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Research Article

Modal Analysis of Composite Sandwich Panel

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Abstract

Use of Sandwich construction for an aircraft structural component is very common to the present day. One of the primary requirements of aerospace structural materials is that they should have low density, very stiff and strong. Sandwich panels are thin-walled structures fabricated from two flat sheets separated by a low density core. The core investigated here is of aluminium honeycomb structure because of excellent crush strength and fatigue resistance. Sandwich panels have a very high stiffness to weight ratio with respect equivalent solid plate because of low density core. Modeling is developed in FEA by consideration of rotary inertia. The free vibration analysis of sandwich panels is studied.[(2)] Four noded isoparametric shell element is used for FEA. The effects of sandwich design parameters, such as face thickness, core thickness and pitch, on the global bending and vibration responses are determined. Convergence study is also included for high accuracy of the results. Analytical results are based on classical bending theory. Mode shapes and corresponding natural frequencies are studied for simply supported sandwich panel and cantilever condition.

***Keywords**: FEA , Mode Shape, Natural Frequencies, Sandwich Construction, Stiffness ratio.*

Introduction

Sandwich panels have been successfully used for many years in the aviation and aerospace industries, as well as in marine, and mechanical and civil engineering applications. This is due to the attendant high stiffness and high strength to weight ratios of sandwich systems. The use of the sandwich constructions in the aerospace structures can be traced back to Second World War when British De Havilland Mosquito bomber had utilized the sandwich constructions. In the early use, the sandwich structure was very simple in construction, with simple cloth, fabric or thin metal facings were used and soft wood were used as the core.(H G Allen 1969).

The conventional sandwich construction comprises a relatively thick core of low-density material which separates top and bottom faceplates (or faces or facings) which are relatively thin but stiff. The materials that have been used in sandwich construction have been many and varied but in quite recent times interest in sandwich construction has increased with the introduction of new materials for use in the facings (e.g. fiber- reinforced composite laminated material) and in the core (e.g. solid foams).

Types of Sandwich Structure

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Detailed treatment of the behavior of honeycombed and other types of sandwich panels can be found in monographs by Plantema (Ferreira 2008) and Allen. These structures are characterized by a common feature of two flat facing sheets, but the core takes many generic forms; continuous corrugated sheet or a number of discrete but aligned longitudinal top-hat, zed or channel sections. The core and facing plates are joined by spot-welds, rivets or self-tapping screws.

Sandwich Construction

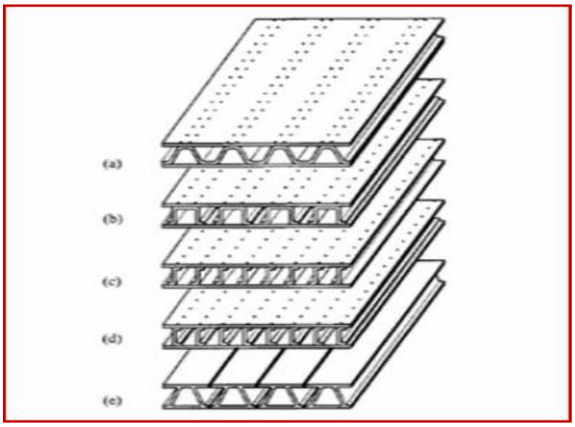


Fig 1.1 Sandwich panel with (a) continues corrugated-core (b) top-hat core (c) zed-core (d) truss-core

Sandwich construction is a special kind of laminate consisting of a thick core of weak, lightweight material sandwiched between two thin layers (called face sheets) of strong material. This is done to improve structural strength without a corresponding increase in weight. The choice of face sheet and core materials depends heavily on the performance of the materials in the intended operational environment.

Properties of Material used in Sandwich Construction

No single known material or construction can meet all the performance requirements of modern structures. Selection of the optimum structural type and material requires systematic evaluation of several possibilities. The primary objective often is to select the most efficient material and configuration for minimum-weight design.

