Rubber-Filled 샌드위치 복합재료의 충격 특성 연구

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A Study on Impact Performance of Rubber-Filled Sandwich Composite

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Key Words : Sandwich composite, Honeycomb, Rubber, Low velocity impact, C-scan

Abstract

A new multifunctional sandwich composite was investigated in this paper. The honeycomb core of this composite was filled with viscoelastic material in order to obtain an improved impact performance. The fillings in the honeycomb cells was hoped to provide the act of energy dissipation in this combined material system. Low-velocity drop-weight test was set up to the specimens with various stacked carbon/epoxy laminate facesheets, $[0/90]_{4s}$, $[45/-45]_{4s}$, $[0/45/-45/90]_{2s}$. Load and energy history were checked and compared for the both groups of specimens, with and without rubber fillings. Further, the damaged faces were inspected visually by ultrasonic C-scan.

1. Introduction

Among the modern composites, honeycomb sandwich composite structure has been widely used in the aircraft and aerospace industries because of its high strength to weight and stiffness to weight ratios. Typically honeycomb sandwich composite is formed by bonding thin, strong facesheets to a thick, lightweight honeycomb core. Each component of this composite is relatively weak and flexible but when working together they provide an extremely stiff, strong and lightweight structure.

However a common concern of this composite is the low velocity impacts, which may initiate localized damage such as fracture of facesheet, delaminating between face and honeycomb core, puncture and etc. Experimental review sandwich composite impact performance can be found in the references [1-3]. The impact response and damage character were described in details. In order to enhance the impact resistance, several ideas were laid. U.K. Vaidya et al. [4-5] considered sandwich constructions with reinforced cores by way of three-dimensional Z-pins embedded into form, honeycomb cells filled with foam, and hollow/space accessible Z-pin. These designs offered advantages over conventional constructions load bearing by enabling functions such as increase transverse stiffness, tailor vibration damping, impact damage and etc.

In this paper, a combined sandwich composite structure is presented. It is formed by a honeycomb core and viscoelastic fillings. The honeycomb core enhances the stiffness of entire composite structure. The viscoelastic fillings inserted in the honeycomb cells can absorb low velocity impact energy. To verification our material design idea, the low velocity impact tests are performed on fabricated specimen in two groups, with and without rubber filled. The damage areas of impacted honeycomb sandwich panel are visually inspected by acoustic C-scan.

2. Experiments

2.1 Material components

The facesheets of the sandwich composites in this study were 16-ply carbon/epoxy laminates, which were stacked by USN125 prepreg and formed in autoclave. This kind of resin-containing carbon /epoxy prepreg was fabricated by SK Chemicals. The honeycomb core used in this study was Nomex-5/32-2.4 supplied by Hexcel Composites. The selected hexagon honeycomb core had a nominal cell size of 5/32 in and a core thickness of 10

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mm with a nominal density as high as 2.4 pcf (pounds per cubic foot). The adhesive used to bond the facesheets to the honeycomb core was FM 73 film from Cytec Industries Inc. It was a 0.05 mm thick toughened epoxy layer reinforced with polyester fabric.

2.2 Preparation of specimen

Two group of sandwich composite specimen were fabricated under laboratory conditions. One is the common honeycomb sandwich composite structure and the other is rubber filled one. The face-skin laminate panels of thickness 1 mm with lay-up carbon/epoxy prepreg, USN125. Three types of facesheets were prepared with different stacking sequence: $[0/90]_{4s}$, $[0/45/-45/90]_{2s}$, $[45/-45]_{4s}$, which were fabricated using an autoclave under the curing cycle shown in Fig. 1. The laminates were cut to dimensions 150 mm × 100 mm by a cutter. The honeycomb core was cut with the ribbon direction in the longitudinal direction of the facesheet panel.

For the first group the pre-cured facesheets subsequently bonded to the Nomex honeycomb core by the FM 73 adhesive film which could develop an adequate fillet bond to the selected core. After fixed by G-clamp the specimens were cured in the chamber. Curing cycle was adopted as follows: 1 hour from the ambient temperature to 121°C; 2 hours at 121°C; and 1 hour from 121°C to the ambient temperature

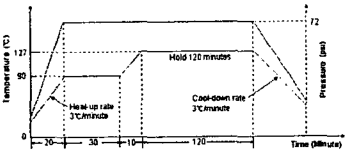


Fig. 1 Curing cycle of facesheet

As to the second group, one piece of facesheets was first bonded to honeycomb core. Cavities were naturally formed between the facesheet and honeycomb-core cell walls and liquid silicon rubber (LSR) was injected into the cavities. The LSR chosen in this study was ShinEtsu Silicon one component RTV. This kind of silicon rubber was originally sealed in liquid state. After curing it became solid silicon rubber. Obviously liquid rubber was the only choice to achieve our proposed material model. After injection the other piece of facesheet with adhesive film was covered to the honeycomb core. The specimens were also cured in the chamber after fixed by G-clamp. Curing cycle could be referred to that of the first group. At the end the cycle specimens were carefully brought out of the oven and then placed in room environment for three days to ensure silicon rubber fully vulcanized.

