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INTE RLAMINAR 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

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 [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)].

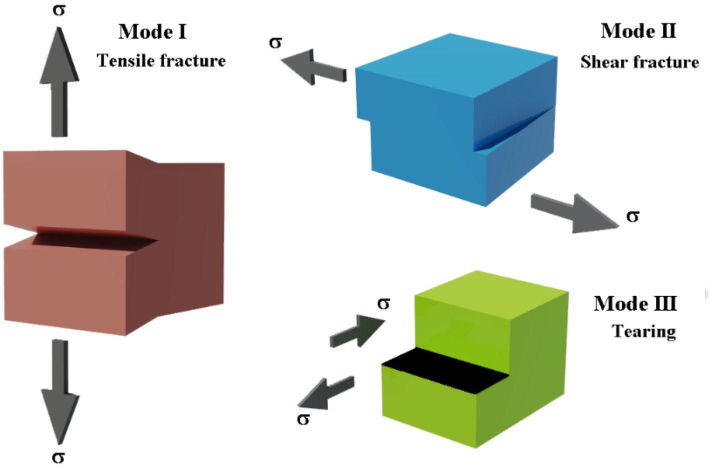


Figure 1 Mode of fractures [2]

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 This type of analysis is usually only valid for high strength-brittle materials and homogenous materials in general.

Modal analysis for Mode I and II

Modal analysis is carried out to establish correlation on structural stiffness. With above set analysis it is evident epoxy plays an important role in material stiffness and strain energy. Hence modal analysis is carried on epoxy-based carbon fiber composites.

Analysis

Two set of analysis is carried out as follows:

1) Free-free modal
2) Constrained modal

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

Materials

Material	Density	Youngs modulus- E- “Pa”			Poisson’s Ratio “ν”			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	$4.7e^{10}$	$3.1e^{9}$	$4.7e^{10}$

Table 1 Material properties [19]

Results

Free modal analysis for Mode I - Epoxy Carbon 230

Mode I Free-Free Modal analysis	
Mode	Frequency-"Hz"
1	0
2	0
3	1.30E-03
4	5.10E-03
5	1.00E-02
6	1.09E-02

Table 2 Mode I Free-Free Modal analysis – Epoxy Carbon Fiber 230

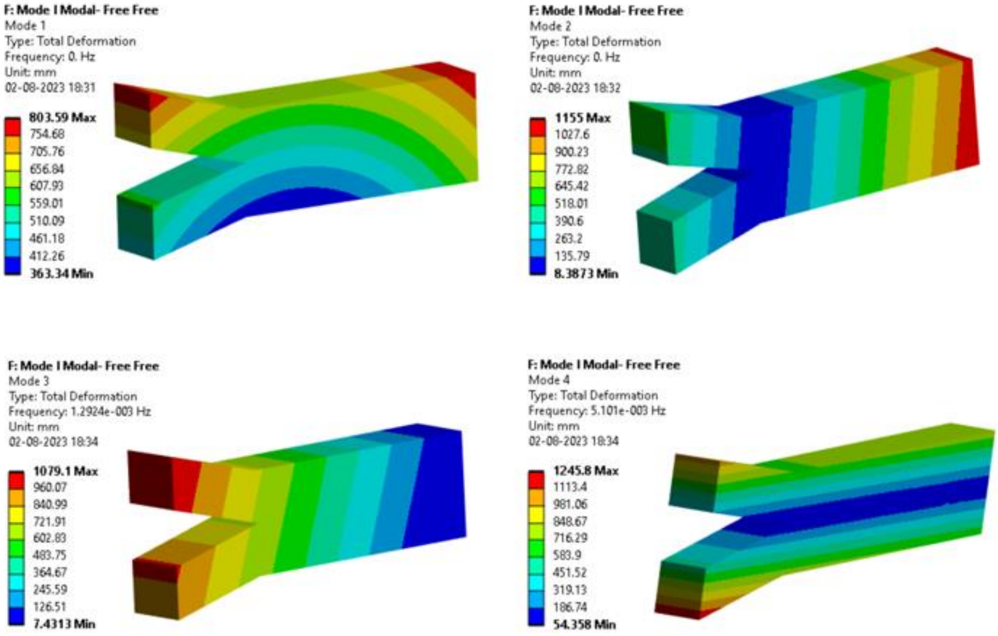


Figure 2 Mode I Free-Free Modal analysis – Epoxy Carbon Fiber 230

Free-free modal analysis all first six modes are below zero and shows rigid body motions.

