STATIC AND HARMONIC ANALYSIS WITH VARIOUS BOUNDARY CONDITION OF A LAMINATED COMPOSITE BEAM

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Abstract – *We know that nowadays composite materials are broadly used due to its light weight and mechanical properties that makes it better than other conventional materials. The intend of this paper is to study Static analysis and Harmonic analysis of laminated composite beam in ANSYS 15.0 with various boundary conditions, to investigate the effect of fiber orientation on transverse deflections and also to Study the effects of fiber angle to the transverse deflections, effect of various thickness ratios on transverse deflections.*

Key Words*: *Composite Materials, Static analysis, Harmonic analysis, ANSYS 15.0, Transverse deflections.

1. INTRODUCTION

A composite material is characterized as a material framework which comprises of a blend or a mix of two or all the more unmistakably distinctive materials which are insoluble in each other and vary in structure or concoction creation. In this manner, a composite material is named as any material comprising of two or more stages. Numerous mixes of materials are termed as composite materials, for example, solid, mortar, fiber strengthened plastics, and fiber fortified metals and comparable fiber impregnated materials. Two-phase composite materials are masterminded into two general orders: particulate composites and fiber fortified composites. Particulate composites are those in which particles having distinctive shapes and sizes are scattered inside a grid in an unpredictable configuration.

Static stress analysis is arguably the most common type of structural analysis using FE method. Stress, strain and deformation of a material or assembled part can be investigated under a variety of load impacts to ensure that high-cost failures are eliminated at the design stage.

The harmonic analysis is performed in ANSYS to find the natural frequency of first mode and to plot the graph between frequency and displacement. Consonant reaction investigation gives us the capacity to foresee the managed dynamic conduct of our structures, subsequently empowering us to confirm regardless of whether our outlines will effectively overcome reverberation, weariness, and other hurtful impacts of constrained vibrations. Symphonious reaction examination is a system used to decide the unfaltering state reaction of a straight structure to burdens that fluctuate sinusoidally (agreeably) with time. The thought is to ascertain the structure's reaction at a few frequencies and get a diagram of some reaction amount (normally relocations) versus recurrence. "Top" reactions are then distinguished on the chart and burdens looked into at those top frequencies. This investigation method ascertains just the unfaltering state, constrained vibrations of a structure.

2. Static Analysis of Laminated Composite Beam

Here static analysis of laminated composite beam with various boundary conditions for different composite materials are analyzed using ANSYS (15.0) software. The Transverse static deflections are determined for the clamped free, clamped-clamped and hinged-hinged beam for boron epoxy, glass polyester, graphite epoxy, AS4-3501-6 graphite epoxy composite materials. Then the static transverse deflections of clamped free, clamped-clamped, hinged-hinged beams are compared for each material.

2.1 Boron Epoxy

Consider a boron-epoxy laminated composite beam of rectangular cross section with all fiber angles arranged to (0°/30°/-45°). The material properties of the beam are given as

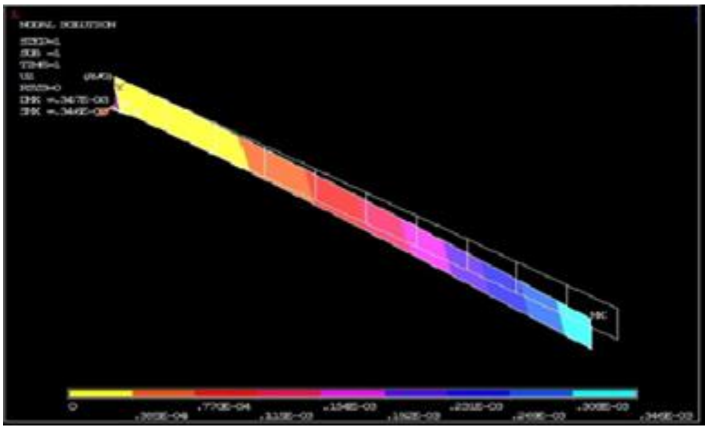
Table -1: Material Properties of Boron Epoxy

Material properties	Boron Epoxy
Ex	206.84 Gpa
Ey	20.68 Gpa
Gxy	6.89 Gpa
Gyz	4.13Gpa
Gzx	6.89 Gpa
µxy	0.3
r	2075.993kg/m3

Let, L= length of the composite laminated beam =0.381 m, b= width of the laminated composite beam= 0.0254 m, h= thickness of the each ply = 0.0254m, with applied load 1000 N.

Case -1: The static deflection of clamped free boron epoxy laminated composite beam using ANSYS 15.0 is 0.346x10−3 m.

Figure -1: static deflection of clamped free boron epoxy laminated composite beam.



Case -2: The static deflection of clamped-clamped boron epoxy laminated composite beam using ANSYS 15.0 is 0.168x10−4m.

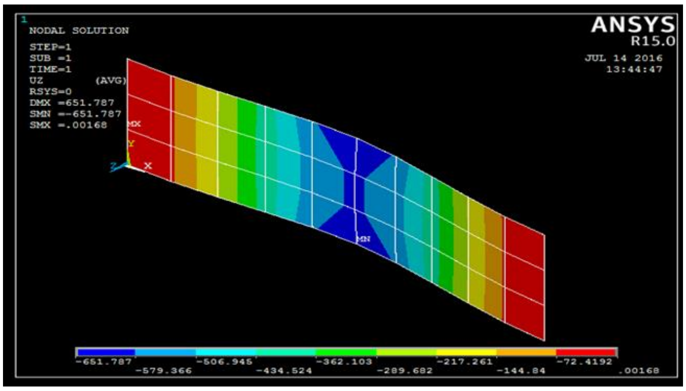


Figure -2: The Static deflection of clamped-clamped boron epoxy laminated composite Beam.

Case -3: The static deflection of hinged-hinged boron epoxy laminated composite beam using ANSYS 15.0 is 0.228x10−4m.

