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Research Article

Honeycomb Sandwich panel analysis-Analytical and FEA approach

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Abstract

Aluminum sandwich construction has been recognized as a promising concept for structural design of light weight systems Sandwich panels have a variety of applications in aerospace, automobile, sports and marine industry. In aerospace industry the parts of the aircrafts like ailerons, flaps and rudders, have been manufactured from honeycomb sandwich panels. These structures are thin-walled structures fabricated from two flat sheet separated by a low density core. Sandwich structures are widely used in many important engineering applications due to their extremely low weight that leads to reduction in the total weight, fuel consumption, excellent crush strength, high stiffness and corrosion resistance. Sandwich structures have a very high Strength to weight ratio with respect to solid plate because of low density core. Comparison of various load deflection parameters of different honeycomb structures with different material face plates is done with static three point bending test

Keywords: *FEA Analysis, Honeycomb panel, Deflection*

1. Introduction

Sandwich panels have a variety of applications in aerospace, automobile, sports and marine industry. In aerospace industry the parts of the aircrafts like ailerons, flaps and rudders, have been manufactured from honeycomb sandwich panels. The behavior of sandwich structure mainly depends on the various properties of core material used in that structure which is normally consist of cellular material, this is because of high bending stiffness and good weight saving. [3]For design and construction of lightweight transportation systems such as satellites, aircraft, high-speed trains and fast ferries, structural weight saving is one of the major considerations. To achieve this requirement, sandwich construction is frequently used instead of increasing material thickness. Materials which are used for A honeycomb sandwich structure consist of two outer facing plates of any metal or composite and one thick light weight core sandwich between two plates these components are bonded to each other by means of pasting material called adhesive generally in liquid form and all these components collectively act as assembly or single unit. As discussed in the literature the core of assembly plays an important role to stabilize the structure and to decide mechanical properties of structure. Number of application is these for sandwich structure because of its lightweight characteristic like in aerospace, automotive, machine etc. It also has application in sport equipment. The main advantage of these structures is that rigidity is function of geometrical parameters means by selecting proper geometrical parameter required rigidify can be achieved for structure. So designed have choice of selection of number of parameter. Another advantages of these structure are high structure efficiency and has high strength to weight ratio even the concept of sandwich structure is not very new old day it has been accepted as non-strength component to increase advantage of application its local strength characteristics comparing it with single metal component which are fabricated in such a manner that should give better strength these structures can start fracture or increase failure chances over sandwich structure which uses adhesive for bonding of its component.

In applications like aerospace honeycomb sandwich structures are used as Lifting surfaces which are designed for taking bending loads due to lift. In this bending stresses are more at the top and bottom surfaces while the stresses are low at the middle of the surface. These conditions are suited by honeycomb sandwich structures where top and a bottom face sheets takes the bending load as they are stiffer. So this honeycomb sandwich construction is considered as one of the most valued structural engineering revolutions developed by the composites industry. Now a day's application of aluminum sandwich panels can find as strength members in high-speed vessel hulls.

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2. Problem Statement

To investigate and compare strength characteristics (load deflection) of sandwich structures of different materials with aluminium honeycomb core.

2.1 Objective

- To compare and verify deflections of different honeycomb.

2.2 Methodology

The panels are made of lightweight aluminium and the core consists of the corrugated cells in a Hexagonal configuration. This is further compared with different facing material. The references of dimensions are taken from previous research of aluminium sandwiches structures by U. Farooq *et al*. (IEEE 2013). The results are compared with the FEA and analytical results. The steps involve preparation of 3D model using CATIA V5R20 with FEA Analysis of 3D model compared with Analytical Approach -Solution using theoretical calculations.

3. Theory

The initial design of honeycomb structure is selection of components this selection of components depends upon application in which it is used the components used in this structure are face sheet, core and adhesive material there are various properties selection criteria of above mention components to get desired mechanical properties of structure in this honeycomb sandwich structure all elements can be of different metals or composites so, combination of elements decides the mechanical properties of structure the core is sandwich between two face sheet as shown in fig. 1 this particular combination is specially design to take loads acting on structure the bending moment and in plane shear which is carried by face sheet while flexural shear is carried by core the structure may observed for local stresses as structure is not homogeneous .as light weight is main advantage of this structure generally aluminium sheets are used as core and face sheet material but material can be varied to get desired mechanical properties from structure.