Constrained modal analysis for Mode I -Epoxy Carbon 230

Mode, I Constrained Modal analysis	
Mode	Frequency-"Hz"
1	5259
2	7266
3	8732
4	20758
5	24679
6	26550

Table 3 Mode I Constrained Modal analysis – Epoxy Carbon Fiber 230

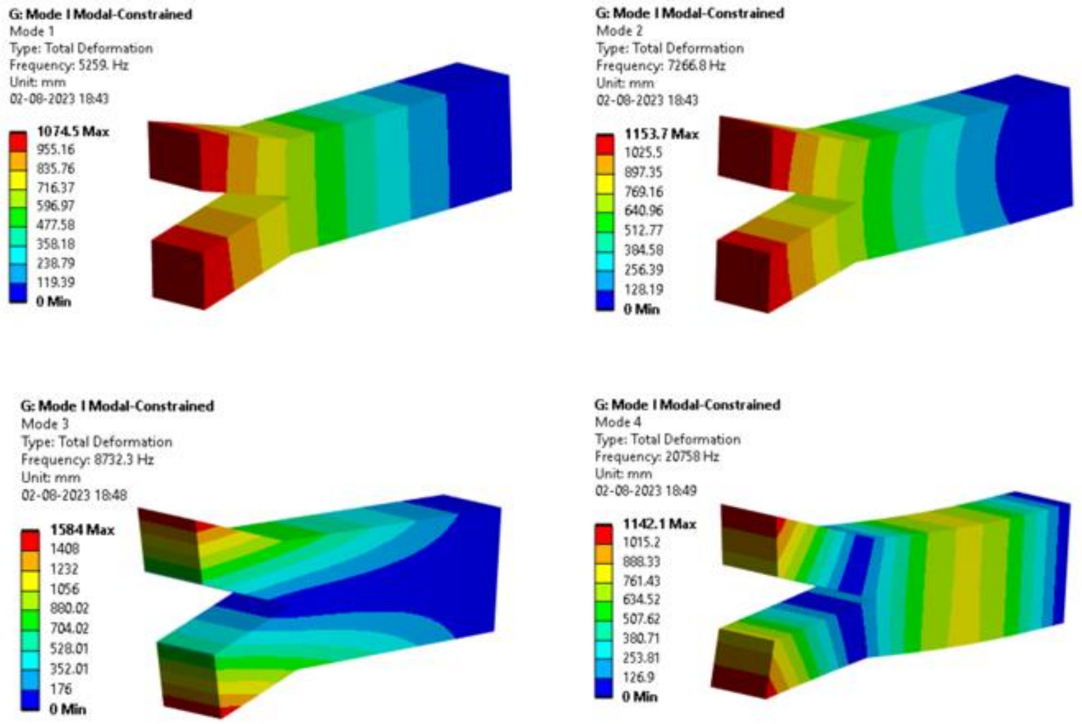


Figure 3 Mode I Constrained Modal analysis – Epoxy Carbon Fiber 230

Constrained modal analysis shows the material is stiff and shows correlation with strain energy and stiffness all first six modes are below zero and shows rigid body motions.

Free modal analysis for Mode I - Epoxy Carbon 395

Mode I Free Free Modal analysis	
Mode	Frequency-"Hz"
1	0
2	0
3	2.74E-03
4	3.13E-03