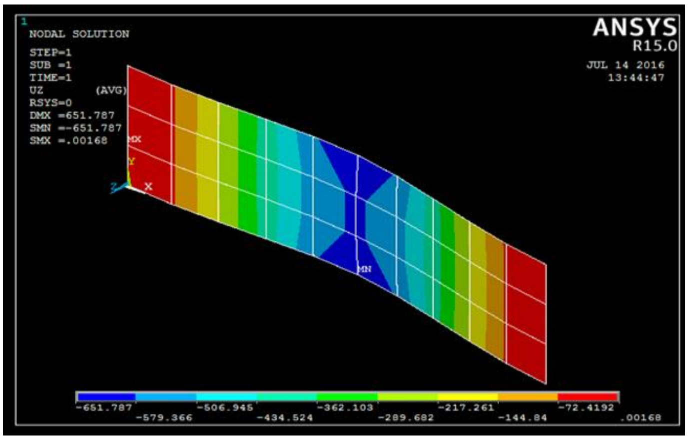


Figure -3: The static deflection of hinged-hinged boron epoxy laminated composite beam using ANSYS 11.0.

Here the static transverse deflections of boron epoxy laminated composite beam as clamped free, clamped-clamped and hinged-hinged beam are shown in following table.

Table -2: Static deflections of boron epoxy laminated composite beam

Type	Static Deflection
Clamped free	0.346x10−3
Clamped- Clamped	0.168x10−4m
hinged-hinged	0.228x10−4m

After studying this table we can easily conclude that the transverse deflections of the clamped free boron epoxy laminated composite beam has higher value than the hinged-hinged and clamped-clamped beam respectively

2.2 Graphite - Epoxy.

Consider Graphite-epoxy composite beam of rectangular cross section with all fiber angles arranged to (30°/50°/30°/50°). The material properties of the beam are given as

Table -3: Material Properties of Graphite Epoxy

Material properties	Graphite Epoxy
Ex	144.80Gpa
Ey	9.65Gpa
Gxy	4.14Gpa
Gyz	3.45Gpa
Gzx	4.14Gpa
μxy	0.3
r	1389.2kg/m^3

Let, L= length of the composite laminated beam =0.381 m, b= width of the laminated composite beam= 0.0254 m, h= thickness of the each ply = 0.0254m with applied load 1000 N.

Case -4: The static deflection of clamped free graphite epoxy laminated composite beam using ANSYS 15.0 is 0.482x10−3 m.

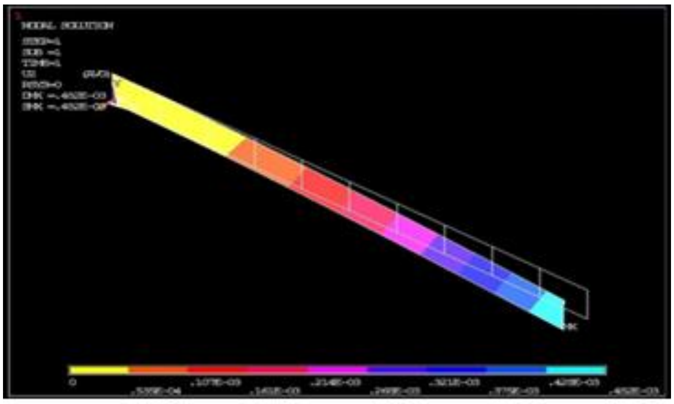


Figure -4: The Static deflection of clamped free graphite epoxy laminated composite beam

Case -5: The static deflection of clamped -clamped graphite epoxy laminated composite beam using ANSYS 15.0 is 0.185x10−4 m.

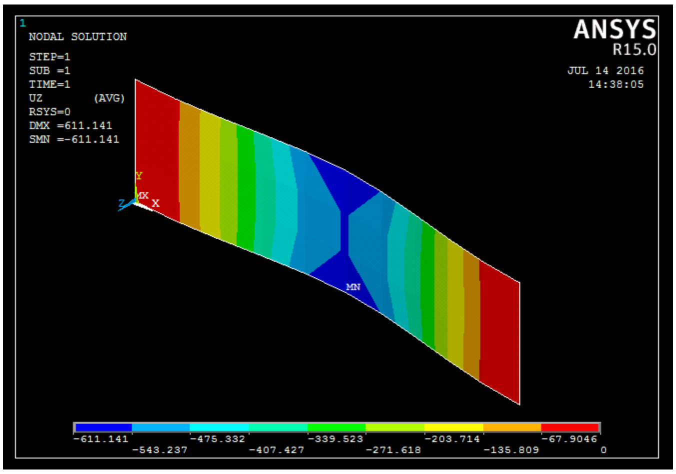


Figure -5: The Static deflection of clamped-clamped graphite epoxy laminated Composite beam

Case -6: The static deflection of hinged-hinged graphite epoxy laminated composite beam using ANSYS 15.0 is 0.380x10−4 m

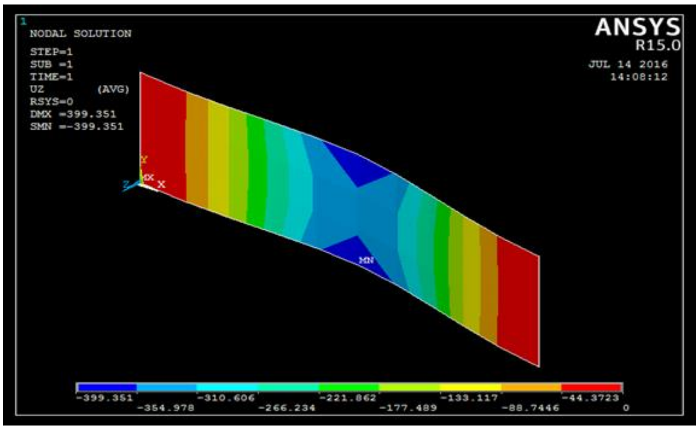


Figure -6: The Static deflection of hinged-hinged graphite epoxy laminated composite Beam

Here the static transverse deflections of graphite epoxy laminated composite beam as clamped free, clamped-clamped and hinged-hinged beam are shown in following table.

