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Original Article

Numerical Analysis of Composite Sinusoidal Honeycomb Structures by using FEM

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Abstract *- Many industries use honeycomb composites extensively, including the aerospace, automotive, furniture, packaging, and logistic sectors. A specific type of composite material known as a honeycomb sandwich is created by joining two stiff but thin skins to a lightweight but dense core. The sandwich composite strong bending stiffness and overall low density are made possible by the core material's larger thickness despite its typical low strength. The Sandwich panel's strength is influenced by the panel's size, the material chosen for the faceplates, and the density of the honeycomb cells inside. This study investigates the critical buckling stresses numerically for different core densities and materials of honeycomb composite panels. In this investigation, the faceplate material is constant while the core material varies. It can be observed that when core density increases, so do the specimens buckling strength. Analytical investigations on honeycomb sandwich panels are used to examine the behavior of sinusoidal and hexagonal honeycomb sandwich panels under impact loads. LS-DYNA was used for analysis, and HYPER-MESH was used for modeling.*

Keywords *- Deflection, Stress in the core, Stress in the plate, Sinusoidal, Hexagonal.*

1. Introduction

Sandwich panels made of honeycomb are frequently used in engineering. Sandwich panels can be found in both natural and man-made structures. Sandwich panels made of honeycomb are utilized in various applications where great rigidity and light weight are required. Sandwich panels made of honeycomb are utilised to reduce the material needed. Honeycomb structures can have several geometries. The cells frequently have hexagonal, sinusoidal, and columnar shapes.

Core and face sheets are the components of sandwich panels. The face sheets are composed of various materials and cover the core from both ends. The core is comprised of a light-density material. The core and face sheets, notably light, are preferably made of metal or non-metal materials.

For mechanical structures with crucial stiffness, strength, and weight efficiency, sandwich honeycomb structures are frequently used. Sandwich panels are ideal for lightweight constructions like satellites, aircraft, missiles, high-speed trains, etc. Sandwich panels, which have a high strength-to-weight ratio, offer improved structural efficiency. The last ten years have seen a significant increase in the use of sandwich construction for non-strength components of structures. When sandwich construction is used to design dynamically loaded buildings, some challenges must be overcome.

2. Finite Element Analysis

The finite element approach uses an approximate numerical procedure to tackle various engineering issues. The finite element approach is used to study stresses in complex aircraft structures. The behavior of the structure in engineering problems must be studied in most structural applications. Finding approximations of the solutions to the problem is more crucial than finding exact ones. The finite element approach can be used to tackle engineering problems like structural analysis, heat transport, and fluid flow. The stresses and deflections at every place of interest in the given problem can be approximated using the finite element approach. Finite Element Analysis has many significant benefits. Design is carefully examined using the Finite Element Method. Less time and prototypes are needed to tackle the issue.

3. Objectives

1. Modelling of sinusoidal honeycomb sandwich panel.
2. To understand the behaviour of simply supported honeycomb sandwich panel structure under concentrated load.
3. Comparing the deflections, critical loads and stresses of a sinusoidal honeycomb sandwich structure to study the effect of different materials and varying thickness of the face plate and wall of the honeycomb core.
4. Carrying out Finite Element Analysis.
5. Comparing FEA results with different honeycomb structures.

4. Materials

Four models with different honeycomb core structure materials and the face plate material are kept constant throughout. Model 1, Model 2, Model 3 and Model 4 is divided into 1.0, 1.1, 1.2, 2.0, 2.1, 2.2, 3.0, 3.1, 3.2, 4.0, 4.1 and 4.2 is named according to the varying thickness of 2mm, 1.5mm and 1mm respectively.

