Experimental Investigation of Buckling Strength Comparison between Metallic and CFRP Sandwiched Composite Panel

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Abstract—*In the current investigation, a comparison will be made between the Aluminum and Aluminum-Carbon Fiber Reinforced Polymer (CFRP) sandwiched composite panels for buckling load carrying capability. The panels with maximum compression load will be identified as critical panels for buckling analysis. Classical approach will be followed to calculate the critical buckling load on each panel.*
Testing of both panel will be carried out using Universal Testing Machine (UTM). Axial compression load will be applied on the panel. Dial gauges will be placed either side of the panel to capture the displacement about the center of the panel for response of the structure under uni-axial compression loading. Interpolation of the test results will be carried out for comparison of the buckling strength between two panels

Keywords—CFRP composite, Buckling strength,Aluminum alloy, Universal testing machine.

I. INTRODUCTION

When designing an aircraft, it's all about finding the optimal proportion of the weight of the vehicle and payload. It needs to be strong and stiff enough to withstand the exceptional circumstances in which it has to operate. Durability is an important factor. Also, if a part fails, it doesn't necessarily result in failure of the whole aircraft.
Glass Fiber Reinforced Polymer (GFRP) and Carbon Fiber Reinforced Polymer (CFRP) are the two commonly used composite materials in the airframe structure. From the past few years these material have found increased usage in the aircraft structural design and development. On the other hand, Aluminum alloys have found to be used in the aircraft structure from past several decades [1-2].
The main sections of an aircraft, the fuselage, tail and wing, determine its external shape. The load bearing members of these main sections, those subjected to major forces, are called the airframe. The airframe is what remains if all equipment and systems are stripped away. Old aircrafts had skin made from impregnated linen that could hardly transmit any force at all [3-5].
Aircraft wings, when subjected to aerodynamic lift loads will deform by putting the top skin in compression and bottom skin in tension. These panels subjected to axial compression are expected to buckle, before leading to failure. Therefore, study of buckling load-carrying capability of stiffened panel becomes an important aspect in design & development of the airframe structure.
In most modem aircrafts, the spar plays an important role in carrying buckling loads. Usually spars are attached to the skin. In an integral structure, the skin and stiffeners have been manufactured from one solid block of material. It is also possible to make some kind of a sandwich structure, in which the skin has a high stiffness due to its special structure [6-7].

II. EXPERIMENT DETAILS

Buckling is characterized by a sudden sideways failure of a structural member subjected to high compressive stress, where the compressive stress at the point of failure is less than the ultimate compressive stress that the material is capable of withstanding. Mathematical analysis of buckling often makes use of an "artificial" axial load eccentricity that introduces a secondary bending moment that is not a part of the primary applied forces being studied.

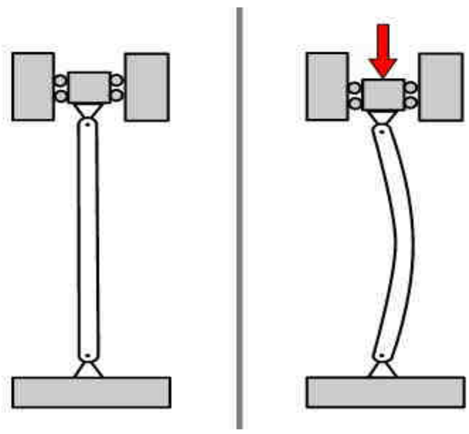

Fig. 2.1: Buckling of column

The steps for design and modeling of the required model are explained in this chapter. The designing of the model is carried out in Solid edge 2D drafting tool. The figure of the 2D model and the fabricated model is shown.

Here we used the two models of same length and width but differ in thickness to compare the buckling strength with the Aluminium panel.

