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Crush response of CFRP square tube filled with aluminum honeycomb

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Abstract

This paper aims to explore the failure mechanism and crashworthiness characteristics of carbon fiber reinforced plastic (CFRP) square tube filled with aluminum honeycomb subjected to quasi-static axial crushing. The crushing characteristics between the honeycomb-filled CFRP tube and the bare CFRP tube were compared. In addition, the influence of the cell width of aluminum honeycomb on the failure mechanism and crashworthiness characteristics of the filled CFRP tubes was further analyzed. Three distinct failure modes, classified as stable progressive end-crushing (I), unstable local buckling (II) and collapse in the mid-length (III), were observed during the crushing tests. By comparison, the peak load and absorbed energy of the filled tubes increased by more than 10 % as compared to those of the bare CFRP tubes, ranging approximately from 12.41% to 27.22% and from 10.49% to 21.83% respectively. It has been shown that the cell width was a critical parameter affecting crashworthiness characteristics, the peak load and absorbed energy increased with the decrease in the cell width, whilst the specific energy absorption (SEA) decreased.

Keywords: CFRP, filled tube, aluminum honeycomb, crashworthiness.

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1. Introduction

The carbon fiber reinforced plastic (CFRP) composite structures have been proven to be an effective energy absorber offering a highly comparable energy absorption capability over the conventional metallic structures, leading to their growing demand in the automobile industry [1-4]. The lightweight material filling for CFRP structures has also attracted considerable interest due to its potentials of enhancing the energy absorption capabilities of tubular structures, and the honeycomb filling (lighter than the aluminum foam) has been shown efficient to improve the specific energy absorption (SEA) of metal tubes [5-7]. It is noted that lightweight honeycomb filled CFRP tubes has not been extensively studied as compared with filled metallic tubes. Therefore, a better understanding of the effect of honeycomb filling on the crashworthiness characteristics of CFRP tubes is of great importance.

In review of the previous works, there have been extensive studies regarding the effect of filling a metal tube with lightweight fillers. Hussein et al. [7] performed some crush experiments on Al hybrid square tubes filled with Al honeycomb, and showed that the SEA of the honeycomb-filled tube was higher than that of the empty tube. Santosa and Wierzbicki [8] investigated the effect of aluminum honeycomb or foam filler on the axial crushing resistance of a square box column, and demonstrated that the energy absorption of the aluminum honeycomb-filled square tube increased by 11%-51% when compared to that of the empty square tube. They also found that the Al honeycomb filling was more weight efficient than the Al foam filling. Aktay et al. [9] carried out experiments and numerical simulations to study the quasi-static crushing behaviors of NomexTM honeycomb-filled thin-walled Al tubes, and showed that the honeycomb filling with the cell size of 6.4 mm and 4.8 mm had no effect on the deformation mode of the empty tube, while the honeycomb filling with the cell size of 3.2 mm changed the tube deformation mode into mixed modes. Paz et al. [10] studied a standard steel square tube filled with a GFRP honeycomb subjected to quasi-static and dynamic crushing by numerical methods, showing that the specific energy absorption of the filled tube increased by 39.5% as compared with that of the empty one according to the numerical results.

Reid et al. [11] studied the static and dynamic axial crushing behavior of foam-filled square and rectangular metal tubes. They found that the mean crushing loads increased with increasing density of foam for the tubes and that the effect of foam was greater for the square tubes compared to rectangular ones under quasi-static tests. Ghamarian et al. [12] studied the crashworthiness characteristic of empty and foam-filled end-capped conical Al tubes by experimental and numerical methods, indicating that the energy absorption capability of foam-filled tube was somewhat higher than that of the combined effect of the empty tube and the foam alone, because of the interaction between the tube walls and the foam. Duarte et al. [13] investigated the static and dynamic axial crush performance of Al alloys tubes filled with foam, and indicated that foam-filled structures showed improvement in the mechanical properties and the energy absorption with increasing foam density.

