DYNAMIC RESPONSE AND DAMAGE MECHANISM OF TWO-CORE COMPOSITE SANDWICH PANELS UNDER LOW-VELOCITY IMPACT

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Abstract

Dynamic response and damage mechanism of two-core sandwich panels with foam and honeycomb cores and glass fiber/epoxy composite sheets under low-velocity transverse impact are investigated. The emphasis is focused on the contact force response and crash mechanism of the two-core sandwich panels. Effects of configurations, impact energy levels and types of the cores on the dynamic response are investigated. A modified drop-test experiment is carried out to obtain contact force history of the two-core sandwich structures under different impact energies. The experimental results show that the 10:10 configurations for both honeycomb and foam core sandwich structures under lower impact energy absorb more impact energy than the other two structures. However, under higher impact energy, the honeycomb core sandwich structures of 15:5 configuration absorbs a little more impact energy than the other two, while for the foam core sandwich structures the 5:15 configuration shows a little better impact resistance. Results also show that when impact energy is low foam core sandwich structures do better in absorbing impact energy than the honeycomb ones.

1 Introduction

Polymer composite sandwich panels are being utilized increasingly as primary load-carrying components in aircraft and aerospace structures. Serving in these cases, the composite sandwich panels are inevitably subjected to impacts such as tool drops, hail, bird strikes and runway debris [1]. Through a study on the graphite/epoxy and Kevlar/epoxy honeycomb sandwiches, Rhodes found that under low-velocity impact sandwich structures had significant damage inside instead of outside [2]. Besides, researchers further studied different material systems by different methods and confirmed that sandwich structures had marked susceptibility to low-velocity impact [3, 4]. This type of barely visible external impact damage has also been demonstrated to substantially reduce the tensile, compressive, bending and shearing strengths of the sandwich structure.

In order to increase the impact resistance of sandwich panels, thin internal sheets are introduced into the core and multi-core sandwich panels are formed. Weeks' studying by air gun proved that multi-core sandwich structures are more excellent on low-velocity impact resisting than single-core sandwich structures [5]. FEA results reported by Jiang revealed that the local crash of core under the point of impact was reduced because the internal sheet has effort to spread the impact energy to the whole panel [6].

In this paper, dynamic response and damage mechanism of the two-core sandwich panels with foam and honeycomb cores and glass fiber/epoxy composite sheets under low-velocity transverse impact are investigated. The emphasis is focused on the contact force response and crash mechanism of the two-core sandwich panels. Effects of configurations, impact energy levels and types of cores on the dynamic response are investigated.

2 Specimen Fabrication

The specimen is a square plate of 180×180mm dimensions with a total thickness of 25mm. The thickness of face sheets and internal sheet are 2mm and 1mm respectively. For each kind of cores, three configurations of sandwich panels are fabricated and marked 5:15, 10:10 and 15:5 respectively. 5:15 means that thickness of cores close to upper and bottom face sheets of the sandwich panel is 5 mm and 15 mm, respectively.

In this paper, foam and honeycomb cores with same density 30kg/m^3 are used to fabricate two-core sandwich specimens. The material used for face sheets and internal sheets is tabby glass cloth pre-impregnated by Bisphenol-A epoxy resin CYD-128 (epoxy equivalent is 184～194) and boron trifluoride ethylamine is used as curing agent. Mould technique for hot pressing is carried out to fabricate composite sheets. The cured cycle consists of staying at 80℃ for 1h, 120℃ for 2.5h and 180℃ for 3h. Table 1 shows mechanical properties of the composite sheets under three point bending test.

The composite sheets and cores are bonded together by the mixture of epoxy, acetone and curing agent called diethylene triamine. Vacuum bag molding process is carried out to increase the interfacial adhesion strength between sheets and cores. Fig. 1 shows the fabricated specimens.

3 Impact Testing

Fig. 2 shows an improved impact testing system. Two strain gauges are instrumented at the end of a long projectile symmetrically. The strain signal can be recorded by digitizing oscilloscope and the contact force history can be derived synchronously. Impact energy with different levels is adopted while a contact velocity of 3.13m/s is used for all the specimens. The energy levels adopted are 34.J, 44.1J and 53.9J respectively. The specimens are put on a hard support directly.

