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Structural Analysis of Simply Supported Composite Beam Exposed to Transient Loading

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ABSTRACT

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. Composites are widely used for many applications because of their high strength and stiffness at a low weight ratio. Studying the mechanical properties and behaviours of such composite materials is one of the promising research areas. In this analysis, two composite beams with different dimensions were taken and materials are applied for the face plate and core layer accordingly and then the loading is applied to the material. Three-point and four-point loading systems are used and the graph is plotted for the values obtained at different time steps during transient loading.

Keywords: Composite beam, Deflection, FEA, Strain, Structural analysis

INTRODUCTION

A composite material system is composed of two or more physically distinct phases whose combination will produce properties that are different from those of its constituents. The composites can be natural or synthetic. The reason why selecting composite materials is because of theirlightweight, non-corrosive, fatigue-resistant properties. The composition of different materials in composite structure leads to a formation of a material with different properties. Two main constituents are included in this which are the reinforcement phase, binder or matrix phase. Composites are classified into three categories: particle-reinforced, fibre reinforced and structural. The most commonly used are fibre reinforced. In this analysis, I have used structural composite which is a sandwich structure. The bottom layer of the composite beamconsists of a composite laminate-facing plate. Generally, the facing plates are having higher strength when compared with the other layer. The centre core layer consisted of the core material. The core material has a lower density but it will have higher strength when compared to a metal or material. The layer between the core and the facing plate is the adhesive bond which connects the face to the core. It is majorly used in the aerospace industry. Almost fifty per cent of the material constituents in an aircraft are composite materials especially in the fuselage, wing body and in other control surfaces. The material differs depending on the strength needed for that particular area.

For the analysis, I have designed two composite sand structures with different dimensions. Two materials were selected for the Composite structure. FRP unidirectional laminate for facing plates and Aluminium honeycomb 5052 for core material. Static Structural analysis is done to find the deflection and strain when different loads which will be acting upon the composite beam.

METHODOLOGY

In this paper, two models were used. The first model is a three-point loading system in which the two edges of the model are simply supported and in the centre of the model point load is applied. The second model is a four-point loading system in which two edges are simply supported and point load is applied at two points over the top of the model.

In both, the case initial load applied will be 125 N. In the first model load, is applied in the centre point and it has been increased in steps of 125N for ten times. In the second case, the initial load will be 125N which is given tothe supporting member anddistributes the value to both edges. The two-point loads will be at quarter points with 62.5N at each point and it has been increased in steps to 62.5N for sixteen times.

GEOMETRY

The geometry of two composite beam models is designed in ANSYS Geometry. The first model a is three-point loading system and the base dimensions will be 150in mm length and 51mm in width. The face, core and total thickness will be 1.35mm, 19mm, and 21.70mm respectively. The second model is a four-point loading system and the base dimensions will be 250mm in length and 51 mm in width. The face, core and total thickness will be the same as that of the first model.

