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Design and Analysis of Semi Monocoque Used Sandwich Composite Beam

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Abstract - A sandwich-structured composite is a special class of composite materials that is fabricated by attaching two thin but stiff skins to a lightweight but thick core. The core material is normally low strength material, but its higher thickness provides the sandwich composite with high bending stiffness with overall low density. Sandwich structures, widely used in aerospace and naval applications, tend to be limited to a small range of material combinations.

In this thesis, a sandwich composite for Semi-monocoque construction in aircraft fuselage is analysed for its strength under different loading conditions using different materials for Stringers balsa wood, syntactic foams, and honeycombs and Carbon Fibre reinforced thermoplastics is used as skin material.

3D modelling is done in Pro/Engineer. Static, Modal and Random Vibration analysis is done on the beam using finite element analysis software Ansys.

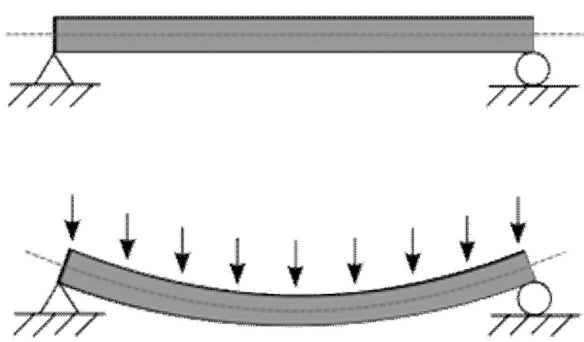
Keywords—Honey comb, synthetic foam, balsa wood. Static, model and random vibration analysis, finite element methods, ANSYS, PRO-ENGINEERING

I. INTRODUCTION

A. Beam

A beam is a structural element that is capable of withstanding load primarily by resisting against bending. The bending force induced into the material of the beam as a result of the external loads, own weight, span and external reactions to these loads is called a bending moment. Beams are characterized by their profile (shape of cross-section), their length, and their material.

Beams are traditionally descriptions of building or civil engineering structural elements, but smaller structures such as truck or automobile frames, machine frames, and other mechanical or structural systems contain beam structures that are designed and analyzed in a similar fashion.



A statically determinate beam, bending (sagging) under a uniformly distributed load

1) Classification of Beams Based on Supports

In engineering, beams are of several types

a) Simply supported - a beam supported on the ends which are free to rotate and have no moment resistance.

b) Fixed - a beam supported on both ends and restrained from rotation.

c) Over hanging - a simple beam extending beyond its support on one end.

d) Double overhanging - a simple beam with both ends extending beyond its supports on both ends.

e) Continuous - a beam extending over more than two supports.

f) Cantilever - a projecting beam fixed only at one end.

g) Trussed - a beam strengthened by adding a cable or rod to form a truss.

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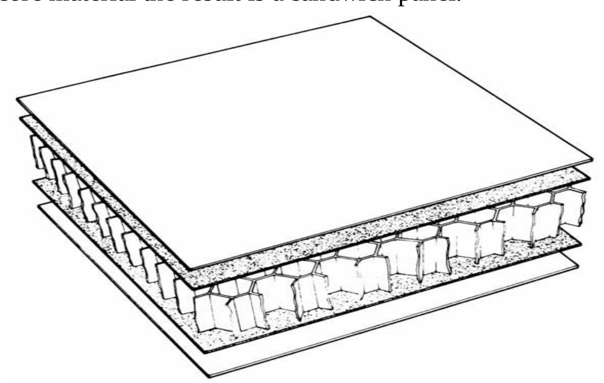
A thin walled beam is a very useful type of beam (structure). The cross section of *thin walled beams* is made up from thin panels connected among them to create closed or open cross sections of a beam (structure). Typical closed sections include round, square, and rectangular tubes. Open sections include I-beams, T-beams, L-beams, and so on. Thin walled beams exist because their bending stiffness per unit cross sectional area is much higher than that for solid cross sections such a rod or bar. In this way, stiff beams can be achieved with minimum weight. Thin walled beams are particularly useful when the material is a composite laminates. Pioneer work on composite laminates thin walled beams was done by Librescu.