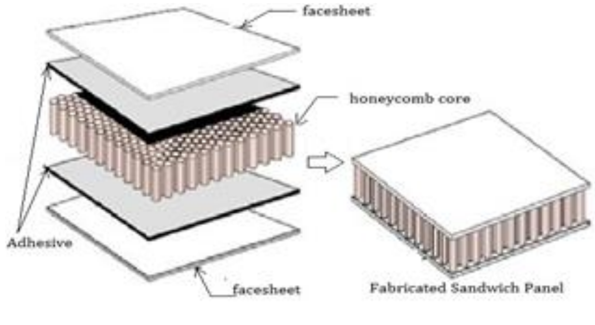


Fig.1 Honeycomb Sandwich Structure

3.1 Material characteristics

The material for the honeycomb structure should be selected such that it should have high strength and low weight. So materials are like Aluminium or Carbon Epoxy composite. The material for our analysis is of Aluminium and Mild steel having its detail properties of plate as given below.

Table 1 Material Properties of Aluminium

Material property	Value
Density	2700 kg/m^3
Young's Modulus	71070 MPa
Yield Strength	268 MPa
Compressive Strength	2.5 MPa
Compressive Modulus	540 Mpa
Tensile Strength	367 Mpa

Table 2 Material Properties of Mild Steel

Material property	Value
Density	7850 kg/m^3
Modulus of elasticity	210 GPa
Yield Strength	410 MPa
Compressive Strength	407.7 MPa
Shear Modulus	80 Gpa

Table 3 Dimensions for the Honeycomb Structure Plate

Parameter	Dimension (mm)
Total length of specimen	203.2
Span length of specimen	150
Width of specimen	76.2
Cell size	5.5
Thickness of facing plate	2
Height of core	10
Total thickness of panel	14

4. Finite Element Analysis

4.1 Introduction

Using FEA, when the structure to be analysed it is split into a mesh of predetermined size of elements of simple profile. For each element, the difference of displacement is supposed to be determined by nodal displacements and simple polynomial shape functions. Comparisons for the stress and strains are created regarding the obscure nodal displacements. From this, the mathematical statements of harmony are amassed in a lattice structure which could be effectively being modified and understood on a computer. In the wake of applying the proper limit conditions, the nodal removals are found by explaining the network firmness mathematical statement. Once the nodal displacement is known, element stress and strain can be calculated.

4.2 Modelling

The 3D model of the sandwich panel with standard dimensions was modelled in CATIA V5R20 software as shown in figure 2. The model was prepared using solid brick elements. Likewise all models were prepared in the same software. After modelling, same model is converted to the IGES (Initial Graphics Data Exchange Format) using IGES translator in CATIA V5R20. These all models were further imported in ANSYS 15.0 for analysis. All three parts like Honeycomb core and the skin plates were separately modelled and then the assembly was prepared. Dimensions for model were chosen from standards mention by ASTM-393.

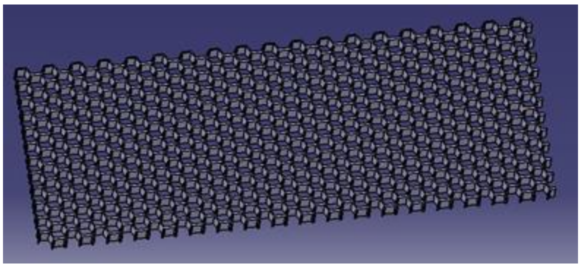


Fig.2 Honeycomb core

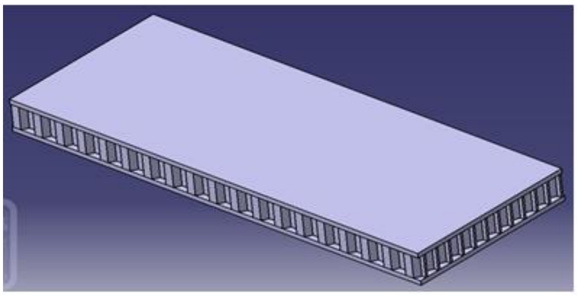


Fig.3 Honeycomb assembly

4.3 Meshing

Meshing is initial step for analysis of any component. It can be done in ANSYS, or can be done for complex geometry of the component using HYPERMESH (software exclusive for meshing). For meshing, the solid model is imported from CATIA V5 to ANSYS software. The selection of which element to use in the problem to be analysed is important. The meshed model is shown in the figure 4.

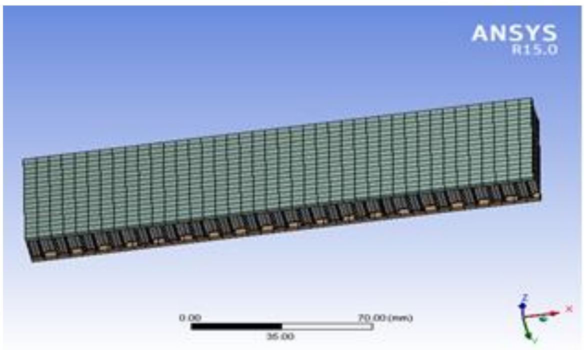


Fig.4 Mesh model of honeycomb core

4.4 Finite Element Analysis Results

Finite element analysis was conducted by applying required material and boundary conditions for the two different type of specimen. The result are tabulated as below and sample analysis is shown for few loads of aluminium sandwich structure and mild steel structure.

