

# Effect of Stitching Angle on Impact Characteristics of Sandwich Panels

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**ABSTRACT:** The low velocity impact responses of sandwich panels with and without stitching were investigated using an instrumented drop weight impact tower. A novel stitching technique was developed to stitch the sandwich panel. Unstitched and stitched sandwich panels with pile orientation of 45° were fabricated using vacuum infusion process. Low velocity impact test were carried out with different energy levels of 2, 5, 10, 20 and 30J. The increase of the impact performances generated by the introduction of reinforcements compared to a traditional sandwich (unstitched) was quantified. The results also show that the ballistic limit of the sandwich panels were improved by employing piles in angle orientation.

**KEYWORDS:** Ballistic limit, Impact, Novel, Pile, Sandwich panels.

## I. INTRODUCTION

Composite sandwich structures offer many advantages such as high flexural stiffness, low weight and flexibility in selection from a broad range of materials. However damage in the structures may negate many of the benefits of sandwich constructions. Structural sandwich composites with composite face sheets are nowadays widely used in aerospace, marine, automotive, wind turbines, building and consumer industries. Impact can induce various types of damage in structure. The face sheet can be damaged through delamination and fibre breakage and the core can be damaged through crushing and shear mechanisms. Therefore the damage and the amount of deformation after an impact event is an important part of the impact study. Much of the earlier work involved in the study on sandwich composites under the impact loading focused on the honeycomb core sandwich constructions [1–3]. But the problem with the honeycomb sandwich structures are low surface area of core for bonding, the manufacturing and maintenance cost is high and is sensitive to hot and humid conditions. The advantages of sandwich constructions include anti hot and humid and adjustable density, and increase face bonding surface [4-5]. H Benson Dexter [6] fabricated a through thickness stitched foam core sandwich composite by using different processes like resin transfer moulding (RTM), resin film infusion (RFI), and vacuum-assisted resin transfer moulding (VARTM) in support of NASA research centre. Through the thickness stitching was one of the three ideas identified for increase damage tolerance [7]. Xia fan [8] conducted study on through the thickness without varying the stitch angle and found out that the average damage angle increase and the maximal cracking width and penetration depth of the stitched samples decrease. At present little work, speciality knowledge and literature are available on topic of varying the angle of stitch reinforcements. It was hypothesized that stitch angles more closely aligned with 45° measured from the horizontal would increase shear performance of the sandwich structure as it is known that under a state of pure shear stress, the greatest tensile stress is on a plane oriented at 45° to the original element.

## II. EXPERIMENTAL PROCEDURE

### 1. Material selection and specimen fabrication

The core material selected for this study was Divinycell closed-cell 'H' grade foam core (density = 80kg/m<sup>3</sup>, thickness = 10 mm). This foam core was chosen because of their superior fatigue and impact resistance, damage tolerance, light weight and excellent cost effectiveness. 320 Gsm with thickness of 10 mils woven open form glass fabric cloth was used as face sheets. The foam core sandwiched between two layers of woven glass fabric on each side. The newly

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developed fixture with multiple needles are shown in Fig.1 was used for stitching. The fixture has got one base plate, two vertical member with groove and two plates with slots. The vertical members are attached to the base plate. Two thin plates with slots were placed in between the vertical members and attached with screw and nut mechanism. The slots are provided in the horizontal plates for the needle to pass through the core and the face sheet. In order to place different thickness foam core, the gap between the two plates can be adjusted with the help of screw and nut mechanism. These two plates can be tilted in between the vertical members and the angles can be adjusted with the help of protector attached to the vertical member. The orientation of the pile can be varied with the help of the above mechanism. The multiple needle has got constrained motion i.e it can move in only one direction (up and down) along the groove provided in the vertical member. The foam core along with the face sheet were placed in between the two plates. The Glass Yarn G37 1/5 3.8S was used for the stitching the core and the face sheet using modified lock stitch method. The stitching has a step of 10mm that can be adjusted in the new set up. The pitch distance can be varied with the help of four small rollers attached at the four corners of plates. Three different types of pile orientation panels ( $45^\circ$ ) are prepared using the fixture. After stitching, the sandwich panels were prepared using the vacuum infusion process at DIAB core at Chennai, India. A low viscous epoxy resin based on bisphenol A modified with an aromatic glycidyl ether called Araldite GY257 and hardner C2693 were used for the fabrication of the panels. The resin: hardener was mixed in the proposition of 100:45 respectively by weight. Details of the properties of foam, resin and hardner and glass yarn were provided by the manufacturer [9-11]. The specimens are allowed to cure for 24 hours before they were taken out.