2.3 Experimental settings

The honeycomb sandwich specimens were subjected to low velocity impact by a drop-weight impact machine, as shown in Fig. 2. It was comprised of an impact tip which was steel and had a hemispherical indentor of 15.75 mm diameter. The weight was dropped through a nominally frictionless guide tube to hit the center of the specimens. Specimens were supported by a 76.2 mm by 127 mm cut-out frame. Light gate was applied to check impact velocity and rebound velocity. A load cell was mounted on falling mass. The force measured between the mass and the specimen was recorded by digital data acquisition system, Lecroy Oscilloscope.

The initial potential energy was set to 25J for each specimen, which was reached by adjust the height of drop-weight releasing. The tests details were referred to SACMA SRM 2R-84 [6]. After impact the carriage was caught to avoid subsequent impacts.

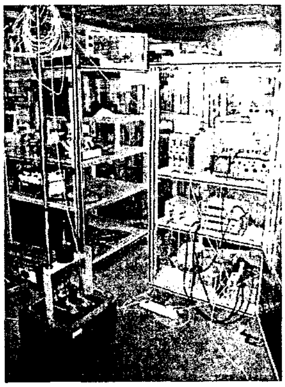


Fig. 2 Low velocity impact test device

After impact test, the damaged specimens were inspected by C-scan method: ULTRAPAC Ⅱ, Ultrasonics by Physical Acoustics. The frequency of probe used was 5MHz. Scans were performed focusing on the bottom plane of the impacted facesheet so as to obtain a good resolution of the damage area.

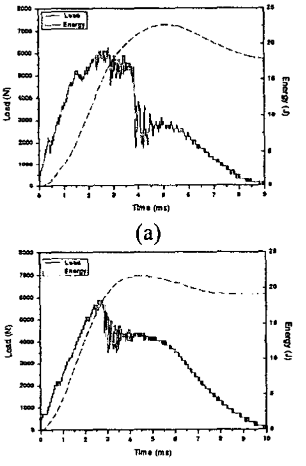
3. Results and discussion

After drop-weight test, the damaged specimens were observed by visual inspection of the specimens faces, shown in Fig. 3. Each impacted faces of the sandwich panels (the one on which the indentor hit) showed a concave indentation which coincided with that of the indentor tip and varied with different stacking sequence. The cracks around the concave developed at the 0° and 90°in the facesheet of $[0/90]_{4s}$ sandwich specimen, while at 45°and -45°in the facesheet of $[45/-45]_{4s}$ ones. The damaged area appeared in a circular location for $[0/45/-45/90]_{2s}$ specimens for its quasi-isotropic laminated facesheets. Among the three types, the damage of the $[0/45/-45/90]_{2s}$ facesheet was the severest. The bottom faces of all the specimens (the facesheet not directly hit by the indentor) had no clear crack which could be distinguished by our naked eyes.

(a) $[0/90]_{4s}$ (b) $[0/45/-45/90]_{2s}$ (c) $[45/-45]_{4s}$

Fig. 3 Visual appearance of impacted face

Fig. 4 represented force-time and energy-time histories of low-velocity drop weight impact for $[0/90]_{4s}$ facesheets with and without rubber filled respectively. The energy-time curve was drawn in dash lines. The energy value at the plateau of the energy curve coincided with the energy loss when the indentor and the specimen contacted. This energy was absorbed by the specimen and named as absorbed energy in this study. In this case, the two kind of specimen has the same dimensions, the same honeycomb core and the same facesheet. But the absorbed energy in the Fig. 4(b) was obviously higher because of the viscoelastic fillings.

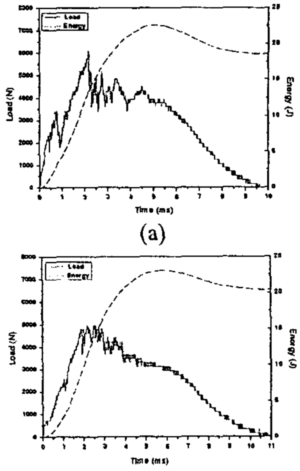


(a)

(b)

Fig. 4 Load & Energy curve of low velocity impact test ($[0/90]_{4s}$ facesheets)
(a) No rubber filled (b) Rubber filled

The similar phenomenon could be explained to the sandwich panels with $[0/45/-45/90]_{2s}$ facesheets in Fig. 5 and $[45/-45]_{4s}$ facesheets in Fig. 6. Further, for each case the load of rubber-filled specimen was less than that of no-rubber-filled one, although the initial impact energy was the same in all the cases. The peak of force-time response of the specimens without rubber filled had a much broader fluctuating area, while the impact load decreased rapidly for the rubber-filled specimen. It was thought that the impacted energy was dissipated by the viscoelastic fillings. The rubber in the cells of the honeycomb core buffered the impact velocity of indentor to some extend, so that the impact load decreased correspondingly.