Moreover, some studies have focused on the crushing behavior and characteristics of thin-wall composite tubes filled with low density fillers. Taher et al. [14] investigated a double-cell foam-filled composite block under axial compression. It was shown that high crushing force efficiency was achieved up to 80% by filling. Niknejad et al. [15] studied the flattening process of empty and polyurethane foam-filled E-glass/vinylester composite tubes, and showed that the specific absorbed energy of the denser foam-filler tube was about two times of that of the empty tube. Lin et al. [16] studied crushing characteristic of fiber reinforced conical tubes with foam-filler by using a validated finite element method, and demonstrated that the energy absorption capability of fiber reinforced tubes increased with the increase in foam density, but the SEA decreased. Rezaei et al. [17] investigated axial splitting of empty and foam-filled circular woven E-glass fiber composite tubes, indicating that the absorbed energy and SEA increased by the foam filling during the axial compression. Guden et al. [18] studied the quasi-static axial crush performance of glass fiber reinforced polyester composite tubes filled with aluminum closed-cell foam. However, it was shown that the foam filling was ineffective in increasing crushing load and SEA values. Palanivelu et al. [19] studied the quasi-static crushing performance of small scale glass/polyester composite tubes filled with polyurethane closed-cell foam, showing that the filling of polyurethane foam reduced the specific energy absorption of the composite tube but contributed to a higher peak crush load and crushing stability.

For these above-mentioned studies, there have been a few work concerning the crushing behavior and characteristics of composite tubes filled with lightweight filler as compared to the filled metallic tubes, particularly for a limited study on the filled CFRP tubes. The purpose of present paper was to evaluate the effect of the Al honeycomb filling on the crushing characteristic of CFRP square tube subjected to axial quasi-static loading. The typical load-displacement curves, failure modes and energy absorption were studied. The effects of the honeycomb filling and cell width on the crashworthiness characteristics were also quantified and discussed. Moreover, the absorbed energy of the filled tube, bare tube and honeycomb core were analyzed.

2. Experiments

2.1 Sample preparation

The specimens used in a series of quasi-static axial crushing tests were identical, the tubes were of the square cross-section of 60×60 mm and the radius of 5 mm at corners (Fig. 1c). The CFRP tubes were fabricated from the Toray plain weave carbon fiber T300/epoxy prepreg by using the bladder molding process, which basically consisted of preparing carbon and resin preform, placing into a metal mold, exerting pressure from the inside with an inflatable bladder and curing within a hot press [2]. The honeycombs filled in the CFRP tubes were made of AA3003 H 18 with a thickness of 0.07 mm. The length of all honeycomb specimens was 100 mm. Three types of specimens with the cell width, w approximately equal to 2.0, 4.0 and 6.0 mm were tested.

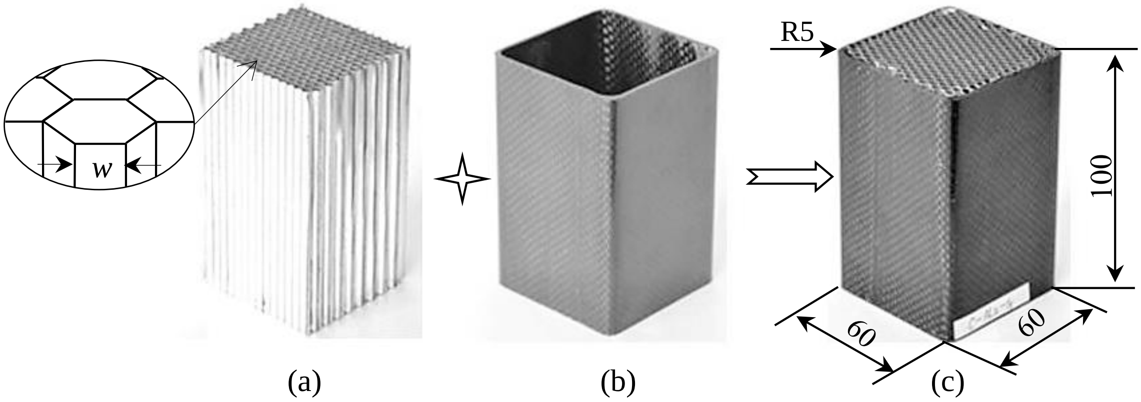


Fig. 1 Schematic of specimen: (a) aluminum honeycomb, (b) bare CFRP tube and (c) filled tube.

