DETERMINATION OF MODE-I FRACTURE TOUGHNESS OF EPOXY-GLASS FIBER COMPOSITE LAMINATE

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ABSTRACT

The conventional materials fail to meet the requirements of high technology applications like space applications. In order to meet the requirements like high temperature and wear resistances new materials are being searched. The composite laminar for the testing will be prepared with glass fiber rain forced with epoxy.

The applications of composite materials have recently increased because of high strength/stiffness for lower weight, superior fatigue characteristics, a facility to change fiber orientations, etc. At the same time, these materials pose a new problems such as inter ply cracking, the inter laminar de-lamination and fiber cracking. A Composite materials failure can be reduced by increasing the fracture toughness.

Our Aim is to Evaluate the fracture toughness of the glass fiber/epoxy composites. The Composites were prepared with a glass fiber reinforced with epoxy based polymer. Fracture Toughness of the specimen is used to conduct mode-I fracture test using special loading fixtures as per ASTM standards.

Key words: Glass Fiber, Fracture Toughness,


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1. INTRODUCTION
The role of engineering materials in the development of a modern technology need not be emphasized. It is the materials through which a designer puts forward his ideas into practice.

Several performance characteristics were expected from these materials. They are:

- Materials must have combinations of properties for specific uses since present day product of modern technological origins operate in environment that are special or
- Extreme like very high temperature (of order of 2500 °K), cryogenic condition, vacuum (as in space), high hydrostatic pressure (as in deep sea).

The conventional material may not always be capable of meeting consumer demands.

Hence new materials being created for meeting these performance requirements and such composite materials from one class of materials were developed.

2. LITERATURE REVIEW

3. EXPERIMENTAL METHODS TO DETERMINE FRACTURE TOUGHNESS
3.1. Specimen Preparation and Testing
Preparation of Specimen

Glass Fiber

Fiber glass has the white color and is available as the dry fiber fabric. Four major types of Glass Fiber used for composites:
E-glass: have good strength & good electrical resistivity.
S-glass: have got 40% higher strength, which is better retention of properties at elevated temperatures.
C-glass: have 8 corrosion resistant.
Quartz: have a low dielectric properties, a good for antennae.
Determination of Mode-I Fracture Toughness of Epoxy-Glass Fiber Composite Laminate

**Epoxy resin**
Epoxy resins are much more expensive than a polyester resin because of a high cost of a precursor chemicals that is most notably epichlorohydrin. However, an increased complexity of 'epoxy' polymer chain and a high potential for a greater degree of control of cross linking process one that gives much improved matrix in terms of a strength and the ductility.

Epoxy polymers are made by reacting epichlorohydrin with the bisphenol-A in an alkaline solution one which absorbs the HCl released during condensation polymerisation reaction. Each chain has a molecular weight between 900 and 3000 within the polymer chain. The epoxy is cured by adding a hardener in equal proportions and being heated to about 120°C. The hardeners are usually short chain diamines such as ethylene diamine.

**Hardener**: A mixture is added to plastic composition to control the curing action by taking part in it. Also, to control the degree of hardness of a cured film.

![Figure 1 Glass fiber](image1.png)

![Figure 2 Epoxy resin and hardener](image2.png)

The required mixture of resin & hardener were made by mixing them in (10:1) parts in a beaker. When the epoxy resins modified with different contents of particles which were prepared through vacuum assisted hand lay-up procedures, they are diffused into unidirectional fibers to form the glass fiber/epoxy composites. The process is that a final mixture of epoxy resin within the H-100 curing agent what was poured on to one dry glass fiber layer and then impregnated into a dry fiber with the assistance of a hand roller until these fiber bundles were permeated completely by a resin. Then, another ply of dry fiber was stacked on to it. The repeating process continued until the 12 layers of glass fibers were fabricated. Since the interlaminar fracture toughness of the composites were measured from the double cantilever beam (DCB) specimens, during this process, a porous film is inserted in a mid-plane of the laminate for the creation of pre-crack. The entire stacking was then sandwiched between two steel plates with porous Teflon fabric on the surfaces and then...
sealed with a vacuum bag. The whole laminates were cured in a hot press with the suggested temperature profile under vacuum conditions.

Prepared Glass fiber laminates

![Prepared Glass fiber laminates](image1)

**Figure 3** Prepared Glass fiber laminates

The prepared samples were cut into required dimensions based on ASTM D 5528 standards for fracture Toughness test.

![Prepared samples Glass Epoxy](image2)

**Figure 4** Prepared samples Glass Epoxy

Laminate after cutting

3.2. Test Procedure

Fracture toughness was evaluated from these specimens that are made of ply laminates with a porous film inserted in the mid-plane during the layup process for creating the initial crack. Symmetric loadings that are applied in opposite directions were transferred into the cracked end of the specimens through a pair of hinges which are bonded on the specimen surfaces the one that resulting in the mode I crack extension. Prior to the fracture tests, specimens were pulled out such that the precrack can extend around 4 mm penetrating the resin enriched area and reach the “true” crack tip where the fracture toughness begin to be measured. All specimen preparations and experimental procedures were performed based on ASTM standard D552+/. CW8.

