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Experimental Study of Composite Foam Sandwich Structures for Aerospace Applications

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Abstract— *The quest for low density, high strength aircraft structures poses immense challenges to materials and aircraft structural engineers. Traditionally these materials are fabricated either by solid Aluminum Titanium alloys or cellular structures such as honeycomb sandwich structures. Both the alternatives are expensive. Thus a simple and economical structural advancement is required. The present study deals with composite foam sandwich structures in comparison to honeycomb sandwich structures. Compressive strength of fabricated composite foam is approximately 5.81 times higher than the honeycomb.*

Keywords — *Composite foam, sandwich structure, aerospace application*

I. INTRODUCTION

Traditional aircraft structures such as the internal structure of the wing, fuselage casing and control surfaces are fabricated using honeycomb sandwich structures [3],[4]. Although these structures have features such as less density and cheaper raw material, the compressive strength of these structures is moderate. Also, the fabrication cost is high; the fabrication process is complex and fabricating curved and complicated structure becomes even more difficult. On the other hand, the solid Aluminum Titanium alloys have higher strength. Still, the raw material is costly and the density of the material very high compared to the honeycomb sandwich structures [5]. Thus, both types of structures have their advantages and disadvantages. To overcome these disadvantages, a simple but novel structure can be used. This paper describes this kind of structure. Metal foams are produced for different applications from quite long times. The properties of metal foams, such as low density and high strength, are very much suitable for aircraft structures [9]. Composite foams are even better when compared to conventional metal foams as these foams are less dense and have high stiffness. Another feature of interest is the energy-absorbing nature of these foams [1]. Thus, it could absorb sound and can be used in areas of shock production. Metals foams have three times higher compressive strength when compared to solid metals [5]. Also, the flexural rigidity of metal foams is higher than that of Titanium alloys which are usually used in aircraft [5]. Thus, a comparison of the honeycomb sandwich panel and composite foam sandwich panel is made in this paper, focusing on the compressive strengths. Composite foams are made using Al-SiC composites as these composites are observed to have several suitable properties for aerospace applications [8]. As there are several methods already available to produce metal foams, these procedures are used as a reference to make the composite foam core for the study.

II. FABRICATION AND TESTING OF PROPERTIES

A. Materials

The materials used for the fabrication of composite foam core are Aluminum 6061, Silicon Carbide, Calcium Carbonate and Cenospheres. The honeycomb core is fabrication using Aluminum 3003. The face sheet is made of bi-directional carbon fibre laminate with epoxy as resin.

B. Fabrication procedure

The composite foam was fabricated using stir casting technique [10] at Casting Laboratory, Karunya Institute of Technology and Sciences. Reinforcement (5%Silicon Carbide) and foaming agents (6%Calcium Carbonate and 3%Cenospheres) are preheated at 350ºC to remove moisture content. Simultaneously, Aluminum metal is melted in the stir casting furnace at 750ºC. After Aluminum is molten, Silicon Carbide and Cenospheres are added together and stirred at 450rpm. Then, Calcium Carbonate is added at the same rate of stirring. At this stage, the foam starts forming. The crucible is kept in the furnace for about 5 minutes to complete the foaming process. Then it is kept out for cooling. Then, the foam is machined to obtain specific core sizes for testing.

Aluminium honeycomb foam was fabricated using corrugation technique.

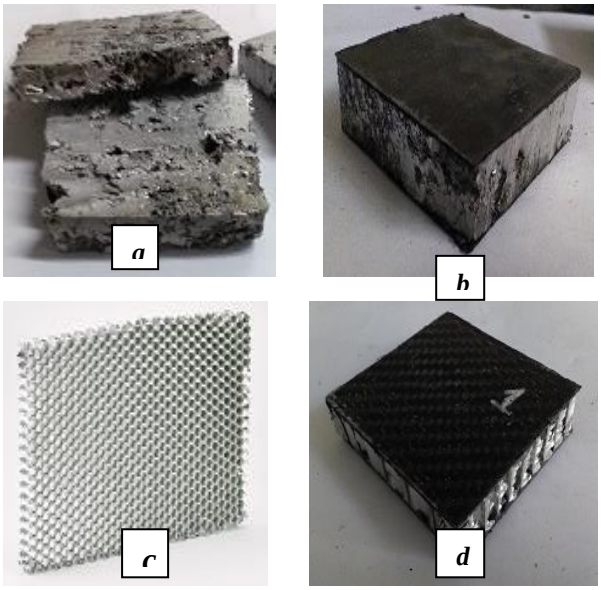

Fig. 1.