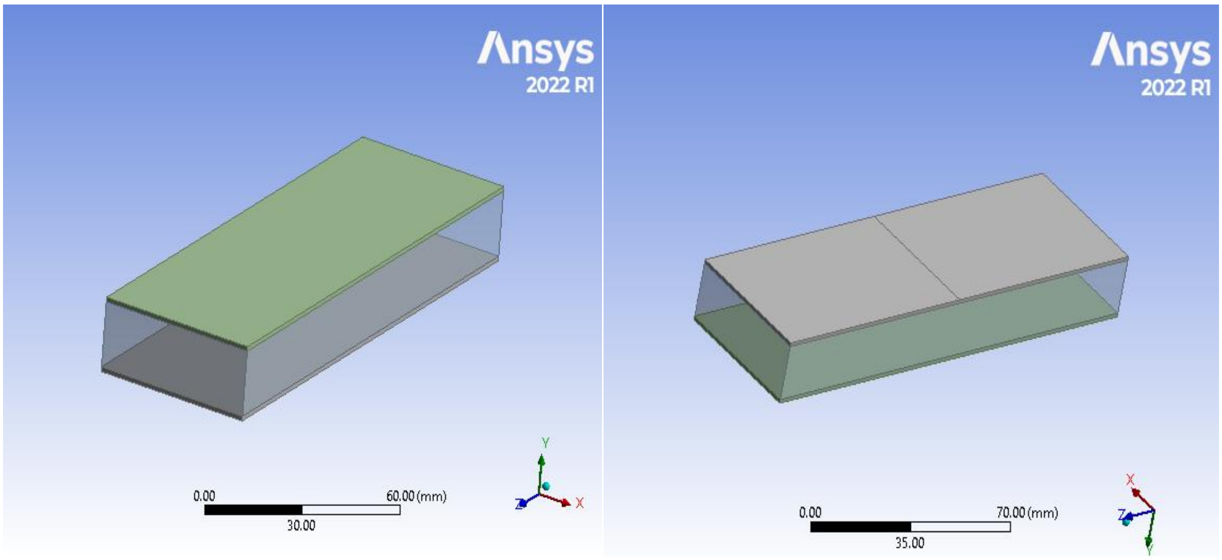


Figure 1: Geometry of Composite beam with basedimension 150 × 51mm

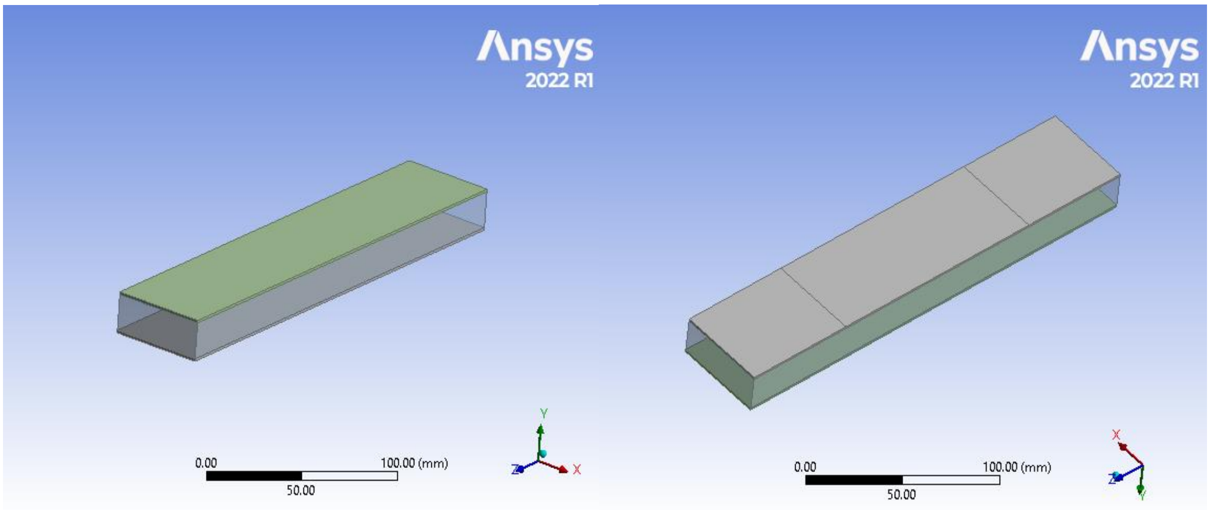


Figure 1: Geometry of Composite beam with basedimension 250 × 51mm

MATERIAL PROPERTIES

The same materials were used for both models. The material for facing plates will be FRP Unidirectional Laminate and the core material will be Aluminium Honeycomb 5052. Material properties were listed as follows.

Table 1: Material properties of FRP Unidirectional Laminate

Density	1.65 (g/cm^3)
Young’s Modulus	55600 Mpa

Poisson's Ratio	0.3
Tensile Ultimate Strength	2311 Mpa
Compressive Ultimate Strength	2311 Mpa

Table 2: Material properties of Aluminium Honeycomb 5052

Density	126.55 kg/cm^3
Young's Modulus	2344.2 Mpa
Poisson's Ratio	0.33
Tensile strength	9.31 Mpa (X direction) 4.96 Mpa (Y direction) 4.96 Mpa (Z direction)
Compressive	-9.31 Mpa (X direction) -4.96 Mpa (Y direction) -4.96 Mpa (Z direction)

MESHING

Meshing is element discretization. It is the most important step to do before doing any FEA analysis. For simple geometries, even with a default mesh, we will get a properly structured mesh and for complex geometries, we need advanced sizing options, edge-to-edge sizing etc. Even though the geometries for this project are simple, to get a fine mesh I have given high smoothing and fast transition.