•Core Materials:

A core material is required to perform two essential tasks; it must keep the faces the correct distance apart and it must not allow one face to slide over the other. It must be of low density.

Balsa wood is one of the original core materials. It is usually used with the grain perpendicular to the faces of the sandwich. The density is rather variable but the transverse strength and stiffness are good and the shear stiffness moderate.

•Face Materials

Almost any structural material which is available in the form of thin sheet may be used to form the faces of a sandwich panel. Panels for high-efficiency aircraft structures utilize steel, aluminium or other metals, although reinforced plastics are sometimes adopted in special circumstances. In any efficient sandwich the faces act principally in direct tension and compression. It is therefore appropriate to determine the modulus of elasticity, ultimate strength and yield or proof stress of the face material in a simple tension test. When the material is thick and it is to be used with a weak core it may be desirable to determine its flexural rigidity.

•Material Properties Aluminium core

Table 1.1

Property	Value
Young's Modulus, E	68.9 GPa
Poisson's Ratio ,ν	0.33
Density, ρ	2700 kg/m^3
Yield Stress, σ_{yield}	214 MPa
Ultimate Tensile Stress, σ_{uts}	241 MPa

•Material properties of Glass fibres:

Table 1.2

Property	Value
Longitudinal Modulus, E_1	59 GPa
Lateral Modulus, E_2	20GPa
Poisson's Ratio ,ν	0.35
Lonitudinal tension strength X_t	2000 MPa
Lonitudinal compression strength X_c	1240 MPa
Transverse tension strength Y_t	82 MPa
Transverse compression strength Y_c	200 MPa
Density, ρ	2.02 g/cm^3
In plane shear S	165 MPa

2. Literature Review

Sandwich panels are thin-walled structures fabricated from two flat sheets, separated by and attached to a core. An analytical solution for the dynamic response of such structures is not available but equivalency in the form of a homogenous orthotropic thick plate can be formulated. Vast majority of the technical literature on sandwich plates and beams involve sandwich construction with a foam core or a honeycomb core. Among the publications involving corrugated core, very few have considered fiber-reinforced composite as the sandwich material. Most of the research studies on corrugated-core sandwich have dealt with the analysis of metallic corrugated-core sandwich panels for vibration control, noise control, shock and impact studies can be divided into three broad categories: (a) elastic stiffness, (b) maximum load capacity, and (c) energy absorption.

Sandwich Principles

The basic prerequisite for high-performance structural component parts as used in aerospace applications is light-weight design wherever possible. An essential component of these light-weight structures is load-bearing and buckling optimized shell elements. The classical method to obtain improved buckling properties is using sandwich structures have also proven their worth in a number of fields. The performance of a sandwich structure depends primarily upon the efficiency of surface skins and the distance between them. A great distance between the surface skins produces a correspondingly great geometrical moment of inertia, thus leading to high bending stiffness. Since this arrangement subjects the core of the sandwich to a relatively small amount of stress, it can be reduced in weight significantly. Extremely thin-walled sandwich structures present the problem of how force is introduced and the sandwich structure's sensitivity towards impact loads. This means that a minimum wall thickness is required for the surface skins to be able to ensure that it is adequate.

•Face Sheets

The face sheets provide the flexural rigidity of the sandwich structure. It should also possess tensile and compressive strength.

•Cores

The purpose of the core is to increase the flexural stiffness of the panel. The core in general has low density in order to add as little as possible to the total weight of the sandwich construction. The core must be stiff enough in shear and perpendicular to the faces to ensure that face sheets are distant apart. In addition the core must withstand compressive loads without failure (Zhen W 2006).

•Aluminum Honeycomb

These cores are available in variety of materials for sandwich structures. These cores can be formed to any shape or curve without excessive heating or mechanical force. Honeycombs have very high stiffness perpendicular to the faces and the highest shear stiffness and strength to weight ratios of the available core materials. The most commonly used honeycombs are made of aluminum or impregnated glass or aramid fiber mats such as nomex and thermoplastic honeycombs.

