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Vibrational Analysis on Sandwich Composites in Aerospace Applications

Sravani Muvvala[1,] Srikanth Sikhakolli[2] ,S. Navya Sree [3]
[1]M.Tech Student, Department of Mechanical Engineering,
[1]MLR Institute of technology,
[1]Affiliated to JNTUH, Hyderabad, INDIA.
[2]Project Assistant Level-III,
[2]CSIR-National Aerospace Laboratories,
[2]Bangalore,
[3]Assistant Professor,
[3]Department of Mechanical Engg.,
[3]MLR Institute of technology,
[3]Affiliated to JNTUH, Hyderabad
[1]sravani.muvvala@gmail.com

Abstract— This paper deals with the static and dynamic analysis of a sandwich beam, comprising of a honeycomb core layer and face layers, each with varying Fibre Reinforced Polymer(FRP) and metallic layers subjected to a) Simply supported and b) Clamped-clamped boundary conditions. It is observed that the thickness of the core layer influences both static and dynamic response. This type of analysis is useful in selecting the materials and their arrangement for the safe design of sandwich structures in view of strength and stiffness. The problem is modelled using in HyperMesh 14.0 and is analysed using MSc NASTRAN

Keywords—Sandwich composites; Mode shapes; Construction; Beam; Plate; Carbon fibres; HyperMesh; MSc NASTRAN.

INTRODUCTION

Sandwich structures are composite constructions of alloys, plastics, wood or other materials consisting of a core laminated and glued between two hard outer sheets (skins). The core is in general light weight foam or solid core, honeycomb, web core, tubular or corrugated/truss core. The facing skins of a sandwich panel can be compared to the flanges of an I-beam, as they carry the bending stresses to which the beam is subjected. With one facing skin in compression, the other is in tension. Similarly, the honeycomb core corresponds to the web of the I-beam. The core resists the shear loads, increases the stiffness of the structure by holding the facing skins apart, and improving on the I-beam, it gives continuous support to the flanges or facing skins to produce a uniformly stiffened panel. The core-to-skin adhesive rigidly joins the sandwich components and allows them to act as one unit with a high torsional and bending rigidity.

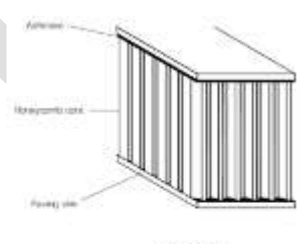


Figure-1. Construction of a sandwich panel.

Unlike structural components which exhibit fairly straight-forward dynamic response, honeycomb materials are somewhat more difficult to model mathematically. Because most high load bearing structures tend to implement high strength metal alloys, which usually have fairly straight-forward stress-strain and strain-displacement relationships, the dynamics of such structures are simple to formulate and visualize.

METHODOLOGY

Two different geometries are considered: A beam and a plate. Both beam and plate is modelled with fixed core thickness and varying face sheet thickness, and then with fixed face sheet thickness and varying core thickness. In the second step the face sheet is changes from metallic to composite and the results are compared for static deflection with different total thickness to core layer thicknesses. the plate is considered under simply supported as well as clamped conditions. the plate is analysed only using simply-supported condition.

Parameter	Value
E	7e4 MPa
ν	0.3
ρ	1e-6 Kg/mm^3

Table - 1. Material properties of metallic face sheet

Parameter	Value for face sheet	Value for honeycomb
E1	1.3e5 MPa	400 MPa
E2	1e4 MPa	1 MPa
ν12	0.35	0.05
G12	5e3 MPa	150 MPa
ρ	1.6e-6 Kg/mm^3	3.7e-8 Kg/mm^3