Table 4: Static deflections of graphite-epoxy laminated composite beam

Type	Static Deflection
Clamped free	0.482x10−3m
Clamped- Clamped	0.0185x10−3m
hinged-hinged	0.0380x10−3m

After studying this table we can easily conclude that the transverse deflections of the clamped free graphite epoxy laminated composite beam has higher value than the hinged-hinged and clamped -clamped beam respectively.

2.3 Glass polyester

Consider a Glass-polyester composite beam of rectangular cross section with all fiber angles arranged to (45°/45°/45°/45°). The material properties of the beam are given as.

Table -5: Material Properties of Glass polyester

Material properties	Graphite Epoxy
Ex	37.41Gpa
Ey	13.67Gpa
Gxy	5.47Gpa
Gyz	6.66Gpa
Gzx	6.03Gpa
µxy	0.3
r	1968.9 kg/m3

Let, L= length of the composite laminated beam =0.381 m, b= width of the laminated composite beam= 0.0254 m, h= thickness of the each ply = 0.0254m with applied load 1000 N.

Case -7: The static deflection of clamped free glass polyester laminated composite beam using ANSYS 15.0 is 0.583x10−3m.

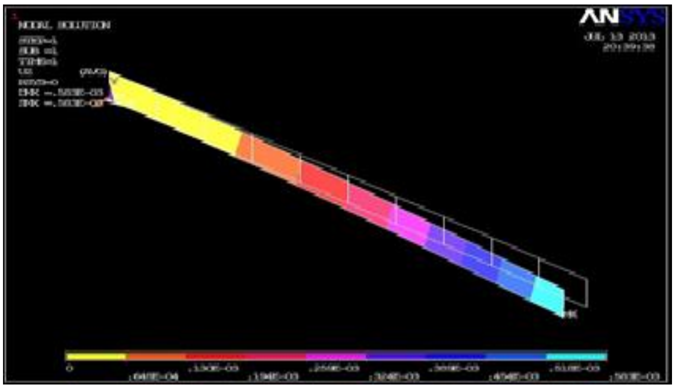


Figure -7: The Static deflection of clamped free glass polyester laminated composite beam

Case -8: The static deflection of clamped-clamped glass polyester laminated composite beam using ANSYS 15.0 is 0.158x10−4m

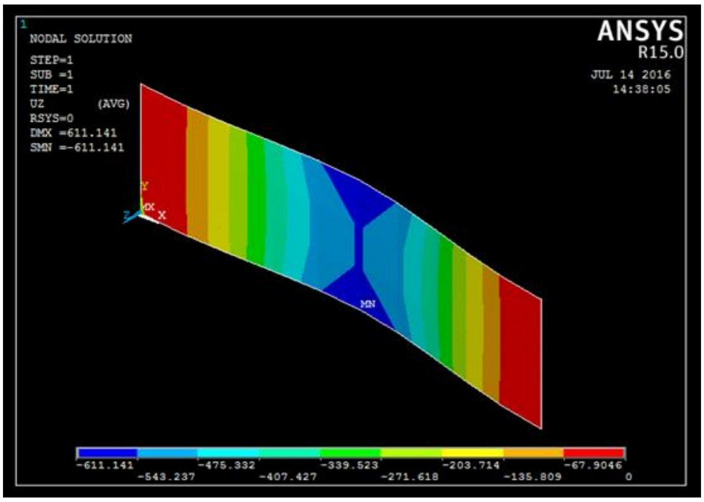


Figure -8: The static deflection of clamped-clamped glass polyester laminated composite beam using

Case -9: The static deflection of hinged-hinged glass polyester laminated composite beam using ANSYS 15.0 is 0.418x10−4m.

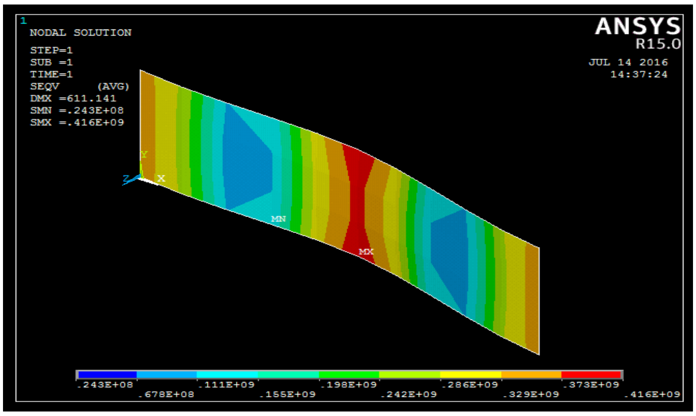


Figure -9: The Static deflection of hinged-hinged glass polyester laminated composite beam

Here the static transverse deflections of glass polyester laminated composite beam as clamped free, clamped-clamped and hinged-hinged beam are shown in following table.

Table 6: Static deflections of glass polyester laminated composite beam

Type	Static Deflection
Clamped free	0.583x10−3m
Clamped- Clamped	0.0158x10−3m
hinged-hinged	0.0418x10−3m

After studying this table we can easily conclude that the transverse deflection of the clamped free glass polyester laminated composite beam has higher value than the hinged-hinged and clamped-clamped beam respectively.

2.4 AS4-3501-6 Graphite-Epoxy

Consider a AS4-3501-6 Graphite-epoxy composite beam of rectangular cross section with all fiber angles arranged to (0°/90°/0°/90°). The material properties of the beam are given as.