5	7.29E-03
6	1.68E-02

Table 4 Mode I Free-Free Modal analysis – Epoxy Carbon Fiber 395

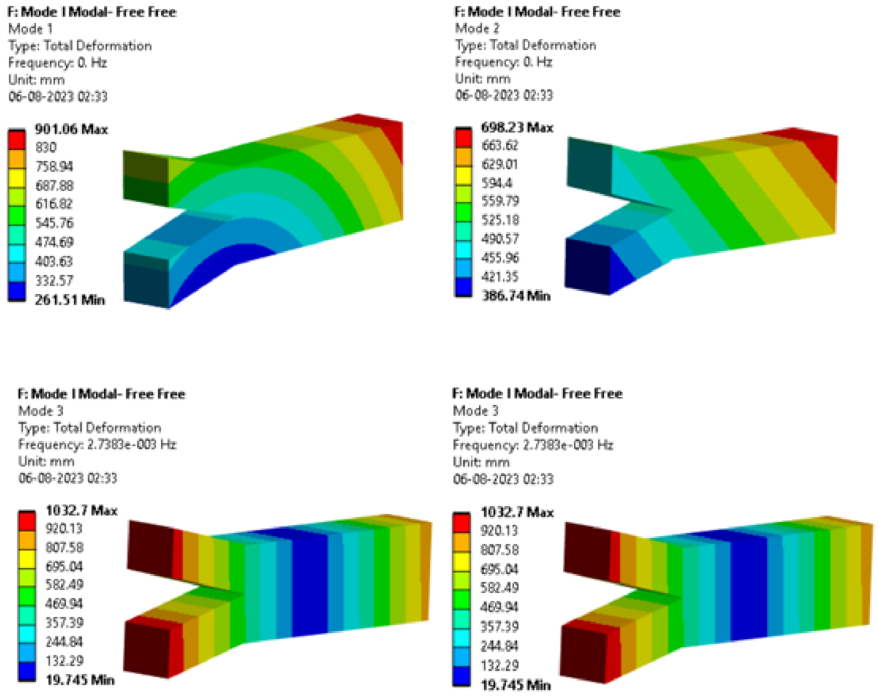


Figure 4 Mode I Free-Free Modal analysis – Epoxy Carbon Fiber 395

Free-free modal analysis all first six modes are below zero and shows rigid body motions.

Constrained modal analysis for Mode I- Epoxy Carbon 395

Mode, I Constrained Modal analysis	
Mode	Frequency-"Hz"
1	6448.9
2	9177.2
3	9647
4	23876
5	29812
6	31073

Table 5 Mode I Constrained Modal analysis – Epoxy Carbon Fiber 395

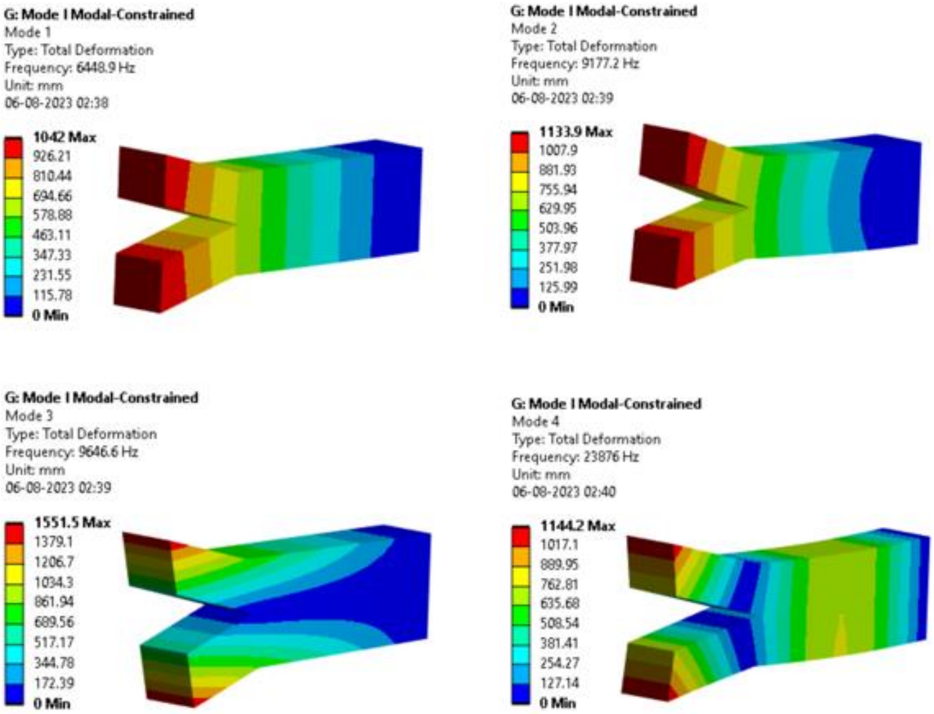


Figure 5 Mode I Constrained Modal analysis – Epoxy Carbon Fiber 395

Constrained modal analysis shows the material is stiff and shows correlation with strain energy and stiffness all first six modes are below zero and shows rigid body motions.

