Experimental Investigation of Fibre Reinforced Composite Materials Under Impact Load

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Abstract: Composite materials are extensively used in various engineering applications. They have very high flexibility design which allows prescribe tailoring of material properties by lamination of composite fibres with reinforcement of resin to it. Complex failure condition prevail in the composite materials under the action of impact loads, major modes of failure in composite may include matrix cracking, fibre matrix, fibre breakage, de-bonding or de-lamination between composite plies. This paper describes the mechanical properties of glass fibre reinforced composite material under impact loading conditions through experimental setup. Experimental tests are performed according to ASTM standards using impact testing machines like Charpy test, computerized universal testing machine.

1. Introduction

A composite material is a material which consists of a mixture or combination of two or more distinctly differing materials with significant difference in physical or chemical properties, when combined produces the material with different characteristics from individual components.

There is an increasing in demand for the advanced materials with improved properties that has led to the improvement or replacing the existing materials. This has contributed the introduction of composites that can allow the design improvements easily. Now-a- days composites are applied in various fields like aerospace, defence, engineering applications.

Fibres like glass is abundantly available with light weight, low density, high toughness etc. Now-a-days glass fibre can be used as the substituent or replacement of the traditional materials because of its high strength to weight ratio and weight reduction. In general interfacial bond should be sufficiently strong to transfer the load from matrix to fibre. In dealing with toughness of the composites, the interface bond may need not to be strong thus allow the toughness mechanisms like de-lamination, fibre pull out to takes place. Volume fraction is one of the important parameter that plays a major role in determining the properties.

In this paper, glass fibre reinforced composite material specimen is fabricated and further experimentally tested under impact and tensile loading conditions.

2. Experimental procedure

2.1 Material: Glass fibre

The most commonly used fibre in polymeric fibre reinforced composite material is glass fibre. The advantage is its low cost. The glass fibre reinforced composite materials have high tensile strength, light weight, better insulating properties. Application of glass fibre includes construction of boat hulls like canoes, speed boats, military and commercial hovercrafts.

2.2 Resin and Hardener
The epoxy resin [11] gives a better adhesion [3] for reinforcing the fibre. The epoxy resin used is LY 556. In glass fibre the resin used transfers the shear and allow the resin to resist the tensile and compressive loads [10]. Hardener is employed to enhance the interfacial adhesion. Resin and hardener is used in the proportion of 10:1 to get optimum matrix composition.

2.3 Fabrication procedure for specimen

The hand layup process is used for the fabrication of the composite material. Resin and hardener mixture is applied to every layer [4]. Firstly the mould is cleaned with acetone and a layer of glass fibre is placed on the mould. Then the resin hardener mixture is applied on layer using the brush. The layers are then rolled to squeeze the trapped air to get the uniform spread of the mixture. In this way the layers are placed one over the other to get the required thickness. The mould is then allowed for curing of about 7–12 hours [6]. The prepared composite laminates are made to required size by cutting the sides. The weight ratio of resin and fibre is given in the table 1.

Table 1 Calculation of weight ratio for resin and fibre.

| S.NO | Fibre | Thickness of fibre (mm) | Weight of fibre (Wf) (gram) | Weight of resin (Wr) (gram) | Weight of hardener (gram) |
|------|-------|-------------------------|----------------------------|-----------------------------|--------------------------|
| 1    | Glass | 3                       | 112.5                      | 225                         | 22.5                     |

1) Volume of composite = 30×25×0.3=225cc
2) Weight of resin = 112.5×2 = 225g
3) Weight of hardener = 225/10 =22.5g

3. Testing of composites

3.1 Impact Test

Generally impact testing is of two types [2]: 1) low velocity impact 2) High velocity impact. Charpy impact testing and Drop weight method belong to low velocity impact testing. Ballistics belongs to high velocity impact testing.

3.2 Charpy impact testing

Charpy impact testing has been used to test the toughness of the materials. It is done as per the ASTM D256 standard. Due to its low cost and fastness it has been extended to composites.

3.2.1 Specimen Specification for the Charpy test. The specimen that is used for Charpy impact testing is rectangular with or without notch cut in one side. Typically here, specimen includes the rectangular bar without notch.

For a typical fibre reinforced polymer Charpy specimen is L=55mm, W=10mm

Figure 1: Charpy impact test specimens

3.2.2 Test setup and procedure. Charpy test method works by placing the specimen [5] (without the notch facing away from the point of contact). The apparatus has the pendulum of known mass and
length. The pendulum is raised to known height and allowed to fall. As the pendulum swings, it impacts and breaks the specimen rising to a measured height.

The difference of the initial and final heights is proportional to the amount of energy lost during the fracture. The total energy absorbed during the fracture is determined by

$$T_{\text{total}} = mg \times (h_i - h_f)$$

$T_{\text{total}}$ is the total energy, $m$ is the mass, $g$ is the acceleration due to gravity, $h_i$ is the initial height, $h_f$ is the final height.