Table -7: Material Properties of AS4-3501-6 Graphite-Epoxy

Material properties	Graphite Epoxy
Ex	144.80 Gpa
Ey	9.65 Gpa
Gxy	4.14 Gpa
Gyz	3.45 Gpa
Gzx	4.14 Gpa
µxy	0.3
r	1550.1kg/m3

Let, L= length of the composite laminated beam =0.381 m, b= width of the laminated composite beam= 0.0254 m, h= thickness of the each ply = 0.0254m with applied load 1000 N.

Case -10: The static deflection of clamped free AS4-3501-6 graphite epoxy laminated composite beam using ANSYS 15.0 is 0.172x10−3m.

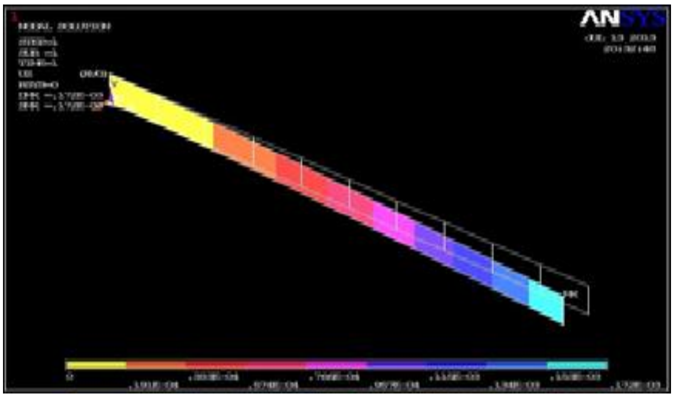


Figure -10: The Static deflection of clamped free AS4-3501-6 graphite epoxy laminated composite beam

Case -11: The static deflection of clamped-clamped AS4-3501-6 graphite epoxy laminated composite beam using ANSYS 15.0 is 0.139x10−4 m.

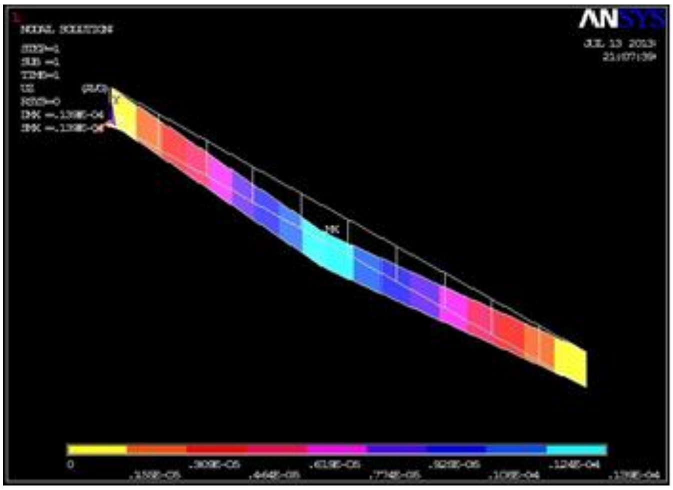


Figure -11: The Static deflection of clamped-clamped AS4-3501-6 graphite epoxy laminated composite beam

Case -12: The static deflection of hinged-hinged AS4-3501-6 graphite epoxy laminated composite beam using ANSYS 15.0 is 0.189x10−4 m.

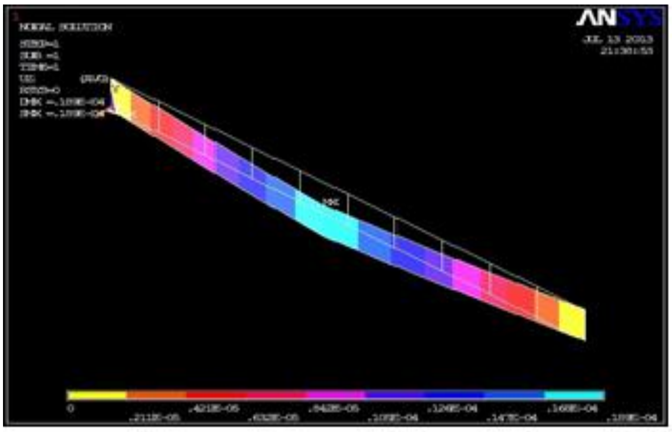


Figure -12: The Static deflection of hinged-hinged AS4-3501-6 graphite epoxy laminated composite beam using

Here the static transverse deflections of AS4-3501-6 graphite epoxy laminated composite beam as clamped free, clamped-clamped and hinged-hinged beam are shown in following table.

Table 8: Static deflections of AS4-3501-6 graphite epoxy laminated composite beam.

Type	Static Deflection
Clamped free	0.172x10−3m
Clamped- Clamped	0.0139x10−3m
hinged-hinged	0.0189x10−3m

After studying this table we can easily conclude that the transverse deflections of the clamped free AS4-3501-6 graphite epoxy laminated composite beam have higher value than the hinged-hinged and clamped -clamped beam respectively.

3. The Harmonic Frequency Response of Laminated Composite Beams

Here frequency responses of laminated composite beam with various boundary conditions for different composite materials are analyzed using ANSYS software. The undamped frequencies are determined for the clamped free, clamped-clamped and hinged-hinged beam for boron epoxy, glass polyester, graphite epoxy, AS4-3501-6graphite epoxy composite materials. Then the undamped frequencies of clamped free, clamped-clamped, hinged-hinged beams are compared for each material. The frequency response graphs of the composite material for different boundary conditions are shown below.

3.1 Boron Epoxy

The undamped frequency response graphs of boron epoxy composite material for clamped free, clamped-clamped, hinged-hinged beams are shown below and undamped frequencies are shown in table 9

Case -13: The following figure shows that frequency response of boron epoxy laminated composite beam as clamped free beam.The undamped frequency of this beam is 403.0 Hz.