Free modal analysis for Mode II -Epoxy Carbon-230

Mode II Free-Free Modal analysis	
Mode	Frequency-"Hz"
1	0
2	0
3	9.01E-04
4	2.91E-03
5	3.58E-03
6	9.63E-03

Table 6 Mode II Free-Free Modal analysis – Epoxy Carbon Fiber 230

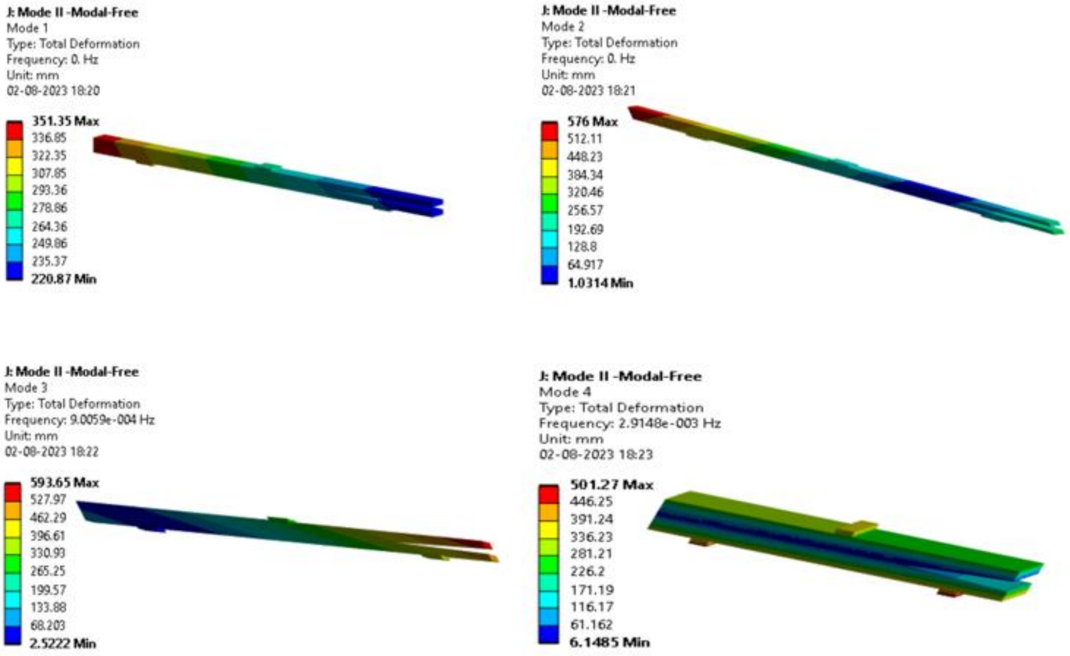


Figure 6 Mode II Free-Free Modal analysis – Epoxy Carbon Fiber 230

Free-free modal analysis all first six modes are below zero and shows rigid body motions.

Constrained modal analysis for Mode II-Epoxy Carbon-230

Mode II Constrained Modal analysis	
Mode	Frequency-"Hz"
1	946.26
2	1442.6
3	1800
4	1902
5	4157
6	4379