Table 1. Model details with different core and faceplate materials

	Model 1	**Model 2**	**Model 3**	**Model 4**
Top face plate material	Steel	Steel	Steel	Steel
Core material	Copper	Steel	Aluminum	Titanium
The bottom face plate material	Steel	Steel	Steel	Steel

Table 2. Material Properties

Materials / Properties	**Steel**	**Copper**	**Aluminum**	**Titanium**
Young's Modulus (GPa)	210	128	68.3	113
Poisson's Ratio	0.29	0.36	0.34	0.35
Yield Strength (GPa)	0.215	0.100	0.276	0.880
Shear Modulus (GPa)	74	45	26	44
Density (Kg/mm)	7.85X 10^{-6}	8.96X 10^{-6}	2.68X 10^{-6}	4.505X 10^{-6}

4.1. Time load graph

The greatest load (in kN) applied to the structure during 100 milliseconds is depicted in the graph above. Model numbers 1.0, 1.1, 1.2, 2.0, 2.1, 2.2, 3.1, and 3.2 are shown in Fig. 3.4 as having a maximum load of 20 kN, while Model numbers 4.0, 4.1, and 4.2 are shown as having a maximum load of 60 kN.

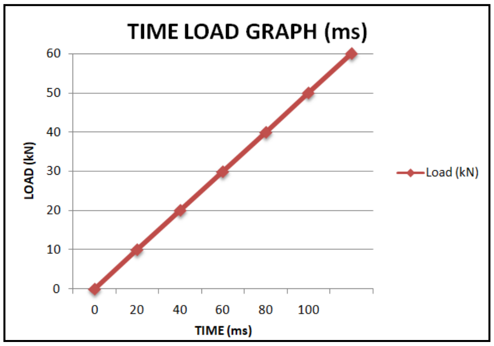

Fig. 1 Load 20kN for 100 ms

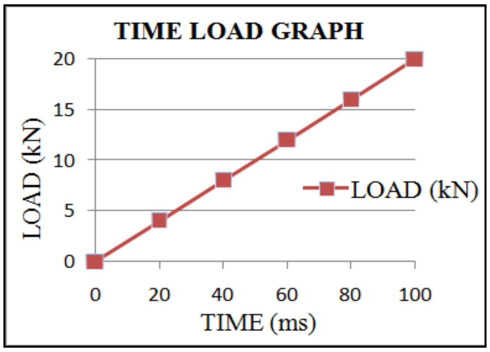

Fig. 2 Load 60kN for 100 ms

5. Methodology

1. 3D Modelling of the honeycomb structure.
2. Generating finite element model.
3. To carry out Finite element analysis.
4. Extracting the results.
5. Comparing the FEA results.

6. Results and Discussion

6.1. Software Results obtained in LS-prepost

Model 1 Top and bottom faceplates are steel, while the honeycomb core is made of copper and measures 5mm in height. Due to changes in the faceplate and honeycomb core cell wall thickness, model 1 is split into three types 1.0, 1.1, and 1.2. The change in thickness has the naming as 2mm, 1.5mm and 1mm, respectively. The figure below shows the stress in the core and plate and the deflection of the honeycomb structure of Model 1.0, 1.1, 1.2. Similarly the results for Model 2.0, 2.1, 2.2, 3.0, 3.1, 3.2, 4.0, 4.1 and 4.2 has been carried out. Table 3 below displays the comparative finite element analysis results of all models of sinusoidal and hexagonal honeycomb sandwich structures.

Table 3. Comparative results of Sinusoidal and Hexagonal Honeycomb

Model No.	Deflection at maximum load(mm)		Analytical Critical load in the core (kN)		Analytical failure load (kN)		Analytical stress in the core at failure load (kN/mm^2)	
	Sinusoidal	Hexagonal	Sinusoidal	Hexagonal	Sinusoidal	Hexagonal	Sinusoidal	Hexagonal
1	**0.63**	1.7	**9.6**	5	**6.4**	5	**0.068**	0.102
1.1	**1.36**	2.648	**4.8**	3.6	**2.8**	3.6	**0.0615**	0.101
1.2	**3.31**	4.2	**2.4**	1.6	**1.4**	1.6	**0.062**	0.108
2	**0.843**	1.6	**14.2**	9.2	**4.4**	5.3	**0.0675**	0.124
2.1	**1.48**	2.5	**9.2**	6.8	**2.8**	4	**0.0652**	0.128
2.2	**3.48**	4.03	**4.6**	4.2	**1.4**	2.4	**0.0679**	0.145
3	**0.816**	1.88	**20**	16.4	**4.6**	4.8	**0.0625**	0.0829
3.1	**1.49**	2.88	**13.8**	11.6	**2.8**	3.8	**0.0579**	0.0897
3.2	**3.91**	4.725	**7**	6.8	**1.4**	2	**0.0574**	0.109
4	**2.72**	4.343	**60**	46	**8**	5	**0.069**	0.102
4.1	**5.3**	6.33	**39.6**	32	**3**	4.5	**0.0654**	0.109
4.2	**27.4**	12	**19.2**	19	**1.8**	1.5	**0.0748**	0.139