(a)

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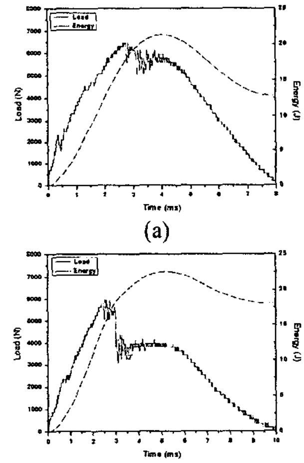
Fig. 5 Load & Energy curve of low velocity impact test ($[0/45/-45/90]_{2s}$ facesheets)
(a) No rubber filled (b) Rubber filled

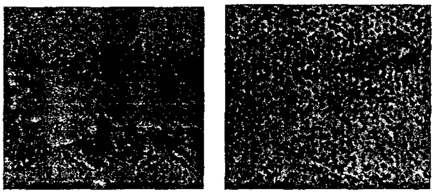


(a)

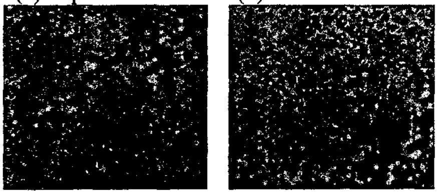
(b)

Fig. 6 Load & Energy curve of low velocity impact test ($[45/-45]_{4s}$ facesheets)
(a) No rubber filled (b) Rubber filled

Actually the impact performance could not be evaluated just by appearance, because we did not know what was really happened inside. Also the judgment should not be easily laid only depending on the absorbed energy, which was composed by specimen strain energy, kinetic energy, the strain energy released through damage progression and etc. A detailed analysis should have the assist of C-scan results. Fig.7~9 provided the C-scan photographs of top and bottom plate for the entire specimens. As seen, the top facesheets of $[0/90]_{4s}$, and $[45/-45]_{4s}$ sandwich panels without rubber filled had large damaged area distinguished as the continuous red area, while that with rubber filled did not have obvious concentrated damaged potions. The red hexagon points in photos of the rubber-filled panel were caused by the strong reflection due to the fillings in the cells of honeycomb core. In the case of $[0/45/-45/90]_{2s}$ facesheets, *it was very difficult to tell something from the top* facesheet. But it was found that the bottom plate of the sandwich panel without rubber filled had the track of damage, which said that the impact damage went rather deeper than that with rubber filled.

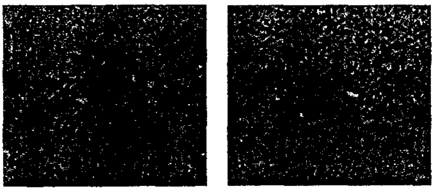


(a) Top facesheet (b) Bottom facesheet

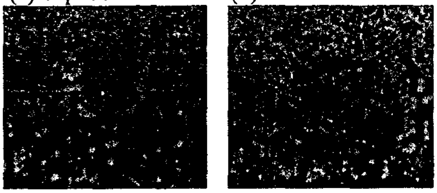


(c) Top facesheet (d) Bottom facesheet

Fig. 7 C-scan of damaged sandwich composite panels ($[0/90]_{4s}$ facesheets) (a), (b) No rubber filled (c), (d) Rubber filled

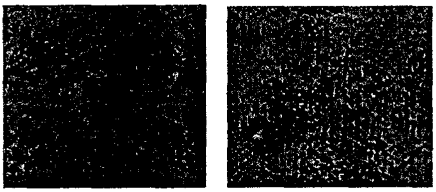


(a) Top facesheet (b) Bottom facesheet

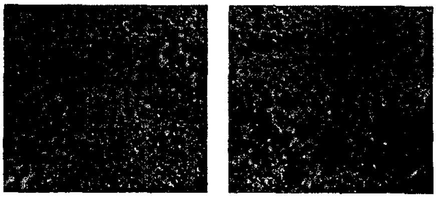


(c) Top facesheet (d) Bottom facesheet

Fig. 8 C-scan of damaged sandwich composite panels ($[0/45/-45/90]_{2s}$ facesheets) (a), (b) No rubber filled (c), (d) Rubber filled



(a) Top facesheet (b) Bottom facesheet



(c) Top facesheet (d) Bottom facesheet

Fig. 9 C-scan of damaged sandwich composite panels ($[45/-45]_{4s}$ facesheets) (a), (b) No rubber filled (c), (d) Rubber filled

4. Conclusion

The low-velocity impact tests were conducted on the rubber-filled sandwich composite panel with three kinds of staked laminates: $[0/90]_{4s}$, $[45/-45]_{4s}$, $[0/45/-45/90]_{2s}$. From the impact result one could find that the absorbed energy of the panels with rubber filled was obviously higher than that without fillings. From the C-scan photographs, it could be seen that sandwich panels without rubber filled had large damaged area, while that with rubber filled did not have obvious concentrated damaged potions.

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