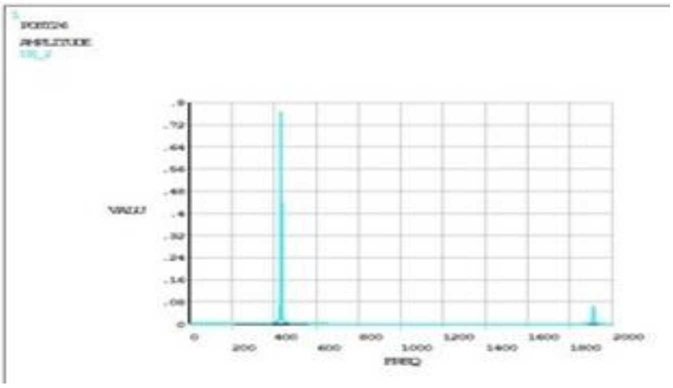


Figure -13: Frequency response of boron epoxy laminated composite clamped free beam.

Case -14: The following figure shows that frequency response of boron epoxy laminated composite beam as clamped-clamped beam. The undamped frequency of this beam is 1720.0 Hz.

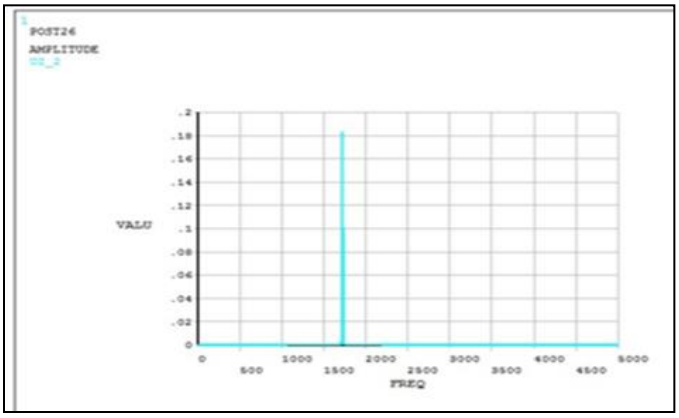


Figure -14: Frequency Response of Boron Epoxy Laminated Composite Clamped-Clamped Beam.

Case -15: The figure shows that frequency response of boron epoxy noted composite beam as hinged-hinged beam.The undamped frequency of this beam is 1290.0 Hz.

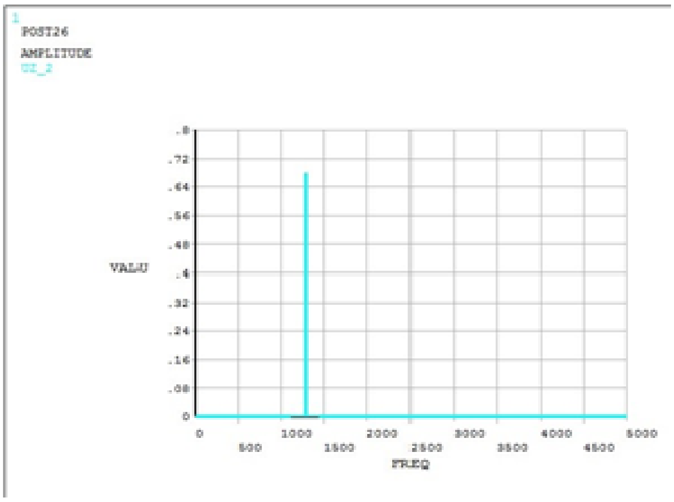


Figure -15: Frequency Response of Boron Epoxy Laminated Composite Hinged-Hinged Beam.

Table 9: Undamped frequency (harmonic analysis) of boron epoxy laminated composite beam for different types of beams

Type	Undamped frequency
Clamped free	403.0Hz
Clamped- Clamped	1720.0Hz
hinged-hinged	1290.0 Hz

After studying above table we can easily conclude that the undamped frequency of boron epoxy laminated composite beam for clamped free has less frequency than the hinged-hinged and clamped-clamped beam respectively

3.2 Graphite Epoxy

The undamped frequency response graphs of graphite epoxy composite material for clamped free, clamped-clamped, hinged-hinged beams are shown below and undamped frequencies are shown in table 10

Case -16: The following figure shows that frequency response of graphite epoxy laminated composite beam as clamped-clamped beam. The undamped frequency of this beam is 1812.0 Hz

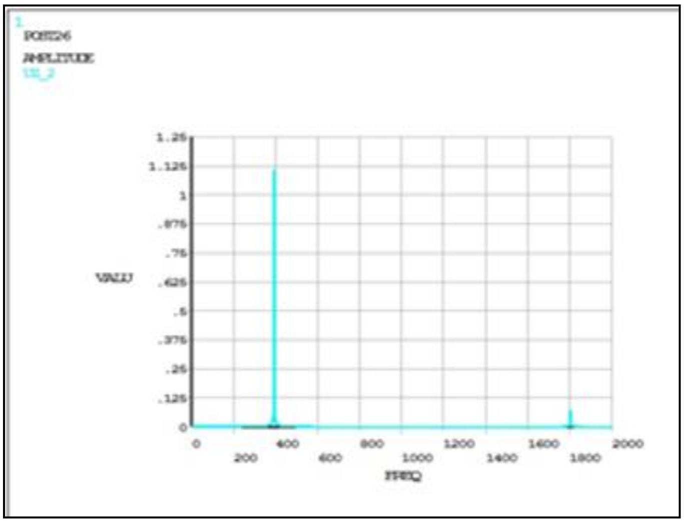


Figure -16: Frequency Response Of Graphite Epoxy Laminated Composite Clamped Free Beam.

