya R, Yahaya AH. Tensile, impact and fiber length properties of injection-molded short and long glass fiber-reinforced polyamide 6,6 composites. 2004.

[9] Murali Mohan Rao K. Extraction and tensile properties of natural fibers: Vakka, date and bamboo. Compos Struc 2007;77:288-295.

[10] Rashed HMMA, Islam MA, Rizvi FB. Effects of process parameters on tensile strength of jute reinforced thermoplastic composites. Journ of Naval Arch and Marine Engg 2006.

[11] Bachtiar D, Sapuan SM, Hamdan MM. The effect of alkaline treatment on tensile properties of sugar palm fiber reinforced epoxy composites. Mater and design 2008;29:1284-1290.

[12] Ku H, Wang H, Pattarachaiyakoop N, Trada M. A review on the tensile properties of natural fiber reinforced polymer composites. Compos Part B 2011;42:856-873.

[13] Kumar N, Das D, Neckar B. Effects of fiber orientation on tensile behavior of biocomposites prepared from nettle and poly(lactic acid) fibers: modeling and experiment. Compos Part B 2108;138:113-121.

[14] Cai D, Zhou G, Wang X, Li C, Deng J. Experimental investigation on mechanical properties of unidirectional and woven fabric glass/epoxy composites under off-axis tensile loading. Poly testing 2017;58:142-152.