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Interlaminar Fracture of Aerospace Composites Materials

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Abstract- Composite materials are extensively used in aerospace industries for manufacturing aerospace parts. These parts very to mold and have high strengths. Aerospace components are subjected to impact loading. The stiffness of composite ply varies with respect to ply orientation and resin percentage used. The resistance to withstand the dynamic behavior of each lamina in the presence of resin which acts as a single core material plays a very significant role in withstanding the loads under various load conditions. The use of fracture mechanics to calculate interlaminar fracture stiffness for different composite materials made of fibers and polymers using test geometries of mode I/II fractures.

Keywords- Interlaminar fracture, Composites, Aerospace structures

I. INTRODUCTION

Fiber reinforced composite materials are replacing standard isotropic materials in many applications. Aerospace vehicles, aircraft, marine equipment, and common items such as civil structures, prosthetic devices, and sports equipment are currently being constructed of such composite materials. The primary advantage of composite materials is their inherent ability to be custom tailored to a specific design situation. Constituents like fibers and matrix material can be used in different combinations, amounts, and architectures to obtain an optimal material composition. A major drawback to laminated composite materials stems from the manufacturing process used to construct them. Placing fabric or fibers in strata to obtain 2 a desired architecture allows resin rich layers to form between fabric layers. These regions are without reinforcement and are prone to develop discontinuities such as pores and voids. The performance of the composite material at these locations is dominated by the properties of the resin. Often the failure of a composite structure begins with the separation of these layers or delamination.[20]

II.MODES OF FRACTURE

Mode, I type fracture has typically been accepted as the most common and important mode of crack propagation. A normal stress field induces an opening or “wishbone” effect. This type of behaviour is common in structure and substructures such as skin stiffeners, I beam, or bonded connections of separate structures [Broek (1996)]. Brittle metals such as cast iron typically fail from mode, I type fracture in service. This is one reason that some homogeneous materials possess a compressive strength that is significantly greater than their tensile strength. Mode, I fracture toughness can be evaluated a variety of ways. For engineering polymers and metals, an ASTM standard compact tension sample (similar to Figure 1) is used [ASTM E 399-90 (1992)].

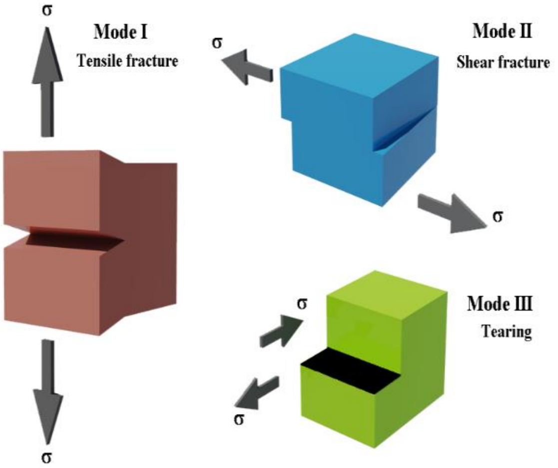


Figure 1 Mode of fractures [2]

These test models have prescribed dimensions that simulate plain strain type loading. Ultimately K_{Ic} is obtained based on initial crack length and remote stress field. K_{Ic} is a stress intensity factor that accounts for the reduced load Opening Mode Sliding Mode Tearing Mode Figure 1.1 Iterations were made to provide valid test results. This type of analysis is usually only valid for high strength-brittle materials and homogenous materials in general.

