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Modelling and Vibration Analysis of Lamina Composite

Prakhar Tonk, Naman Jain[1], Vinay Kumar Singh[1]

[1]*Department of Mechanical Engineering, G. B. Pant University of Agriculture and Technology, Pantnagar, India*

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Abstract - *A composite material is a material made from two or more constituent materials with significantly different physical or chemical properties that, when combined, produce a material with characteristics different from the individual components. Composites are one of the most widely used materials because of their adaptability to different situations and the relative ease of combination with other materials to serve specific purposes and exhibit desirable properties. In this paper, we have done static load analysis on Pre- impregnated Unidirectional Epoxy Carbon and Unidirectional Epoxy E-Glass in different fiber orientations (from 0° to 90°) in steps of 15°. Also, we have done modal analysis on Pre- impregnated Unidirectional Epoxy Carbon in different fiber orientations. Since the composites analyzed have orthotropic properties, the relationship between the fiber orientation and X and Y stresses is shown by a graph.*

Key Words: Laminate *Composites; Static Analysis; Vibration Analysis*

1. INTRODUCTION

A composite material is made by combining two or more materials – often ones that have very different properties. The two materials work together to give the composite unique properties. However, within the composite you can easily tell the different materials apart as they do not dissolve or blend into each other. Composites, also known as Fiber-Reinforced Polymer (FRP) composites, are made from a polymer matrix that is reinforced with an engineered, man-made or natural fiber (like glass, carbon or aramid) or other reinforcing material. The matrix protects the fibers from environmental and external damage and transfers the load between the fibers. The fibers, in turn, provide strength and stiffness to reinforce the matrix—and help it resist cracks and fractures. Although the first carbon fiber was patented in 1961, it took several more years for carbon fiber composites to become commercially available. The use of carbon fiber helped advance many applications in a number of industries, including aerospace, automotive, marine and consumer goods. In 1966, Stephanie Kwolek, a DuPont chemist, invented Kevlar, a para-aramid fiber that is strong enough to be used in advanced composites; Kevlar is best known for its use in ballistic and stab-resistant body armour. New and improved resins helped grow the demand for composites, particularly for use in higher temperature ranges and corrosive applications.

1.1 Composite Materials

Composites are composed of fiber reinforcements and a resin matrix that bonds the fibers. They can also include core materials, fillers, additives and surface finishes to provide unique performance attributes.

Resins- The primary functions of the resin are to transfer stress between the reinforcing fibers, act as a glue to hold the fibers together, and protect the fibers from mechanical and environmental damage. There are two major groups of resins that make up what we call polymer materials—thermosets and thermoplastics. These resins are made of polymers (large molecules made up of long chains of smaller molecules or monomers). Thermoset resins are used to make most composites. They're converted from a liquid to a solid through a process called polymerization, or cross-linking. When used to produce finished goods, thermosetting resins are "cured" by the use of a catalyst, heat or a combination of the two. Once cured, solid thermoset resins cannot be converted back to their original liquid form. Common thermosets are polyester, vinyl ester, epoxy, and polyurethane. Thermoplastic resins, on the other hand, are not cross-linked and, so, can be melted, formed, re-melted and re-formed. Thermoplastic resins are characterized by materials such as ABS, polyethylene, polystyrene, and polycarbonate.

Reinforcements- The mechanical properties of FRP composites are dependent on the type, amount, and orientation of fiber that is selected for a particular service. Fiber reinforcements carry load along the length of the fiber to provide strength and stiffness in one direction. Many materials are capable of reinforcing polymers. Some materials, such as the cellulose in wood, are naturally occurring products. Most commercial reinforcements, however, are man-made. There are many commercially available reinforcement forms to meet the design requirements of the user. The ability to tailor the fiber architecture allows for optimized performance of a product that translates to weight and cost savings. Although many forms of fiber are used as reinforcement in composite laminates, glass fibers account for more than 90 percent of the fibers used in reinforced plastics because they are inexpensive to produce and have relatively good strength-to weight characteristics.