2.1 Specification of the model 1

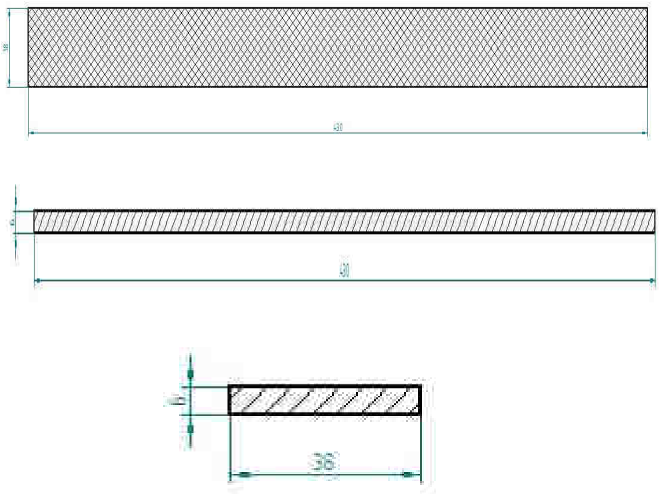

Fig. 2.2: Specification of model 1

Dimensions (mm)

Width = 38mm

Length = 430mm

Thickness = 6mm

Here the total required thickness is obtained by alternately placing the 5 layers of Carbon fiber reinforced polymer of 0.8mm thickness and 4 layers of Aluminum mesh of 0.5mm thickness.

2.2 Specification of model 2

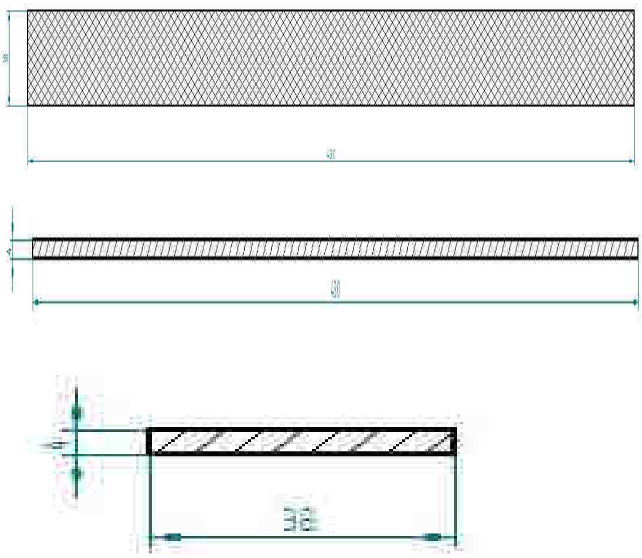

Fig. 2.3 Specification of model 2

Dimensions (mm)

Width = 38mm, Length = 430mm, Thickness = 4mm

Here the total required thickness is obtained by alternately placing the 5 layers of Carbon fiber reinforced polymer of 0.4mm thickness and 4 layers of Aluminium mesh of 0.5mm thickness.

2.3 Sandwiched panel

In the current investigation, a comparison will be made between the Aluminium and CFRP-Aluminium composite stiffened panels for buckling load-carrying capability. The schematic diagram of a sandwiched panel is shown below.

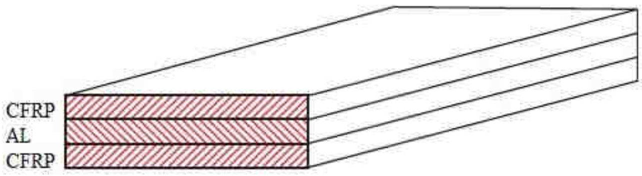

Fig. 2.4: Sandwiched panel

2.4 Fabricated model

The image of the fabricated model is shown below

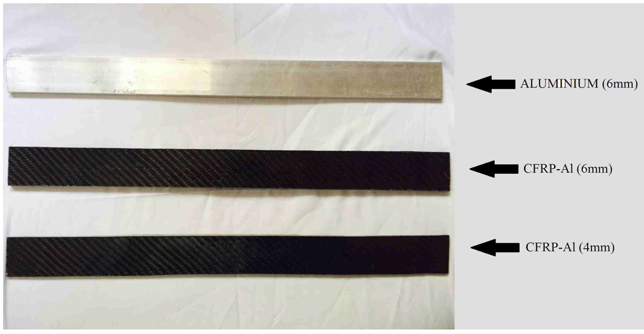

Fig. 2.5: Fabricated model

Fig. 2.6: Side view of fabricated model

III. MATERIALS AND ITS PROPERTIES

3.1 Aluminium Mesh

Aluminium is a very versatile metal, touches every aspect of our lives, from aircrafts to Automobiles, from power cables to foils, aluminium can be fashioned into myriad shapes in a variety of applications and lately the building industry has caught the fancy of the versatility and Performance of the material.

