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EXPERIMENTAL ANALYSIS OF FLEXURAL STRENGTH ON GLASS FIBER SANDWICH COMPOSITE BY VARYING Z-PINS PITCHES

Pravin*, Jeyapratha

* School of Aeronautical Science Hindustan Institute of Technology & Science, Hindustan University, Chennai, Tamil Nadu, India

School of Aeronautical Science Hindustan Institute of Technology & Science, Hindustan University, Chennai, Tamil Nadu, India

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ABSTRACT

This paper ambit to evaluate the flexural strength of glass fiber sandwich panels with varying z-pins pitches. Failure of sandwich panel are delamination and core shear, to minimize the crack propagation, pins are inserted in z-direction, by varying pitches through its thickness. During the insertion of pin, may cause the material some damage. Despite the damage, flexural property does not affected due interpolation of pins. Although the experiment were pull out with a phenomenal results of z-pins compared to the unpinned sandwich panel.

KEYWORDS: z-pin, glass fiber, pitches, delamination, square pattern.

INTRODUCTION

In aerospace department a lot of research work is going in sandwich composite structure to fulfil this requirement like lighter and stronger materials to satisfy the advancing technology. The composite structure has weight reduction up to 30% can be achieved over conventional structure, outstanding rigidity and high stiffness. This also used in many areas of aircraft like wing, fuselage, spar, webs, tail plane skin and radome. Furthermore in sandwich structure, a phenomenal innovation is the z-pin. A thin metallic rod which is interpolated through the thickness in z-direction is called z-pin. These pins are made from a structure material like mild steel. Z-pin helps to increase the damage tolerance structure and minimize the core shear failure. The pin dia 1mm and length of 1.5cm is chamfered for an ease insertion. The low pin volume is used for increase damage tolerance. Z-pins are inserted into polyvinyl foam with two different pitches into the thickness. Pitch I has a square pattern with 1cm distance with each pins. Pitch II has a square pattern with 2cm distance with each pins. Finally the plate is undergoing vacuum infusion process for the cure cycle for the sandwich composite. The effect of both pinned and unpinned performance of sandwich panel in bending test is compared and the pinning can arrest the crack propagation and improve the strength. In experimental research has revealed the delamination of composite material properties can be increased greatly by interpolation of z-pinning. According to research survey result, it reveals that the mechanical properties of the material is improved by z-pinning. A literature on the mechanical properties of x-cor and k-cor sandwich panels was investigated by Marasco et al (2006). He tested the materials which are inserted with fibers in the core z-direction (z-pinned).

Rice et al (2006) discussed the flexural behavior of hybrid sandwich panels. The steel or carbon fibers pins were inserted into the foam core. The flexural behavior of the panels are used to evaluate the collapse characteristics of the sandwich panels. Kocher et al (2002) discussed the advantages of a truss-reinforced panel which includes delamination control and face stability. The skin local stability is greatly improved by truss foam filled core, particularly if the angle between the facings and pins is large. The highest stress concentration zone was observed in truss facing junction of the truss-core sandwich panels. According to this study, the main advantage of adding the foam in the core was to protect the steel pins from corrosion.

Then A.P.Mouritz (2006) investigated the effect of pinning of flexural properties, of carbon/epoxy laminates. However, the flexural modulus is not changed for the range of pin contents and pin sizes studied. This paper examine the influence of z-pin length on the delamination of glass fiber sandwich composite. The flexural properties of both pitch I and pitch II are experimentally determined.

EXPERIMENTAL PROCEDURE

The flexural test specimens are of two type pitch I and pitch II were made using glass fiber sandwich composite. The z-pins used in this study is steel rods with dia 10mm and length of 15mm is made. These pins are inserted through the polyvinyl foam which is the core form of sandwich panel with density 80 kg/m^3 and thickness 10mm. The pins were inserted in two different pitches, pitch I is 1cm square pattern and pitch II is 2cm square pattern. Square patterns is equal distance between each pins. Then the glass fiber cloth with unidirectional ply for face sheet is placed on top three layers and bottom three layers of glass fiber cloth is placed with 30cmx30cm.