Additive and Fillers- Additives are used in composites to modify materials' properties and tailor the laminate's performance. When added to the resin, fillers can improve properties including water resistance, weathering, surface smoothness, stiffness, dimensional stability and temperature resistance.

Core- Core materials are used extensively throughout the composites industry to fabricate stiff and yet lightweight composites products. Core material is "sandwiched" between fiber reinforced laminate skins to significantly increase stiffness and flexural strength while reducing warpage of flat surfaces.

2. MATERIAL AND METHOD

For Analysis Purposes, we used Mechanical APDL. For analysis of composites, we used Shell type 4 node 181 elements. Two Material Models were made and material properties for Pre- impregnated Unidirectional Epoxy Carbon and Unidirectional Epoxy E-Glass were added. The properties for the two materials are as shown in Table 1 and Table 2:

Table1: Material Properties of Pre- impregnated Unidirectional Epoxy Carbon

S. No.	Property	Value
1	Density (kg/m^3)	1490
2	Young's Modulus X direction (GPa)	121
3	Young's Modulus Y direction (GPa)	8.6
4	Young's Modulus Z direction (GPa)	8.6
5	Poisson's Ratio XY	0.27
6	Poisson's Ratio YZ	0.4
7	Poisson's Ratio ZX	0.27
8	Shear Modulus XY (GPa)	4.7
9	Shear Modulus YZ (GPa)	3.1
10	Shear Modulus ZX (GPa)	4.7

Table2: Material Properties of Unidirectional Epoxy E-Glass

S. No.	Property	Value
1	Density (kg/m^3)	2000
2	Young's Modulus X direction (GPa)	45
3	Young's Modulus Y direction (GPa)	10
4	Young's Modulus Z direction (GPa)	10
5	Poisson's Ratio XY	0.3
6	Poisson's Ratio YZ	0.4
7	Poisson's Ratio ZX	0.3
8	Shear Modulus XY (GPa)	5
9	Shear Modulus YZ (GPa)	3.846
10	Shear Modulus ZX (GPa)	5

New Lay-up is been created for modeling of composites as a rectangular area of dimensions 80mm × 20mm on the XY plane. For analysis purposes, we will be using a single layer of 1 mm thickness and orientation is been varies from 0° to 90° in steps of 15°. For meshing smart size at 3 and Quadrilateral elements is been used.

Fixed support on one end and 100 N force in the X direction on one node at the other end are applied for static analysis. For vibration analysis changed the analysis type to modal. Going to analysis options, we chose to extract 10 modes and the frequency range was set from 0 to 10Hz.

3. RESULTS AND DISCUSSIONS

3.1 Static Load Analysis

For Static Load Analysis we used two materials, Pre-impregnated Unidirectional Epoxy Carbon and Unidirectional Epoxy E-Glass. Using each material, we changed the fiber orientation with respect to the applied load direction from 0° to 90° in steps of 15°.

Table 3: The tabulated results Pre-impregnated Unidirectional Epoxy Carbon

Angle	Stress in X-direction (MPa)	Stress in Y-direction (MPa)
0	35886.6	31677.3
15	36234.2	27475.2
30	37206	21772.1
45	38955.7	16755.8
60	41726.3	11818.9
75	45176.2	7476.53
90	47151.1	5564.73

Figure 1: graph for stress vs fiber orientation Pre-impregnated Unidirectional Epoxy Carbon

Pre-impregnated Unidirectional Epoxy Carbon

The results obtained for the X-direction and Y-direction stresses are presented in Table 3 and Figure 1. We can see from the following graph that as the fiber orientation changes from 0° to 90°, the maximum induced stresses in X-direction increases and maximum stresses in Y-direction decreases.

