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Research Article

Development of FRP Sandwich Panels for Outer Body of Boat

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Abstract

Polymeric composites are usually used in the monocoque form for making outer body of boat. In this form, the material becomes expensive and the laminas of the middle portion near the neutral plane are not used to their full strength. To make better use of material and to have light weight structures, thin sandwich panels (TSPs) are being developed for the outer body of boat. TSPs are fabricated by vacuum bagging technique. TSPs are characterised under drop weight impact test and three point bend test.

Keywords: *Sandwich panel, Monocoque structure, Impact loading, Delamination, Flexural strength*

1. Introduction

Composite materials have appeared as one of the most important class of materials in present scenario. They are being used as the structural members of aircrafts, automobiles, boats, etc. The reason for their being popular day-by-day is that they possess certain attractive properties like lightweight, high stiffness to weight and strength to weight characteristics, and good corrosion resistance, etc.

A lateral load on the boat structure is first sustained by the skin material. Usually the area of the skin material is large which increases the mass of structure substantially. A reduction in mass per unit area of the skin decreases the overall mass significantly. Therefore, the skin material should be light weight, strong and stiff enough to sustain the local damage especially under a foreign body impact.

Fig.1 Outer body of a boat

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Polymeric composites are usually used in the monocoque form for making outer body (skin material) of boat. In monocoque structure, the fibre reinforced polymer (FRP) laminas are stacked one on the top of the other. In this form, the material becomes expensive and the laminas of the middle portion near the neutral plane are not used to their full strength. To make better use of material and to have light weight structures, thin sandwich panels (TSPs) are being developed for the outer body of boat.

2. Constituent materials

Three kinds of TSPs are fabricated. TSPs were made of following constituent materials:

- (a) Face sheet reinforcement
  - (i) Glass fabric and glass chopped strand mat
- (b) Core material
  - (i) Polyester foam Coremat XM
  - (ii) Polyester foam Coremat Xi
  - (iii) Jute fabric
- (c) Matrix material
  - (i) Epoxy

The face sheet reinforcement material and the core material were reinforced at the same time in the matrix material by the wet lay-up processes such as the vacuum bagging technique.

3. Vacuum bagging technique

Three kinds of thin sandwich panels (TSPs) such as V-Gg/XM, V-Gg/Xi and V-Gg/J were fabricated. TSP prepared through vacuum bagging technique (V) with glass fabric (G), glass chopped strand mat (g) and

Coremat XM foam is represented as V-Gg/XM for the further study. In the similar way, other two kinds of TSPs are represented by V-Gg/Xi and V-Gg/J.

The schematic layout of vacuum bagging technique is shown in Figure 2. For fabricating a sandwich panel of 380 mm x 380 mm size, the face sheet material and core material were cut into pieces of 400 mm x 400 mm size. The epoxy was mixed with the 10% hardener thoroughly. All layers were placed one above the other on thick glass base plate. Epoxy coat was applied on each constituent layer. This layup was placed inside the vacuum bag and the pressure was applied gradually and finally set to 0.52 bar by vacuum pump. Breather material (felt) was used to absorb excess resin and Teflon sheets were used as release sheets.

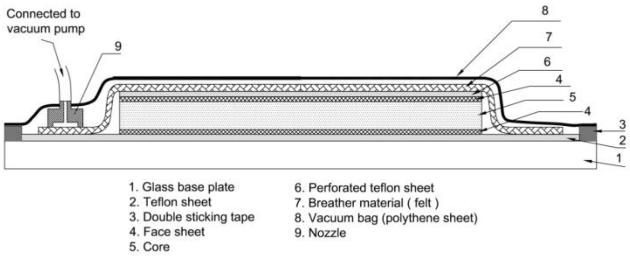

Fig.2 Vacuum bagging technique

4. Results and Discussion

a) Drop weight impact loading

All kinds of TSPs fabricated by vacuum bagging technique (V-TSPs) were studied under normal impact loading with an impact or having incident impact energy of 6 J, 12 J, 18 J and 24 J. The loading was performed on the plate specimen, rigidly clamped at the circumference by the fixture. The central unsupported area of the plate was of 150 mm diameter.