The specimen is moved to the vacuum infusion process. This dry materials are taken into a mold surface and a thin plastic vacuum bag is sealed around the part perimeter. Air and the applied atmospheric pressure are pumped out through vacuum pump to consolidate the dry materials and create a vacuum place. Resin is then introduced into the cavity via placed resin feeder lines.

(a)Vacuum pump **(b) Resin trap or catch**

Fig 1

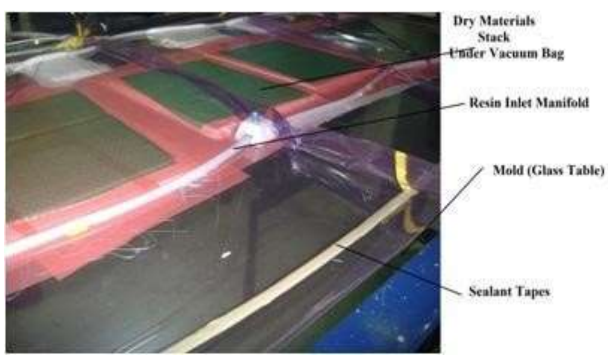

Fig 2

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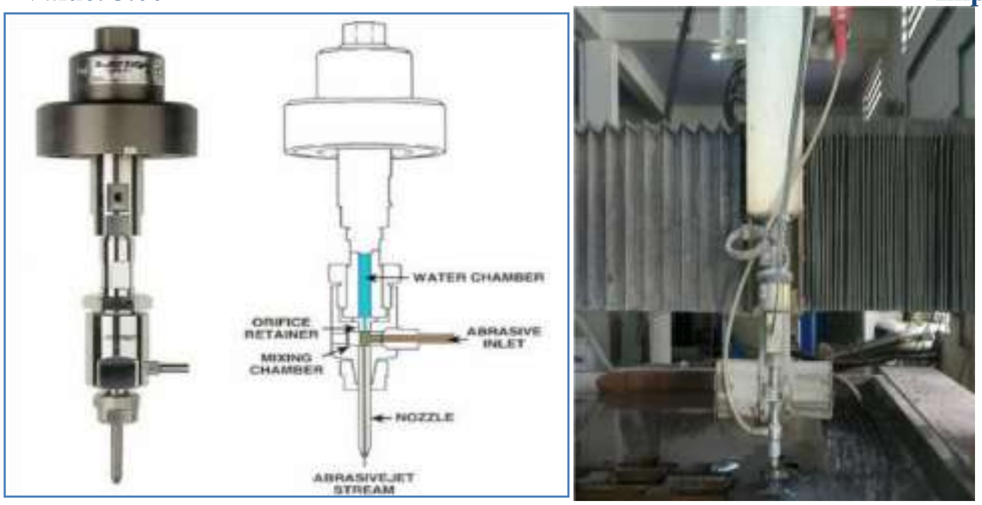

(a) Nozzle and schematic diagram **(b) Machine cutting the specimen**

Fig 3

Then the epoxy resin (GY 556) and curing agent harder (C2963) is mixed in the ratio of 10:1. The pressure differential between the outside atmospheric pressure and the cavity pushes the resin through the porous materials until the part is completely saturated. After several hours of curing, specimen is taken for the water jet cutting process which is shown in Fig 3. Then these specimens are taken for bending test.

FLEXURAL TEST

Flexural test was carried out according to ASTM C 393-62. As per the standard the test specimen cross section is rectangular in shape. The final dimensions were taken as 30mm wide and 180mm long. Fig 4 shows the dimension. The bending strength was calculated by using the following equation,

$$\sigma_B = \frac{3PLs}{2bd^2} \quad (1)$$

The bending test was conducted with a cross head speed of 2mm/min using universal machine and the support span length used was 120mm as per standard. First the unpinned sandwich panel and then the both different pitch sandwich panel is tested.

