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Noval Method for Fabrication of 3-D Spacer Fabric Composite and Investigation of Mechanical Property

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Abstract: *The paper deals with the fabrication and flexural property studies of 3D Spacer fabrics with three different stiffener height, i.e., 5mm, 10mm and 15mm. The specimens were fabricated over two bidirectional woven fabric surfaces of glass fiber reinforced composite face sheet which were mechanically connected with vertical threads. An innovative stitching technique was used. The flexural strength and deflection of fabricated specimens were determined through three point bending test (ASTM C 393-62). A significant increase in flexural rigidity was observed when it compared with other panels, and found it is highest for 3D Spacer fabric with stiffener height 3415mm. Also, the results proved that flexural strength of 3D Spacer fabric increases with respect to the height of the stiffener. Also the results were compared with simply glued sandwich composite of thickness 15mm and found a significant improvement in flexural strength of 3D spacer fabric composite compared to glued composite.*

Keywords: *Deflection, Elastic modulus, Flexural rigidity, Stitched core sandwich, 3-point bending*

I. INTRODUCTION

The concept of use spacer fabrics in composite sandwich structures was first devised in 1985 in both katholieke universiteit leuven (Belgium) and university of Stuttgart and MBB (Germany). Some researchers have evaluated drum- peel strength, flat-wise compressive strength and transverse shear modulus of the mono-spacer fabric composite panels. It was proved that the fabric composites featured a very high skin core debonding resistance and the pile played an important role on the flat wise compression and shear properties. 3D spacer fabric constructing is a newly developed concept. The fabric are strongly connected to each other by the vertical pile fibers which are interlinked with the skins.

In comparison with the face sheet reinforcement spacer fabric composite, here the composite without additional weaves is called monospacer fabric composite two kinds of mono-spacer composites with integrated hollow cores have been developed, one with 8-shaped piles and the other with corrugated piles. The mechanical characteristics and the damage modes of these mono-spacer fabric composites under different load conditions show considerable change in results. Besides, effects of pile distribution density and pile structure on the composite mechanical performances were different.[1]

Mechanical properties of 3-D spacer fabric, a new sandwich structure, developed by integrally woven technique composites have super-high specific strength and specific stiffness. Face sheet-reinforced 3-D spacer fabric composites were investigated experimentally by laminating additional glass weave at the skin sheets. Effects of various factors on the mechanical properties, such as the additional layer number, the type of glass weave, and the lay-up type were also discussed. Furthermore, an innovative integral multi-face sheet structure composite was developed by directly weaving three uniformly spaced factsheets' in one construction. The mechanical performance was compared with bonded multi-face sheet spacer fabric composite and mono-spacer fabric composite under the same conditions. The results indicated that additional weaves could strengthen the composite face sheets greatly, and the multi-face sheet structure could improve the properties correlated with the piles effectively.[2]

Compressive behaviors of 2-D basalt fiber laminated plain woven composite and 3D basalt fiber orthogonal woven composite were tested under various strain rates and compressive stress strain curves were obtained at various strain rates ranging. The compressive curves exhibited strong strain-rate sensitivity. Compression modulus and failure stress of the 2D woven composites are both greater than those of the 3D woven composite under the same strain rate. The main failure mode of the 2D woven composite is delamination both along in-plane direction and through thickness direction. As the impact velocity increases, the 2D woven composite will be in debris owing to the resin cracks, whereas for that the 3D orthogonal woven, there is no delamination between each layer because of the binds of Z-yarns. The 3D woven composites will also be in debris under high strain rate compression when the Z-yarns break.[3]

The characteristics of different spacer fabrics including low-stress mechanical properties, air permeability and thermal conductivity were investigated in three dimensional spacer. Low-stress mechanical properties obtained by the KES-fabric evaluation system revealed that all tensile, bending and compression properties of spacer fabrics are greatly depending on the type of spacer fabric, the type of spacer yarn used , the yarn count of the spacer yarn, the stitch density and the spacer yarn configuration. Air permeability and thermal conductivity of spacer fabric are closely related to the fabric density. This experimental work suggests that carefully selecting the spacer fabric according to the envisaged application is of primary importance.[4]

II. MATERIALS AND EXPERIMENT

Three-dimensional sandwich composite is a newly developed sandwich structure, the reinforcement of which is integrally woven by advanced textile technique. Two face-sheets are connected by continuous fibers, named pile in the core, providing excellent properties like outstanding integrity, debonding resistance, lightweight, good design ability and so on. In this paper, specimens were fabricated with various stitching orientation with glass fiber reinforced face sheet and Divinycell core and compared with unstitched sandwich composite. Both the fabrication and testing methods are mentioned in following paragraph.