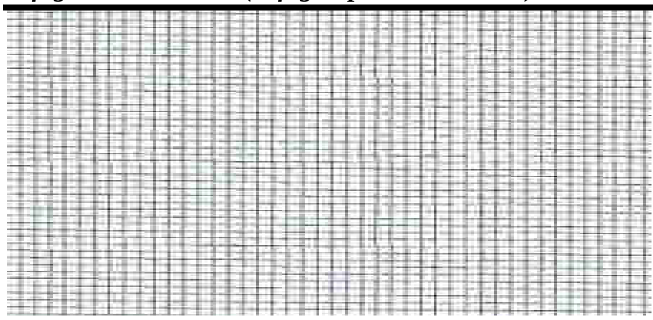

Fig. 3.1: Aluminium Mesh

Mesh size = 1*1mm square mesh

Thickness = 0.5 mm

Aluminium products are more commonly used in the construction of Airframe structure, as composite panels in wall claddings, marine etc. Aluminium is an energy intensive material.

3.1.1 Aluminium properties

Table 3.1 Properties of Aluminium mesh

Properties/materials	Aluminum
Stiffness N/m	22.9×10^3
Density kg/m^3	2700
Weight	Low
Young modulus of elasticity N/m^2	70000×10^6
Shear modulus N/m^2	27000×10^6
Poisson ratio	0.33
Co-efficient of thermal expansion l/K	23×10^{-3}
Corrosion resistance	High
Ductility	High
Recyclability	Very good
Cost	Low

3.2 Carbon Fiber Reinforced Polymer

This is an extremely strong and light fiber-reinforced plastic which contains carbon fibers. CFRPs can be expensive to produce but are commonly used wherever high strength-to weight ratio and rigidity are required, such as aerospace, automotive and civil engineering, sports goods and an increasing number of other consumer and technical applications.Carbon Fiber, not surprisingly, is made of carbon crystals aligned in a long axis. These honeycomb shaped crystals organize themselves in long flattened ribbons. This crystal alignment makes the ribbon strong in the long axis.

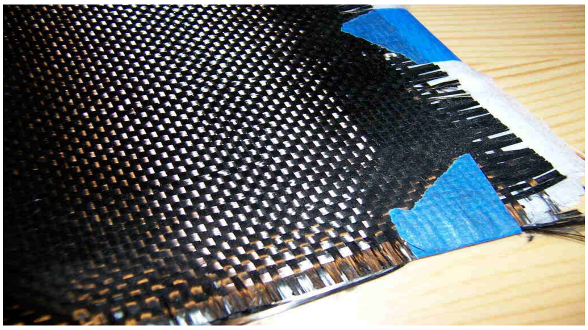

Fig. 3.2: Carbon fiber reinforced polymer cloth

The mechanical properties of CFRP are given below.

Table 3.2 Properties of CFRP cloth

Property	Value	Unit
Longitudinal Modulus	17	GPa
Transverse Modulus	17	GPa
In Plane Shear Modulus	33	GPa
Poisson's Ratio	0.77	-
Tensile Strength	110	MPa
Compressive Strength	110	MPa
In Plane Shear Strength	260	MPa
Thermal Expansion Co-efficient	2.15 E-6	Strain/K
Moisture Co-efficient	3.22 E-4	Strain/K

3.3 Properties of Epoxy

Table 3.3 Properties of Epoxy resin

Epoxy resin L 9	Value	Unit
Delivered state	Liquid	-
Color	Yellowish	-
Density	1.15	g/cm^3/20^{0}C
Viscosity	900	mPa's/25^{0}C
Epoxy value	0.56	100/equivalent
Epoxy equivalent	179	g/equivalent
Chlorine content hydrolysable	< 0.3	Ppm
Vapor pressure	$< 10^4$	Mbar/25^{0}C
Flash point	>120	^{0}C
Storage	12	Months

The hardener used is K-10, and curing time is 24 hours.