Table 4 FEA result of load deflection for aluminium specimen

Load (KN)	Aluminium honeycomb Deflection (mm)
1	1.99
1.5	2.99
2	3.98
2.17	4.33

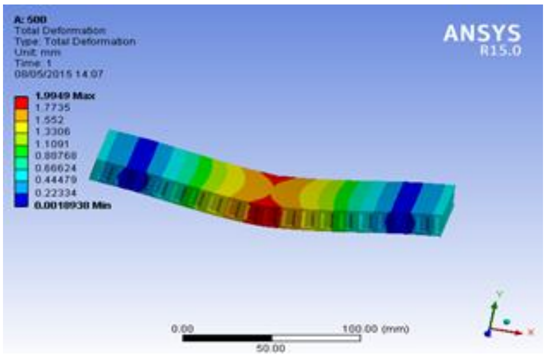


Fig.5 Deflection of aluminium panel for 1 KN

Table 5 FEA result of load deflection for aluminium-MS specimen

Load (KN)	Aluminium-MS Honeycomb Deflection (mm)
1	1.57
1.5	2.36
2	3.15
2.1	3.42

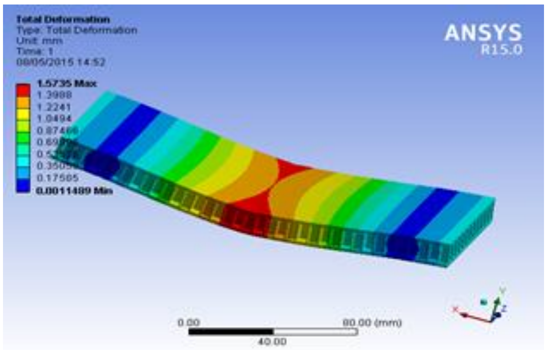


Fig.6 Deflection of aluminium- MS panel for 1 KN

5. Analytical approach

Theoretical modelling of test sandwich panel (bending behaviour) with the following objectives

1. To find critical load of all types of sandwich panels
2. To find deflection of all sample sandwich panels at various loads
3. Plot of load versus deflection

5.1 Sample calculations for Aluminium honeycomb plate

Mass of facing plates (mf)

$$m_f = A \, X \rho_f \, X \, t_f$$
$$= 203.2 \text{ X } 76.2 \text{ X } 2700 \text{X} 10^{-9} \text{X } 2$$
$$= 0.171 \text{ Kg}$$

Mass of core (mc)

ρ_{ca} = average core density

$$\rho_{ca} = \frac{8}{3\sqrt{3}} \frac{t_c \times \rho_c}{d}$$

$$= \frac{8}{3\sqrt{3}} \text{ x } \frac{0.5 \text{ X } 2700 \text{ X } 10^{-9}}{3.17}$$

= 6.71 x10^{-7} Kg/mm^3

$m_c = a \times b \times h_c \times \rho_{ca}$

= 203.2 X76.2 X 10 X 6.56 X10^{-7}

=0.104 Kg

Mass of specimen (m)

m=2 X (m_f+ m_c) (factor 2 for two facing plates)

= 2X (0.171+ 0.104)

=**0.275 Kg**

To find Critical load on sandwich specimen (P_0)

$$Po = C.\frac{bh^2\sigma_f}{a}\left\{1-\left(\frac{hc}{h}\right)^2\right\}$$

Where $C = \frac{c_1}{c_1+c_2}$

$$c_1 = \frac{a^3}{48E_fI_f} \quad and \quad c_2 = \frac{a}{4A_cG_{ca}}$$

Moment of inertia of facing plate

$$I_f = \frac{h^3 - {h_c}^3}{12}.b$$

$$I_f = \frac{14^3 - 10^3}{12} \, X \, 76.2$$

I_f= 11.07 X 10^3 mm^4

Young's modulus of facing skin (E_f)

E_f= 71070 N/mm^2

Area of core (A_c)

A_c=b x h_c

= 72.2 X 10

= 720 mm^2

Calculation of constant (C)

$$c_1 = \frac{150^3}{48 \text{ X } 71070 \text{ X} 11.07 \, X \, 10^3}$$

= 8.93 x10^{-5}

$$c_2 = \frac{150}{4 \text{ X } 720 \text{ X } 42000}$$

= 1.24 X 10^{-6}

$$C = \frac{8.93}{8.93 + 0.124}$$

=0.191

Critical load (P_0)

$$Po = 0.191 \text{ X } \frac{76.2 \text{ X } 14^2 X \, 268}{150}\left\{1-\left(\frac{10}{14}\right)^2\right\}$$