Damage area

The damage area of all three kinds of impacted sandwich panels, V-Gg/XM, V-Gg/Xi and V-Gg/J was studied. At higher impact energy of 24 J and impact velocity 6.65 m/s, the sandwich specimens were partially penetrated, and therefore, the analysis was restricted to low impact energy of 6 J, 12 J and 18 J. The damage area was seen against a strong source of light to determine overall damage area of sandwich panels under experimentation. The average overall damage area of V-Gg/XM, V-Gg/Xi and V-Gg/J panels was 418 mm^2, 651 mm^2 and 134 mm^2 respectively at 6 J impact energy. It was increased to 805 mm^2, 840 mm^2 and 623 mm^2 for V-Gg/XM, V-Gg/Xi and V-Gg/J panels respectively at 12 J impact energy. The average overall damage area was further increased to 1027 mm^2, 1021 mm^2 and 869 mm^2 respectively at 18 J impact energy. The damage area of V-Gg/XM panel and V-Gg/Xi panel was almost same at all the three impact energies. The damage area of V-Gg/J specimen was substantially lower at low impact energy of 6 J but was comparable to those of V-Gg/XM and V-Gg/Xi specimen for higher impact energy of 12 J and 18 J.

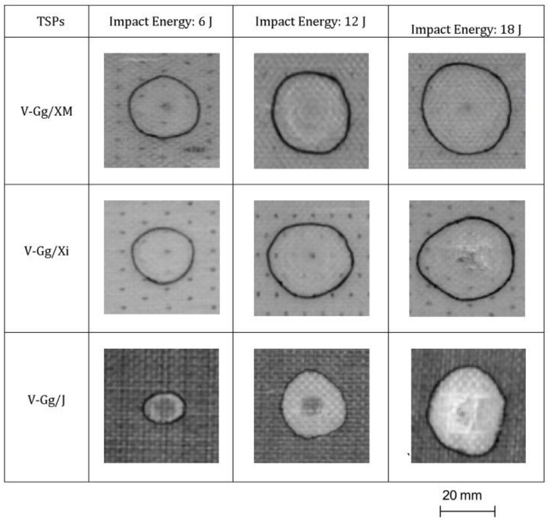

Fig.3 Experimentally observed overall damage areas of V-TSPs under impact loading

The delamination between the rear face sheet and core was estimated for all three kinds of TSPs through numerical simulation by LS-DYNA. The resultant of shear stresses τ_{zx} and τ_{zy}, $\tau_R = \sqrt{\tau_{zx}^2 + \tau_{zy}^2}$, was determined at the rear interface (z-axis was normal to the specimen plate) of V-Gg/XM panels. It was determined at the elements along 0^0 directions from center of impact and along 45^0 directions from center of impact. The induced resultant shear stress at the rear interface was compared with the interlaminar shear strength of 5.2 MPa between the face sheet and the core. The shear strength is shown through a horizontal dotted line in Figures 4 and 5. The figures show that the extent of delamination was 9 mm, 12 mm and 18

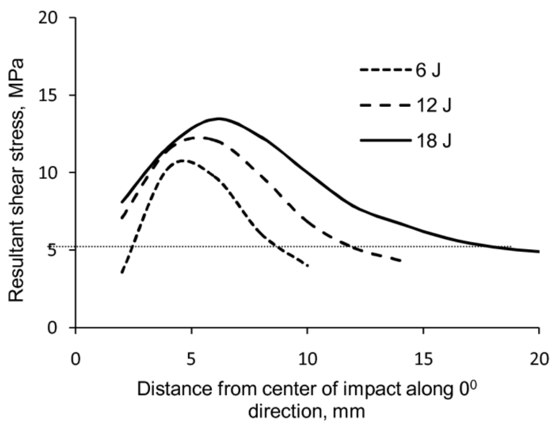

Fig. 4 Resultant of shear stresses,τ_R at rear interface along 0^0 direction of V-Gg/XM panel mm along 0^0 direction for 6 J, 12 J and 18 J impact. In 45^0 directions, the extent of delamination damage was 9 mm, 12 mm and 16 mm for 6 J, 12 J and 18 J impact