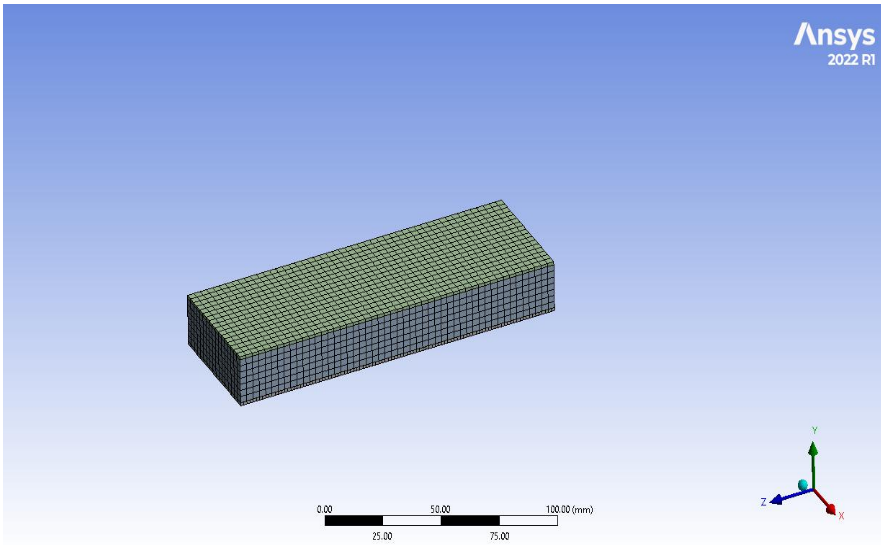


Figure 3: Mesh generated for Composite beam with base dimension 150 × 51mm

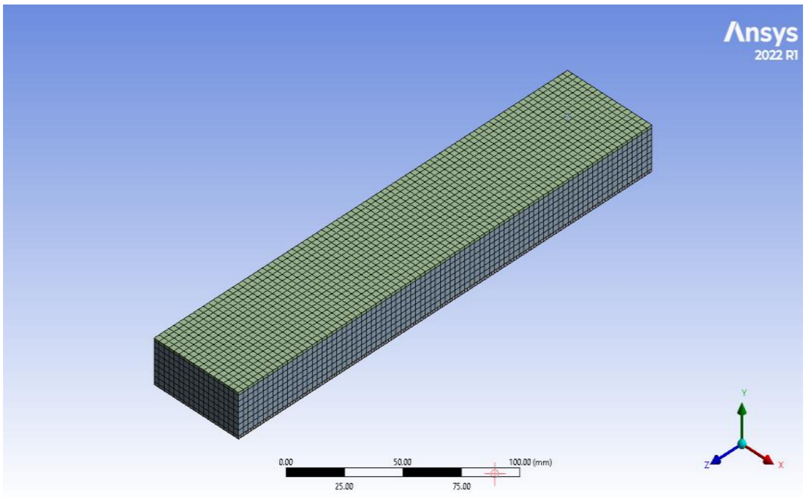


Figure 4: Mesh generated for Composite beam with base dimension 250 × 51mm

BOUNDARY CONDITIONS

For both the models the conditions which is fixed support, Displacement and force are given. Fixed support is given on one edge of the model and displacement is applied on other edge. The displacement condition is given in which x and y components gets arrested and z component is set as free. For the first model force is applied on the centre part of the model and for the second model force is applied on quarter points.