4 Results and Discussions

4.1 Contact Force History

Fig. 3 shows the contact force vs. time curve of the foam sandwich specimen marked 15:5 at impact energy of 34.3J. The regions marked A, B or C represents the dynamic response of upper face sheet, internal sheet and bottom face sheet under impact respectively. Contact force begins to increase when the projectile comes into contact with upper face sheet and achieves the peak when the deformation of upper face sheet reaches the maximum. Once the upper face sheet is penetrated, the contact force begins to decrease because the foam core has lower stiffness. The second peak appears when the projectile penetrates the internal sheet. Because the distance between internal sheet and bottom face sheet is only 5mm, the second peak lasts very short time. Since the specimens are put directly on the cement ground which has very high stiffness, the third peak is usually very high.

Fig. 4 shows the contact force vs. time curve of the honeycomb sandwich specimen marked 15:5 at impact energy of 34.3J. There are two differences between Fig. 3 and Fig. 4. Firstly, the values of three peaks in Fig. 4 are bigger than the counterparts in Fig. 3. Secondly, the time when contact force reaches its peak value in Fig. 4 is earlier than in Fig. 3. One reason is that the stiffness of honeycomb sandwich structures is higher than the counterparts of foam sandwich structures. Another reason is foam sandwich structures have better impact resistance than honeycomb ones of the same configuration at impact energy of 34.3J.

4.2 Damage

Fig. 5 and Fig. 6 show damage of foam core sandwich specimen and honeycomb core sandwich specimen marked 15:5 at impact energy of 34.3J, respectively. Both the upper sheet and internal sheet are penetrated and the lower core is also compressed. The damage modes can validate the formation of the wave peaks on contact force history curves. The existence of internal sheet contributes to the appearance of the second peak in contact force history curve.

4.3 Discussions

The area of region marked A represents the decrement of projectile’s impulse when the upper face sheet is penetrated. From it the residual energy of projectile is derived. By this means the residual energy of projectile at any time can be obtained. According to the residual energy of projectile the impact resistance of different two-core sandwich panels can be evaluated.

To learn how the position of internal sheets influence the resisting ability of sandwich structures under low-velocity impact, the integral value of the contact force history curves is calculated under specific impact energy. Because area C is formed by the projectile impacting the specimen and the ground support, we just study the contact force history curve formed before the projectile comes into contact with the bottom sheet. Fig. 7 and Fig. 8 show the relationship between the absorbed impulse by specimens and the position of internal sheets at different impact energy levels. HC1 represents the distance between upper face sheet and internal sheet.

Results from Fig. 7 and Fig. 8 show that the 10:10 configurations for both honeycomb and foam core sandwich structures under lower impact energy absorb more impact energy than the other two structures. However, under higher impact energy, the honeycomb core sandwich structures of 15:5 configuration absorbs a little more impact energy than the other two, while for the foam core sandwich structures the 5:15 configuration shows a little better impact resistance.

5 Conclusions

Results obtained in this paper shows that the contact force history of the two-core sandwich panels is affected significantly by the location of the internal sheet and core types. At different impact energy levels, the optimal configuration of the two-core sandwich panels with better impact resisting is different. The results can help to choose the best sandwich structure for different situations. For example in the case when sandwich structures may suffer lower energy impact, the 10:10 configuration of foam sandwich structures has a better ability of resisting impact.

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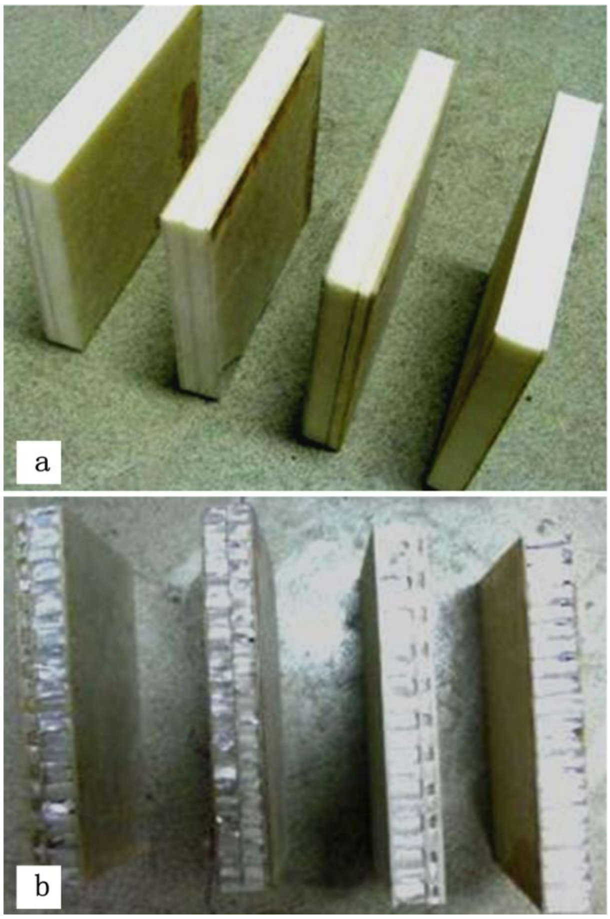