Table - 2. Material properties of composite face sheet and honeycomb

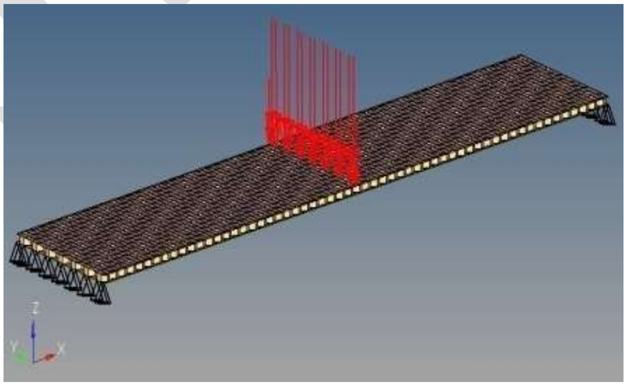
FINITE ELEMENT MODELLING AND ANALYSIS

A. Modelling:

A Three layered sandwich beam and plate of 0.5 m length, 0.1m wide and 0.004 m height is modelled in HyperMesh 14.0 Software using CQuad4 elements. The thickness of the face sheets is varied as per t_2/h ratio (0.6, 0.7, and 0.8). Where t_2 is core layer thickness and h is the total height of the beam. The core layer is located at the centre of the beam.

B. Analysis:

A line load of 1000N is applied at the top centre nodes of the beam shown in Figure6 after meshing. A pressure load of 1.5 KN/m^2 is applied on the top face sheet of the plate for both the TYPE-A and TYPE-B plates (Figure2). For the analysis of sandwich plates, simply supported boundary condition is used i.e., this simply supported boundary condition is applied to both the cases of plates. once the static analysis is done modal analysis is done to get the natural frequency.



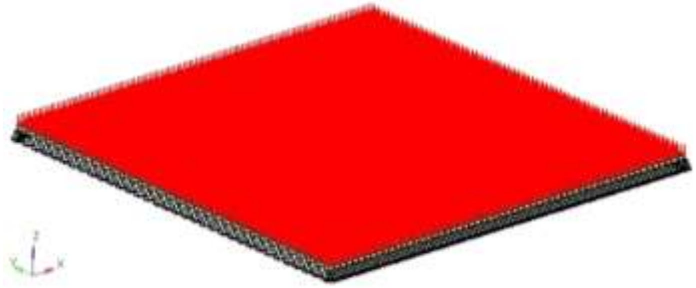


Figure - 2. Beam and plate with applied loads and BC's

RESULTS AND DISCUSSIONS

The static deflection versus the t2/h ratios are plotted and are observed as follows:

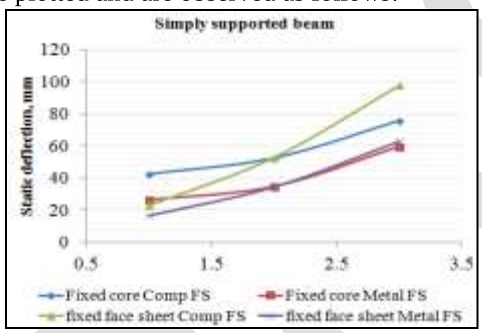


Figure - 3. Comparison of static deflection in simply supported beam

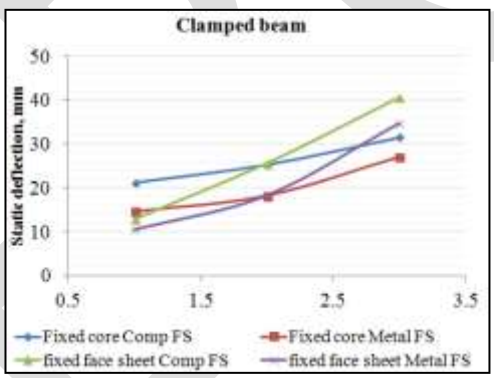


Figure - 4. Comparison of static deflection in clamped beam

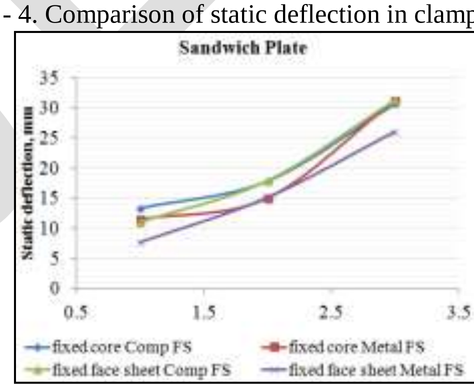


Figure - 5. Comparison of static deflection in simply supported plate

It is observed that the static deflection is increasing with the increase in t2/h value because beam stiffness is decreasing. Fig.4 shows the variation of static defection with respect to t2/h for all the cases of beam conditions considered. Figure - 5 shows the variation of static deflection in simply supported plate. The dynamic analysis (modal analysis) is performed on the beam under simply supported loading conditions and clamped boundary conditions subjected to line load at the top centre nodes of the beam. The First four mode shapes of the beam for t_2/h =0.7.