## 2. Low velocity Impact tests

An instrument equipped Fractovis Plus Drop -Weight Impact Testing Machine equipped with a data acquisition system and a pneumatic clamping fixture were used to conduct the impact test (reference ASTM D 5628 FE), shown in Fig. 2. The steel hemispherical impactor with a diameter of 20mm and weight of 3.2kg were adopted for all test, the 60mm×60mm samples were placed between the pneumatic clamps. The specimen support fixture at the bottom of the drop tower facilities a circular clamped condition with the clear span of 45mm. Heights were adjusted depending on the desired impact energy levels, impact energy levels of 2, 5, 10, 20 and 30 corresponding to drop heights of 64, 160, 318, 637 and 957 mm were used. In addition, the load time graphs for all samples were recorded. Peak load, energy absorbed, total time and load drops in the plot were indications of damage progression in the samples. M.Motuku et al [12] in their study conducted on Response of foam core sandwich composite: Effect of foam core density and face sheet thickness has clearly stated and demonstrated through experimentation that the increase in face sheet thickness of homogenous foam core sandwich composites does not have strong dependency on the compression response. This also corroborates with the study made by Reissner [13]. These have led not to include face sheet thickness as a variable for studying the low velocity impact response.

## III. RESULTS AND DISCUSSION

The contact force can also be defined as the reaction force applied by the specimen to the impactor. As indicated earlier the contact force or load verses time was obtained by a data acquisition system. When the impact energies are low the Load-time (L-t) curves are parabolic shapes and the maximal contact force increases with the increase of impact energy. Figure 2-6 shows the load time plot and the picture of the impact surface of the unstitched and stitched panels at different impact energies (2~30 J). The result shows that there is no visual damage on the top facing sheet when the impact is carried out with 2 J energy levels on all the panels.



Fig.1 Impact testing facility

The peak load capacity of the samples increase with the introduction of stitching through the thickness of the sandwich panel. At 2 J impact energy shown in Fig.3 that there was a steady increase in load carrying capacity from 773.37 N (unstitched panel) to 785 N (45° stitched panel) was observed. A small dent and a few fibres cracking appears on all the panels at 5J impact energy levels. The facing sheet of the unstitched sample is cracked at the maximum peak load of 916.41N and the foam crushing is limited to a small region below the cracked face sheets. For the 45° the face sheet is not fully crushed shown in Fig.4. It was noticed in the unstitched panel the top face sheet was punctured and the core was crushed at 10 J impact energy level shown in Fig.5. On 45° stitched panel top face sheet was punctured and the core failure was minimum shown in Fig.5. At 20 J impact energy level the two peak loads were observed on the unstitched panel indicating the damage of the top face sheet and the bottom skins starts to debond shown in Fig.6. On 45° panel top face was punctured fully and core failure was observed shown in Fig.6. At 30 J impact energy level the two peak loads were observed in the 45° stitched panel shown in Fig.7. Maximum load carrying capacity and ballistic limit of all the panels were presented in table.1.

**IV. FIGURES AND GRAPHS**

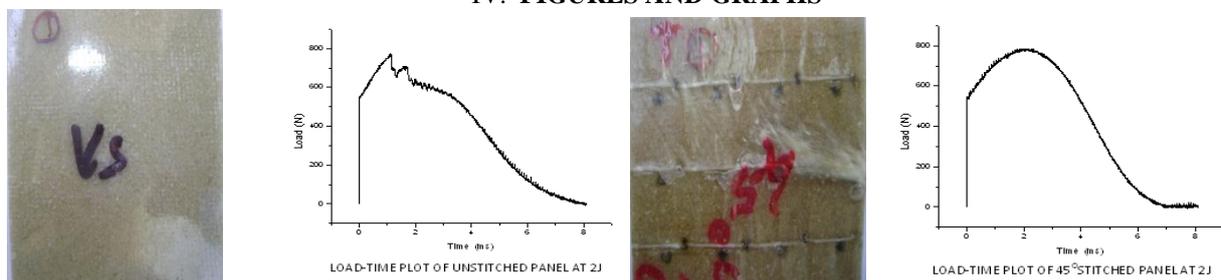


Fig. 2 Load-time plots and the pictures of impact surface after the impact at 2 J  
(a) Unstitched Panel (b) 45° stitched Panel

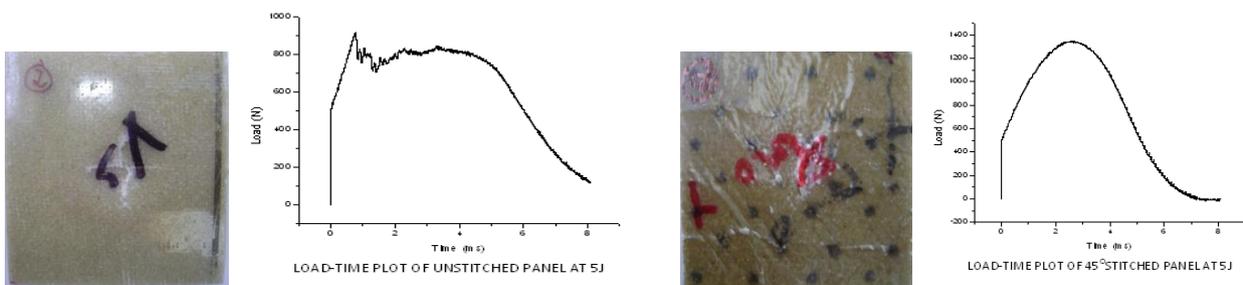


Fig. 3 Load-time plots and the pictures of impact surface after the impact at 5 J  
(a) Unstitched Panel (b) 45° stitched Panel

