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.


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](Image)
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.

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,

\( \sigma_c \) = Composite strength
\( E \) = Young’s modulus
\( \varepsilon \) = 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)
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.**

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Strain</th>
<th>Strengths (MPa)</th>
<th>Error (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Experimental</td>
<td>Numerical</td>
</tr>
<tr>
<td>$S$ ($V_f = 40%$)</td>
<td>0.036</td>
<td>37.734</td>
<td>34.209</td>
</tr>
<tr>
<td>$S$ ($V_f = 50%$)</td>
<td>0.036</td>
<td>44.892</td>
<td>41.107</td>
</tr>
<tr>
<td>$S$ ($V_f = 60%$)</td>
<td>0.037</td>
<td>47.168</td>
<td>49.339</td>
</tr>
<tr>
<td>$S$ ($V_f = 70%$)</td>
<td>0.037</td>
<td>57.731</td>
<td>56.429</td>
</tr>
<tr>
<td>$S$ ($V_f = 80%$)</td>
<td>0.038</td>
<td>66.654</td>
<td>65.236</td>
</tr>
</tbody>
</table>

- 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**