Table 4: The tabulated results Unidirectional Epoxy E-Glass

Angle	Stress in X-direction	Stress in Y-direction
0	37459.2	24651.1
15	37584.7	23175.7
30	38093.4	20201.9
45	39259.4	16840.7
60	41180.9	13310.2
75	43358.9	10298.2
90	44424.8	9047.44

Unidirectional Epoxy E-Glass

The results obtained for the X-direction and Y-direction stresses are presented in Table 4 and Figure 2. We can see from the following graph that as the fiber orientation changes from 0° to 90°, the maximum induced stresses in X-direction increases and maximum stresses in Y-direction decreases. The increase and decrease is less pronounced in UD E-Glass Epoxy as compared to UD Carbon Epoxy. As UD Carbon Epoxy is more anisotropic than UD E-Glass Epoxy and thus, change in fiber orientation causes more change in the induced stresses.

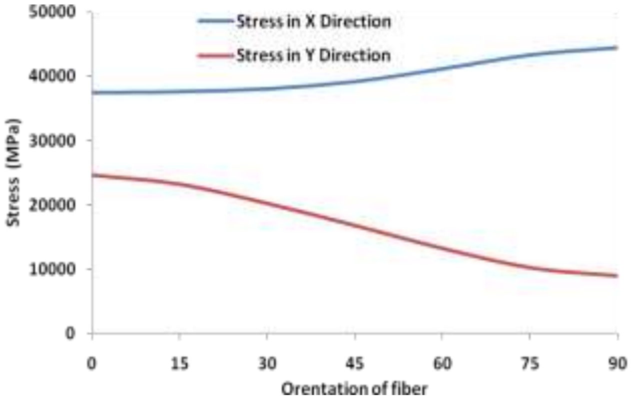
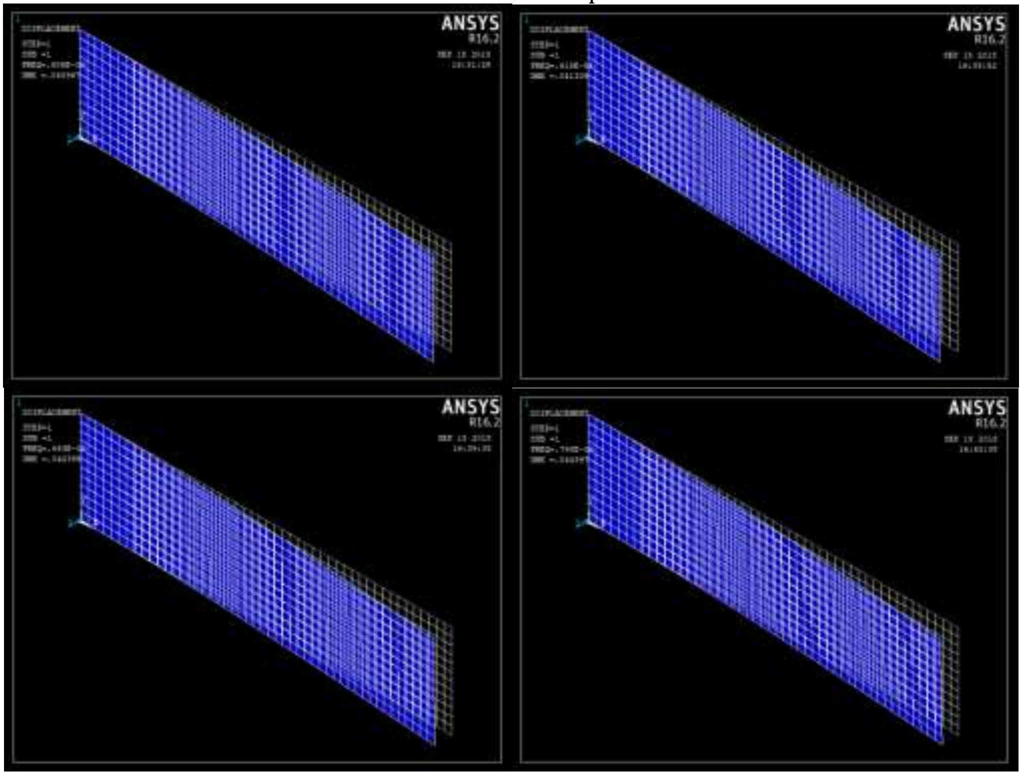


Figure 1: graph for stress vs fiber orientation Unidirectional Epoxy E-Glass

3.2 Vibration Analysis

In present investigation vibration analysis of Pre-impregnated UD Epoxy Carbon as shown in figure 3, 4 & 5 has been performed to investigate the behaviour of composite under free vibration.