II. INTRODUCTION TO COMPOSITE STRUCTURES

Innovative high performance design of load bearing components is always sought in high tech applications such as aircrafts, spacecraft satellites or F racing cars. These structures should be as light as possible while having high stiffness sufficient strength and some damage tolerance. This requires structurally efficient construction Structural efficiency can be maximized by using the most efficient materials and optimizing the structures geometry. To produce an optimum design both these factors need to be considered throughout the design process. The catalogue of materials is one of forbidding length. Thus a designer needs a systematic way to be guided through the maze of material classes so as to gradually narrow down the material choices and choose the optimum material. Ashby proposed a material selection procedure using material selection charts Birmingham et al have introduced an integrated approach to the assessment of alternative materials and structural forms at the concept stage of structural design based on the above methodology.

A. Sandwich Structures

Amongst all possible design concepts in composite structures the idea of sandwich construction has become increasingly popular because of the development of manmade cellular materials as core materials. Sandwich structures consist of a pair of thin sti strong skins faces facings or cover a thick lightweight core to separate the skins and carry loads from one skin to the other and an adhesive attachment which is capable of transmitting shear and axial loads to and from the core Fig; The separation of the skins by the core increases the moment of inertia of the panel with little increase in weight producing an efficient structure for resisting bending and buckling loads Table shows illustratively the exural stiffness and strength advantage of sandwich panels compared to solid panels using typical beam theory with typical values for skin and core density. By splitting a solid laminate down the middle and separating the two halves with a core material the result is a sandwich panel.



B. Sandwich-Structured Composite

It is a special class of composite materials that is fabricated by attaching two thin but stiff skins to a lightweight but thick core. The core material is normally low strength material, but its higher thickness provides the sandwich composite with high bending stiffness with overall low density.

1) Open and Closed Cell: structured foams like polyethersufone polyvinylchloride, polyurethane, polyethylene orpolystyrene foams, balsa wood, syntactic foams, and honeycombs are commonly used core materials. Sometimes, the honeycomb structure is filled with other foams for added strength. Open- and closed-cell metal foam can also be used as core materials.Laminates of glass or carbon fibre-reinforced thermoplastics or mainly thermo set polymer unsaturated polyesters, epoxies are widely used as skin materials. Sheet metal is also used as skin material in some cases. The core is bonded to the skins with an adhesive or with metal components by brazing together.
2) *Types of sandwich structures:* Metal composite material (MCM) is a type of sandwich formed from two thin skins of metal

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bonded to a plastic core in a continuous process under controlled pressure, heat, and tension.

Recycled paper is also now being used over a closed-cell recycled kraft honeycomb core, creating a lightweight, strong, and fully repulps able composite board. This material is being used for applications including point-of-purchase displays, bulkheads, recyclable office furniture, exhibition stands, and wall dividers.

To fix different panels, among other solutions, a transition zone is normally used, which is a gradual reduction of the core height, until the two fibre skins are in touch. In this place, the fixation can be made by means of bolts, rivets, or adhesive.

With respect to the core type and the way the core supports the skins, sandwich structures can be divided into the following groups: homogeneously supported, locally supported, regionally supported, unidirectional supported, bidirectional supported. The latter group is represented by honeycomb structure which, due to an optimal performance-to-weight ratio, is typically used in most demanding applications including aerospace.

C. Properties Of Sandwich Structures

1) *The strength of the composite material is dependent largely on two factors:*The outer skins: If the sandwich is supported on both sides, and then stressed by means of a downward force in the middle of the beam, then the bending moment will introduce shear forces in the material. The shear forces result in the bottom skin in tension and the top skin in compression. The core material spaces these two skins apart. The thicker the core material the stronger the composite. This principle works in much the same way as an I-beam does. The interface between the core and the skin: Because the shear stresses in the composite material change rapidly between the core and the skin, the adhesive layer also sees some degree of shear force. If the adhesive bond between the two layers is too weak, the most probable result will be delimitation.
2) *Application of sandwich structures:* The composite honeycomb structure of a helicopter nozzle Sandwich structures can be widely used in sandwich panels; these kinds of panels can be in different types such as FRP sandwich panel, aluminium composite panel etc. FRP polyester reinforced composite honeycomb panel (sandwich panel) is made of polyester reinforced plastic, multi-axial high-strength glass fibre and PP honeycomb pan special antiskid tread pattern mould through the process of constant temperature vacuum adsorption & agglutination and solidification
3) *Semi-monocoque:* The term semi-monocoque refers to a stressed shell structure that is similar to a true monocoque, but which derives at least some of its strength from conventional reinforcement. Semi-monocoque construction is used for, among other things, aircraft fuselages, car bodies and motorcycle frames
4) *Semi Monocoque Construction:*

