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Experimental Study of Three Dimensional Spacer Fabric Composite

D. Shalini priya[1], Dr.R.Santhana krishnan[2]
School of aeronautical science, hindustan institute of technology and science, chennai, India
School of aeronautical science, hindustan institute of technology and science, chennai, India.

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ABSTRACT
Three dimensional spacer fabric composite are generally knitted fabric that have two, usually faces and a pile of varying thickness between the faces. Spacer fabrics have properties such as debonding resistance, good design ability, light weight etc. In this current study, two face sheet of 3-D spacer fabric are connected by continuous fiber and core named pile to be developed with varying pile orientations. Then the pile cores are filled with poly urethane foam by injection method there by threepoint bending test were conducted to determine the flexural rigidity. For this purpose 3D foam filled and without foam filled spacer fabric was laminated where the glass fabric is considered as a material which is not able to carry bending moments, while the surrounding resin behaves as a homogenous solid. In order to evaluate the mechanical tests, three point bending were accomplished according to ASTM standards which shows 3D integrated foam core provides better bending stiffness than the traditional sandwich composites.
KEYWORDS: *spacer fabric, weft and wrap direction, piles, mechanical perfomances.*

I. INTRODUCTION
Three-dimensional composites utilize fiber preforms constructed from yarns or tows arranged into complex three-dimensional structures. These can be created from a 3D weaving process, a 3D braiding process, or a 3 D lay of short fibers. A resin is applied to the 3D preform to create the composite material. Three-dimensional composites are utilized in highly engineered and highly technical applications in order to achieve complex mechanical properties[1]. an overview of the mechanical properties of the core of woven sandwich panels is studied. The basic mechanical properties of the sandwich core were evaluated with those of other core materials[2-5]. Acceptable mechanical properties for cores of higher thickness (10mm) can be obtained by weaving part of pile fibres in the core under angles 45deg,by creating networks of piles at lower degrees of streching and sufficient pile density, or by filling the core with the foam. Thus appears strongest effect between the pile and foam propertiessandwich panels[6-8].Investigation shows that the Compression resistance is good and the shear resistance can be brought to acceptable level by weaving piles of 45deg[9].Spacerfabrics areakindof3Dmanufacturedtextilestructuresinwhich two outer fabric layers are connected by a layer of pile thread where the Spacer fabrics are created by connecting two independently knitted fabrics with spacer yarns so that the fabrics have a three-dimensional appearance.In general, spacer fabrics are categorized by their knitted structure, which is eitherwarporweftknitted[10].Theinsertionoftheweft andwarpyarnsenables this structure to have the characteristics of both biaxial and spacer structures, which can be summarized asfollows:

1. High structural stability is obtained due to the insertionofthe non-crimp biaxial yarns in the knitted surfacestructures
2. Delamination is avoided because the two surfaces are connected byyarns.
3. All kinds of yarn can be used as insertion yarns and connecting yarns.
4. Good acoustic and thermal insulation properties are obtaineddue to the 3D spacer structure; the space between the two surface layers can be altered according to theapplicationrequirements
5. Combinations of the different kinds of the yarn in a structure are alsopossible.

TheycanalsobeusedtoreplacePUfoambecausetheyhavebetterheatand moistureexchangecharacteristics.Sincespacerfabrics canbeproducedina single process, the laminating and bonding processes areeliminated.Spacer fabrics have advantage to achieve high thickness in composites to avoid drawbacks that the laminates entail such as delamination. Spacer fabrics show lower elasticity compared to conventionaltextilestructures,andtheirthicknessislimitedbythepileyarn property. Five samples of size 180 mm× 30mm were subjected to load increased linearly with increasing midspan deflection.

