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Assessment of Fracture Toughness of Epoxy-Glass Fiber Composite Laminate

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ABSTRACT

The conventional material does not meet the requirements of high technology applications like space applications. There is continuous research to meet the requirements of high temperature and wear resistances. In this paper, the composite laminar for the testing is prepared with glass fiber reinforced with epoxy. Composite materials applications have increased because of high strength/stiffness for lower weight, superior fatigue characteristics. At the same time, there are challenges such as inter ply cracking; inter laminar de-lamination and fiber cracking. Failure of composite materials can be reduced by increasing the fracture toughness.

The objective of our work is to evaluate the fracture toughness of the glass fiber/epoxy composites. The composites are 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.

Keywords: ASTM standards, Glass Fiber, Fracture Toughness,

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
- 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

As stated above, researchers are working with the problems of inter ply cracking, de-lamination and fiber cracking. This work is aimed at predicting the extent of crack propagation in a FRP composite laminate that subjected to finite and known loads. Chamo is presented the difference between fiber composites and traditional materials. Any predictive approach for simulating structural fracture in fiber composites needs to formally quantify: all possible fracture modes the types of flaws they initiate, and the coalescing and propagation of these flaws to critical dimensions for imminent fracture. O'Brien T K, and Martin R H.(1993).briefly explained Results of ASTM Round Robin Testing for Mode I Inter laminar Fracture Toughness of Composite Materials. D. Srikanth Rao and N. Gopikrishna (2017) evaluated Strain Energy Release Rate of Epoxy Glass Fibre Laminate (Mode - I).A B

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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 low dielectric properties, a good for antennae.

Figure1 Glass fiber

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 term 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 polymerization 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.Thehardenersareusuallyshort chain diamines such as ethylenediamine.

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

Figure2 Epoxy resin and hardener

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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 inter laminar 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

Figure3 Prepared Glass fiber laminates

The prepared samples were cut into required dimensions based on ASTM D5528 standards for fracture Toughness test.

Figure4 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 pre-crack 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.

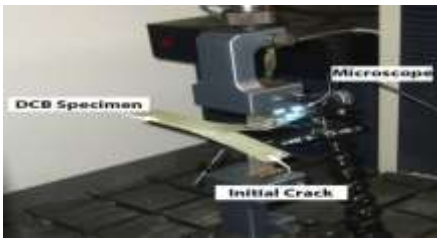

Figure5 Microscope

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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 ASTMD 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

Extension(mm)	Load(N)	Strain(mm/mm)	Stress(MPa)	Fracture Toughness (J/m^2)
0.1994	7.934	0.00199	0.05828	0.137
48.5	28.526	0.485	0.2095	1.86
97	75.554	0.97	0.5540	0.699

Calculations:

The formulae used

For toughness,

$G_{Ic}= \sigma\pi^2 a^2/2EF$ or fracture toughness,

$K_{IC}=(E^I G_{IC})^{1/2}$

Where,

$E^I=E/(1-P^2)$

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

E = σ/e = 0.2218

$G_{ic}=\sigma\pi^2 a/2E=3.992ssssssE^I= E/(1-P^2)=0.231K_{IC}=(E^I G_{IC})^{1/2}=0.9605$

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

Extension(mm)	Load(N)	Strain(mm/mm)	Stress(MPa)	Fracture Toughness
0.099	0.05476	0.001	0.00045	0.0001
48.49	3.145	0.485	0.0259	0.614
96.99	5.922	0.969	0.04879	0.02308
48.52	3.040	0.485	0.1027	0.2123

Calculations:

The formulae used

For toughness,

$G_{Ic}=\sigma\pi^2 a^2/2E$

For fracture toughness, $K_{IC} = (E^I G_{IC})^{1/2}$

Where,

$E^I=E/(1-P^2)$

Evaluation of Fracture Toughness for Perpendicular laminated sample using the average values of above obtained values:

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$E = \sigma/e = 0.0515$

$G_{ic} = \sigma\pi^2 a^2/2E = 0.92$

$E^I = E/(1-P^2)$

$= 0.0536K_{IC} = (E^I G_{IC})^{1/2}$

$= 0.22$

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

Extension(mm)	Load(N)	Strain(mm/mm)	Stress(MPa)
0.00732	0.0142	0.00007	0.00012
6.48045	3.05834	0.0648	0.02494
12.9332	5.91605	0.12933	0.04824
6.4736	2.996	2.0138	0.0743

Calculations:

The formulae used

For toughness,

$$G_{Ic}=\sigma\pi^2 a^2/2EF$$

or fracture toughness,

$$K_{IC} = (E^I G_{IC})^{1/2}$$

Where,

$$E^I=E/(1-P^2)$$

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

$E = \sigma/e = 0.3729$

$G_{ic} = \sigma\pi^2 a/2E = 0.5219$

$E^I = E/(1-P^2) = 0.3884K_{IC} = (E^I G_{IC})^{1/2} = 0.18$

5. CONCLUSIONS

- The samples with the ratio 0:70 of resin and fiber have more fracture toughness comparing the ratio of 40:60.
- The samples with the ratio of 40:60 have more fracture toughness comparing 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

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