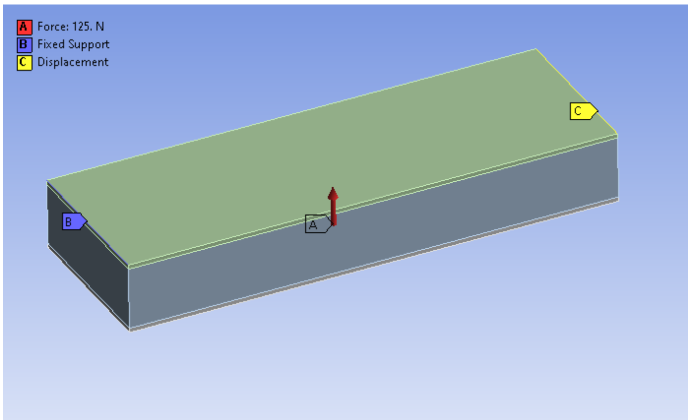


Figure 5: Boundary conditions for the composite model

Tabular Data

	Steps	Time [s]	X [N]	Y [N]	Z [N]
1	1	0.	= 0.	0.	= 0.
2	1	1.	0.	125.	0.
3	2	2.	= 0.	250.	= 0.
4	3	3.	= 0.	375.	= 0.
5	4	4.	= 0.	500.	= 0.
6	5	5.	= 0.	625.	= 0.
7	6	6.	= 0.	750.	= 0.
8	7	7.	= 0.	875.	= 0.
9	8	8.	= 0.	1000.	= 0.
10	9	9.	= 0.	1125.	= 0.
11	10	10.	= 0.	1250.	= 0.

Figure 6: Tabular data of force for y component (Three-point loading)

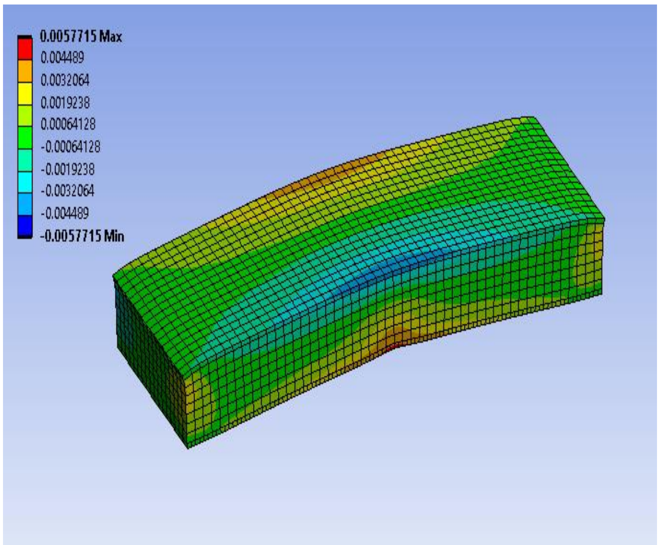
Tabular Data

	Steps	Time [s]	X [N]	Y [N]	Z [N]
1	1	0.	= 0.	0.	= 0.
2	1	1.	0.	62.5	0.
3	2	2.	= 0.	125.	= 0.
4	3	3.	= 0.	187.5	= 0.
5	4	4.	= 0.	250.	= 0.
6	5	5.	= 0.	312.5	= 0.
7	6	6.	= 0.	375.	= 0.
8	7	7.	= 0.	437.5	= 0.
9	8	8.	= 0.	500.	= 0.
10	9	9.	= 0.	562.5	= 0.
11	10	10.	= 0.	625.	= 0.
12	11	11.	= 0.	687.5	= 0.
13	12	12.	= 0.	750.	= 0.
14	13	13.	= 0.	812.5	= 0.
15	14	14.	= 0.	875.	= 0.
16	15	15.	= 0.	937.5	= 0.
17	16	16.	= 0.	1000.	= 0.

Figure 7: Tabular data of force for y component (Four-point loading)

RESULT

a) The result obtained for three-point loading are as follows
Directional deformation

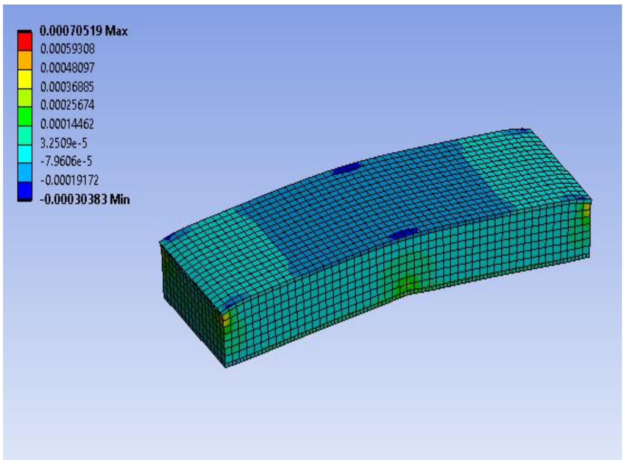


Force	Directional deformation
125	5.7715e-004
250	1.1543e-003
375	1.7315e-003
500	2.3086e-003
625	2.8858e-003