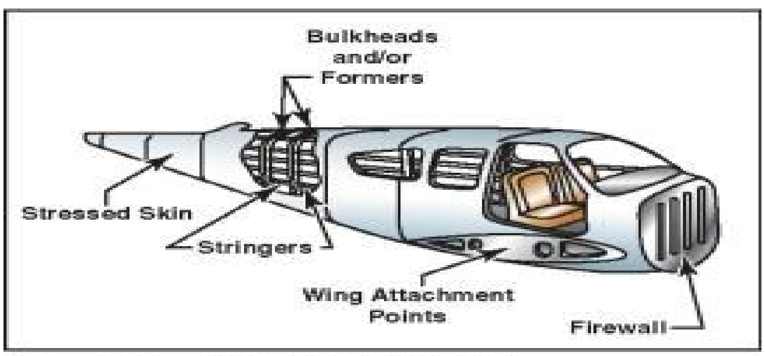

Figure 1-4. Semi-monocoque construction.

Bulkheads and supporting beams (stringers) reinforce stressed skin in semi monocoque airplanes In order to build bigger and stronger airplanes, a hybrid of the two construction techniques was put forward and remains in use today. The idea behind semi monocoque construction is quite simple. Instead of building a full internal skeleton, aircraft designers chose to build a *partial skeleton* to reinforce the skin in critical areas. A semi monocoque airplane's skin supports much of the load, with some internal bracing and bulkheads in place to maintain structural integrity. This design works surprisingly well, and remains in place on most modern aircraft from single engine pistons to the brand new Boeing 787 Dreamliner

III. INTRODUCTION TO CAD

A. Introduction To Pro/Engineer

Pro/ENGINEER is the industry's standard 3D mechanical design suit. It is the world's leading **CAD/CAM /CAE** software, gives a broad range of integrated solutions to cover all aspects of product design and manufacturing. Much of its success can be attributed

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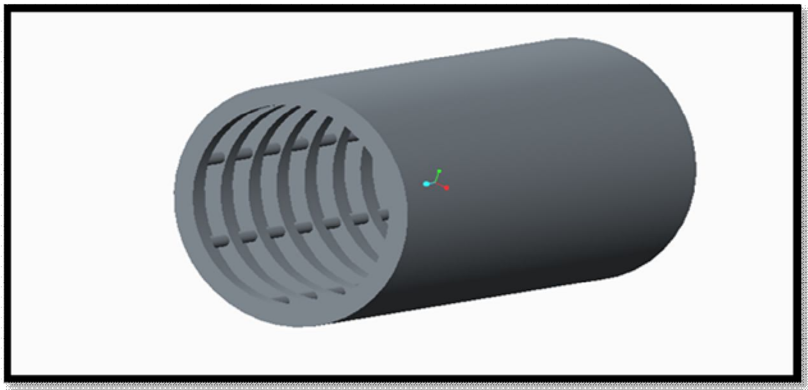
to its technology which spurs its customer's to more quickly and consistently innovate a new robust, parametric, feature based model, because the Pro/E technology is unmatched in this field, in all processes, in all countries, in all kind of companies along the supply chains. Pro/Engineer is also the perfect solution for the manufacturing enterprise, with associative applications, robust responsiveness and web connectivity that make it the ideal flexible engineering solution to accelerate innovations. Pro/Engineer provides easy to use solution tailored to the needs of small, medium sized enterprises as well as large industrial corporations in all industries, consumer goods, fabrications and assembly, electrical and electronics goods, automotive, aerospace etc.