Case -17: The following figure shows that frequency response of graphite epoxy laminated composite beam as clamped-clamped beam. The undamped frequency of this beam is 1812.0 Hz

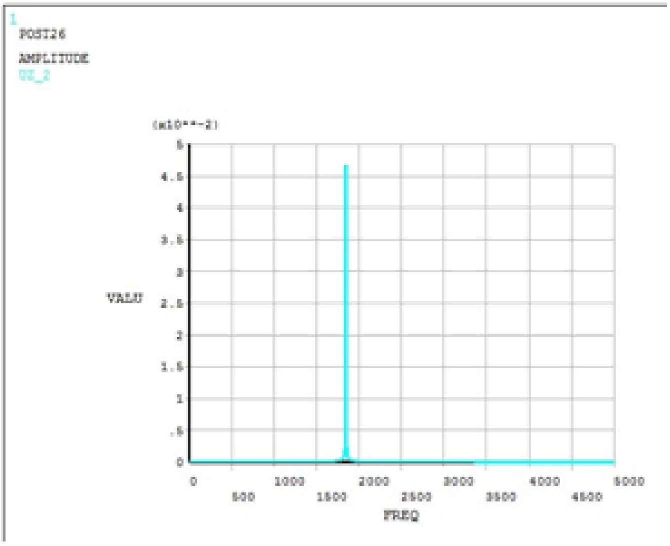


Figure -17: Frequency Response of Graphite Epoxy Laminated Composite Clamped- Clamped Beam.

Case -18: The shows that frequency response of graphite epoxy noted composite beam as hinged-hinged beam. The undamped frequency of this beam is 1028.0 Hz

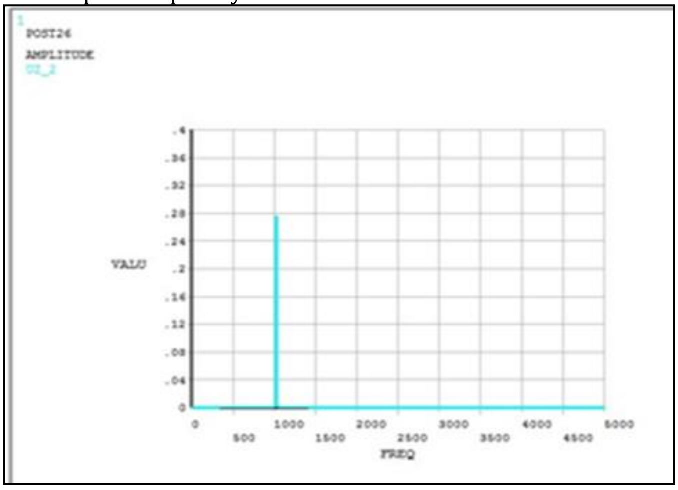


Figure -18: Frequency response of graphite epoxy laminated composite hinged-hinged beam.

Table 10: Undamped frequency (harmonic analysis) of graphite epoxy laminated composite beam for different types of beams

Type	Undamped frequency
Clamped free	393.0 Hz
Clamped- Clamped	1812.0 Hz
hinged-hinged	1028.0 Hz

After studying above table we can easily conclude that the undamped frequency of graphite epoxy laminated composite beam for clamped free has less frequency than the hinged-hinged and clamped-clamped beam respectively.

3.3 Glass polyester

The undamped frequency response graphs of glass polyester composite material for clamped free, clamped-clamped, hinged-hinged beams are shown below and undamped frequencies are shown in table 11

Case -19: figure shows that frequency response of glass polyester laminated composite beam as clamped free beam.The undamped frequency of this beam is 302.0.0 Hz

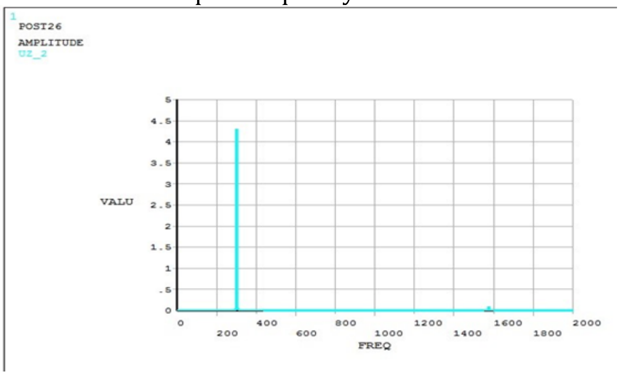


Figure -19: Frequency response of glass polyester laminated composite clamped free beam

Case -20: Figure shows that frequency response of glass polyester laminated composite beam as clamped-clamped beam.The undamped frequency of this beam is 1470.0 Hz

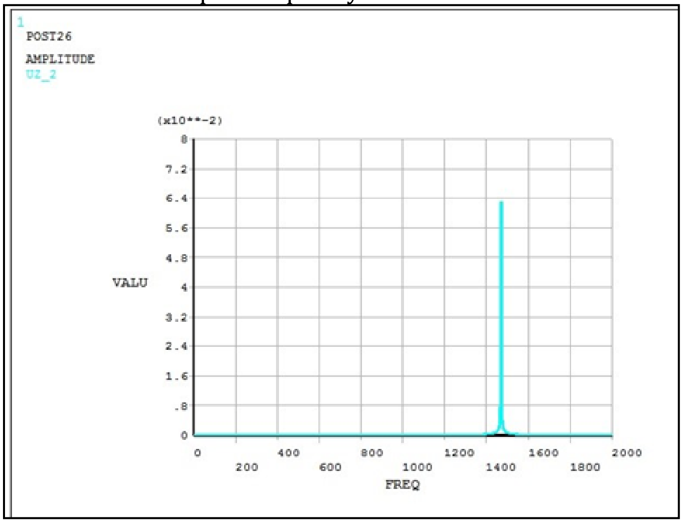


Figure -20: Frequency response of glass polyester laminated composite clamped-clamped beam.