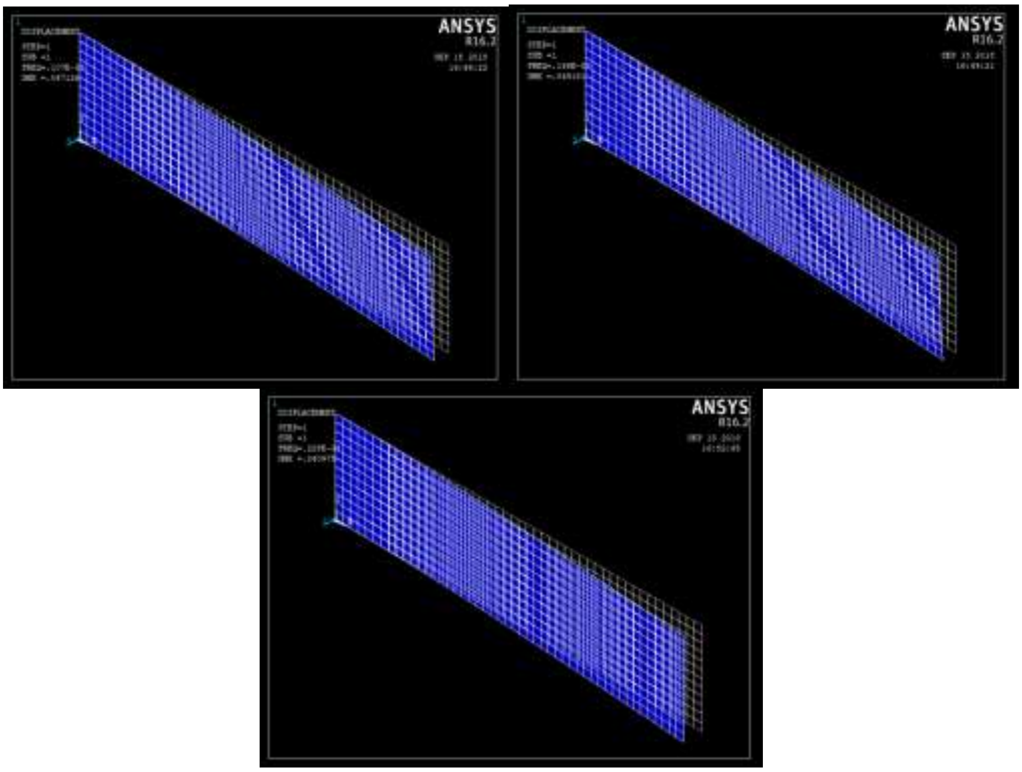
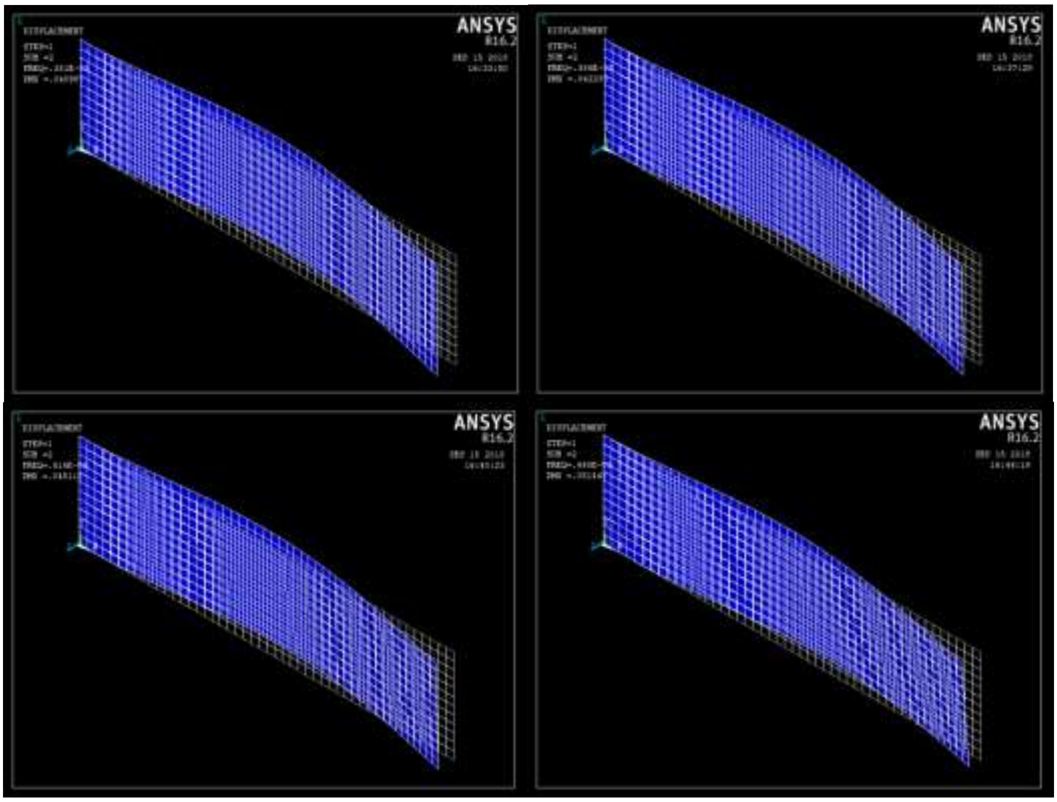