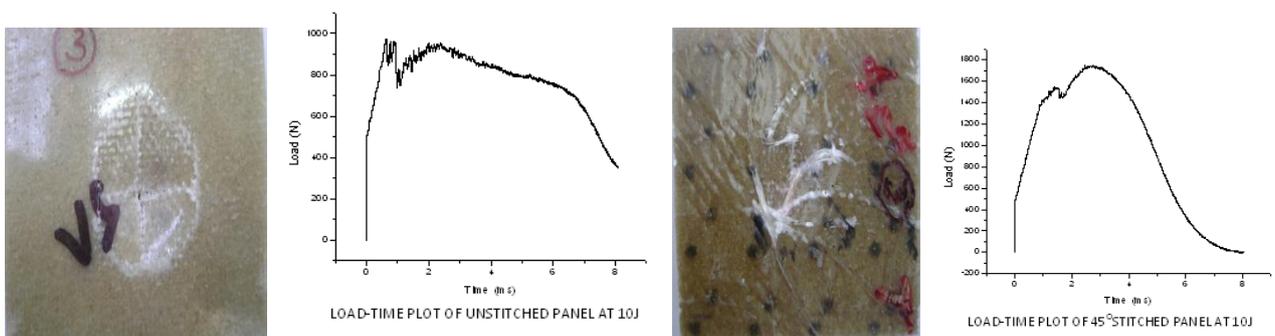


Fig. 4 Load-time plots and the pictures of impact surface after the impact at 10 J  
(a) Unstitched Panel (b) 45° stitched Panel

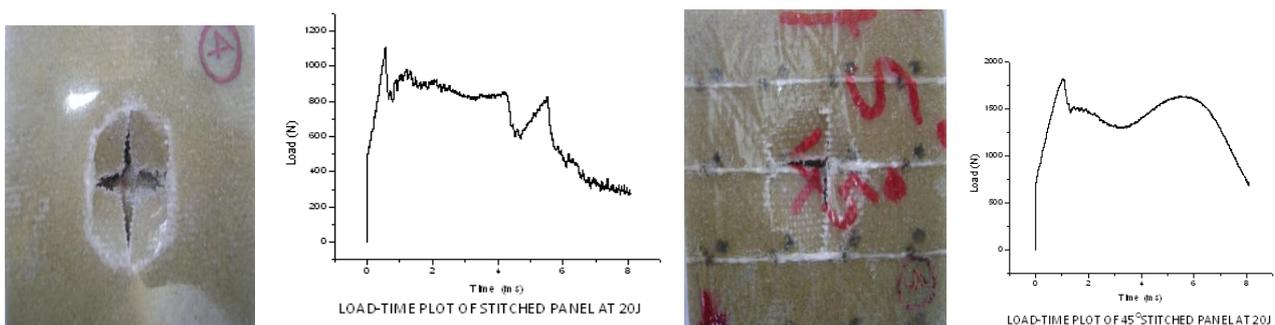


Fig. 5 Load-time plots and the pictures of impact surface after the impact at 20 J  
(a) Unstitched Panel (b) 45° stitched Panel

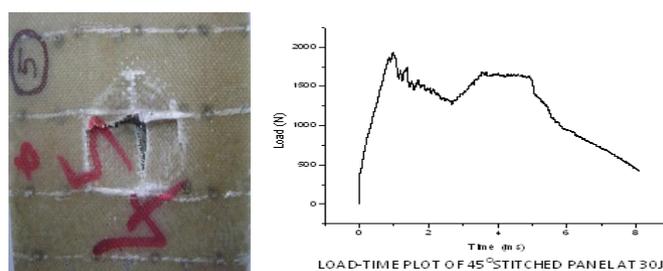


Fig. 6 Load-time plots and the pictures of impact surface after the impact at 30 J. (a) 45° stitched Panel

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#### V. CONCLUSION

With the impact energy increasing, the following characteristics were shown on the load time plots of the through thickness stitched sandwich panel and unstitched panel. The load time graph shows no peak load then first sharp peak load, which usually gives the highest load carrying capacity. Then a low loading plateau which corresponds to the crushing of the core material, then non remarkable peak load and the second sharp peak load which corresponds to the breaking of the bottom facing sheets. The sharp loads on the plots indicate the penetrating. The stitching considerably improves the impact properties and load carrying capacities. The stitched panels have more load carrying capacity than the unstitched panel and the 45° stitched panel has the highest load carrying capacity unstitched and stitched panels. The result shows the ballistic limit of 45° was 73% greater than unstitched panel.

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