Case -21: The figure shows that frequency response of glass polyester noted composite beam as hinged-hinged beam. The undamped frequency of this beam is 812.0 Hz

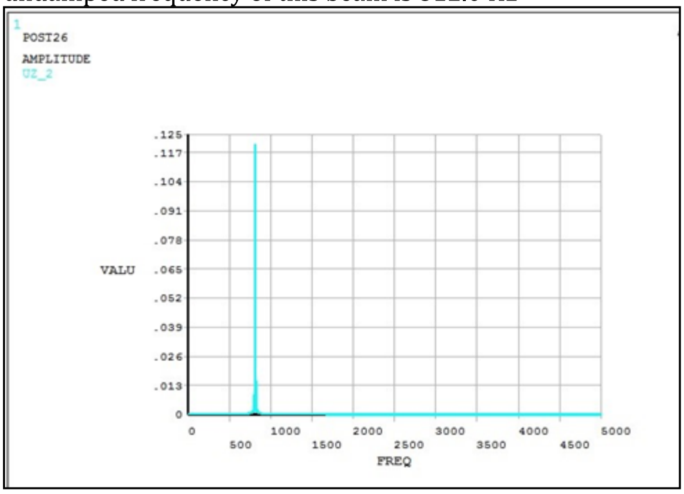


Figure -21: Frequency response of glass polyester laminated composite hinged-hinged beam.

Table 11: Undamped frequency (harmonic analysis) of glass polyester laminated composite beam for different types of beams

Type	Undamped frequency
Clamped free	302.0Hz
Clamped- Clamped	1470.0Hz
hinged-hinged	812.0 Hz

After studying above table we can easily conclude that the undamped frequency of glass polyester laminated composite beam for clamped free has less frequency than the hinged-hinged and clamped-clamped beam respectively

3.4 AS4-3501-6 graphite epoxy

The undamped frequency response graphs of AS4-3501-6graphite epoxy composite material for clamped free, clamped-clamped, hinged-hinged beams are shown below and undamped frequencies are shown in table 12

Case -22: The following figure shows that frequency response of AS4-3501-6 graphite epoxy laminated composite beam as clamped free beam.The undamped frequency of this beam is 586.0 Hz

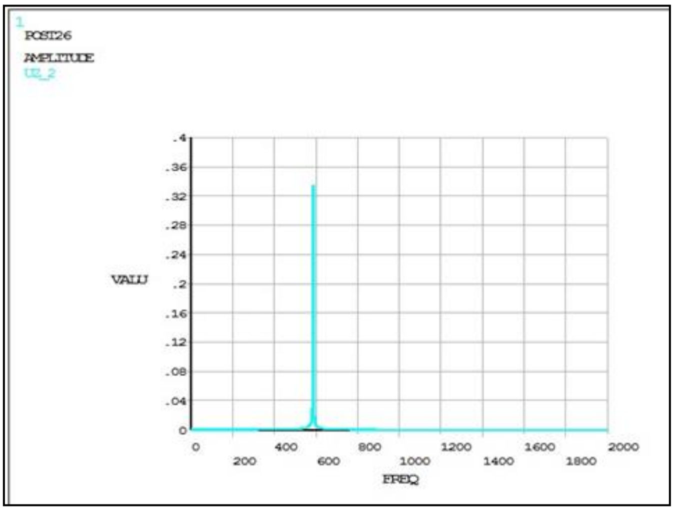


Figure -22: Frequency response of AS4-3501-6 graphite epoxy laminated composite Clamped free beam.

Case -23: The following figure shows that frequency response of AS4-3501-6 graphite epoxy laminated composite beam as clamped-clamped beam. The undamped frequency of this beam is 1858.0 Hz

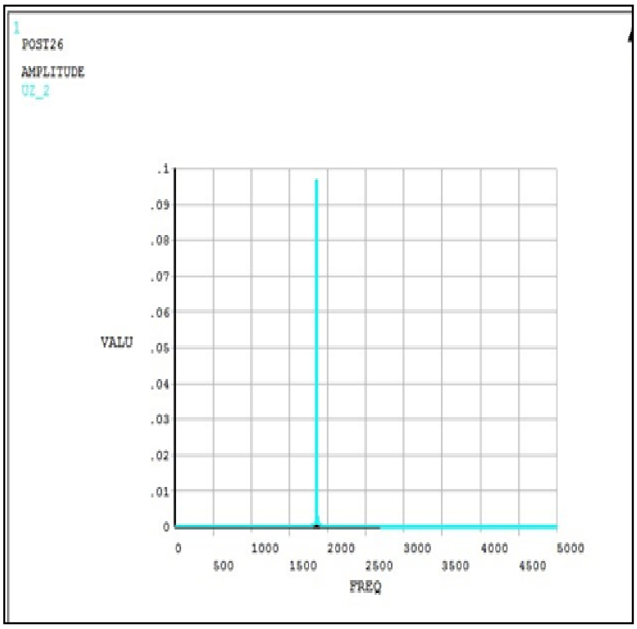


Figure -23: Frequency response of AS4-3501-6 graphite epoxy laminated composite Clamped-clamped beam

Case -24: The following figure shows that frequency response of AS4-3501-6 graphite epoxy laminated composite beam as hinged-hinged beam.The undamped frequency of this beam is 1430.0 Hz

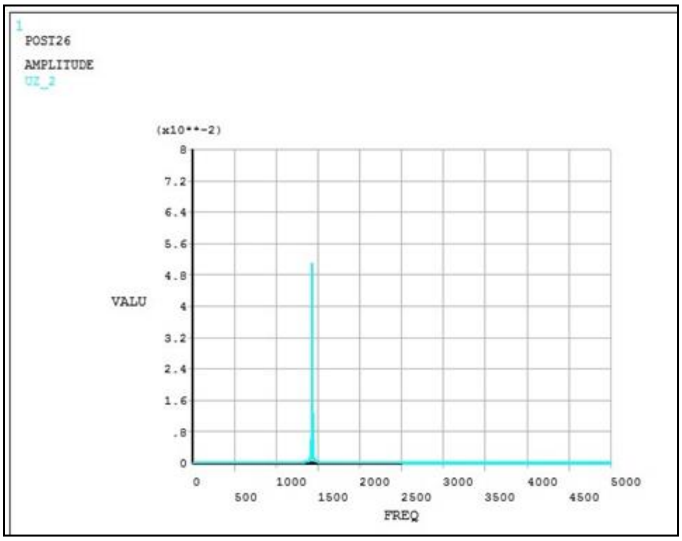


Figure -24: 5.26: frequency response of AS4-3501-6 graphite epoxy laminated composite Hinged –hinged beam.