Table 7 Mode II Constrained Modal analysis – Epoxy Carbon Fiber 230

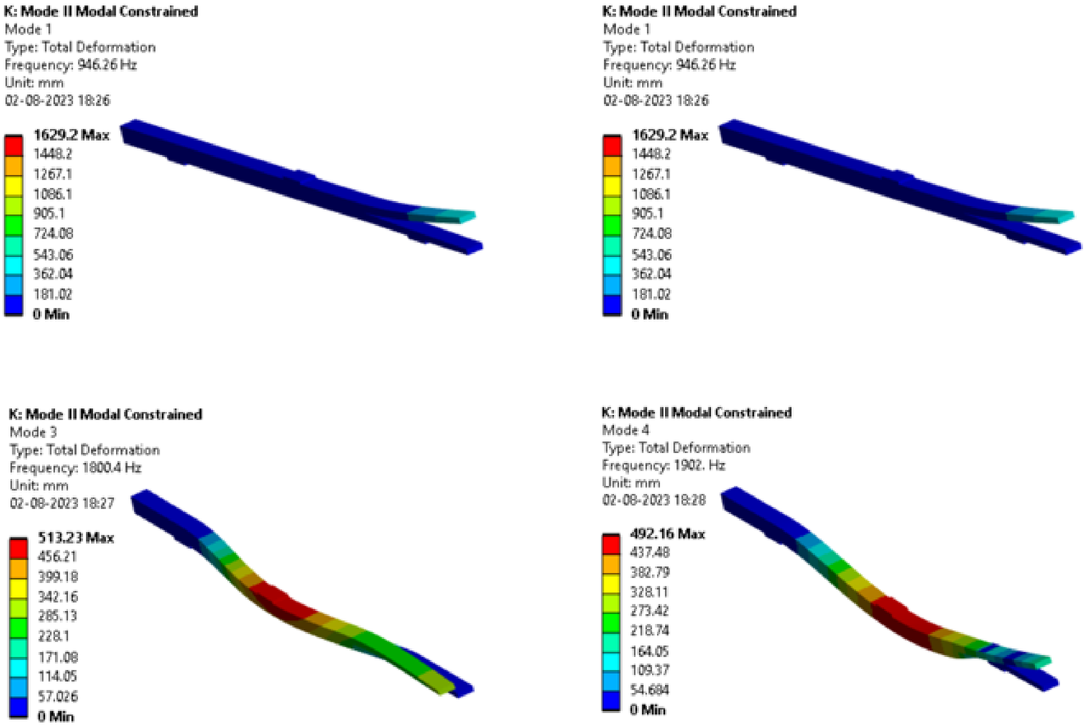


Figure 7 Mode I Constrained Modal analysis – Epoxy Carbon Fiber 230

Constrained modal analysis shows the material is stiff and shows correlation with strain energy and stiffness all first six modes are below zero and shows rigid body motions.

Free modal analysis for Mode II -Epoxy Carbon-395

Mode II Free-Free Modal analysis	
Mode	Frequency-"Hz"
1	0
2	0
3	0.00E+00
4	4.20E-04
5	1.48E-03
6	2.07E-03

Table 8 Mode II Free-Free Modal analysis – Epoxy Carbon Fiber 395

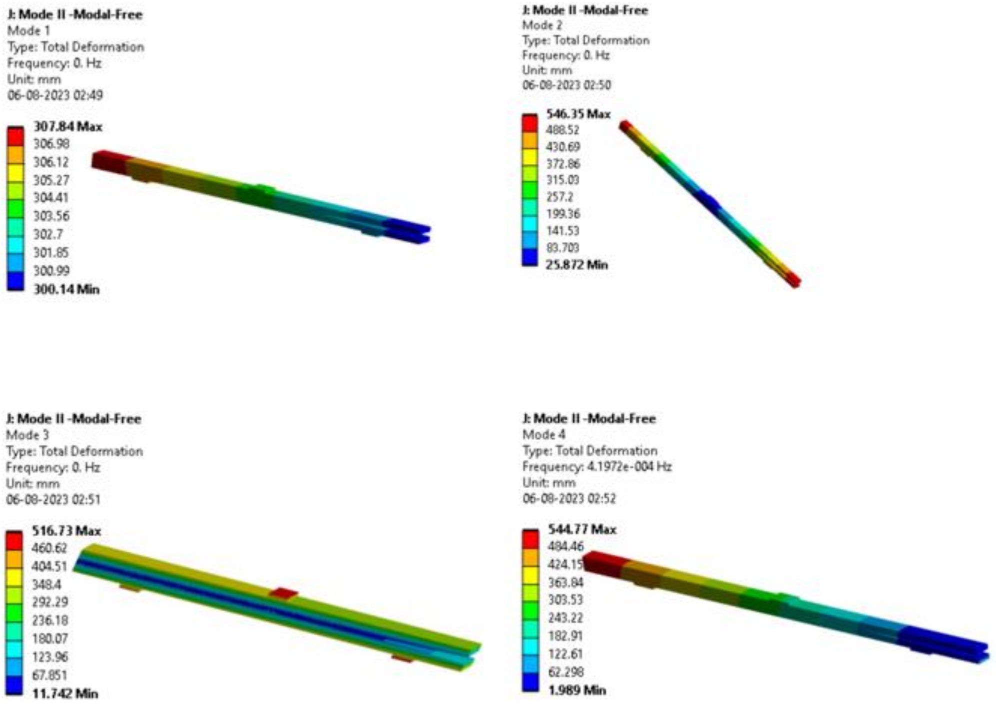


Figure 8 Mode II Free-Free Modal analysis – Epoxy Carbon Fiber 395

Free-free modal analysis all first six modes are below zero and shows rigid body motions.