![Microscope](image3)

**Figure 5** Microscope

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4. RESULTS

Mode 1 Fracture Toughness test as per ASTM D 5528 standard have been carried out on Fracture toughness testing machine. The Results from the test have been evaluated as per ASTM D 5528 and computed and recorded.

The following are the results of experiment

For the sample with the ratio of fiber and epoxy is 50:50

<table>
<thead>
<tr>
<th>Extension(mm)</th>
<th>Load(N)</th>
<th>Strain(mm/mm)</th>
<th>Stress(MPa)</th>
<th>Fracture Toughness(J/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1994</td>
<td>7.934</td>
<td>0.00199</td>
<td>0.05828</td>
<td>0.137</td>
</tr>
<tr>
<td>48.5</td>
<td>28.526</td>
<td>0.485</td>
<td>0.2095</td>
<td>1.86</td>
</tr>
<tr>
<td>97</td>
<td>75.554</td>
<td>0.97</td>
<td>0.5540</td>
<td>0.699</td>
</tr>
</tbody>
</table>

Calculations:

The formulae used

For toughness,
\[ G_{IC} = \frac{\sigma^2 a^2}{2E} \]

For fracture toughness,
\[ K_{IC} = (E \cdot G_{IC})^{1/2} \]

Where,
\[ E = \frac{\sigma}{e} = 0.2218 \]
\[ G_{IC} = \frac{\sigma^2 a^2}{2E} = 3.992ssssssss \]
\[ E = \frac{E}{1 - \delta^2} \]
\[ K_{IC} = (E \cdot G_{IC})^{1/2} = 0.9605 \]

For the sample with the ratio of fiber and epoxy is 40:60

<table>
<thead>
<tr>
<th>Extension(mm)</th>
<th>Load(N)</th>
<th>Strain(mm/mm)</th>
<th>Stress(MPa)</th>
<th>Fracture Toughness(J/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.099</td>
<td>0.05476</td>
<td>0.001</td>
<td>0.00045</td>
<td>0.0001</td>
</tr>
<tr>
<td>48.49</td>
<td>3.145</td>
<td>0.485</td>
<td>0.0259</td>
<td>0.614</td>
</tr>
<tr>
<td>96.99</td>
<td>5.922</td>
<td>0.969</td>
<td>0.04879</td>
<td>0.02308</td>
</tr>
<tr>
<td>48.52</td>
<td>3.040</td>
<td>0.485</td>
<td>0.1027</td>
<td>0.2123</td>
</tr>
</tbody>
</table>

Calculations:

The formulae used

For toughness,
\[ G_{IC} = \frac{\sigma^2 a^2}{2E} \]

For fracture toughness,
\[ K_{IC} = (E \cdot G_{IC})^{1/2} \]

Where,
\[ E = \frac{E}{1 - \delta^2} \]

Evaluation of Fracture Toughness for Perpendicular laminated sample using the average values of above obtained values :
E = \sigma/e = 0.0515

Gic = \sigma n^2 a^2/2E = 0.92

E^I = E/(1- \theta^2) = 0.0536

Kic = (E^IGic)^{1/2} = 0.22

For the sample with the ratio of fiber and epoxy is 30:70

<table>
<thead>
<tr>
<th>Extension(mm)</th>
<th>Load(N)</th>
<th>Strain(mm/mm)</th>
<th>Stress(MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00732</td>
<td>0.0142</td>
<td>0.00007</td>
<td>0.00012</td>
</tr>
<tr>
<td>6.48045</td>
<td>3.05834</td>
<td>0.0648</td>
<td>0.02494</td>
</tr>
<tr>
<td>12.9332</td>
<td>5.91605</td>
<td>0.12933</td>
<td>0.04824</td>
</tr>
<tr>
<td>6.4736</td>
<td>2.996</td>
<td>2.0138</td>
<td>0.0743</td>
</tr>
</tbody>
</table>

Calculations:
The formulae used

For toughness,

\[ G_{ic} = \sigma n^2 a^2/2E \]

For fracture toughness,

\[ K_{ic} = (E^IGic)^{1/2} \]

Where,

\[ E^I = E/(1- \theta^2) \]

Evaluation of Fracture Toughness for Parallel laminated sample using the above values:

E = \sigma/e = 0.3729

Gic = \sigma n^2 a/2E = 0.5219

E^I = E/(1- \theta^2) = 0.3884

Kic = (E^IGic)^{1/2} = 0.18

5. CONCLUSIONS

- The samples with the ratio 30:70 of resin and fiber have more fracture toughness comparing to the ratio of 40:60.
- The samples with the ratio of 40:60 have more fracture toughness comparing to the ratio of 50:50.
- The Fracture Toughness increases as ratio of fiber increase.
- That indicates that the material states behaving like ductile material that is as the fibre content increases ductility increases
- The crack propagation decreases with the increase of fracture toughness

REFERENCES


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