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Modeling And Fe Analysis Of Semimonocoque At Different Load Conditions

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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 present work, 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, synthetic foams, and honeycombs and Carbon Fiber reinforced thermoplastics is used as skin material. 3D modeling is done in CATIA V5 R20. Static and Modal analysis is done on the beam using finite element analysis software ANSYS 14.5

1.INTRODUCTION_ The main body section of an aircraft is called a fuselage. This forms the central body of the aircraft onto which wings, control surfaces and sometimes engines are connected. The fuselage houses the crew, any passengers, cargo, an array of aircraft systems and sometimes fuel. A well designed fuselage will ensure that the following are met: The intended payload is adequately and efficiently housed. The fuselage is sized such that the various control and stabilization surfaces (typically the vertical and horizontal tail) are located such that the aircraft is stable in flight. Loading the aircraft with goods, fuel and passengers does not negatively impact on the stability of the aircraft for a range of payload configurations (center of gravity is adequately located). The fuselage structure will not fail due to excessive loading throughout the entire aircraft flight envelope. The mass of the fuselage is optimized to ensure safe operation without carrying any additional or excess weight. The aerodynamic shape of the fuselage is such that the minimum drag is produced during typical operation while still ensuring that the design payload is adequately housed. The fuselage design is versatile enough to offer the potential to stretch the aircraft if a number of aircraft configurations are desired. Let's start by examining three popular design methodologies for the structural design of a fuselage. Structural Design Principles Throughout the years a number of design principles have been adopted regarding the structural layout of a fuselage. Three common design methodologies are described below in chronological order leading up to the semi-monocoque design that is most prevalent today.

Space Frame (Truss)

The earliest aircraft fuselages were built with a space frame or truss like construction. Often wood was used as the primary structural material with a fabric covering providing the aerodynamic shape. In this fuselage configuration the force members of the truss provide the structural stiffness, and the aerodynamic covering provides the shape, but does not add much to the overall stiffness of the structure. A space frame is a simple albeit inefficient way of building a fuselage structure as the fabric skins add weight without contributing to the rigidity of the structure. One popular aircraft designed with a space frame fuselage is the iconic PA-18 Piper Super Cub which is pictured below.

Monocoque

By the end of the First World War limitations in the the use of wooden truss configurations were being identified. As the flight speed and wing loading of newer designs increased, the variation of the structural properties of the wood and its susceptibility to environmental degradation meant that wooden structures were no longer an efficient means of production. New methods were sought and steel was investigated as a replacement for wood. Steel is stiff and strong (both prerequisites in the design of an efficient structure) but its high density makes it very heavy (density of wood approximately 500 – 800 kg/m^3 vs steel 7800 kg/m^3). To efficiently design with steel, engineers had to make use of very thin sections which were intricately curved and shaped to prevent buckling of the thin structure. The term monocoque structure refers to a structural arrangement where the skins take all of the loading and contribute to all of the structural rigidity of the design. One major downfall when designing a pure monocoque structure is the difficulty of incorporating concentrated loads into the structure such as engine mountings or the wing-fuselage interface. The distribution of these point loads into the skin structure becomes very difficult to efficiently achieve. Interestingly, in recent times the introduction of composites as a material from which to build aircraft structures has seen a move back towards designing a pure monocoque structure, although typically a hybrid design of a metallic substructure with composite skin panels is typically used on larger composite aircraft.

Semi-Monocoque

Somewhere between the space frame arrangement (skin takes no load) and pure monocoque arrangement (skin takes all the load) lies the semi-monocoque design which is the most common method of constructing aircraft structure today. In a semi-monocoque structure both the skin and set of frames are load carrying and contribute to the overall stiffness of the structure. This design methodology was born out of the use of aluminium rather than steel as the primary structural material used in the design of aircraft structures. Aluminium has many advantages over steel, principally its density is approximately one-third that of steel. For a constant structural mass, the aluminium sections can be thicker which reduces the susceptibility of those skins to buckling, which in turn produces a more efficient structure.