P_0=2497.43 N

Calculation of deflection (w)

For P= 2 KN

From equation of deflection

$$w = \frac{Pa^3}{48E_fI_f} + \frac{Pa}{AcGca}$$

$$w = \frac{2 \text{ X} 150^3}{48 \text{ X } 71070 \text{ X } 11.07 \, X \, 10^3} + \frac{2 \text{ X } 150}{762 \text{ X } 44000}$$

= **4.115 mm**

5.2 Load deflection results

Mathematical equations are use as shown in above sample calculation for the two different type of specimen to validate the result obtained from FEA work the result are tabulated as below for aluminium sandwich structure.

Table 6 Analytical result of load deflection for aluminium specimen

Load (KN)	Aluminium honeycomb Deflection (mm)
1	2.05
1.5	3.08
2	4.11
2.1	4.46

Similarly for aluminium steel specimen to validate the result obtained from FEA work the result are tabulated as below

Table 7 Analytical result of load deflection for aluminium mild steel specimen

Load (KN)	Aluminium-MS Honeycomb Deflection (mm)
1	1.6177
1.5	2.4266
2	3.2354
2.17	3.5104

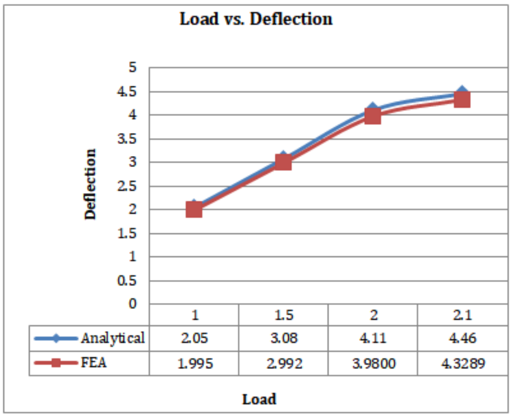
5.2 Comparison of Experimental FEA and Analytical Results

Load deflection characteristics are compared with FEA and analytical results for both type of structures and these are tabulated as below

Table 8 Comparison of load deflection aluminium honeycomb

load (KN)	Deflection (mm)		% Variation (FEA & analytical)
	Analytical	FEA	
1	2.05	1.9949	2.6878
1.5	3.08	2.9923	2.8474
2	4.11	3.98	3.16302
2.17	4.46	4.3289	2.93946

Above results are graphically represented as below

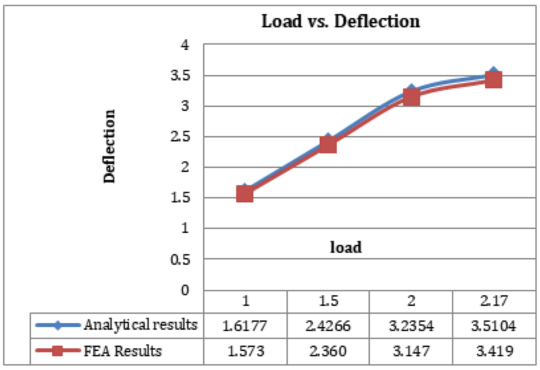


Graph.1 Comparison of load deflection aluminium honeycomb

Table 9 Comparison of load deflection aluminium MS honeycomb

load (KN)	Deflection (mm)		% Variation (FEA & analytical)
	Analytical	FEA	
1	1.6177	1.5732	2.75082
1.5	2.4266	2.3602	2.73634
2	3.2354	3.1469	2.73537
2.17	3.5104	3.4191	2.60084

Above results are graphically represented as below



Graph.2 Comparison of load deflection aluminium MS honeycomb

Conclusion

1) In this study, an attempt has been made to find deflection characteristics for sandwich type of structure with different facing material.
2) The deflections observed in Aluminium panel for the load 2.1 is 4.46 mm and 4.32 mm for Analytical and FEA repectively whereas in Mild steel facing material specimen was observed for the load 2.17 as 3.51 and 3.41 for analytical and FEA respectively.
3) It is observed that variation in deflection for Aluminium and Aluminium-MS panel is not much significant.
4) Comparison between FEA and Analytical results shows maximum variation of approximately 2% indicate that process adopted in FEA and formulation made in analytical were correct.
5) It is observed that, for both type of the specimen with aluminium and mild steel facing material failure was debonding of facing and core material of specimens.

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