Mode II fracture toughness analysis is frequently conducted; however, a specific test method has yet to be standardized by ASTM. Most commonly, a specimen similar to that shown in Fig. 2, but without end attachments (hinges), is simply loaded in three-point bending. The shear stress at the mid-plane (centre) of the specimen initiates the desired Mode II sliding failure (crack propagation) at the end of the insert. This test method is commonly referred to as End-Notched Flexure (ENF). [20]

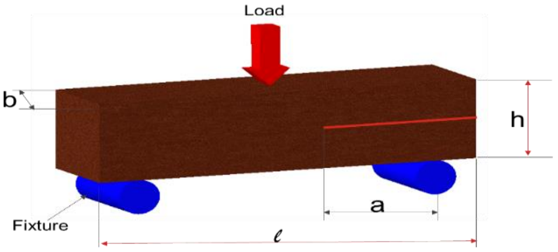


Figure 2 Mode II fracture analysis specimen

Mode II Fracture

$$G_{II} = \frac{9Pa^2\partial}{2b(2l^3+3a^3)}$$
Eqn -1

Where, $P = Load\ (kN)$
$\delta = Load\ point\ displacement\ (mm)$
$b = specimen\ width\ (mm)$
$a = Delamination\ length\ (mm)$,
$l = the\ effective\ length\ of\ the\ specimem$.

Analysis

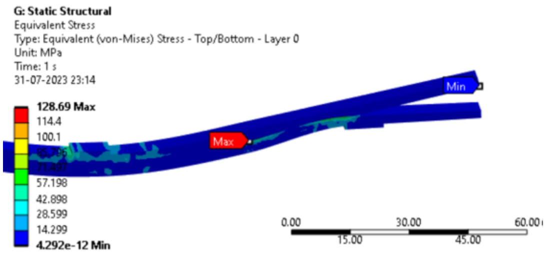
Symmetric model of 0/90/45/-45/90/0 composite ply DCB material is used to analyse Mode 1 fracture evaluation with respect to effect of load on stress, shear, and strain energy.

III. MATERIALS

Table 1 Material properties [19]

Material	Density	Youngs modulus- E- "Pa"			Poisson's Ratio "v"			Shear Modulus -G-"Pa"		
		X	Y	Z	XY	YZ	XZ	XY	YZ	XZ
Carbon fiber -230	1800	$2.3e^{11}$	$2.3e^{10}$	$2.3e^{10}$	0.2	0.4	0.2	$9e^{10}$	$8.21e^{9}$	$9e^{10}$
Epoxy Carbon fiber -230	1490	$1.21e^{11}$	$8.6e^{9}$	$8.6e^{9}$	0.27	0.4	0.27	$4.7e^{10}$	$3.1e^{9}$	$4.7e^{10}$

IV.RESULTS



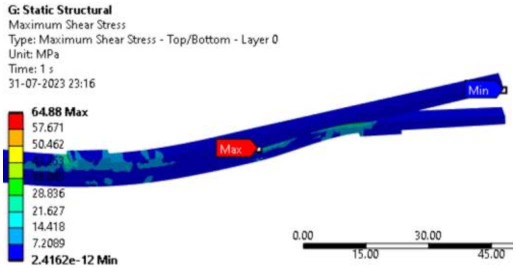


Fig 3.Max vonMises Stress "MPa"

Max Shear Stress "MPa"

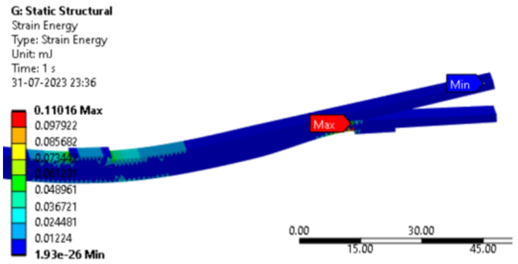
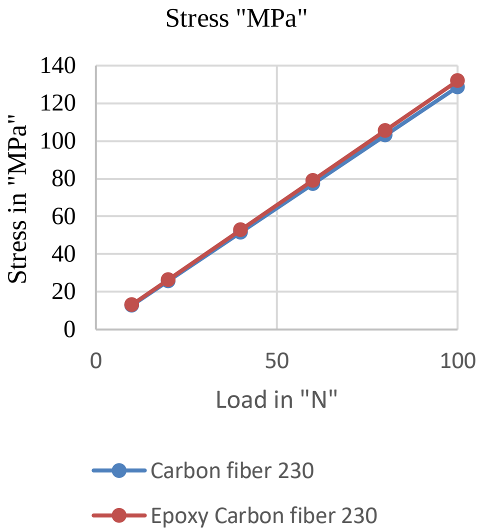