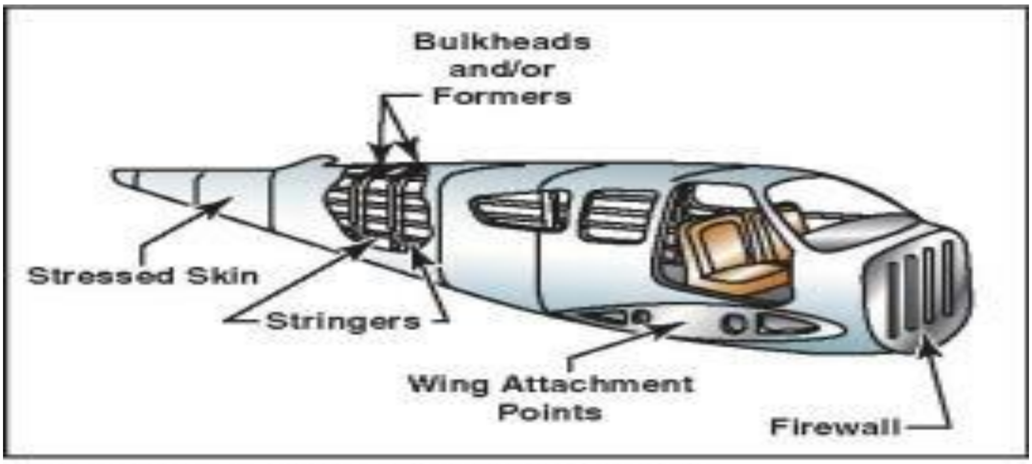

Figure 1-4. Semi-monocoque construction.

2.LITERATURE SURVEY

1.The dynamic response of composite sandwich beams to transverse impact.

The dynamic response of glass fibre–vinylester composite beams is measured by impacting the beams at mid-span with metal foam projectiles. The beams exist in composite monolithic form, and in sandwich configuration with composite face sheets and a core made from PVC foam or end-grain balsa wood. High-speed photography is used to measure the transient transverse deflection of the beams and to record the dynamic modes of deformation and failure. For both monolithic and sandwich configurations, a flexural wave travels from the impact site towards the supports. Ultimate failure of the monolithic and sandwich beams is by tensile tearing of the faces. The sandwich beams also exhibit cracking of the core, and face sheet delamination. The dynamic strength of the beams is quantified by the maximum transient transverse deflection at mid-span of the beams as a function of projectile momentum. It is demonstrated that sandwich beams can outperform monolithic beams of equal mass. The trade-off between core strength and core thickness is such that a low density PVC foam core outperforms a higher density PVC foam core. End-grain balsa wood has a superior stiffness and strength to that of PVC foam in compression and in shear. Consequently, sandwich beams with a balsa core outperform beams with a PVC foam core for projectiles of low momentum. The order reverses at high values of projectile momentum: the sandwich beams with a balsa wood core fail prematurely in longitudinal shear by splitting along the grain.

2.The fatigue strength of sandwich beams with an aluminium alloy foam core.

Sandwich beams with aluminium face sheets and an aluminium alloy foam core are tested in cyclic four point bend, and S–N fatigue curves are determined for the failure modes of face fatigue, core shear and core indentation. The operative failure mode is dictated by the relative fatigue strength of face sheets to core, and upon the geometry of the sandwich beams. Simple analytical models are developed to predict the fatigue strength for each of the competing failure modes, and a design map is produced to display the fatigue strength and mode of failure as a function of sandwich beam geometry.

3.Fabrication and Mechanical Testing of a New Sandwich Structure with Carbon Fiber Network Core

The aim is the fabrication and mechanical testing of sandwich structures including a new core material known as fiber network sandwich materials. As fabrication norms for such a material do not exist as such, so the primary goal is to reproduce successfully fiber network sandwich specimens. Enhanced vibration testing diagnoses the quality of the fabrication process. These sandwich materials possess low structural strength as proved by the static tests (compression, bending), but the vibration test results give high damping values, making the material suitable for vibro-acoustic applications where structural strength is of secondary importance e.g., internal panelling of a helicopter.