Model	Mode 1	Mode 2	Mode 3
Fixed core with composite face sheet(clamped)	2.65	7.59	9.21
Fixed core with composite face sheet(Simply supported)	4.20	9.34	10.91
Fixed core with metallic face sheet(clamped)	6.20	13.36	14.16
Fixed core with metallic face sheet(simply supported)	4.13	11.45	11.93

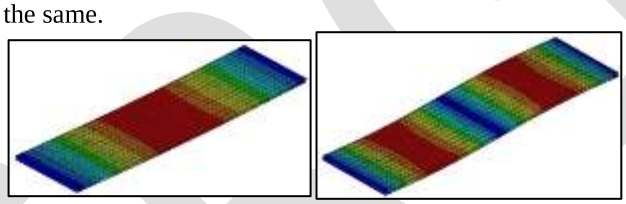
Table - 3. Mode frequencies of the beam

Model	Mode 1	Mode 2	Mode 3
Composite face sheets	4.73	9.78	9.81
Metallic face sheets	6.49	13.17	13.31

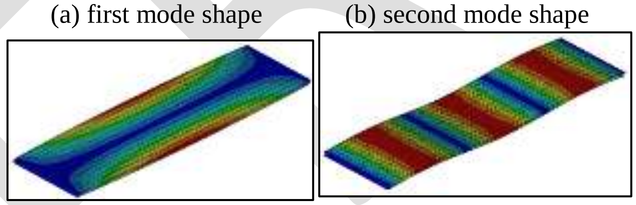
Table - 4. Mode frequencies of the plate

MODE SHAPES

The first four mode shapes of the beam are captured for all the cases and Figure11 (a-d) represent the contour plots of first four mode shapes for simply-supported beam with composite face layers. Here we can observe that the 0.7 thickness ratio of fixed core and fixed face sheet (Type - A & B models) are the same.



(a) first mode shape (b) second mode shape

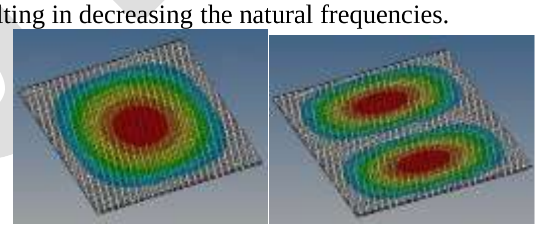


(c)third mode shape (d) forth mode shape

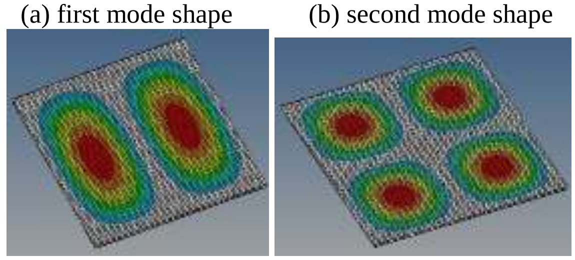
Figure - 6. Mode shapes of the beam

The mode shapes of the second type of the beam also looks similar.

There is an increase in frequency with mode number and decreasing trend with respect to t_2 is observed. Increase in t_2 causes for the reduction in stiffness of the structure resulting in decreasing the natural frequencies.



(a) first mode shape (b) second mode shape



(c)third mode shape (d) forth mode shape

Figure - 6. Mode shapes of the plate.

CONCLUSIONS

The following conclusions can be drawn from the analysis:

- The static deflection (δ) is increasing with t2/h value for beam subjected to clamped- clamped and simply supported boundary conditions for same loading.
- The model frequency values of the beam increased with t2/h value.
- The static deflection (δ) is decreasing with t2/h value for beam subjected to clamped- clamped and simply supported boundary conditions for same loading. The model frequency values of the beam decreased with t2/h value.

The present analysis can be extended in following ways:

- Composite layers can be considered for the manufacturing of honeycomb core.
- Contact bonding between the honeycomb core and the face sheets can be analysed.
- Further analysis can be done on the lap joint of the honeycomb sandwich plates.
- The honeycomb materials can be analysed further in the component point of view as well.

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