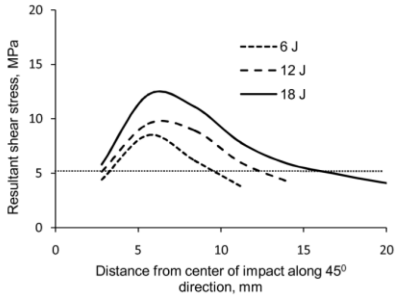

Fig. 5 Resultant of shear stresses, τ_R at rear interface along 45^0 direction of V-Gg/XM panel

Similarly, the resultant of shear stresses, τ_R , was determined at the rear interface of V-Gg/Xi panel and V-Gg/J panel at the elements along 0^0 direction from center of impact and along 45^0 direction from center of impact through numerical simulation. The induced resultant shear stress at the rear interface was compared with the interlaminar shear strength of 4.9 MPa between the face sheet and the core for V-Gg/Xi panel and 8.2 MPa for V-Gg/J panel .

The estimated results of numerical simulation were compared with the experimentally observed overall damage area of all three kinds of panels as shown in Figure 6. Experimental results are shown by continuous lines, while the estimated results are shown by dashed lines (Figure 6). The estimated results match well with the experimental results.

b) Three-point bending test

The three-point bending test was conducted as per ASTM D 790 on a UTM. The strip specimens of TSPs having dimensions 90 mm x 20 mm were used for the test. The span to thickness ratio was controlled to be close to 16. A load cell of 2 kN was used at the loading rate of 1 mm/min.

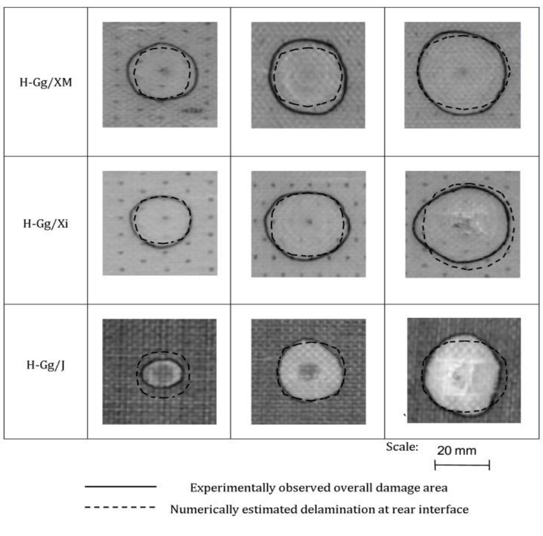

Fig. 6 Experimentally observed overall damage area and numerically estimated delamination damage area at rear interface of V-TSPs under impact loading

Flexural strength

The thin sandwich panels failed due to failure of the face sheet on the compressive side of the bend specimen under three point bending. The stress corresponding to the critical load was determined by numerical evaluation. It was determined for ten specimens of each kind of V-TSP. The average flexural strength with standard deviation is as shown in Figure 7. The numerically determined average flexural strength of V-Gg/XM panel, V-Gg/Xi panel and V-Gg/J panel were 360 MPa, 328 MPa and 357 MPa respectively.

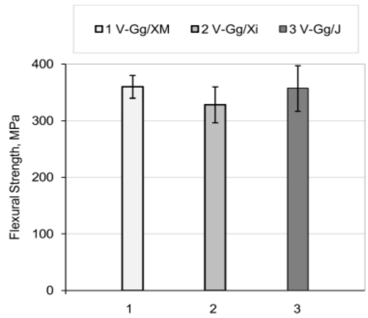

Fig. 7 Numerically determined flexural strength of V-TSPs

Conclusions

Out of all three kinds of V-TSPs, the TSP made of polyester foam Coremat XM, V-Gg/XM, showed better results under impact loading and static loading. Flexural stiffness and flexural strength of V-Gg/XM panel were high. This was due to the structure of core material, Coremat XM which connected the front and rear face sheets better due to filling of epoxy in the highly porous hex-walls of the foam core. As compared to monocoque laminate, the damage area is not much high but weight is much low. Therefore, V-Gg/XM panel is very much suitable for outer body of boat.

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