IV. FABRICATION PROCESS

There are numerous methods for fabricating composite components. Some methods have been borrowed (injection moulding for example), but many were developed to meet specific design or manufacturing challenges. Selection of a method for a particular part, therefore, will depends on the materials, the part design and end-use or application.

Composite fabrication processes involve some form of moulding, to shape the resin and reinforcement. A mould tool is required to give the unformed resin /fiber combination its shape prior to and during cure. For an overview of mould types and materials and methods used to make mould tools.

Fig. 4.1: Marking of CFRP cloth

Fig. 4.2: Cutting of Aluminium mesh

Fig. 4.3: Cutting of CFRP cloth

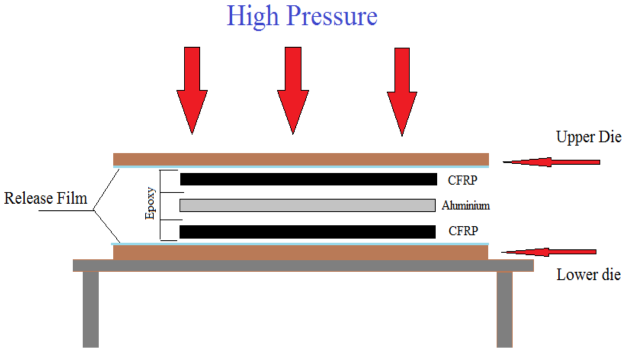

Fig. 4.4: Hand layup Technique

Fig. 4.5: Placing of one ply of CFRP over another

Fig. 4.6: Applying of resin over each ply

Fig. 4.7: Removing of air bubbles

Fig. 4.8: Applying weight on mould

Fig. 4.9: Cuttineg operation

V. TESTING OF THE PANELS

5.1 UTM (Universal Testing Machine)

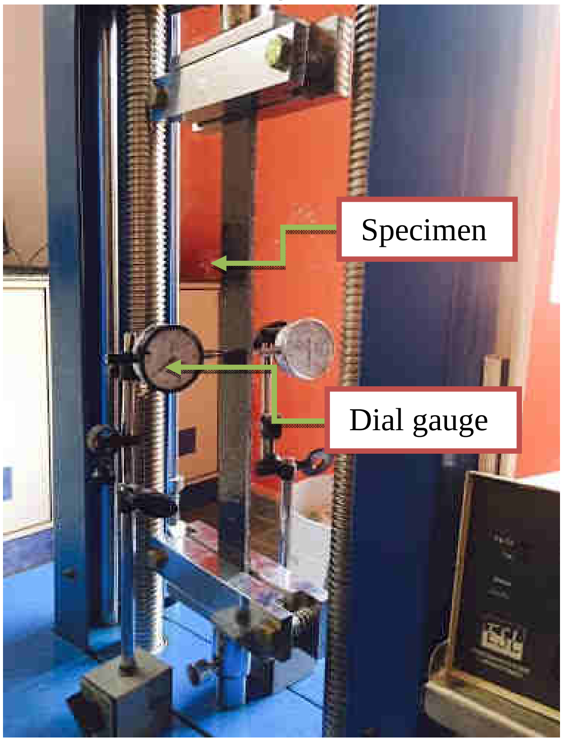

Fig. 5.1: Testing of model in UTM

In our experiment to check the buckling strength of the Aluminium and Al-CFRP sandwiched panel, we have taken the gauge length of 400 mm. Then we have fixed the model at both the ends as it shown in the figure 5.1.

As the load increases the model tends to buckle because of its large length compare to other two dimensions. As the model tends to buckle the dial gauge will show the sideways deflection of the panel. The readings will be noted for each increment of 0.2KN. As the dial gauge has the maximum deflection capacity of 11mm readings, at the deflection near to 10mm the dial gauge will be removed. Then the material is allowed to load again continuously till the material break, and the breaking load and the peak load will be noted. The aluminium panel gave the maximum deflection without breaking the panel.