Fig 4 Strain Energy "mJ"

Von Mises Stress

Table 2 vonMises Stress

Stress "MPa"		
Load	Carbon fiber 230	Epoxy Carbon fiber 230
10	12.87	13.19
20	25.74	26.4
40	51.48	52.764
60	77.21	79.146
80	102.96	105.53
100	128.69	131.91

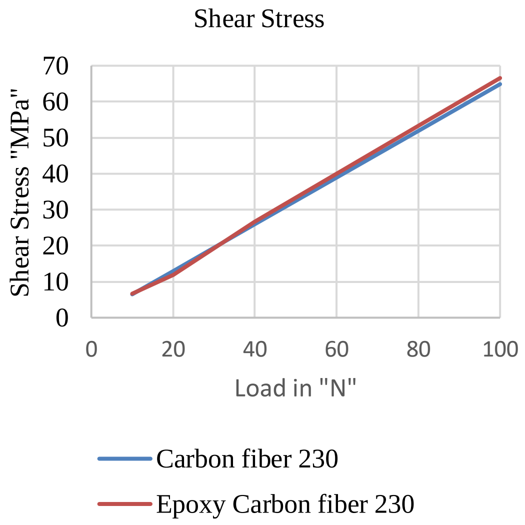


Graph 1 Load v/s vonMises stress

Maximum Shear Stress

Table 3 Shear Stress

Shear Stress		
Load	Carbon fiber 230	Epoxy Carbon fiber 230
10	6.49	6.67
20	12.97	11.84
40	25.95	26.64
60	38.93	39.958
80	51.9	53.278
100	64.88	66.577

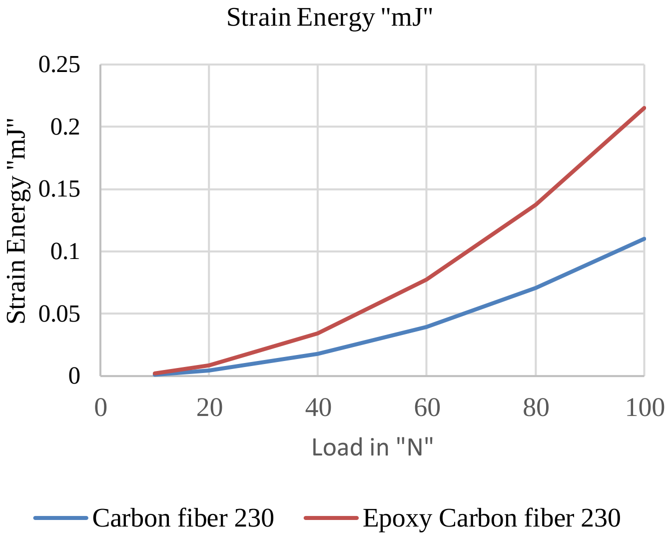


Graph 2 Load v/s Shear stress

Strain Energy

Table 4 Strain Energy

Strain Energy "mJ"		
Load	Carbon fiber 230	Epoxy Carbon fiber 230
10	0.0011016	0.0021514
20	0.004406	0.0086057
40	0.0176	0.034423
60	0.0396	0.077452
80	0.070504	0.13769
100	0.11016	0.21514



Graph 3 Load v/s Strain energy

V.CONCLUSION

- Stress is behaving linear with respect to Carbon fiber and Epoxy carbon fiber.
- Shear stress is behaving linear with respect to Carbon fiber and Epoxy carbon fiber.
- Strain energy is exponential with respect to Carbon fiber and Epoxy carbon fiber.
- Material exhibits ductile state by using of composition of materials.
- Increased strain energy makes carbon epoxy fiber more resilient.
- The crack propagation decreases with the increase of strain.

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