3.RESULTS TABLES

STATIC ANALYSIS

Load condition(Pressure Psi)	Material	Deformation (mm)	Stress (N/mm^2)	Strain
14	Honeycomb	0.0046335	1.8908	1.24e-5
	Synthetic foams	0.28059	1.8319	0.0007355
	Balsa wood	0.19874	1.7143	0.00048783

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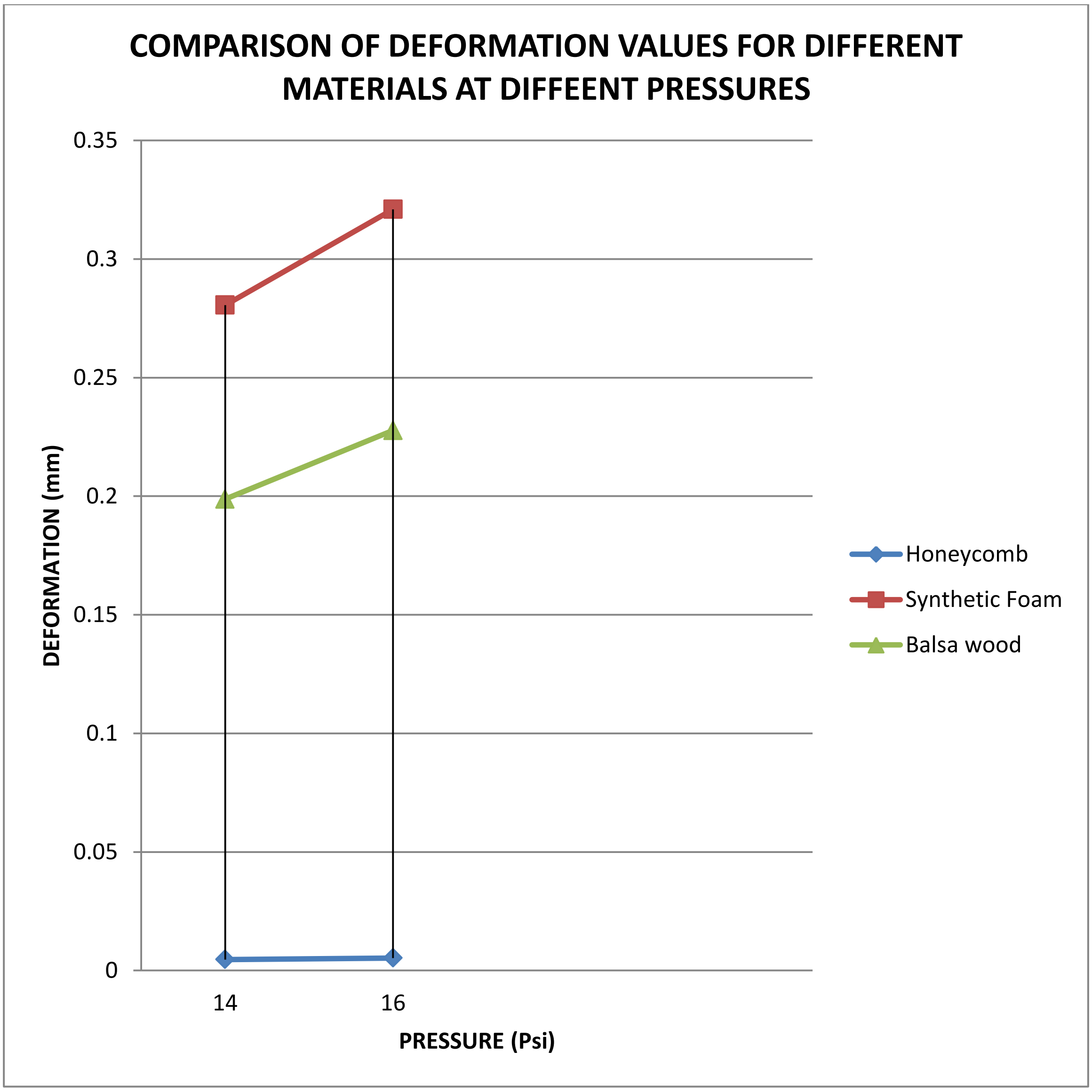
16	**Honeycomb**	0.00530	2.166	1.43e-5
	Synthetic foams	0.321	2.099	0.00084626
	Balsa wood	0.2277	1.9643	0.0005589