2.2 Test procedure

The quasi-static axial crushing tests were performed at room temperature in a Sans 5205 digitalized testing machine with a loading capacity of 200 kN. Figure 2 shows a schematic diagram for axial crushing test, in which the tested specimen was firstly machined to flat, without trigger features, and then placed between the loading platen and support platen. The specimens were loaded at a rate of 2 mm/min, and with a consistent crushing distance of 80 mm. Load and displacement data were recorded directly by an automatic data acquisition system. The peak load, absorbed energy and specific energy absorption were then calculated based on the load-displacement curves.

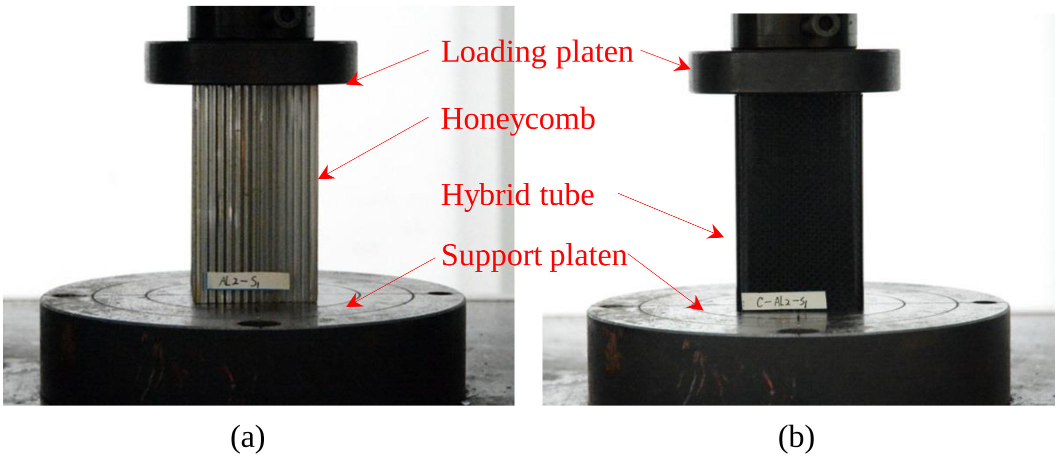


Fig. 2 Schematic of test setups: (a) aluminum honeycomb and (b) filled CFRP tube

Table 1 Geometry and crashworthiness characteristics of the tested specimens

Specimen	Mass (g)	Ply numbe	Length (mm)	Tube thickness (mm)	Cell width (mm)	Collapse mode	Peak load (kN)	Absorbed energy(J)	SEA(J/g)
C-S1	73.48	9	100	1.94		I	87.05	4550.96	77.42
C-S2	73.60	9	100	2.02		I	82.58	4639.31	78.79
C-S3	73.65	9	100	1.96		II	(95.58)	(2598.41)	(44.10)
C-S4	74.07	9	100	1.99		I	84.97	4603.13	77.67
Average	73.70			1.98			84.87	4597.8	77.96
S.D	0.34			0.06			3.16	62.81	1.03
C-Al6-S1	80.75	9	100	1.98	6.00	I	94.46	5106.44	79.05
C-Al6-S2	82.78	9	100	1.92	6.00	III	(119.27)	(3491.63)	(50.88)
C-Al6-S3	80.87	9	100	2.00	6.00	I	96.07	5131.45	79.31
C-Al6-S4	81.79	9	100	2.08	6.00	I	95.68	5002.39	79.51
Average	81.55			2.00			95.4	5080.09	79.29
S.D	1.63			0.11			1.41	96.8	0.11
C-Al4-S1	86.97	9	100	1.98	4.00	I	97.49	5367.32	77.14
C-Al4-S2	86.99	9	100	1.98	4.00	I	98.12	5259.14	75.57
C-Al4-S3	85.39	9	100	1.88	4.00	III	(95.67)	(3883.22)	(45.48)
C-Al4-S4	87.75	9	100	2.03	4.00	I	98.94	5207.55	75.61
Average	86.78			1.97			98.18	5278.00	76.11
S.D	1.71			0.11			1.03	122.73	1.27
C-Al2-S1	106.27	9	100	1.90	2.00	III	(124.99)	(4642.78)	(54.61)
C-Al2-S2	105.03	9	100	1.96	2.00	II	(105.13)	(4085.35)	(48.63)
C-Al2-S3	103.18	9	100	1.98	2.00	I	106.51	5521.55	66.89
C-Al2-S4	103.54	9	100	2.04	2.00	I	109.42	5681.13	67.38
Average	104.51			1.97			107.97	5601.34	67.14
S.D	2.47			0.10			2.05	112.84	0.35