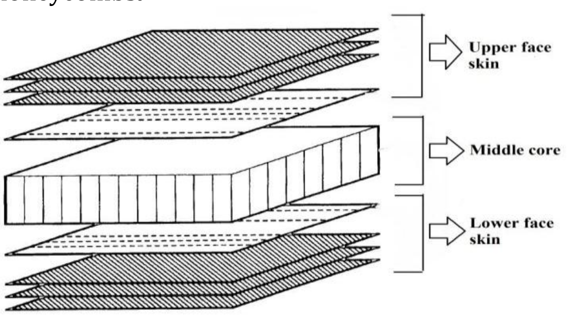


Fig 2.1 Typcal sandwich structure

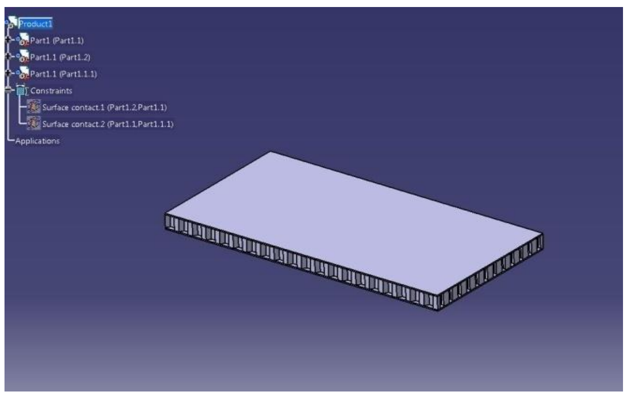
Composite material is the combination of two or more constituent materials, and forms a light weight and high strength structure. The matrix and reinforcement material make the material stiffer and stronger. A typical sandwich structure, the below shown figure is a special class of composite material in which a thick foam core is attached by two thin, stiff, skin and a thick core which is lighter in weight. Honeycombs have a higher strength-to-weight ratio than foam, but foams may be used in several forms of structural constructions, for the same characteristics. Also, the compression strength of a foam core prevents the thin face sheet / skin from failure due to buckling. Its mainly a thermoset, polymer, light weight and strong structure.

Finite Element Modeling

•Introduction

The Finite Element Method is essentially a product of electronic digital computer age. Though the approach shares many features common to the numerical approximations, it possesses some advantages with the special facilities offered by the high speed computers. In particular, the method can be systematically programmed to accommodate such complex and difficult problems as non homogeneous materials, non linear stress-strain behaviour and complicated boundary conditions. It is difficult to accommodate these difficulties in the least square method or Ritz method and etc. an advantage of Finite Element Method is the variety of levels at which we may develop an understanding of technique. The Finite Element Method is applicable to wide range of boundary value problems in engineering. In a boundary value problem, a solution is sought in the region of\ body, while the boundaries (or edges) of the region the values of the dependant variables (or their derivatives) are prescribed (Yan 2008).

•CAD model of composite panel



•Meshing in Hypermesh

The CAD model is imported to Hypermesh and the geomery cleanup is done. The appropriate element size is selected according to the geometry features. Then using quad element the aluminium honeycomb is meshed and then the composite plates maintaining the connectivity. The meshed model is checked for element criteria.

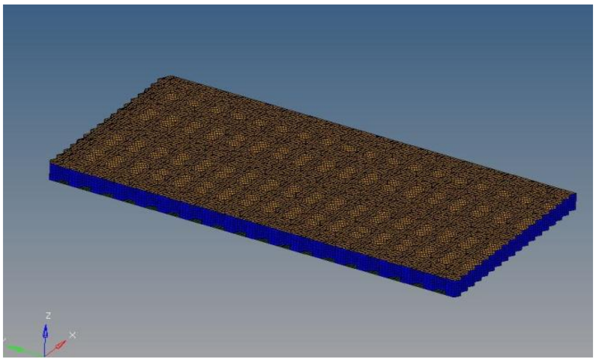
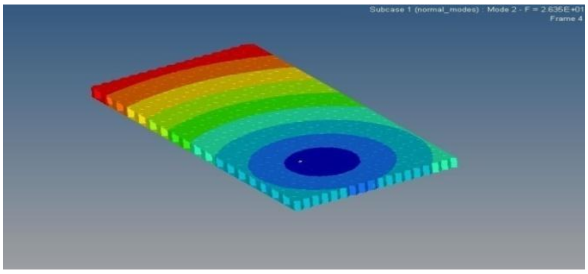