1. Preparation of 3D Spacer Fabric Composite Specimen

Divinycell closed-cell 'H' grade foam core (density = 80kg/m3, thickness = 10 mm) was used as the core material along with the woven open form glass fabric face sheets of 10 mils thickness. Panels with closed cell foam sandwiched between two layers of bi-directionally woven glass fabric on each side were put for fabrication. Newly developed fixture was used for stitching the sandwich panels with stiffner height 5mm, 10mm and 15mm as shown in Figure-1. The fixture consists of two wooden slots. The material has to be place in between them. The rubber dampers had been used for to give additional stiffness for stitching.The Glass Yarn G37 1/5 3.8S was used for the stitching of the sandwich panels. A low viscous epoxy resin based on bisphenol constituent and modified with aromatic glycidyl ether called Araldite GY257 with hardner C2963 manufactured by Huntsman, Australia, was used for the fabrication of the panels. The resin and hardener was mixed in a proposition of 100:45 respectively. After stitching, the spacer fabric composites were prepared using the hand layup process. The specimens were allowed to pre cure for 24 hours at room temperature conditions at laboratory, and then kept for 7 days for post cure before taken out for experimental studies. The configuration of 3D spacer fabric composite specimen are shown in Fig. 2 and 3, respectively.

2. Tension Test

3D spacer fabrics were prepared and tested according to ASTM C297 to determine the tensile properties. The 3D spacer fabrics were cut such that the properties in the direction perpendicular to rise would be the direction of flexural stresses in the sandwich panel. The specimen had a 70 x 70 mm cross-section.. The tests were conducted in Universal Testing Machine with wedge-type mechanical grips and with a displacement rate of 0.5 mm/min at Microlab, Ambattur industrial estate, Chennai as shown in Fig. 4 The force - strike curves were obtained for each stiffener height as shown in Fig. 5, 6 &7.

3. Flexural Test Procedure

The sandwich panels were tested in a 3-point bending test as per ASTM standard C393-63. The support span dimension a1 was calculated from equation 1.

$$a_1 = 2fF/S \qquad (1)$$

The allowable facing stress F (182Mpa) for the E glass fabric was found out by 3-point bending test using ASTMD790M, f represents facing sheet thickness (0.4 mm). The allowable core shear stress S (1.15 Mpa) was taken from the manufacture's data sheet (24). The 3-point bending test was conducted. The theoretical flexural rigidity (D) value was found as shown in equation 3.

$$\delta = \frac{Pl^3}{48EI} \qquad (3)$$

$$EI = \frac{Pl^3}{\delta\ 48} \qquad (4)$$

Where *P* is the load, *l* is the length of the specimen, δ is the deflection, *E* is the Young's modulus and *I* is the moment of inertia. Five specimens of each type of sandwich composite were tested in three point bending test and average results were presented in Table 1.

III. Results And Discussions

The flexural stiffness of sandwich composite is an essential determining factor for application of the material on design. Generally, the compositions of sandwich material have higher elastic modulus of face sheet compare to elastic modulus of face core. Here, it is approximately 243 times higher as observed from experiment. In addition, the thickness of the face sheet (i.e., only 0.4mm) is quite small compare to the thickness of core material (i.e., 10 mm). It has been observed that the 3D space fabric with stiffener height 15 mm has highest flexural rigidity compared to all other specimen tested.