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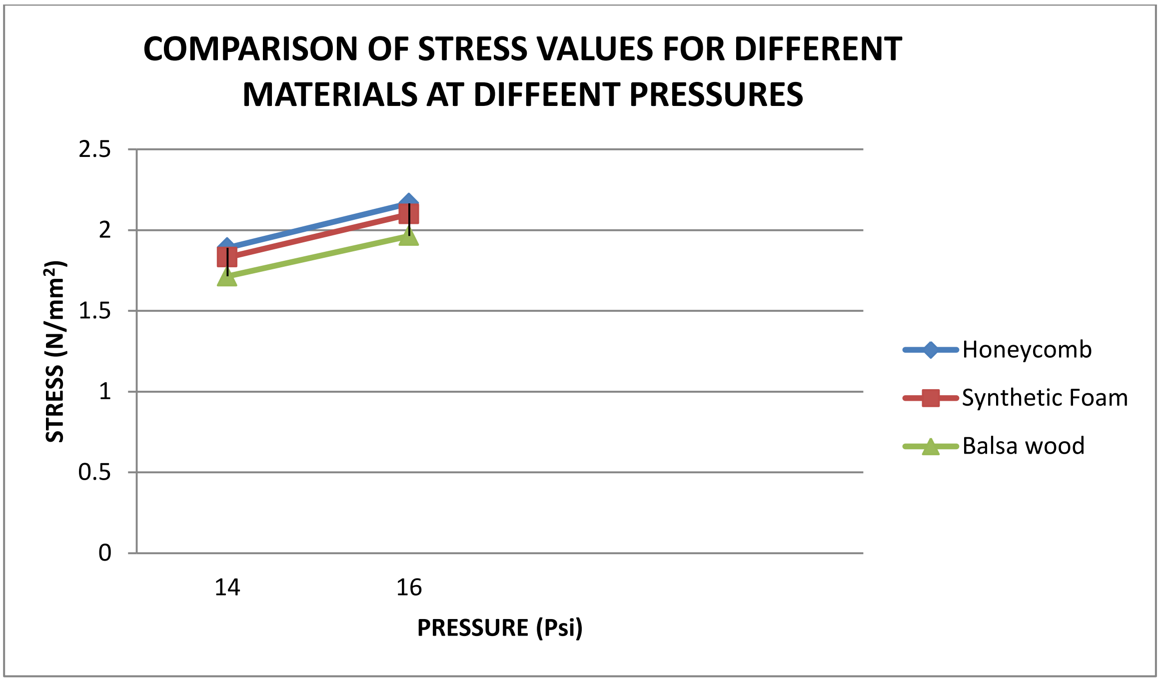