Table 2.1 Element Specification

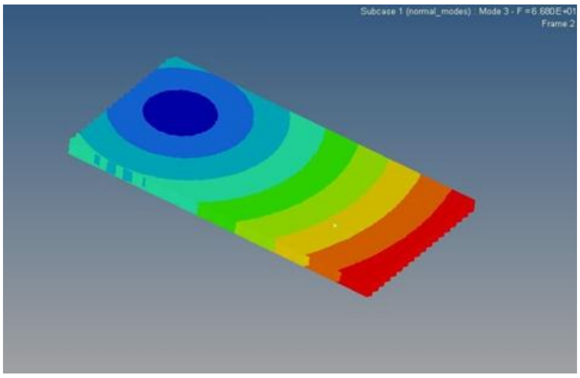
Element type	Quad 4
Element size	3
No of elements	59316
No of nodes	50562

•Modal Analysis

Free Free modal analysis-Total six modes of vibration are plotted by free free modal analysis. The Composite panel natural frequencies can be obtained by modal analysis, The following modes are listed as shown in figure.



Mode2



Mode3

Table No : 2.2

Sr. No.	Modes	Frequencies
1	Mode 1	Zero Hz
2	Mode 2	2.635E+1 Hz
3	Mode 3	6.680E+1 Hz

•Modal Analysis of composite panel with cantilever support. Meshed model

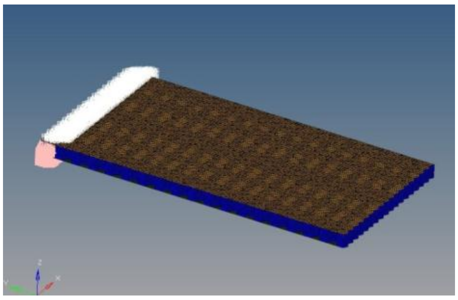


Fig 2.2 Meshed Model Of a cantilever beam

Natural Frequency and Mode shapes of a cantilever beam.- A Cantilever is a continuous system-its mass and elasticity are distributed all over its volume. It can be considered to have infinite very small masses connected by infinite very small springs resist the banding of the Cantilevers. Hence there are infinite degrees of freedom and infinite natural frequencies.

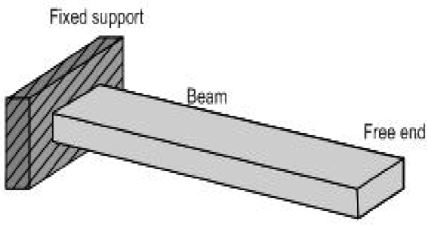
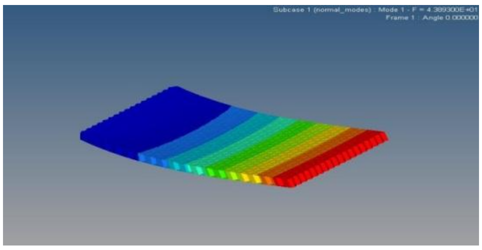
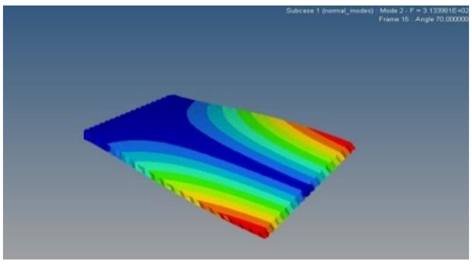