750	3.4629e-003
875	4.0401e-003
1000	4.6172e-003
1125	5.1944e-003
1250	5.7715e-003

Figure 8: Tabular data of Directional deformation for all the forces

Normal elastic strain

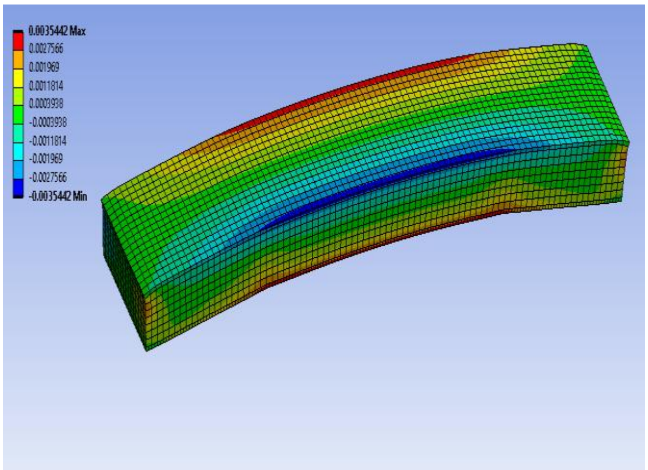


Force	**Normal elastic strain**
125	7.0519e-005
250	1.4104e-004
375	2.1156e-004
500	2.8208e-004
625	3.526e-004
750	4.2312e-004
875	4.9364e-004
1000	5.6416e-004
1125	6.3468e-004
1250	7.0519e-004

Figure 9: Tabular data of normal elastic strain for all the forces

b) The result obtained for four-point loading are as follow:

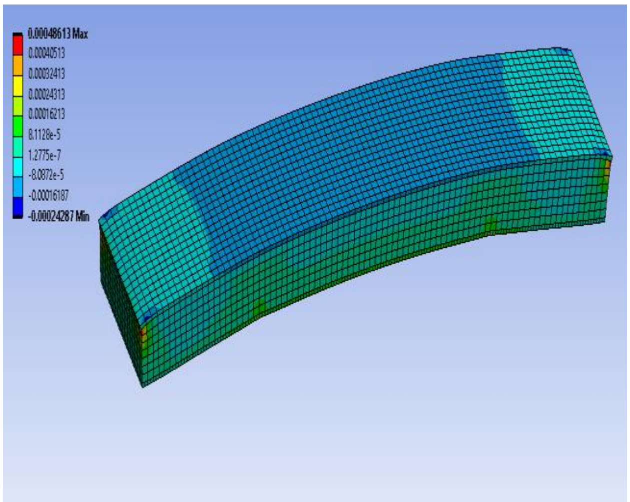
Directional deformation



Force	Directional deformation
62.5	2.2151e-004
125	4.4303e-004
187.5	6.6454e-004
250	8.8606e-004
312.5	1.1076e-003
375	1.3291e-003
437.5	1.5506e-003
500	1.7721e-003
562.5	1.9936e-003
625	2.2151e-003
687.5	2.4367e-003
750	2.6582e-003
812.5	2.8797e-003
875	3.1012e-003
937.5	3.3227e-003
1000	3.5442e-003

Figure 10: Tabular data directional deformation for all the force

Normal elastic strain



Force	Normal elastic strain
62.5	2.2151e-004
125	4.4303e-004
187.5	6.6454e-004
250	8.8606e-004
312.5	1.1076e-003
375	1.3291e-003
437.5	1.5506e-003
500	1.7721e-003
562.5	1.9936e-003
625	2.2151e-003
687.5	2.4367e-003
750	2.6582e-003
812.5	2.8797e-003
875	3.1012e-003
937.5	3.3227e-003
1000	3.5442e-003