Fig. 1. Fabricated specimens: (a) Foam sandwich structures; (b) Honeycomb sandwich structures.

Fig. 2. Impact testing system

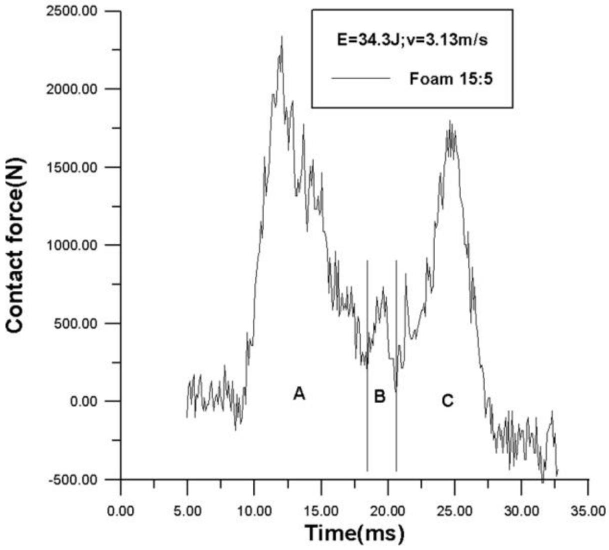

Fig. 3. Contact force history of the foam specimen with a 15mm upper core under impact energy of 34.3J.

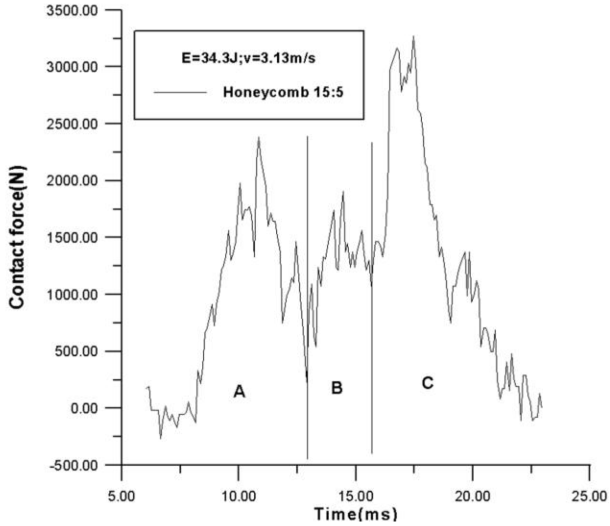

Fig. 4. Contact force history of the honeycomb specimen with a 15mm upper core under impact energy of 34.3J.

