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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 have very high strengths and low weight. Aerospace components are subjected to impact load, fatigue load and transient load. The stiffness and strength 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 stress contours to calculate interlaminar von Mises stress for each ply which is placed at different orientation in structure. Mode I fracture with increasing load are analyzed for stress contours.

Keywords: Interlaminar fracture, Stress Contours, Composites material, Aerospace structures

Introduction: Standard isotropic materials are being replaced by fiber reinforced composite materials in many applications. Currently, these composite materials are used to build aerospace vehicles, aircraft, marine equipment, and everyday objects like sports equipment, civil structures, and prosthetic devices. The main benefit of composite materials is that they can already be specifically tailored to a given design situation. To create the ideal material composition, different combinations, dosages, and architectural arrangements can be used with components like fibers and matrix material. The manufacturing method used to create laminated composite materials is a significant disadvantage. When fabric or fibers are arranged in strata to create the desired architecture, resin-rich layers can form in the spaces between the fabric layers. These areas lack reinforcement and are vulnerable to discontinuities.

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 behavior is common in structure and substructures such as skin stiffeners, I beam, or bonded connections of separate structures [17]. 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) [16].

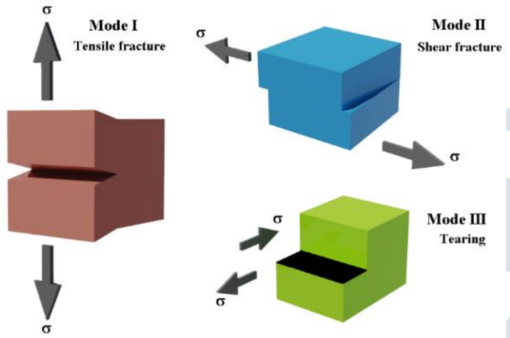


Figure 1 Mode of fractures [5]

Mode II fracture : The end-notched flexure (ENF) specimen has a noteworthy to be specific for crack propagation with respect to linear increasing load application. The mode II end loaded split (ENF) specimen was used by different researchers [18]. Despite the fact that it is appropriate for crack propagation examination, the issue of crack instability still remained. In addition, enormous displacements regularly happen during testing/analysis are another disadvantage of this arrangement.

Static load analysis for Mode I : These analysis models have prescribed dimensions that simulate plain strain type loading. Static load analysis is carried out to evaluate the stresses at each ply which have been placed at different orientation in the structure. Research review clearly emphasizes stating epoxy plays an important role in material stiffness and strain energy. Here we have analyzed double cantilever beam (DCB) Mode I fracture by using symmetric model of carbon epoxy fiber with ply orientation of 0/90/45/-45/90/0 to evaluate effect of load on stresses.

Materials

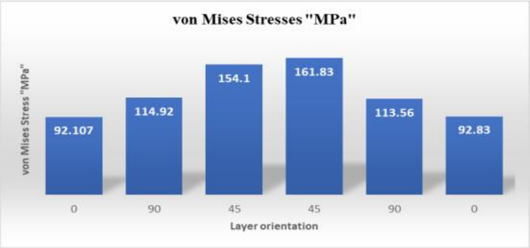
Material	Density	Youngs modulus- E- "Pa"			Poisson's Ratio "v"			Shear Modulus -G- "Pa"		
		X	Y	Z	XY	YZ	XZ	XY	YZ	XZ
Carbon fiber -230	1800	$2.3e^{11}$	$2.3e^{10}$	$2.3e^{10}$	0.2	0.4	0.2	$9e^{10}$	$8.21e^{9}$	$9e^{10}$
Epoxy Carbon fiber -230	1490	$1.21e^{11}$	$8.6e^{9}$	$8.6e^{9}$	0.27	0.4	0.27	$4.7e^{10}$	$3.1e^{9}$	$4.7e^{10}$
Epoxy Carbon fiber -395	1540	$2.09e^{11}$	$9.45e^{9}$	$9.45e^{9}$	0.27	0.4	0.27	$5.5e^{9}$	$3.9e^{9}$	$5.5e^{10}$

Table 1 Material properties [21]

Results : von Mises Mode I - Epoxy Carbon 230

Layer	Orientation	von Mises Stresses "MPa"
Layer 1	0	92.107
Layer 2	90	114.92
Layer 3	45	154.1
Layer 4	45	161.83
Layer 5	90	113.56
Layer 6	0	92.83

Table 2 Mode I Mode I von Mises Stress at Each Layer for Carbon Fiber 230



Graph 1 Mode I Load v/s von Mises stress at each layer for Carbon fiber 230.

von Mises stresses at middle layer are higher in comparison to subsequent layers. This shows 45° orientation layer is subject to maximum stress level.