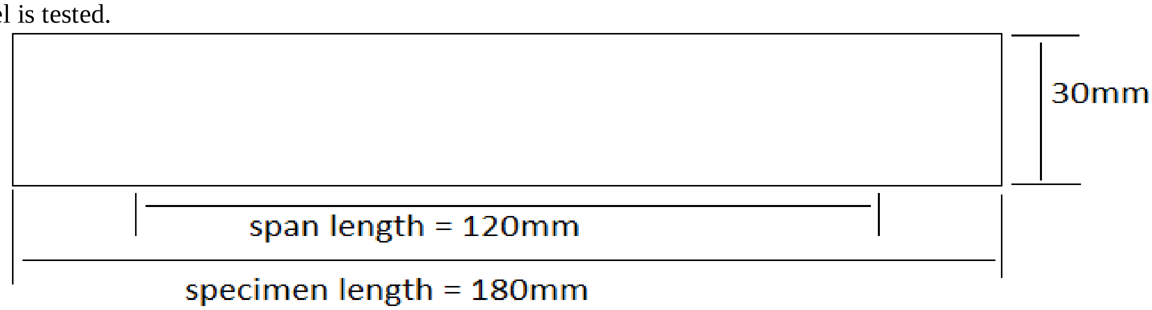

Fig 4 Specimen

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Fig 5 Specimen for testing

RESULT AND DISCUSSION

The theoretical flexural rigidity (D_T) value was found out using the sum of flexural rigidities of the constituent parts about the centroidal axis of the sandwich beam shown in equation (2)

$$D^T = E_f \frac{bf^3}{6} + E_f \frac{bfd_c^2}{2} + E_C \frac{bc^3}{12} \quad (2)$$

where, E_f stands for modulus of facing (bending), E_c is modulus of core, b is width of sandwich beam, 'f' is face thickness, 'c' is core thickness and 'd_c' stands for distance between the facing centroids. The moduli of the core are taken from manufacturer's data sheet. The experimental determination of flexural properties of pinned foam sandwich panel with pitch 1 and pitch 2 were found out. The specimens from each type of unpinned, pitch I square pattern with 1cm and pitch II square pattern with 2cm sandwich composite were tested in bending test and average results were presented in Table 1. Figure 6 shows Load vs. Deflection (comparison) curve of pinned and unpinned specimens.

Table 1 Properties of sandwich composite tested under 3- point bending

Specimens	**P_{cr} (N)**	**Flexural Stiffness (MN-mm^2)**	V_f **(MPa)**	τ_c **(MPa)**
Unpinned	313	7.12	95.48	0.862
Square pattern pins (1cm)	248	5.58	62.12	0.452
Square pattern pins (2cm)	357	7.85	110.33	0.980

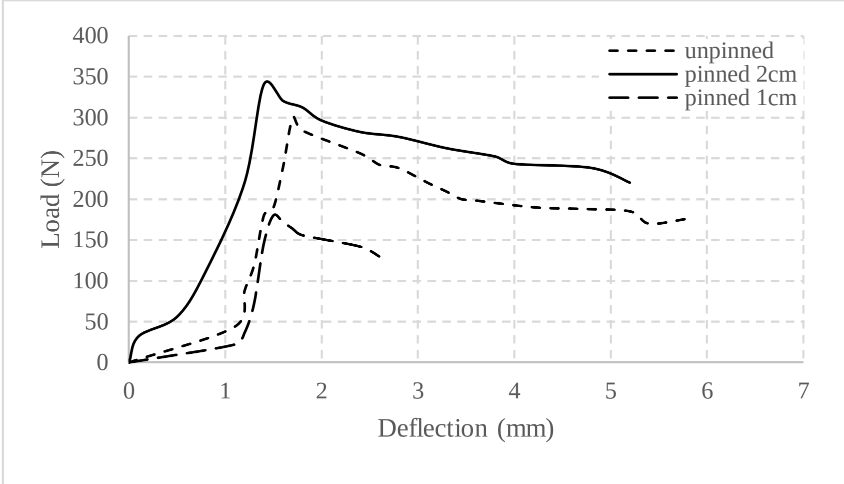

Figure 6 Load vs deflection (comparison) curve

4.1 Effect of stress

The stresses have main role on the material strength and durability. According to sandwich beam theory, the maximum normal stress on the face is