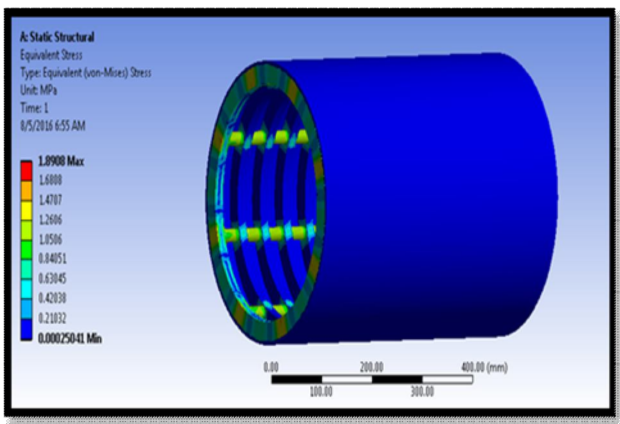
3D Model of sandwich beam (semi monocoque)

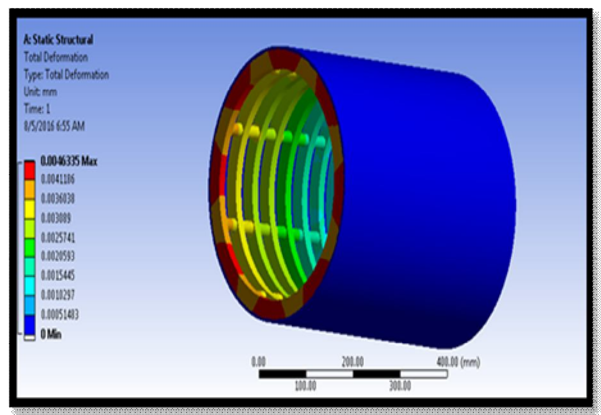


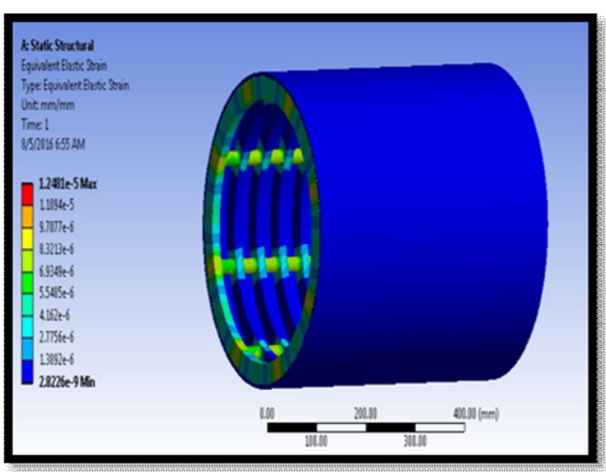
IV. ANALYSIS OF SANSDWICH BEAM

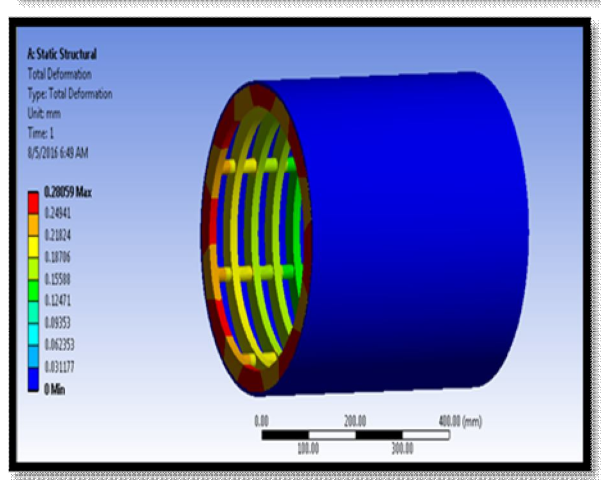
(SEMI-MONOCOQUE)