Figure 3: 1st mode analysis of Pre-impregnated UD Epoxy Carbon for different fiber orientations



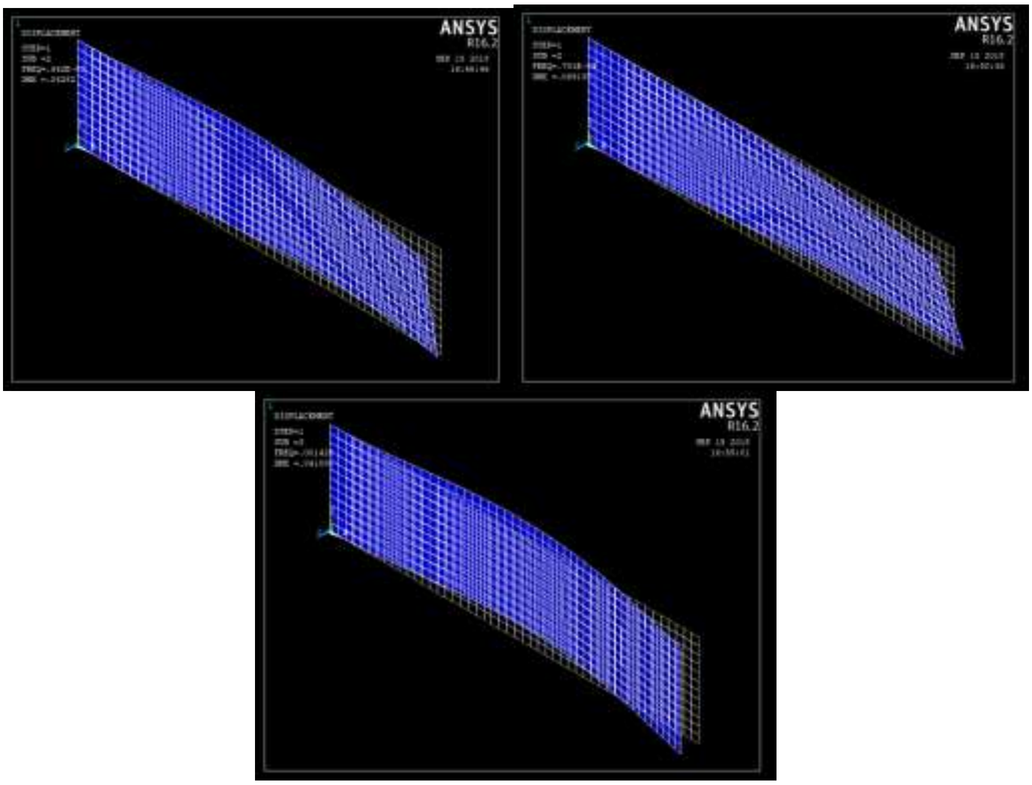