The failure of the charpy test composite specimen depends on the specimen orientation. Often fibre exhibits the fibre fracture and fibre pull out but sometimes de-lamination failure is the primary mode of failure. Figure 2 shows the Charpy impact specimen failure modes.

![Figure 2: Charpy impact test specimen failure modes](image)

### 3.3 Tensile test

The tensile test of composite specimen was done according to the ASTM D638 [9] standard and the specimens are shown in figure . A computerized Universal Testing Machine was used to carry out the test. The composite specimen for the tensile test was prepared by marking according to the dimensions and cut with hack saw blade and smoothened by the belt grinder. Here the test was done for 3 specimens of glass fibre to get the average mechanical properties. The tensile test composite specimen was placed in the grip of the universal testing machine and the test is performed by applying the tensile load until it undergoes fracture and the corresponding load and displacement plots were obtained.

#### 3.3.1 Specimen specification for the tensile test

The specimen that is used for the tensile test is the rectangular bar. For the typical fibre reinforced polymer, tensile test specimen is $L=250$ mm, $W=25$ mm and tensile test specimens are shown in Figure 3

![Figure 3: Tensile test specimens](image)
3.3.2 Test set up and procedure. Initially before loading the specimen into the machine it is necessary to ensure that the computer connected to the machine was set with required input parameters like gauge length [9] and width of the specimen. The computer was then prepared to record the data and get the necessary output. Then the specimens were loaded into the machine and tensile test was performed until the specimen fractures by applying the tensile load. Then the required outputs were obtained. Figure 4 shows the tensile test specimen failure modes.

![Tensile test specimen failure modes](image)

Figure 4: Tensile test specimen failure modes

4. Results and discussion

4.1 Impact test

Impact test is conducted to know the impact capability of the glass fibre composite. The loss in energy of the composite is found using the charpy impact test machine. The average impact strength of glass fibre reinforced composite is 0.129 J/mm².

Table 2 Results of impact test

| Sample No | Fibre | Thickness (mm) | Width (mm) | Actual energy absorbed (K1) Joules | Actual energy absorbed (K2) Joules | Actual energy absorbed (K3) Joules | Average actual energy absorbed (K) Joules |
|-----------|-------|----------------|------------|------------------------------------|------------------------------------|------------------------------------|-----------------------------------------|
| 1         | Glass | 3.1            | 10         | 4                                  | 2                                  | 6                                  | 4                                        |
| 2         | Glass | 3.1            | 10         | 4                                  | 4                                  | 4                                  | 4                                        |

Table 3 Calculation of impact strength

| Sample No | Fibre | Thickness (mm) | Width (mm) | Area (a) mm² | Average actual energy absorbed (K) Joules | Impact strength (I_k) \( I_k = k/a^2 \) J/mm² |
|-----------|-------|----------------|------------|--------------|-------------------------------------------|---------------------------------------------|
| 1         | Glass | 3.1            | 10         | 31           | 4                                         | 0.129                                       |
| 2         | Glass | 3.1            | 10         | 31           | 4                                         | 0.129                                       |

4.2 Tensile Properties

The glass fibre reinforced composite specimen is tested in the universal testing machine under tensile load. Plots of load vs displacement are shown in Fig. 5-7.
The various mechanical properties are summarized in the table 4. From the results it is concluded that GFRP has an average tensile stress [11] of 135.36 N/mm² and the corresponding elongation is 5.90% at a strain rate of 2.5 mm/min. The ultimate average breaking load at which the sample breaks is 640 N.

**TENSILE TEST RESULT**

![Sample 1](image1)

![Sample 2](image2)

![Sample 3](image3)

**Table 4** Tensile test specimen mechanical properties

| Sample no | Thickness (mm) | Strain rate (mm/min) | Ultimate stress (N/mm²) | Maximum Displacement (mm) | Breaking load(N) | Elongation (%) |
|-----------|----------------|----------------------|-------------------------|--------------------------|-----------------|----------------|
| 1         | 3.16           | 2.5                  | 131.27                  | 2.83                     | 1140            | 7.14           |
| 2         | 3.24           | 2.5                  | 125.64                  | 2.92                     | 380             | 6.86           |
| 3         | 3              | 2.5                  | 149.198                 | 4.80                     | 400             | 3.72           |
5. Conclusions
In this context, the composite was fabricated with glass fibre. Their mechanical properties like impact strength from impact test and tensile strength from computerized UTM are investigated and the following conclusions were drawn.

- The average impact strength of GFRP composite is 0.129 J/mm² with an energy absorption of 4 J.
- The average tensile strength of the GFRP composite is 135.36 N/mm² and it has an average breaking load of value 640 N.
- For the above average tensile strength, the average percentage elongation of GFRP composite is 5.90%. It means that it withstands more strain before failure in tensile test.

From the above experimental data, it can be concluded that because of its mechanical properties glass fibre reinforced composites can be extensively used in automobile applications, medical purposes, boat hulls etc.,

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