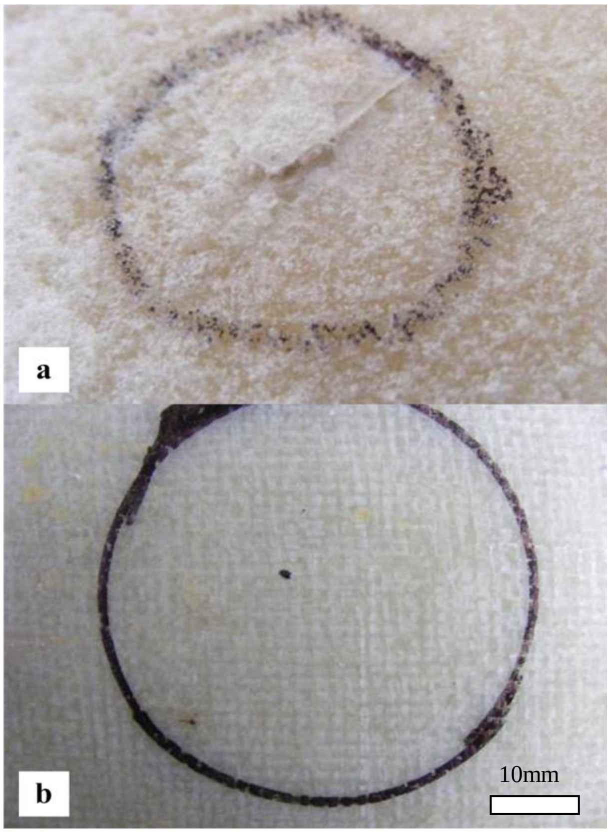

Fig. 5. Views of the damage in the impact region of the foam sandwich specimen with a 15mm upper core under impact energy of 34.3J:

(a) View of the internal sheet after impact;

(b) View of the bottom face sheet after impact.

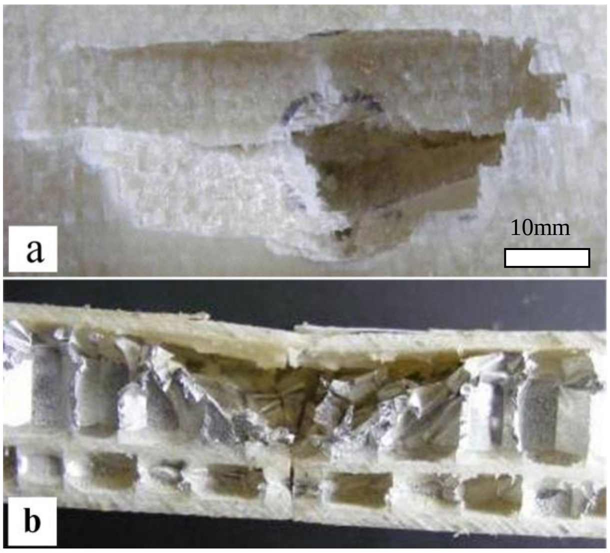

Fig. 6. Views of the damage in the impact region of the honeycomb sandwich specimen with a 15mm upper core under impact energy of 34.3J:

(a) View of the upper face sheet after impact;

(b) Cross-sectional view of the impact region.