VI. RESULTS AND DISCUSTION

6.1 Results obtained from Aluminum and composite panels

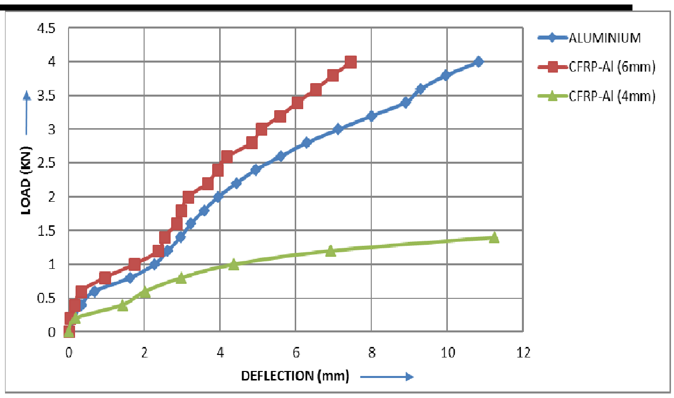

Fig. 6.1: Load Vs deflection graph for Al, CFRP-Al (6mm) & CFRP-Al (4mm) panel

From the above graph, we have noted that, the CFRP-Al sandwiched panel of 6mm gives the less deflection compare to Aluminum panel of same thickness at same applied load. And also the peak value for CFRP-Al panel is more compare to the Aluminum panel.

When comes to the CFRP-Al panel of 4mm thickness, it shows that as the thickness decreases it loses the buckling strength and also it increases the deflection compare to aluminium for same applied load.

The results obtained from the testing of fabricated model by comparing the Carbon fiber reinforced polymer-Aluminium sandwiched panel with Aluminium panel it is found that, the weight of CFRP-Al panel has been reduced by 40% compared to Aluminium panel of same dimensions.

And also by comparing the values obtained from the Buckling test of the models, it shows that, the buckling load carrying capacity of CFRP-Al panel is increased by 38% as compared to Aluminium panel of same thickness. Hence CFRP-Al panel can withstand force greater than that of Aluminium panel.

The density for Aluminium is found to be 2.88 gm/cc and for CFRP-Al sandwiched panel (of 6mm thickness) is 1.71 gm/cc. Hence it can be noted that there is a huge decrease in density of fabricated sandwiched panel.

VII. CONCLUSIONS

1.The weight of CFRP-Al panel has been reduced by 40% compared to Aluminium panel of same dimensions.

2.Since the weight of CFRP is less, it can be used as an alternative to the Aluminium alloy in aircraft industry.

3.The buckling load carrying capacity of CFRP-Al panel is increased by 38% as compared to Aluminium panel of same thickness. Hence CFRP-Al panel can withstand force greater than that of Aluminium panel.

4.Deformation will be less in CFRP-Al panel compared to Aluminium panel.

5.From the graph, it has been observed that as the CFRP-Al sandwiched panel thickness decreases the buckling load carrying capability decreases. And also the sideways deflection increases for given load.From this we can conclude that, for a given thickness of panel, the CFRP-Al sandwiched panel can withstand more buckling load compare to Aluminium without leads to failure.

REFERENCES

[1] R. Thamarai Kannan, Shibu.S, "Fabrication and Buckling analysis of Glass Fiber Reinforcement Polymer cylinder and Aluminium cylinder". - JCHPS Special Issue 9: April 2015.
[2] Deepak G, G. Tejani, "Experimental test on sandwich panel composite material", -IJIRSET, Vol 2, Issue 7, July 2013.
[3] Shivraj, Ranganatha, K.E.Girish "Plasticity Correction Factors for Buckling of Flat Rectangular Glare plates loaded in Compression or Shear". - ICAS 2002 CONGRESS.
[4] Haim Abramovich, Tanchum weller, "Buckling and postbuckling behavior of laminated composite stringer stiffened curved panels under axial compression: experiments and design guidelines". - Journal of mechanics of materials and structures Vol 4, No.7-8, 2009.
[5] Joseph Clint, Santosh kumar, "Buckling and linear analysis of fuselage structure subjected to air load distribution". - IJARSE, Vol. No.3, Issue No.9, September 2014.
[6] Nazumuddin Sheik, "An Experiment investigating into the buckling of GFRP stiffened shells under axial loading". Scientific Research and essay Vol.4(9), pp.914-920, September 2009
[7] V.S. Ramamurthy, G. Vamja,"Buckling Analysis on Aircraft Fuselage Structure Skin". - 2014 IJEDR, Volume 2, Issue 4.