$$\sigma_f = \frac{M}{bfd} \qquad (3)$$

Where, V_f is the maximum normal stress and M is the bending moment. It has been found that the stress is varying from 95.48 MPa for unpinned specimen to 110.33 MPa for square pattern of 2cm pitch pinned specimen. Similarly, the shear stress in the core is

$$\tau_c = \frac{P}{bd} \qquad (4)$$

and it has been found that the stress is varying from 0.862 MPa for unpinned specimen to 0.980 MPa for square pattern of 2cm pitch pinned specimen. This variation was attributed to the type of pile support provided by pins and their orientation which received sufficient stiffness by soaking up resin materials. Adding up, it can be ensured that bending moments for both tensile and compressive stress is carried out while the core carried the transverse force in form of shear stress. The compression is sizably repelled by the pinned during bending. Pitch I values for both is less because due to closer interpolation of pins crack propagate more and in return the material fail.

4.2 Effect of pinning

Two different pinning pitches for sandwich panel has been shown as significant variance in deflection values as well as bending load tolerance as shown in Figure 6. It has been found that the specimens have 2cm pitch pinning orientation produced highest bending load as shown in Table 1 in comparison to other pinned and unpinned conditions. Lowest values were observed for the 1cm pitch square pattern pinned sandwich panel and it is about 52.86% less compared to 2cm pitch pinned panel. This was attributed to additional support provided by pins. In addition, these pin contributions are depended on pitches. In case of 2cm pin pitches which led to the higher bending strength and higher core shear strength compared to 1cm pin pitches and unpinned panels. For other pitches like 1cm and unpinned sandwich panels it was observed that there is less load carrying capability compared to 2cm pins pitches.

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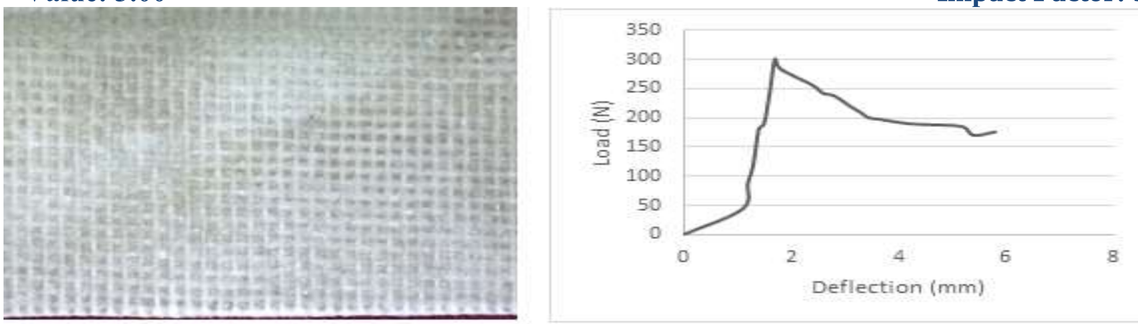
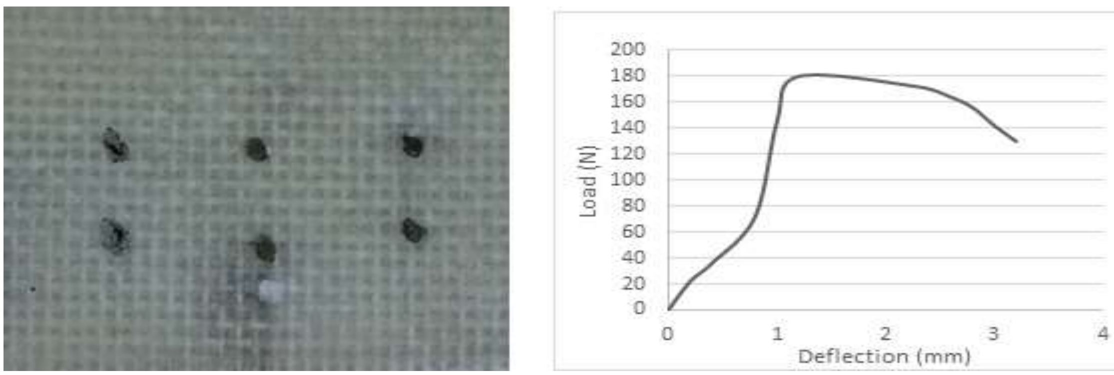