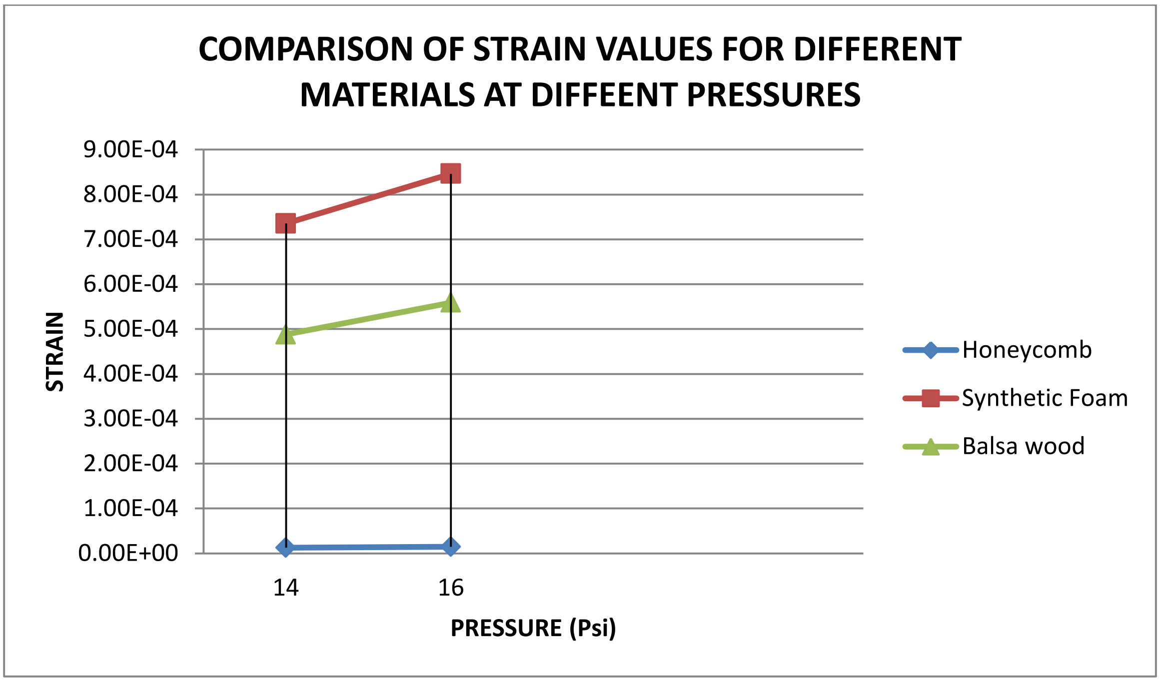
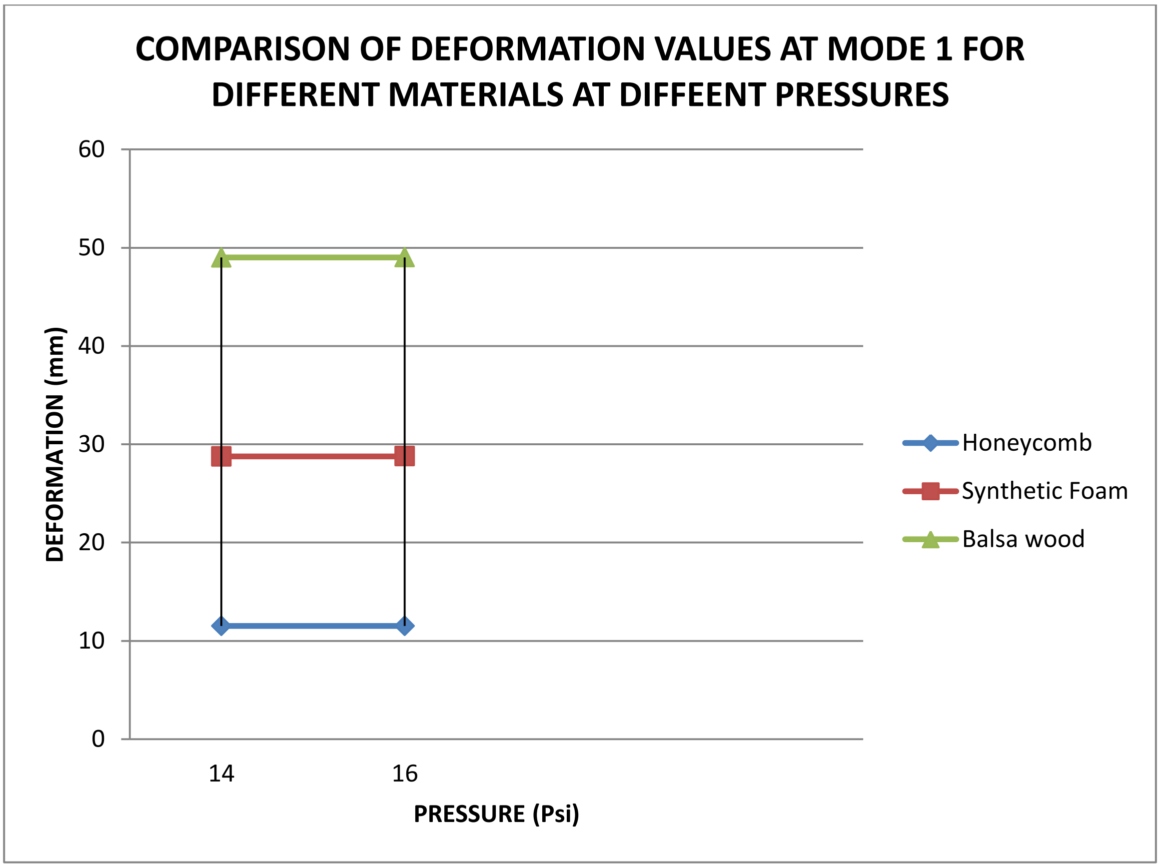