Stress Behavior Contour on Composite Fiber Layer Wise for Mode I Type of Fracture.

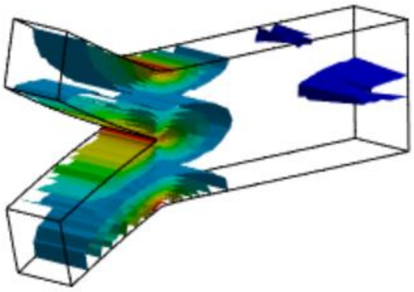
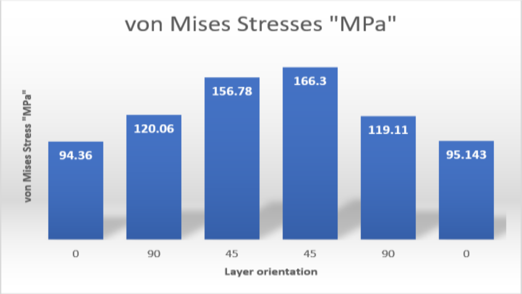


Figure 1 Mode I von Mises stress contour layer wise – Carbon Fiber 230

von Mises Stress for Mode I At Each Layer for Epoxy Carbon Fiber 230

Table 3 Mode I von Mises stress at each layer for Epoxy carbon fiber 230

Layer	Orientation	von Mises Stresses "MPa"
Layer 1	0	94.36
Layer 2	90	120.06
Layer 3	45	156.78
Layer 4	45	166.3
Layer 5	90	119.11
Layer 6	0	95.143



Graph 2 Mode I Load v/s von Mises stress at each layer for Epoxy carbon fiber 230.

von Mises stresses at middle layer are higher in comparison to subsequent layers. This shows 45° orientation layer is subject to maximum stress level.

Stress Behavior Contour on Composite Fiber Layer Wise for Mode I Type of Fracture.

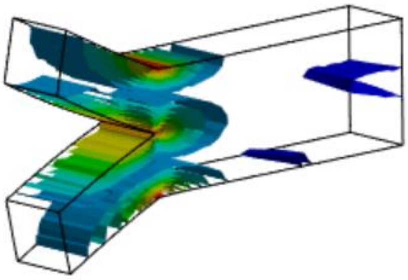
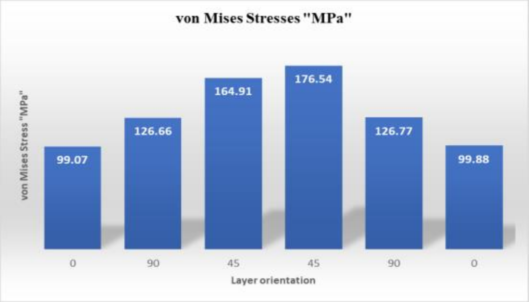


Figure 2 Mode I von Mises stress contour layer wise – Epoxy Carbon Fiber 230

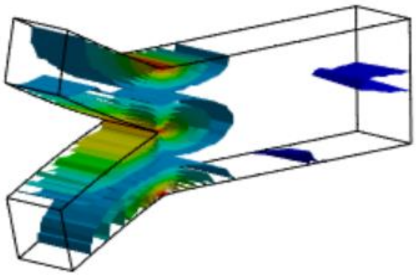
von Mises Stress for Mode I at Each Layer of Epoxy Carbon Fiber 395

Table 4 Mode I von Mises stress at each layer for Epoxy carbon fiber-395

Layer	Orientation	von Mises Stresses "MPa"
Layer 1	0	99.07
Layer 2	90	126.66
Layer 3	45	164.91
Layer 4	45	176.54
Layer 5	90	126.77
Layer 6	0	99.88



Stress Behavior Contour on Composite Fiber Layer Wise for Mode I Type of Fracture.



Graph 3 Mode I Load v/s von Mises stress at each layer for Epoxy carbon fiber-395.

Figure 3 Mode I von Mises stress contour layer wise for Epoxy carbon fiber- 395

von Mises stresses at middle layer are higher in comparison to subsequent layers. This shows 45° orientation layer is subject to maximum stress level.

Conclusion

Mode I von Mises stresses are higher at middle layer in comparison to subsequent layers. This shows mid ply which is at 45° orientation layer is subject to maximum stress level. Though there is change in resin type the stress level are higher at mid plane ply. Resin shows least effect on stress pattern for stress contours with effect to load and resin matrix. Predicting fracture effect for mode I is difficult as the stress level are higher are mid ply.

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