Figure 11: Tabular data of normal elastic strain for all the forces

c) Plots
d)

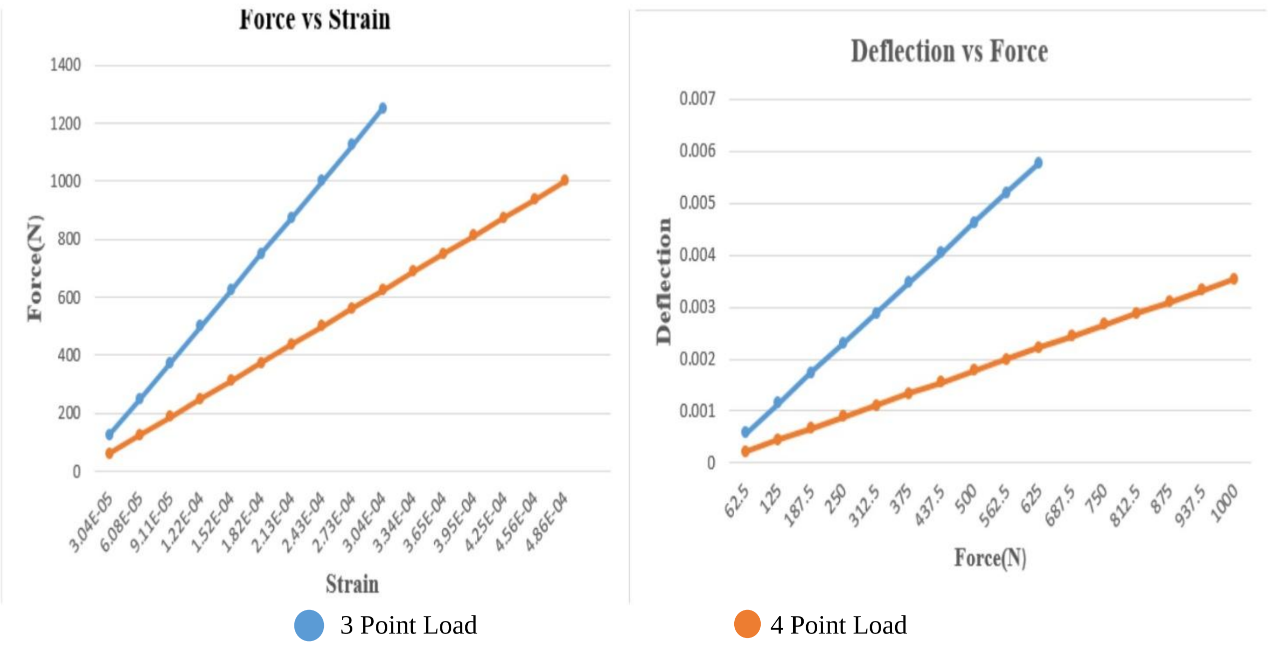


Figure 12: Force versus deflection and strain graph for three and four-point loading

DISCUSSION

Two graphs were obtained from the above simulation results. Directional deformation and normal elastic strain were obtained from all the given forces for three-point and four-point loading. The mechanical properties of the composite beamscan be calculated by using the data of force versus strain and deflection. Figure 12 shows Force versus strain and deflection curves for FRP unidirectional laminate with an aluminium honeycomb core. The graphs of force versus strain and deflection will be linear till the time the specimen reaches the breaking point. The straindeflections undergone by the specimen were large in the case of three-point load simulation results when compared to four-point load results for a given force.

CONCLUSION

Structural analysis has been done on composite beams with different dimensions to find deflection and strain on transient loading. As the models were simple geometry two composite beams with dimensions 150*51; 250*51 mm are designed through Ansys Design Modeler. The simulations were performed in Ansys Mechanical. Force, Displacement and fixed support are the boundary conditions given for the analysis. A 3mm element size is given to generate the mesh. In this analysis Force, strain and directional deformation are considered major parameters. The simulations were done by considering ten different forces for three-point loading and sixteen different forces for four-point loading. Normal elastic strain and directional deformation (deflection) are obtained from the analysis of different forces applied. The graph is plotted for the values obtained at different time steps during transient loading.

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