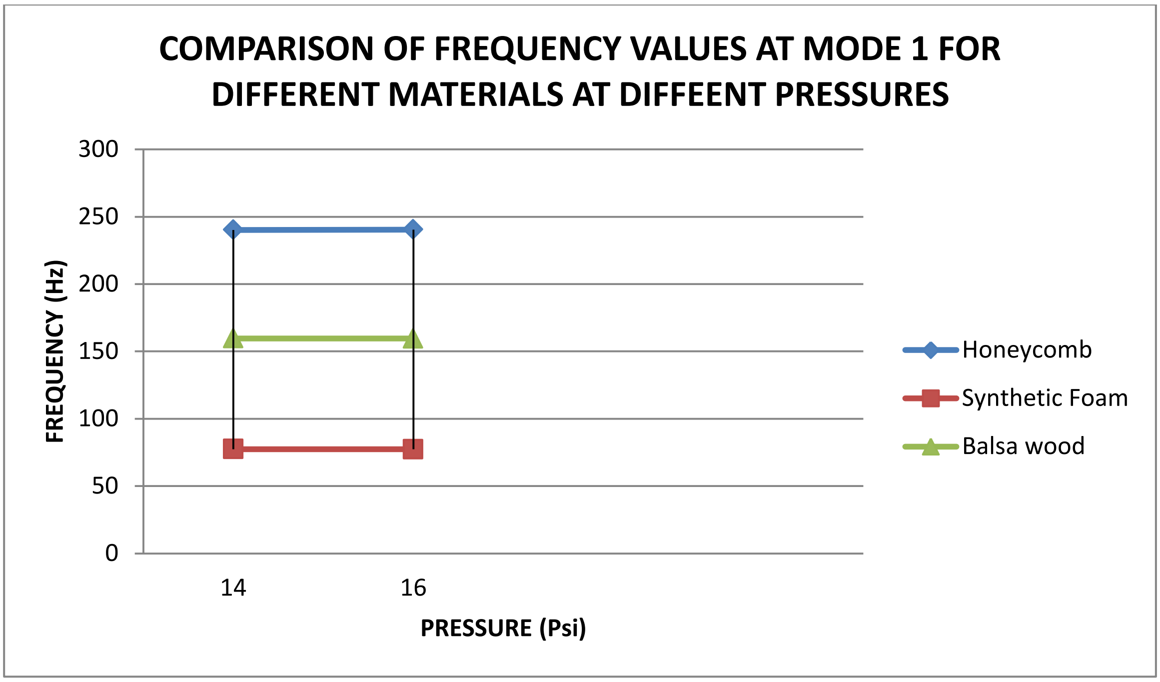


MODAL ANALYSIS

Load condition (Pressure Psi)	Material	Frequency (Hz)	Deformation 1 (mm	Frequency (Hz)	Deformation 2 (mm	Frequency (Hz)	Deformation 3 (mm

			)		)		)
14	**Honeycomb**	240.2 9	11.50 2	240.2 9	11.50 3	240.4 6	11.50 4
	Synthetic foams	77.37 8	28.76 3	112.2 3	28.89 8	236.6 5	29.01 5
	Balsa wood	159.6 7	48.99 5	233.6 6	49.06 7	488.2	49.36 3
16	**Honeycomb**	240.4 6	11.50 3	346.9 9	11.50 5	538.8 8	34.23 3
	Synthetic foams	77.31 2	28.78	112.1 6	28.89	236.4 4	29.00 1
	Balsa wood	159.5 8	49.01 5	233.5 7	49.06 8	487.9 1	49.34 8





Calculations

Hoop Stress = $\frac{P\,r}{t} \times E$ **N/mm²**

where

P is the internal pressure

t is the wall thickness

r is the mean radius of the cylinder

At internal pressure 14 Psi

Material –honey comb

Hoop Stress = $\frac{P\,r}{t} \times E$ N/mm²

$$\frac{0.096\times 162}{29} \times 165 \text{ N/mm}^2$$

$$=88.4 \text{ N/mm}^2$$

Material –synthcis form

$\frac{0.096\times 162}{29} \times 2.7$ N/mm^2

Hoop stress =1.44 N/mm^2

Material –balsa wood

$\frac{0.096\times 162}{29} \times 3.7$ N/mm^2

Hoop stress =1.98 N/mm^2

At internal pressure 16 Psi

Material –honey comb

Hoop Stress = $\frac{P\,r}{t} \times E$ N/mm^2

$\frac{0.15\times 162}{29} \times 165$ N/mm^2

=138.25 N/mm^2

Material –synthcis form

$\frac{0.15\times 162}{29} \times 2.7$ N/mm^2

Hoop stress =2.241 N/mm^2

Material –balsa wood

$\frac{0.15\times 162}{29} \times 3.7$ N/mm^2

Hoop stress =1.683 N/mm^2

4.CONCLUSION

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 material. 3D modeling is done in CATIA. 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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