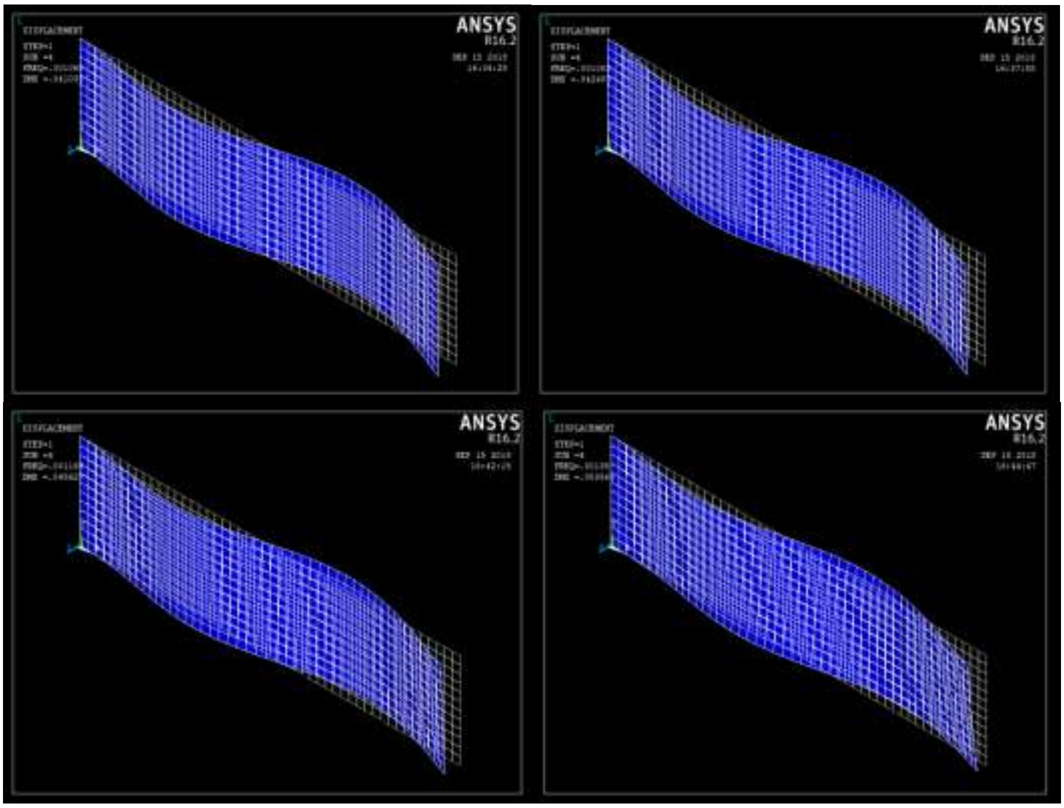


Figure 4:2ndmode analysis of Pre-impregnated UD Epoxy Carbon for different fiber orientations