IV. Figures And Tables

Fig. 1

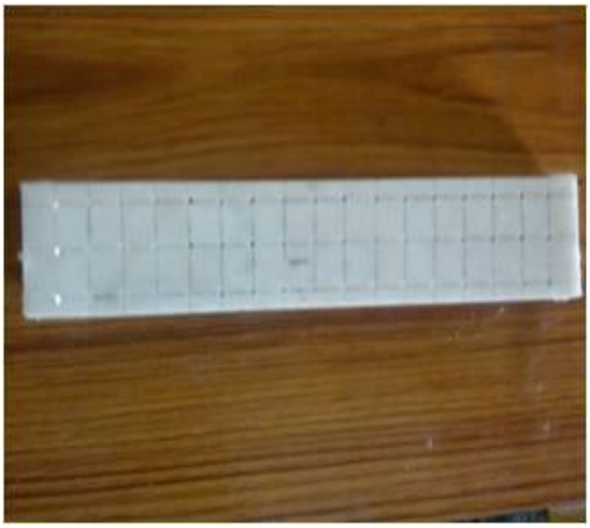

Fig. 2

Fig. 3

Fig. 4

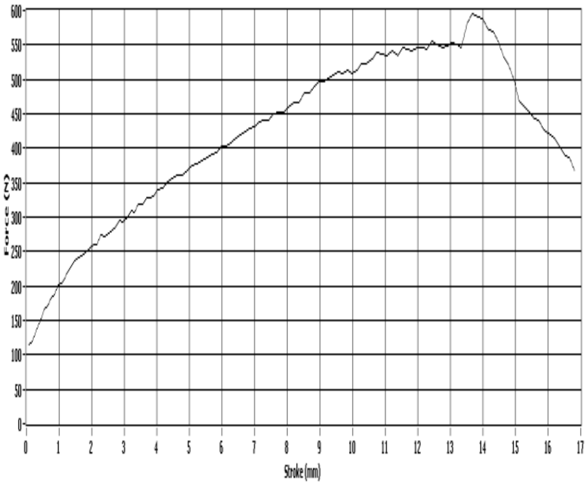

Fig. 5

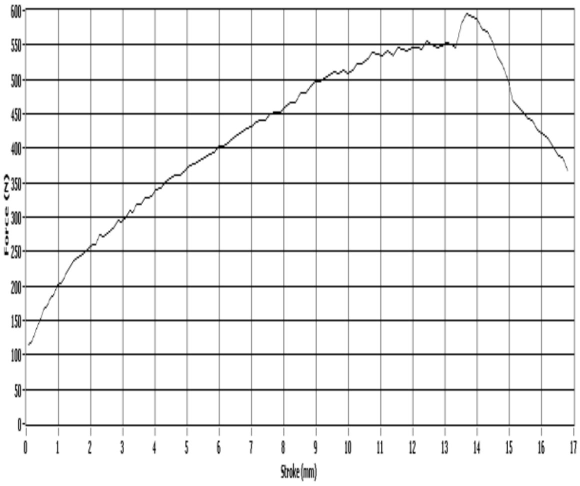

Fig. 6

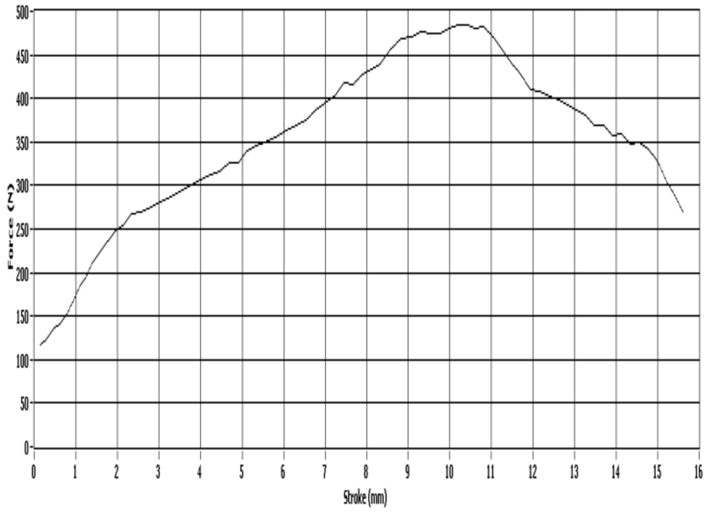

Fig. 7

Specimen	Length mm	Width Mm	Thickness Mm	C.S Area mm²	Flexural Rigidity (E*I) Nmm²
Stiffener height 5 mm	300	36	396	50	3645000
Stiffener height 10 mm	300	36	420	50	5062500
Stiffener height 15 mm	300	36	576	50	5315625
Sandwich with thickness 15mm	300	36	612	50	4339285

Table 1

V. CONCLUSION

The present paper focused on the mechanical experimental characterization and numerical simulation of Divinycell closed - cell 'H' grade foam/glass fibre composite sandwich conceived as a lightweight material for various engineering applications. The experimental campaign confirmed the remarkable potentialities of the innovative sandwich structure with core and skins interconnected by transverse stitched plies. Based on the experimental and numerical analysis the following concluding remarks revealed.

1. If the thickness of the 3D spacer fabric increases the flexural rigidity of the specimen will also lead to increase.
2. The failure mode of the 3D spacer fabric composite has distinct into two different categories as the face sheets failed by compressive and tensile load whereas the core failure occurred due to shear failure.
3. The use of foam to fill the sandwich core appears to increase the sandwich stiffness and strength quite remarkably with respect to lighter but weaker solutions: at the same time it furnishes a drastic weight saving with respect to a fully laminated glass fibre reinforced plate.
4. As a main point of remark from the experimental studies, it emerges the considerable weakness of the sandwich extra-skins in real engineering applications could then be quite relevant this should be at least partially eliminated or reduced by improving the production technology on this specific aspect.

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