Fig.2.3 Cantilever sandwich panel

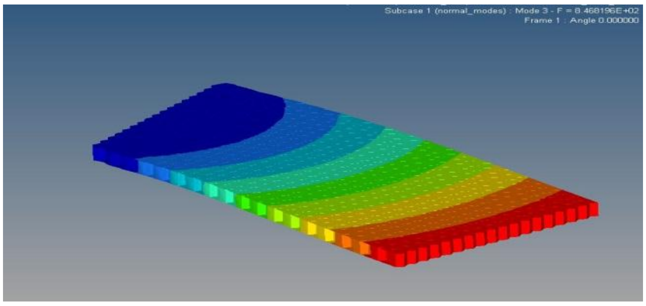
The following Three mode shapes are obtained from the Modal analysis of composite panel with cantilever support.



Mode1



Mode2



Mode3

Table No : 2.3

Sr.no	Modes	Frequencies
1	Mode 1	4.389E+1
2	Mode 2	3.133E+2
3	Mode 3	8.468E+2

•Experimentation

Modal testing is frequently used to validate the accuracy of structural dynamic models. Modal tests are performed on a structure to measure the modal frequencies, damping factors, and mode shapes. However during the modal test, a structure must be supported in some manner by the surrounding environment. Very frequently ,free boundary conditions are the desired support conditions for comparison with computational results. Free conditions can only be approximated in the lab using soft supports, but the stiffness and damping of these added supports will affect the modal parameters of the combined structural system.

•Fabrication Procedure: The composite honeycomb sandwich panel is constructed at fabrication shop. Honeycomb sandwich panels can be machined using a variety of power driven tools commonly found in the light metal working and joinery industries. For short run production or one-off fabricated components, cutting with hand held tools against a guide or simple template is adequate.

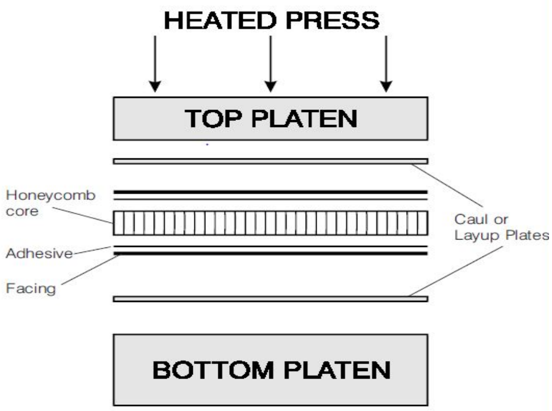


Figure:2.4 Fabrication of composite honeycomb sandwich panel

•Experimental Setup and Test Procedure

The sandwich panel is clamped at one end to simulate a cantilevered condition. One end of the sandwich panel is clamped in G-clamping. This condition is considered as the clamped boundary condition for both the face sheet and the core at this particular end. The modal testing of the beam is conducted with an impact hammer and spectra pro analyzer. The beams were subjected to a dynamic pulse load applied at the free end using the modally tuned hammer.

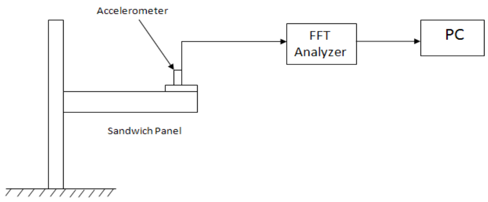
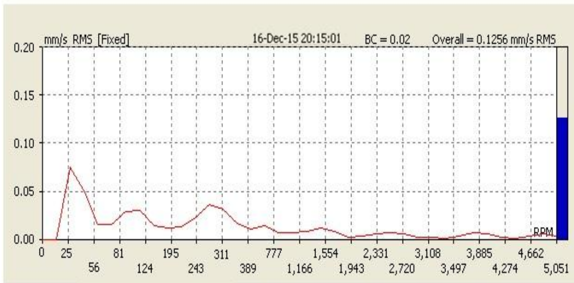