- ***a- Composite foam core***
- ***b- Composite foam sandwich panel***
- ***c- Honeycomb core***
- ***d- Honeycomb sandwich panel***

Face sheets are fabricated using bi-directional carbon fibre of thickness 0.2mm and epoxy. Four layers of carbon fibres are stacked at $[0^o|90^o]_s$. Hardener: Epoxy ratio used is 1:4.

After cutting the core to required size 6mm×6mm×1.5mm, the face sheets are fabricated, and epoxy is used as an adhesive between the core and face sheets. Load of 100N was applied to make sure that excess resin comes out, and the adhesiveness between the face sheets and the core is high.

C. Properties of the sandwich core

The properties of composite foam core are fabricated using the formulae as follows [2].

Relative density= Density of foam/Density of solid metal

Relative porosity= (Density of Aluminum- Density of foam)/ Density of Aluminum

The density of the foam is 576.6kg/m3. Therefore relative density is 0.213. The foam is 78.66% porous.

The density of aluminium honeycomb is 285.2kg/m3.

D. Flat wise compression test

Flat wise compression test was done using Universal Testing Machine at Strength of Materials Laboratory, Karunya Institute of Technology and Sciences. Compressive strength was noted, and strength to weight ratio was calculated using the results obtained from the test. The compressive strength of the composite foam core sandwich was found to be 5.81 times higher than that of the honeycomb core sandwich panel.

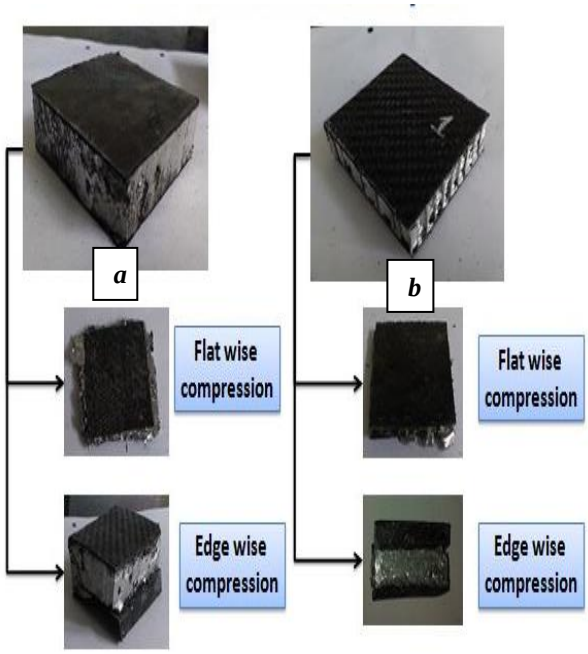

Fig. 2. Before and after images of compression tests.

- ***a- Composite foam sandwich panel***
- ***b- Honeycomb sandwich panel***

E. Edgewise compression test

Edgewise compression test was done using Universal Testing Machine at Strength of Materials Laboratory, Karunya Institute of Technology and Sciences. Compressive strength was noted, and strength to weight ratio was calculated using the results obtained from the test. The compressive strength of both types of samples was almost in the same range.

Table 1.
Compression test result comparison for composite foam sandwich panel and honeycomb core sandwich panel

Core	*Foam (N/mm^2)*	*Honeycomb (N/mm^2)*
Edgewise	6.385	4.692
Flat wise	158.833	13.521

F. Strength to weight ratio

Strength to weight ratio of composite foam core sandwich and Aluminum honeycomb core sandwich for flatwise compression and edgewise compression are tabulated below.

Table 2.
Comparison of Strength/Weight ratio of composite foams and honeycomb core sandwich panel

Core	*Foam (kNm/kg)*	*Honeycomb (kNm/kg)*
Strength / Weigth ratio (Edge wise compression)	11.073	16.451
Strength / Weight ratio (Flat wise compression)	275.464	47.408

III. APPLICATIONS

The composite foam sandwich panel is very suitable for applications such as wing spars as compressive loads are predominant in it. It can be used in fan and turbine blades because of its lightweight. It can be used in control surfaces.
In general, it can replace the honeycomb sandwich panel and solid metal bodies, thus making the fabrication economical and highly beneficial.

IV. CONCLUSION

The paper discusses composite foam and its sandwich panel, its basic properties and comparison of compressive properties with honeycomb sandwich panel. The compressive strength of the composite sandwich panel was found to be 5.81 times higher than that of the honeycomb sandwich panel.

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