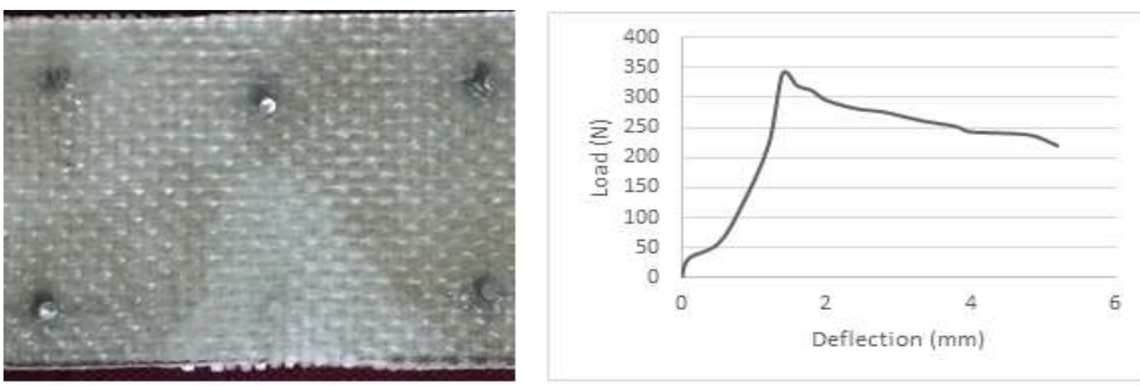
(a) Unpinned specimen ***(b) Graph for unpinned***

Fig 7



(a) 1cm pitch specimen ***(b) Graph for 1cm pitch***

Fig 8



(a) 2cm pitch specimen ***(b) Graph for 2cm pitch***

Fig 9

CONCLUSION

This project deals with the flexural characterisation of pinned foam sandwich panels based on experimental studies and observations. This research work has phases such as materials selection, characterisation of GFRP skins, drilling of foam core using hand layup and design of multiple pin, design of fixture for pinning the sandwich panels at different pitch orientations with varying pitches, vacuum infusion method adopted for fabrication of specimen as per ASTM standards. Finally the flexural characteristics of sandwich panels has been determined.

Open form GFRP 10mil cloth, PVC closed cell form of density 80kg/m^3, low viscous epoxy resin and pins were selected for this work. Flexural characterization of GFRP face skin were carried out as per the ASTM standards in the work. The Young's modulus of elasticity, modulus of elasticity due to bending were found out and multiple pins were designed and fabricated. Foam core at different patterns such as square pattern with 2cm and square pattern with 1cm were drilled using hand layup. Closed cell foam core both pinned and unpinned sandwich panels were fabricated using vacuum infusion method. Infusion offers several benefits over convention hand lay-up techniques. It protects workers and the environment from harmful VOC emissions and eliminates the hazardous act of applying resin by hand. It also permitted a large set up time as the resin was not catalysed until the materials were in place. The vacuum bag as well as improved mechanical properties and low void content.

The final phase deals with the flexural characterisation of sandwich panel with and without pinning. The observation and inferences are (i) The pinned sandwich composite significantly increased the load carrying ability of the sandwich compared to unpinned sandwich composite. (ii) As the experimented with various orientations of pinning, it was found that the square pattern with 2cm pinned pitch have highest load bearing compared to other orientations. While the impact energy has increased, the following characteristics were also observed from the load time plots of the through thickness pinned sandwich panel and unpinned panel. (iii) As a main point of remark from the experimental studies, it emerged that the considerable weakness of the sandwich extra-skins in engineering applications could be quite relevant and this should be at least partially eliminated.

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