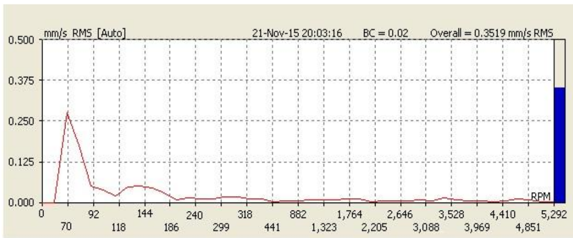
Figure 2.5: Experimental setup

Results and Discussion

Modal Analysis Of Free Free Sandwiched Panel-



Graph 2



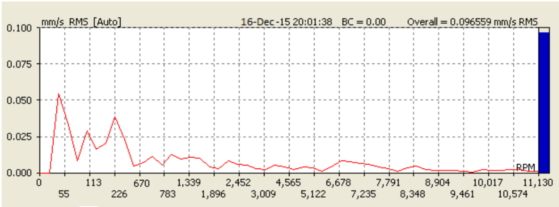
Graph3

Table No : 2.4 Frequency of corresponding mode

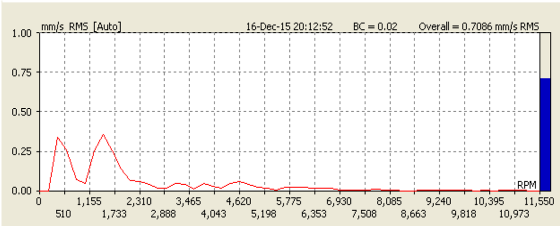
Sr. No	Modes	Frequency
1	Mode1	Zero Hz
2	Mode 2	25 Hz
3	Mode 3	70 Hz

The natural frequencies obtained from the experimental analysis are as follows.

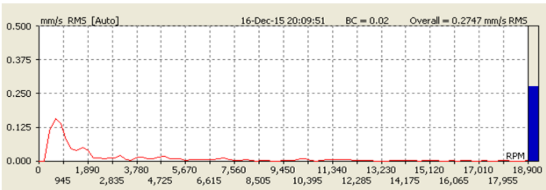
•Modal analysis-Cantilever.
Reading at Front end point



Graph1



Graph2



Graph3

Table No : 2.5 Frequency of corresponding mode

Modes	Theoretical results	Experimental results
Mode 1	48.10	40
Mode 2	301.86	300
Mode 3	845.22	820

•Result analysis and discussion

Since the result of FEA, Experimental and Analytical of both the conditions that is first one is one side is fixed and the other is hanging And the second is both the sides are free are tabulated as shown in following.

Table No : 2.6 Comparision Of FEA and Experimental Result

Boundary conditions	Mode Numbers	FEA (ANSYS)	Experimental results	Error in %
Free Free	1	Zero Hz		
Free Free	2	2.635E+01Hz	25 Hz	5.12
Free Free	3	6.680E+01Hz	70 Hz	4.57
Cantilever	1	4.389E+1Hz	40 Hz	8.86
Cantilever	2	3.133E+2Hz	300 Hz	4.24
Cantilever	3	8.468E+2Hz	820 Hz	3.16

Conclusion

The Comparision shows that the experimental values of simply supported honeycomb core sandwich panel differ somewhat with FEA (ANSYS) and analytical values. Error in sandwich panel is within 5% range. This can be attributed to the fact that many properties of sandwich panel which are not given and hence assumed during FEA (ANSYS) and analytical calculations.

Convergence analysis has been done by finite element model. The uniformly converging results of free vibration of simply supported sandwich panel assure the accuracy and correctness of the present analysis .Modal analysis of simply supported aluminium core sandwich plate and same dimension equivalent face plate shows that sandwich plate having 1.4 times higher fundamental frequency than equivalent face plate difference in frequency is more at higher modes. increase in frequency is due to increase in flexural stiffness of the plate.

Increase in thickness of core increase in natural frequency of the higher mode. Increase in density of the core decreases the natural frequency of the sandwich plate. Theoretically density is inversely proportionally to natural frequency hence density increases natural frequency decreases.

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