Table 12: Undamped frequency (harmonic analysis) of AS4-3501-6 graphite epoxy laminated composite beam for different types of beams

Type	Undamped frequency
Clamped free	586.0Hz
Clamped- Clamped	1858.0Hz
hinged-hinged	1430.0 Hz

After studying above table we can easily conclude that the undamped frequency of AS4-3501-6 graphite epoxy laminated composite beam for clamped free has less frequency than the hinged-hinged and clamped-clamped beam respectively.

4. Effect of Fibre Orientation on Transverse Deflections

Consider a generalize laminated composite beam of rectangular cross section the material properties of the beam are given as

Table 13: Material properties of the beam

Material properties	Graphite Epoxy
E1	129.207 GPa
E2= E3	9.42512 GPa
G12	5.15658 GPa
G13	4.3053 GPa
G23	2.5414 GPa
n12= n23	0.3
n13	0.218837
r	1550.0660 kg/m^3

L= length of the composite laminated beam =0.1905 m, b= width of the laminated composite beam= 0.0127m, with applied load 1 N.

Here deflections for clamped-free composite beams subjected to a concentrated transverse load P at the free end (x= 1) for various values of 1/ h ratios and fibre orientation θ determined using ANSYS 15.0

Table 14: Deflections for clamped-free uniaxial composite beams under action of a Concentrated load (P) at the free edge.

Fibre angle	l/h=60	l/h=20	l/h=10	l/h=5
0	0.529×10^{-3}	0.0202×10^{-3}	0.00281×10^{-3}	0.000492×10^{-3}
30	3.067×10^{-3}	0.117×10^{-3}	0.0152×10^{-3}	0.00205×10^{-3}
45	5.048×10^{-3}	0.190×10^{-3}	0.0242×10^{-3}	0.00317×10^{-3}
60	6.466×10^{-3}	0.241×10^{-3}	0.0304×10^{-3}	0.00391×10^{-3}
90	7.218×10^{-3}	0.268×10^{-3}	0.0336×10^{-3}	0.00492×10^{-3}

Graphical representation of effect of fibre angles vs transverse deflections of the clamped-free uniaxial composite beams under action of a concentrated load (P) at the free edge having l/h=60.

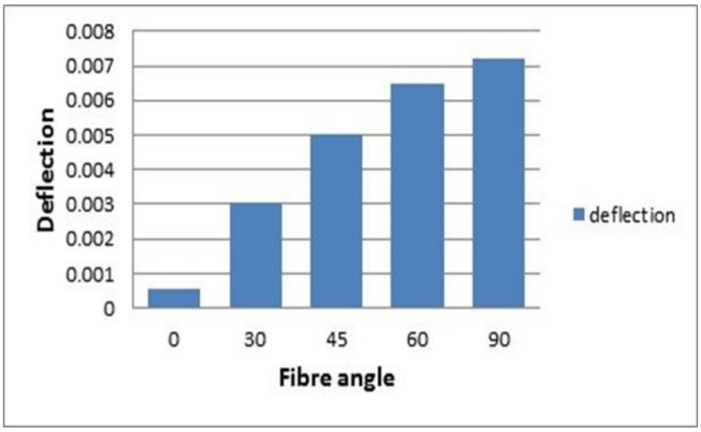


Figure 25: Fibre angle vs deflections.

By studying this graph we easily tell that as the fibre angle increases the transverse deflection also increases proportionally as angle increases.

Graphical representation of the various thickness ratios to the transverse deflection having same fibre angle of the clamped-free uniaxial composite beams under action of a concentrated load (P) at the free edge having l/h=60, l/h=20, l/h=10, l/h=5 and fibre angle 0.

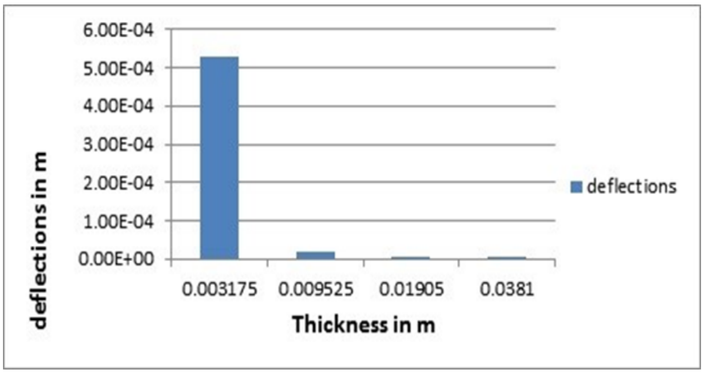


Figure 26: Thickness vs transverse deflection.

After studying this we can conclude as the thickness of the laminated composite beam is increases then the transverse deflections are decreases or when the thickness ratio (l/h) decreases then the transverse deflections are also decreases.

5. CONCLUSIONS

On the basis of present study following conclusions are drawn

- Static analysis of laminated composite beams found that the transverse deflections of the clamped free laminated composite beam have higher value than the hinged-hinged and clamped-clamped beam respectively for all composite material we studied.
- Harmonic analysis of laminated composite beams found that undamped frequency (harmonic analysis) is minimum for clamped–free supported beam and maximum for clamped-clamped supported beam .In between these two, undamped frequencies of hinged-hinged supported beam lies for all composite material we studied.
- As the fibre angle of the unidirectional lamina of composite beam increases the transverse deflection also increases proportionally.
- As the thickness of the laminated composite beam is increases then the transverse deflections are decreases or when the thickness ratio (l/h) de
- creases then the transverse deflections are also decreases.
- The changes in fiber angle give to distinct dynamic behavior of the component, that is, different natural frequencies and deflection for the equal geometry, mass and boundary conditions.

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