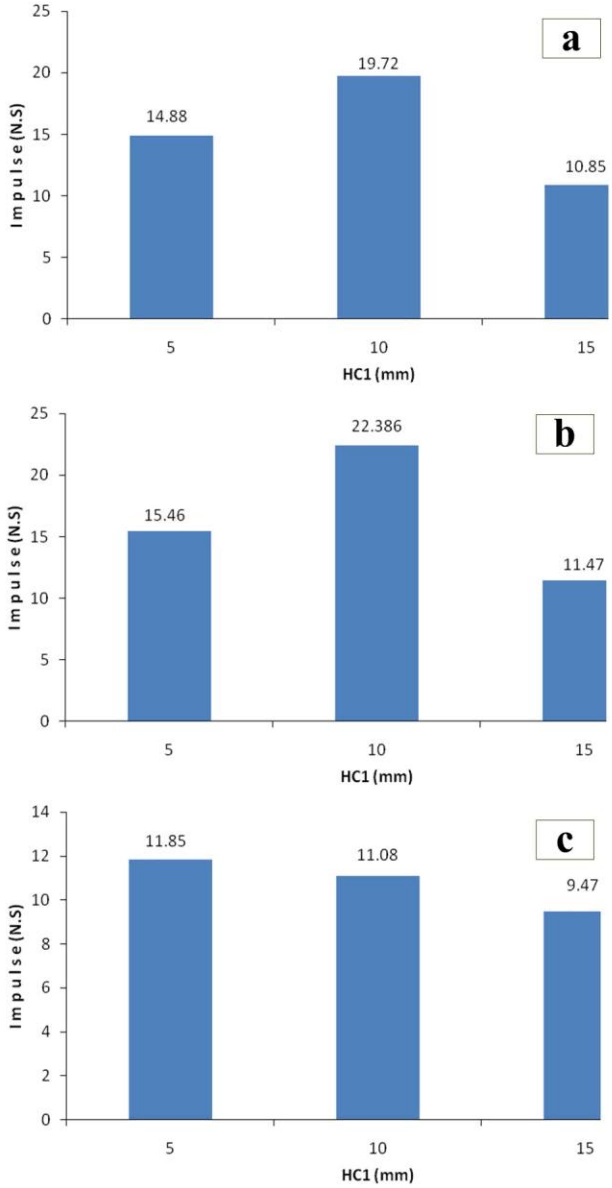

Fig. 7. The reduced impulse of the projectile changes along with the position of the internal sheet of the two-core foam sandwich structures at different energies:

(a) E=34.3J; (b) E=44.1J; (c) E=53.9J.

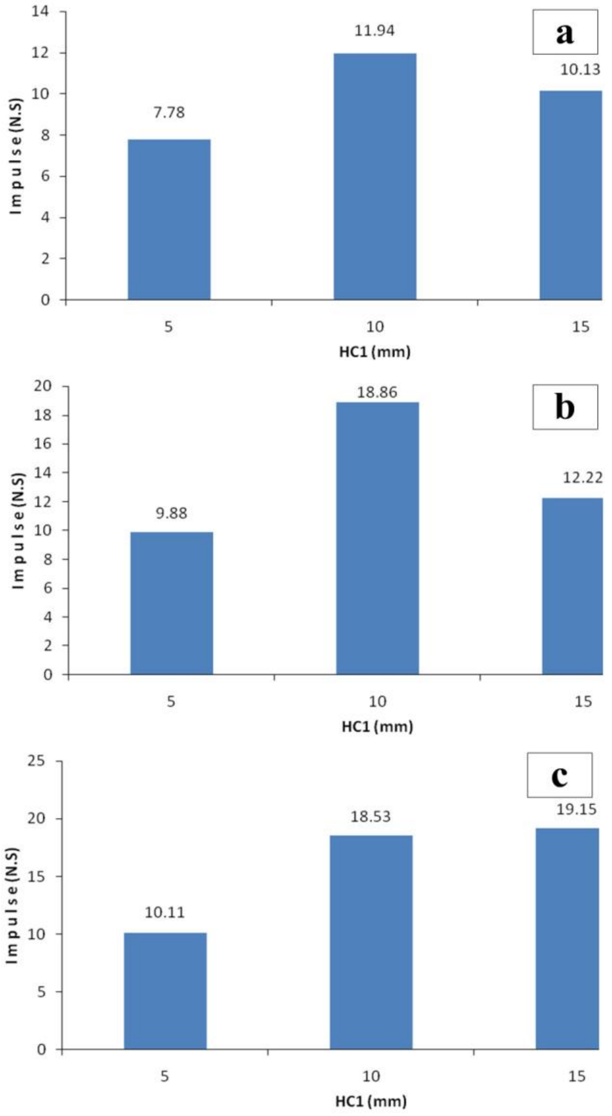

Fig. 8. The reduced impulse of the projectile changes along with the position of the internal sheet for the two-core honeycomb sandwich structures at different energies: (a) E=34.3J; (b) E=44.1J; (c) E=53.9J.

Table 1 Mechanical properties of composite sheets under three point bending test

	Flexural strength (MPa)	Flexural modulus (GPa)
Face sheet	256.4	13.6
Internal sheet	175.2	7.3

Table 2 The integral of area-A in the contact force history curve.

Energy (J)	Core	Impulse(N·s)		
		5:15	10:10	15:5
34.3	Honeycomb	3.122	4.197	3.265
	Foam	6.404	5.086	3.372
44.1	Honeycomb	2.447	1.903	5.448
	Foam	5.998	3.786	3.138
53.9	Honeycomb	6.401	7.421	12.965
	Foam	3.463	3.162	6.712

Table 3 The integral of area-A and area-B in the contact force history curve.

Energy (J)	Core	Impulse(N·s)		
		5:15	10:10	15:5
34.3	Honeycomb	7.78	11.94	10.13
	Foam	14.88	19.72	10.85
44.1	Honeycomb	9.88	18.86	12.22
	Foam	15.46	22.386	11.47
53.9	Honeycomb	10.11	18.53	19.15
	Foam	11.85	11.08	9.47