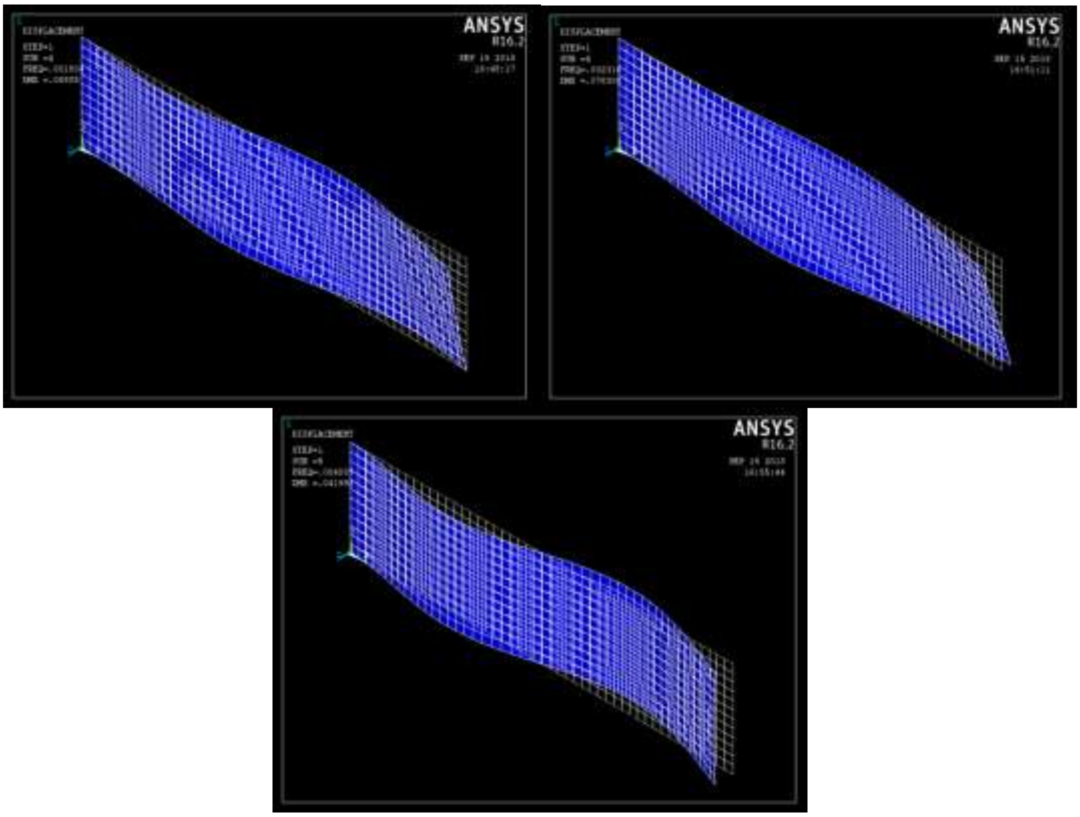


Figure 5: 3rd mode analysis of Pre-impregnated UD Epoxy Carbon for different fiber orientations

Table 5: 1st, 2nd and 3rd mode analysis for different fiber orientations

Angle	**Frequency (Hz ×10^{-03})**		
	1st Mode	**2nd Mode**	**3rd Mode**
0	0.0606	0.381	1.068
15	0.0615	0.386	1.082
30	0.0663	0.414	1.163
45	0.079	0.49	1.38
60	0.107	0.642	1.804
75	0.166	0.781	2.316
90	0.228	1.428	4.007

CONCLUSION

In present investigation modeling of Pre-impregnated Unidirectional Epoxy Carbon and Unidirectional Epoxy E-Glass composites have been done. Static loading analysis of both the model has been done and result shows that with increase in fiber orientation stress in x-direction increases whereas in y-direction decreases. Vibration analysis of Pre-impregnated Unidirectional Epoxy Carbon has been performed and result shows that with increase in angle of orientation 1st, 2nd and 3rd mode frequency increases.

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BIOGRAPHIES

Prakhar Tonk
Pursuing Bachelor of Technology In Mechanical Engineering from G.B. Pant University of Agriculture and Technology, Pantnagar, India. His areas of interest are finite element analysis, thermal conduction, composites and automobiles.

Naman Jain
Naman Jain obtained his Master's degree in Design and Production Engg. From G. B. P. U. A & T. He is currently pursuing Ph.D. in Mechanical Engineering from G. B. P. U. A & T. His areas of interest are finite element analysis, computer aided mechanical design, optimization and Numerical Modeling and Simulation.