STRUCTURAL ANALYSIS AT PRESSURE 14 PSI FOR DIFFERENT MATERIALS









MODEL ANALYSIS OF DIFFERENT MATERIAL AT DIFFERENT PRESSURE

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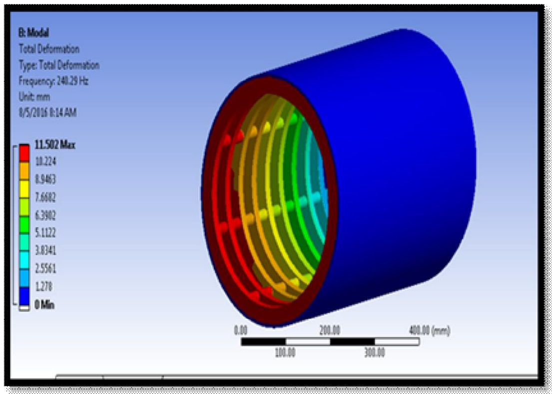
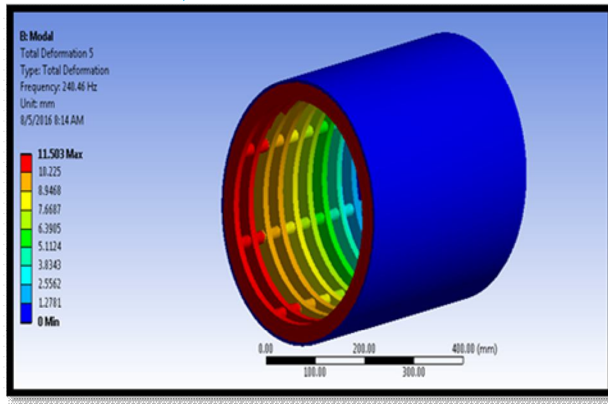
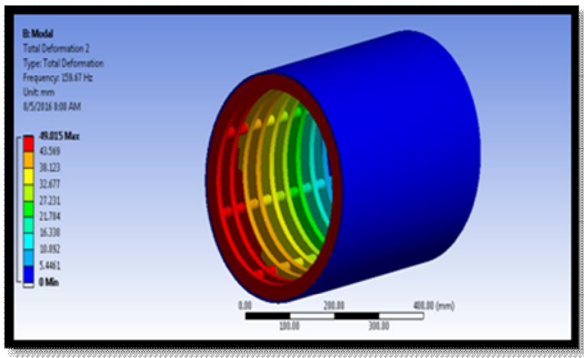
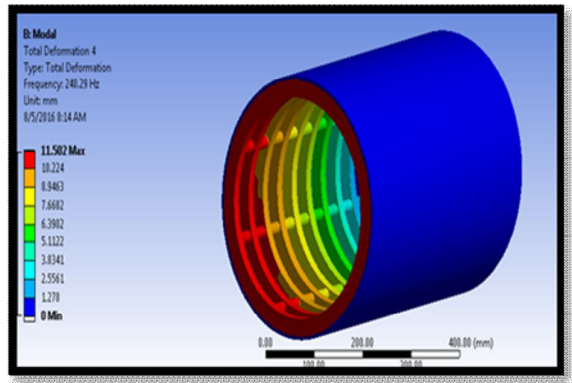
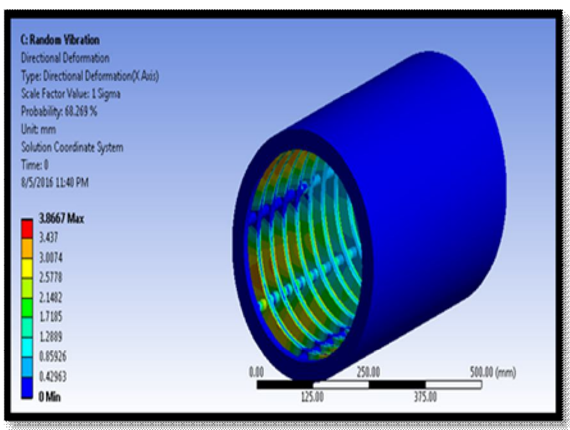