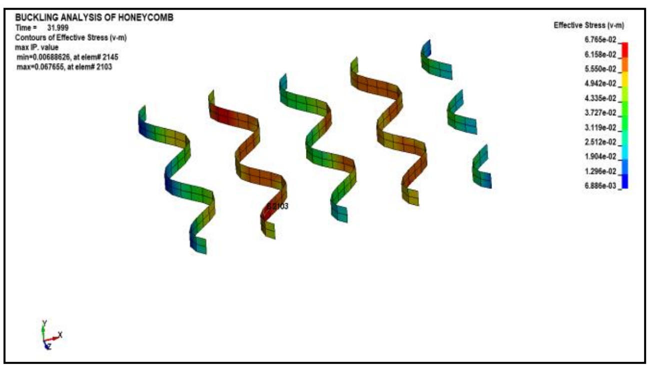

Fig. 3 Stress in the core for Sinusoidal structure of Model 1.0

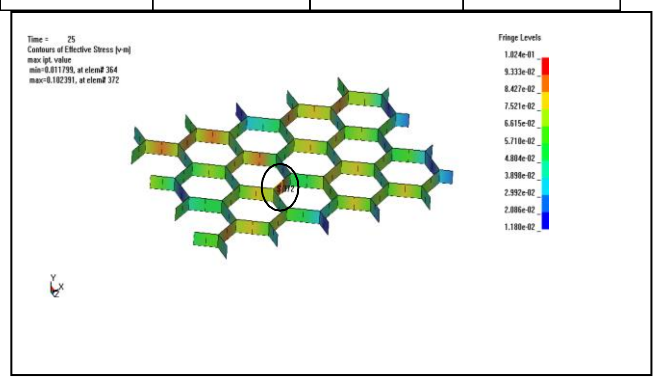

Fig. 4 Stress in the core for Hexagonal structure of Model 1.0

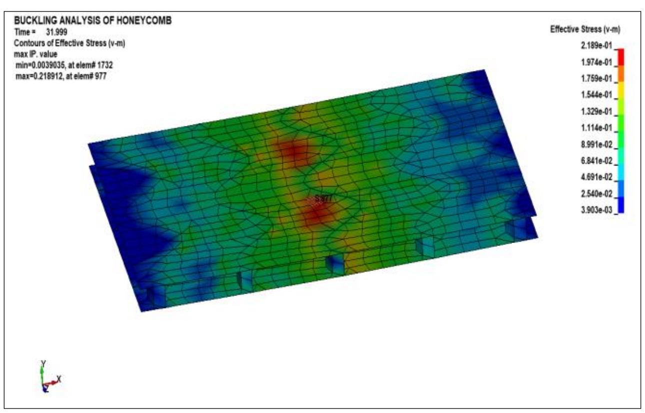

Fig. 5 Stress in the plate for Sinusoidal structure of Model 1.0

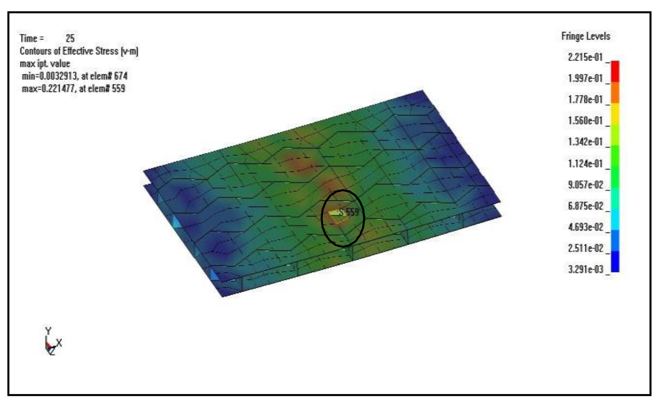

Fig. 6 Stress in the plate for Hexagonal structure of Model 1.0

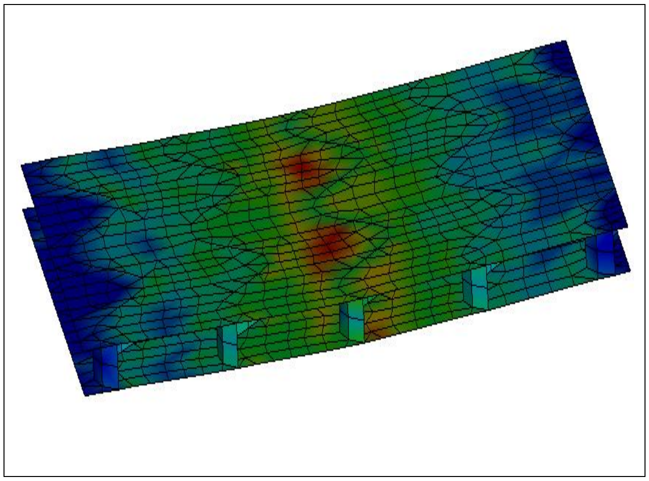

Fig. 7 Deflection at max load for Sinusoidal structure of Model 1.0

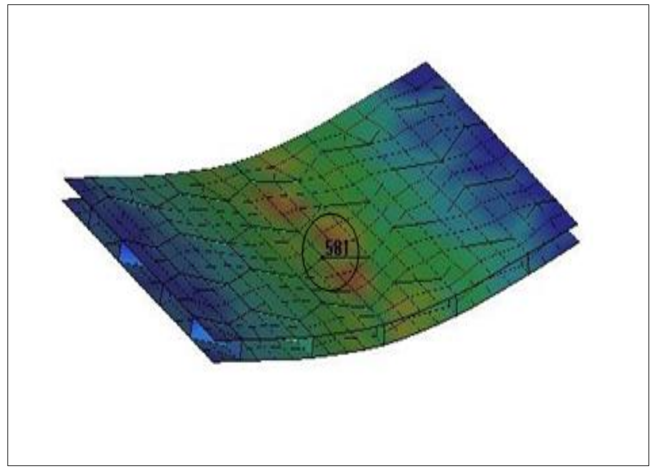

Fig. 8 Deflection at max load for Hexagonal structure of Model 1.0

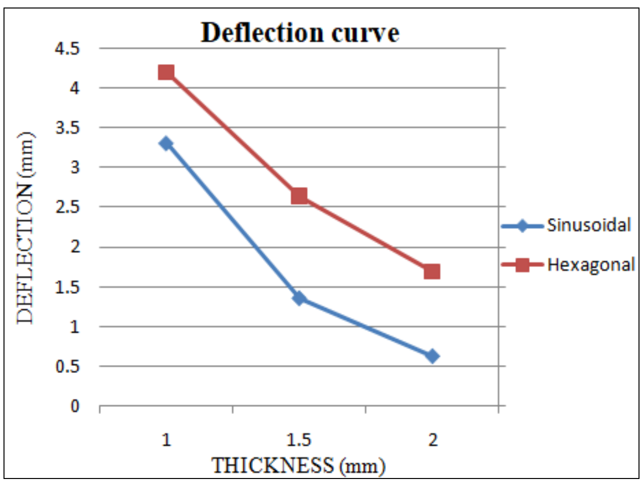

Fig. 9 Deflection curve for Model 1.0, 1.1 and 1.2

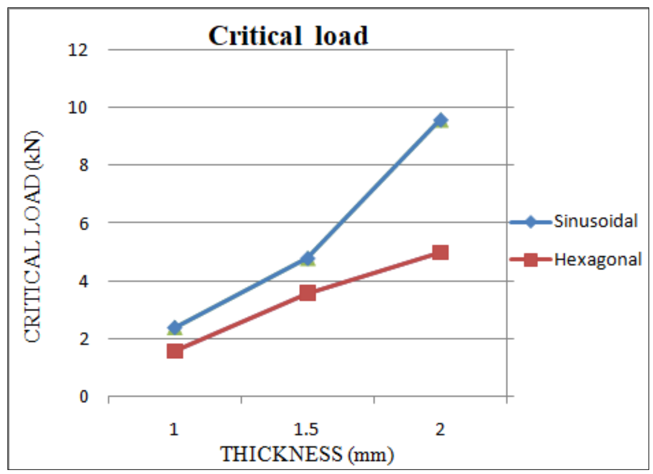

Fig. 10 Critical load curve for Model 1.0, 1.1 and 1.2

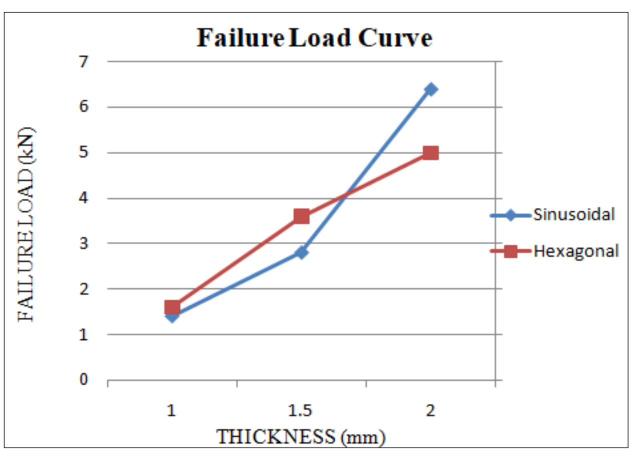