Constrained modal analysis for Mode II-Epoxy Carbon-395

Mode II Constrained Modal analysis	
Mode	Frequency-"Hz"
1	933.13
2	1354.9
3	1667.6
4	1882.1
5	3882.3
6	4111.1

Table 9 Mode II Constrained Modal analysis – Epoxy Carbon Fiber 395

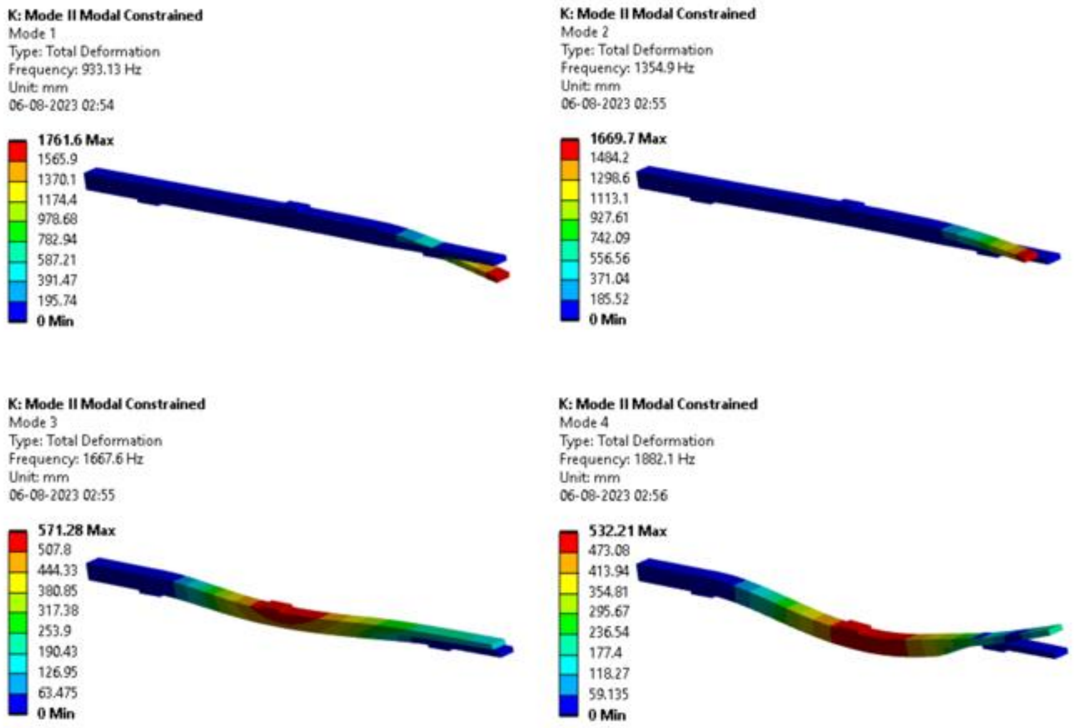


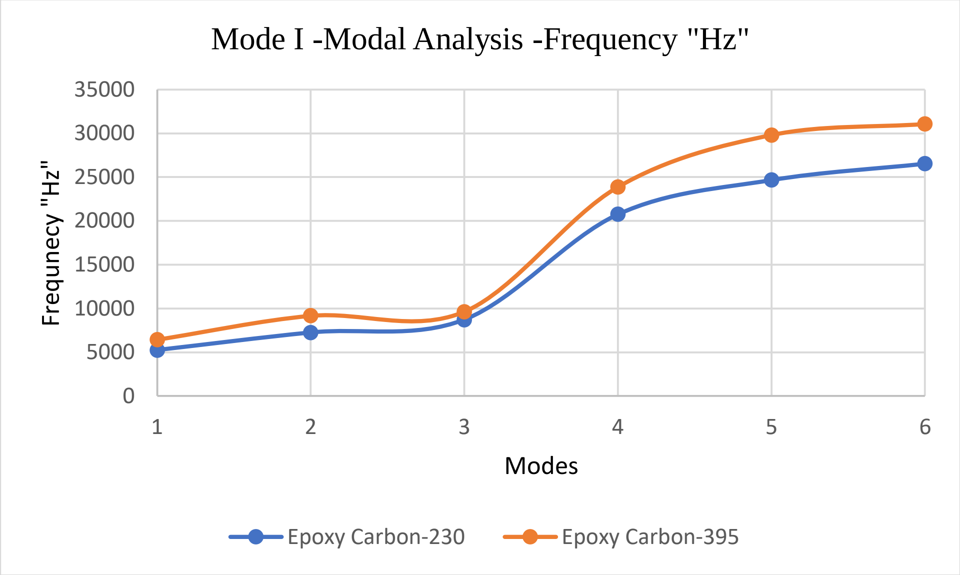
Figure 9 Mode I Constrained Modal analysis – Epoxy Carbon Fiber 395

Constrained modal analysis shows the material is stiff and shows correlation with strain energy and stiffness all first six modes are below zero and shows rigid body motions.

Modal Analysis - Data Interpretation

Mode I "Frequency-Hz"		
Mode	Epoxy Carbon-230	Epoxy Carbon-395
1	5259	6448.9
2	7266	9177.2
3	8732.3	9646.6
4	20758	23876
5	24679	29812
6	26550	31073