II. MATERIAL AND SPECIMEN FABRICATION

2.1 3-D spacer fabric composite

Two face sheets of 3-D spacer fabric are connected by continuous fibers, named pile in the core providing excellent properties like outstanding integrity, less weight, good design ability. The thickness of the fabric is 10mm with 320gsm. In this work 3D woven fibers are used.ARALDITE GY257 resin is used here. Due to its low viscosity and the full crystallization resistance it has very good processing properties, good mechanical performances and good surface penetration.ARADUR 2963 hardener is used here. It have properties of good flexibiity and hardness, low viscosity and good cure speed with boiling pointof 200^{0}C and flash point of 108^{0}C.3D Woven fabric has been used for recent years to provide through the thickness reinforcement in composite structures, primarily to improve the mechanical performances. Researchers are mainly concentrated on the characterization of piles in the panels, leaving the general aspects on how to manufacture such through thickness reinforced structures largely untouched.In this work, three spacer fabric composite specimen were prepared by using hand. In order to minimize possible damage to the panels, through- the-thickness piles is performed on the panels before applying the resin application. However , from the reinforcement point of view, piles strength and stiffness also preferred strong between the top and bottom face sheets.

The pile between the two layers of woven fabric 15 × 15 cm is injected by polyurethane foam to determine its flexural properties with varying pile orientation of spacer fabric composite.The 3D spacer fabric of bi- directional woven face sheet are connected with vertical piles. Two S- shaped yarns combined to form 8 –shaped piles in the X-direction called warp direction and a I-shaped piles in the Y-direction called weft direction. The pile yarns in the face sheets are in the warp direction, along which the 3-D spacer fabric is rolled up. The fabric structure parameters are designed with variable pile heights and orientation, and the distribution density of piles in the warp and weft directions. As a reinforcement of composites, the 3D spacer fabric can be made of glass fiber, carbon fiber, basalt fiber or hybrid yarns. In this work 3-D spacer fabrics were woven with E –glass fiber and the resin used to produce composite was ARALDITE GY257 cured with hardener ARADUR 2963 which had an appropriate viscosity at room temperature and good wetting ability. The ratio of resin to the hardener is 100:45

2.2 Fabrication of spacer fabric composite

The fabric was cut into proper size 15cm ×15cm and the amount of resin was calculated and it should be deaired before using toprevent air bubbles carried into fabriccomposites.

A flat wooden plate mold assisted by cushion blocks and clip holders was used and first 30% of resin applied evenly on the mold and the fabric was placed it with wrap direction parallel to the longitudinal direction of cushionblock.Again other 70% of resin applied to top facesheet where viscosity plays an vital role. Moreover a pair of opposing were exerted in the weftdirectionontopandbottomfacesheetstoensurepileangleand height.The resin content of spacer fabric was tested by burningweight-loss method. After resin cured and edges are trimmed, then testing are to bedone.The facesheet thickness of spacer fabric composite was found to be 10mm.A schematic of the obtained sandwich panel is shown in Fig 1 a selection of panels are based on glass fibre fabrics. The pile length varies from 8 to 10mm .The fabric structure parameters can be designed variably including the pile height,the distribution , density of piles the anisotropy distribution of the yarns in the weft and wrap directions.

(a)

2.3 Fabrication of foam-filled spacer fabric composite

The laminates manufactured was dried for 24 hrs,then by preparing mold according to fabric core material position liquid wasinjected.

By applying hydraulic pressure of about 0.5bar polyutherene liquid spreads eventually along thefabric.

The complete rise does not takes place at low temperature , hence to avoid it mixture should be injected into the hollow interstitial space of 3D integrated core sandwich panel temperature of entire assembly has to beraised.The nominadensity of the foam is 63.8kg/m^3.Different steps involved in the process are represented pictorially in below figure 2.

(b)

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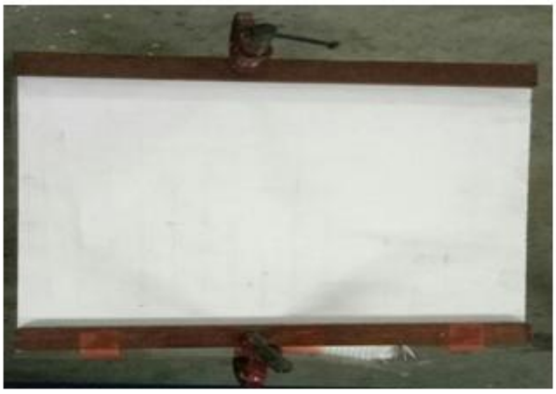

Fig 1 **(a)** without foam filled spacer fabric **(b)** foam filled spacer fabric © fixture for mold

III. MATERIAL TESTING

3.1 Three point bendingtest

All of the mechanical tests in the current study were performed by a Zwick Rockwell universal testing machine. The jack has a static capacity of 50 kN with a maximum stroke of 300 mm A constant movement rate of 0.5 mm/min of the movable head of the testing machine was applied through all types of mechanicaltests.