Fig. 11 Failure load curve for Model 1.0, 1.1 and 1.2

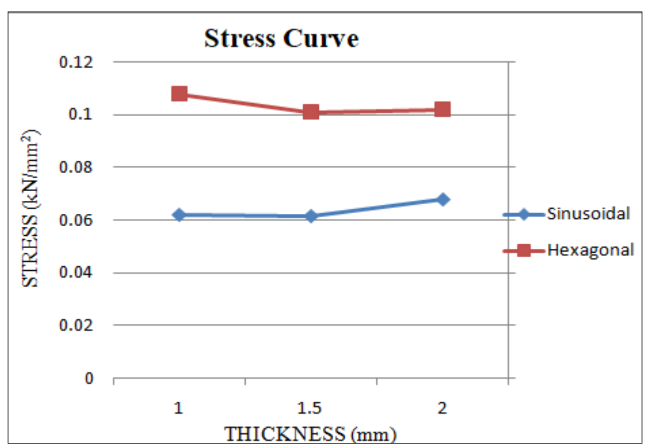

Fig. 12 Stress curve for Model 1.0, 1.1 and 1.2

7. Conclusion and Scope for future studies

7.1. Conclusion

In the current study, steel face plates with thicknesses of 2 mm at the top and bottom of the honeycomb core of 5mm height were compared to hexagonal and sinusoidal honeycomb sandwich structures. Three-point bending for various honeycomb core materials, including copper, steel, aluminium, and titanium, and various faceplate and honeycomb core wall thicknesses, such as 2mm, 1.5mm, and 1mm, were examined. Various variables were investigated, including deflection, critical load, and stress.

1. The deflection of the sinusoidal honeycomb structure is less as compared to the hexagonal honeycomb structure.
2. The sinusoidal honeycomb structure's core experiences a greater critical load than a hexagonal honeycomb structure.
3. The sinusoidal honeycomb structure has a greater load carrying capability than the hexagonal honeycomb structure.
4. Compared to hexagonal honeycomb structures, sinusoidal honeycomb structures have higher core stress at failure loads.

7.2. Scope for future studies

The results of the finite element analysis for the Sinusoidal honeycomb sandwich structure have been compared with those from the hexagonal honeycomb structure for different core materials and the same face plate material with changing the thickness of plate and core. The outcomes were ideally gratifying. By adjusting the core height and material for subsequent tests, this investigation can be carried out experimentally in future studies. The Circular shape of the core can be constructed with varying thickness and material properties and can be analyzed for further studies.

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