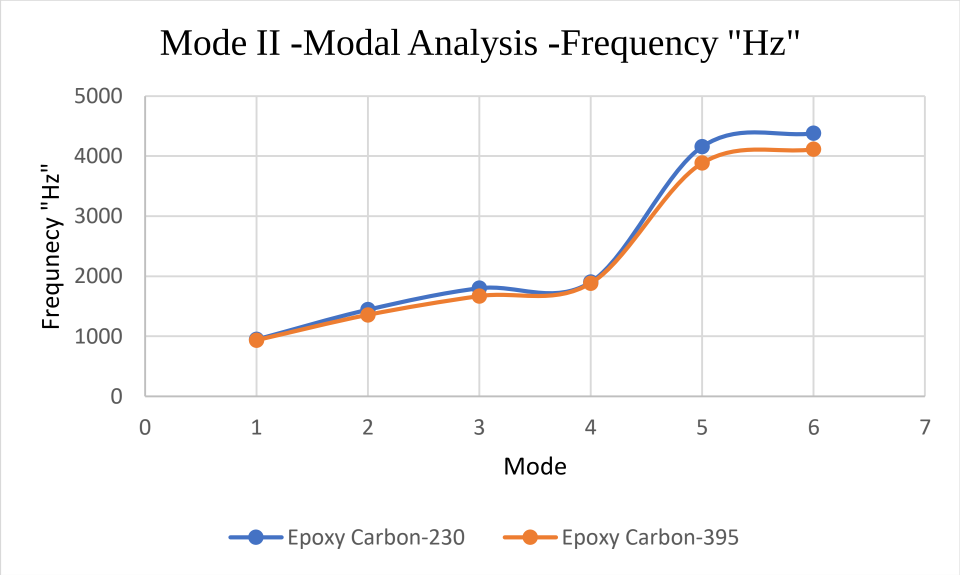
Table 10 Mode I Constrained Modal analysis.



Graph 1 Mode I Mode I Constrained Modal analysis.

Mode II "Frequency-Hz"		
Mode	Epoxy Carbon-230	Epoxy Carbon-395
1	946.26	933.13
2	1442.6	1354.9
3	1800.4	1667.6
4	1902	1882.1
5	4156.6	3882.3
6	4378.5	4111.1

Table 11 Mode II Constrained Modal analysis.



Graph 2 Mode I Mode I Constrained Modal analysis.

Conclusion

Epoxy resin adds stiffness to composite materials there by changing the behavior of composite ply to optimized brittleness with transition stage. Mode, I depict brittle nature and Mode II depict ductile nature of stiffness. Hence Mode I failure generate more catastrophic failure than Mode II in composite parts.

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