The specimen made of a parabeam 3D woven E-glass fabric impregnated with ARADUR 2963 resin using hand lay-up process. The resin content of the final panels was 55% in weight. Specimens with thicknesses of 10 mm were used for each type of tests. Area density of panel is 2583 g/m^2 respectively. The thickness of panels' facesheets were about 0.60 mm and average distance between neighboring piles were 6.02 mm in warp and 3.73 mm in weft directions. The piles had an average diameter of 0.70 mm and made an average angle of 75° to the facesheets. Each of the presented data is obtained by at least five specimens in order to get maximum accuracy and to avoid probable errors.

(a)

(b)

Fig 2.Cross-section view **(a)**wrap direction **(b)**weft direction

3.2 Testingprocedure

In order to examine the behavior of 3D-fabric sandwich composites under bending loads, three point bending tests were carried out according to ASTM C393-63 test standard on specimens with an size of 180 mm × 40 mm Fig.5a shows the specimens under three point bending test respectively. The rate of displacement was fixed at 0.5mm/min and flexural stiffness (D) was calculated asfollows,

For simply supported beam ,

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$$\delta = PL^3 / 48EI$$

$$EI = D = PL^3 / 48\delta$$

Where, P = Lineraly increasing load

L = Span length

δ = deflection

In general, the load increased linearly with increasing midspan deflection . Besides, the facture in the facesheet while the facture in the wrap direction appeared to be in a region .

(a)

(b)

Fig 3. Samples of with and without foam filled spacer fabric

IV. BENDING TESTRESULTS

4.1 Without foam-filled 3D spacer fabriccomposite

The load–deflection diagrams of 3D without foam filled fabric sandwich composites under three-point bending are depicted in Fig 6.1 respectively. The results show that the warp direction show higher bending stiffness as is depicted in figure5 and 6, which was predictable by taking into account the higher shear modulus of warp direction in comparison withweft direction. The deflection curves exhibitit four stages : the elastic deflection, the skin compression fracture, the plastic rotation and the skin tensilefracture.

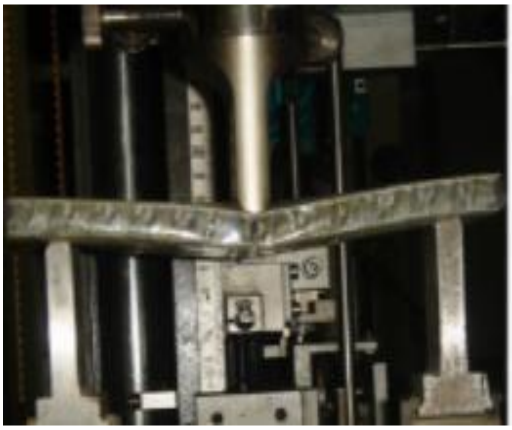


Fig 4 Specimen under bending

The maximum load of the beam with the short span is slightly larger. Besides the wrap beam , only a single crack was observed in upper skin desnse weft core constrained the local fracture in upper skin. The plastic rotation mechanism supported the bend force eventually the lower face was gradually fractured.