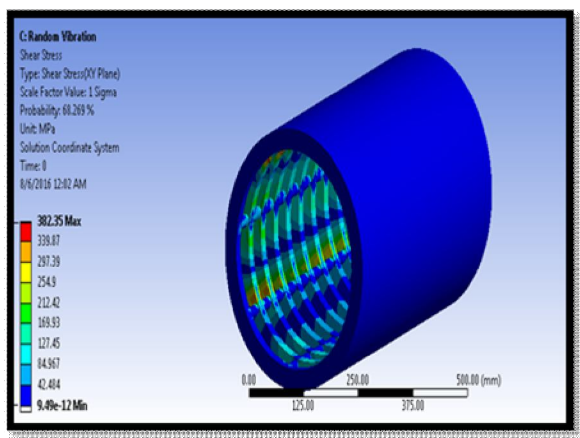


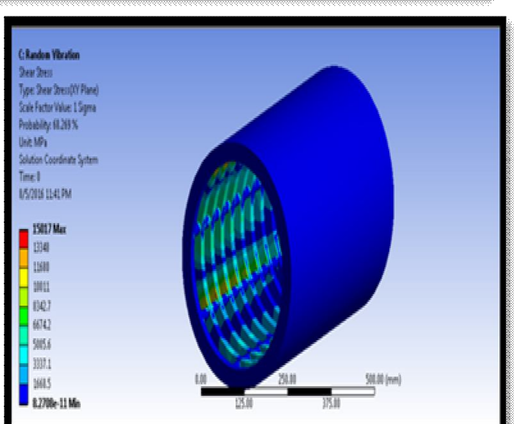


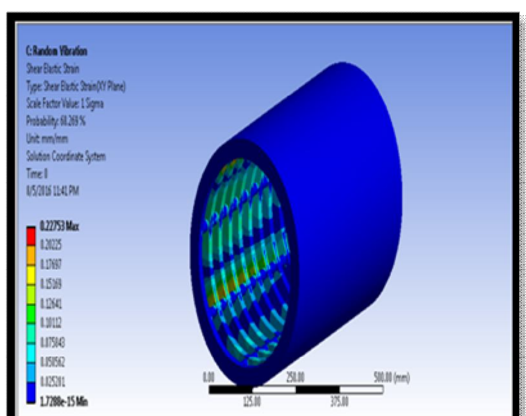


RANDOM VIBRATIONAL ANALYSIS FOR SANDWICH BEAMS









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V. RESULTS TABLES

A. Load condition(Pressure Psi)	*B.* Material	*C.* Deformation (mm)	*D.* Stress (N/mm^2)	*E.* Strain
F. *G.* 14	*H.* Honeycomb	*I.* 0.0046335	*J.* 1.8908	*K.* 1.24e-5
	L. Synthetic foams	*M.* 0.28059	*N.* 1.8319	*O.* 0.0007355
	P. Balsa wood	*Q.* 0.19874	*R.* 1.7143	*S.* 0.00048783
T. 16	*U.* Honeycomb	*V.* 0.00530	*W.* 2.166	*X.* 1.43e-5
	Y. Synthetic foams	*Z.* 0.321	*AA.* 2.099	*BB.* 0.00084626
	CC. Balsa wood	*DD.* 0.2277	*EE.* 1.9643	*FF.* 0.0005589

VI. CONCLUSIONS

In this thesis, a sandwich composite for Semi-monocoque construction in aircraft fuselage is analyzed for its strength under different loading conditions using different materials for Stringers balsa wood, syntactic foams, and honeycombs and Carbon Fiber reinforced thermoplastics is used as skin material3D modeling is done in Pro/Engineer. Static, Modal and Random Vibration analysis is done on the beam using finite element analysis software Ansys. By observing the structural analysis results, the deformation, stress and strain values are increasing by increasing the pressure. The deformation and strain values are more when Synthetic foam is. used than honeycomb and balsa wood. The stress values for all materials are less than their respective allowable strength values. The stress values are slightly more when honeycomb is used than synthetic foam and balsa wood.By observing the modal analysis results, the deformation values are less when honeycomb is used but the frequencies are more. If the frequencies are increasing, vibrations will increase. By observing the random vibration analysis results, the directional deformation and shear strain are less when honeycomb is used but the shear stress values are more .By observing the harmonic analysis results, the Frequency response of stress, Frequency response of strain and Frequency response of displacement are less when honeycomb is used but the Frequency response of stress values are more.

Though the stress values when honeycomb is used than synthetic foam, its strength is more, so it can be concluded that using honeycomb as stringer material is better.

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