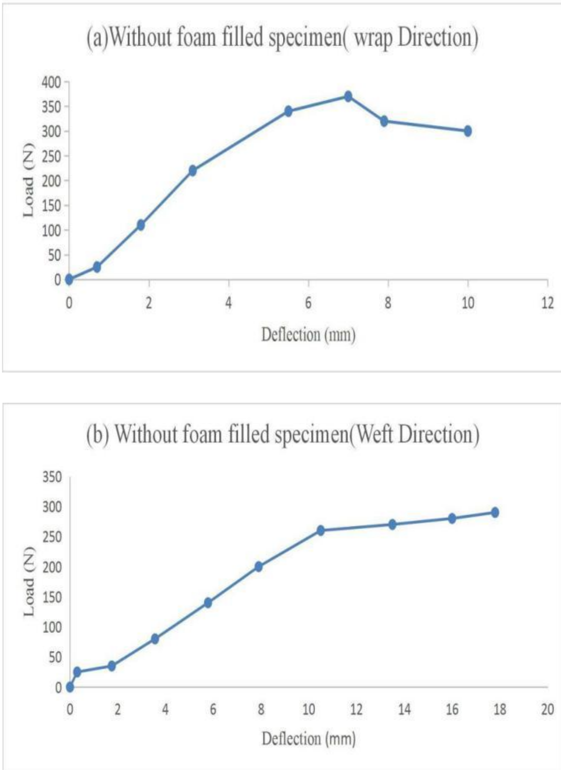
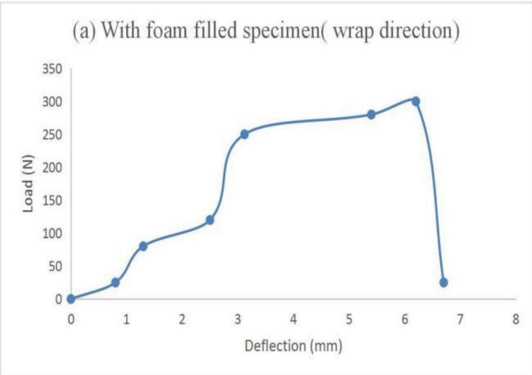


Fig 5 **(a)** Load -deflection based on three point bending (without foam) **(b)** Load-deflection based on three point bending test (with foam)

4.2 Foam-filled 3D spacer fabric composite

The load–deflection diagrams of 3D foam filled spacer fabric sandwich composites under three-point bending are depicted above respectively. The results show that the increasing load increases with decrease in deflection than without foam filled spacer fabric composites . Due toimpregnated polyutherene liquid it can sustain increasing load rather than plain spacer fabric, which considerably improves the load carry capability. The laminates of wovened glass fabric provides better performance due to theirstiffness.

The wrap and weft direction of spacer fabric deflection curves ae decipted in graph which shows weft direction deflects considerably with increasing load. The polyuthrenefoam filled helps laminate to resist debonding occurs in usal sandwich panels. The deflection curves reaches elastic deformation , compression fracture, plastic deformation and finally fracture/rupture.



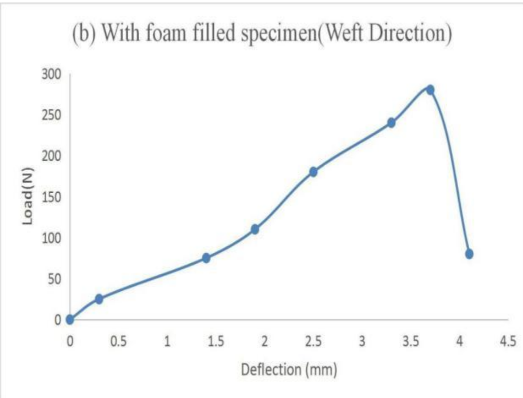


Fig.6 **(a)** Load -deflection based on three point bending (without foam) **(b)** Load -deflection based on three point bending (with foam)

V. CONCLUSION

The present paper concerns the prediction of the mechanical behavior of 3D woven glass fiber sandwich composites under dif- ferent mechanical test. For this purpose 3D foam filled and without foam filled spacer fabric was laminated where the glass fabric is considered as a material which is not able to carry bending moments, while the surrounding resin behaves as a homogenous solid. In order to evaluate the mechanical tests, three point bending were accomplished according to ASTM standards which shows 3D integrated foam core provides better bending stiffness than the traditional sandwich composites.

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