3 Results and discussion

3.1 Load-displacement curves

The quasi-static axial crushing of three different densities of aluminum (Al) honeycombs (Dimension: 56.5×56.5×100 mm, and cell width equals of 2, 4 and 6 mm) were carried out to validate the material parameters. Figure 3 plots the load-displacement curves of specimens under compression tests. The specimens deformed progressively fold by fold in a regular manner, the load increased linearly to the peak value and then dropped rapidly to make the cell wall go into the stage of the plastic deformation with wrinkling and fracture [20]. As shown in Fig.3, the Al honeycomb with the cell width of 2 mm shows the highest peak and mean load, whereas the honeycomb with the cell width of 6 mm shows the lowest peak and mean load. This finding agrees with the Zhang et al.' study [21], in which the peak and mean loads of the aluminum honeycomb increased exponentially with the decrease in the cell size. However, there is an interesting finding that the compressive strengths of these specimens were quite close, 272.96, 271.59 and 273.21 MPa for the honeycombs with the cell width of 2, 4 and 6 mm, respectively.

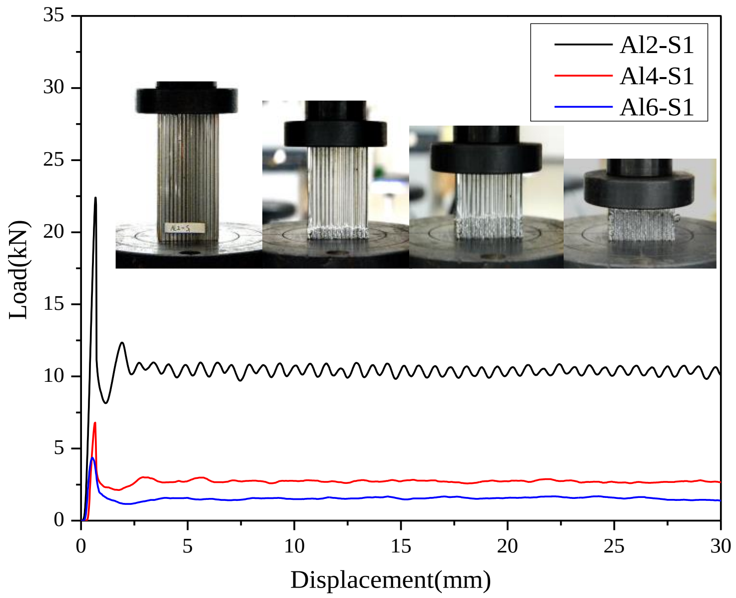


Fig. 3 Typical load-displacement curves of aluminum honeycombs in axial crushing tests.

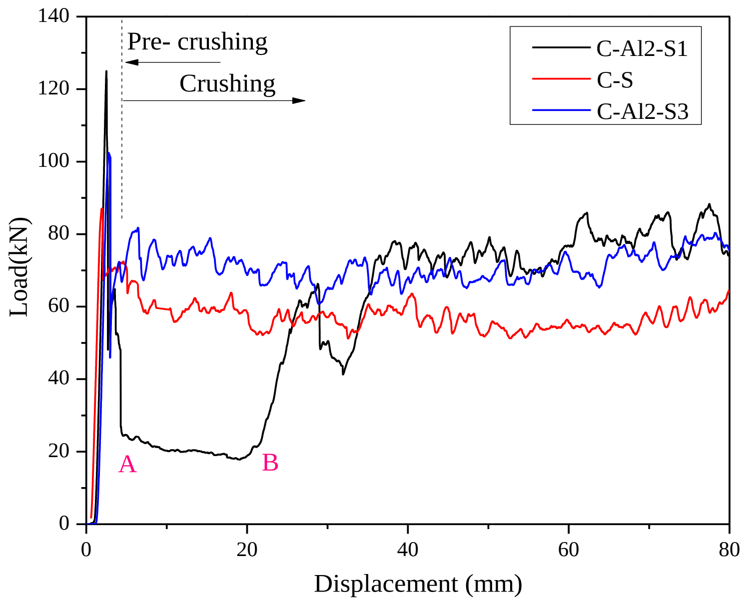


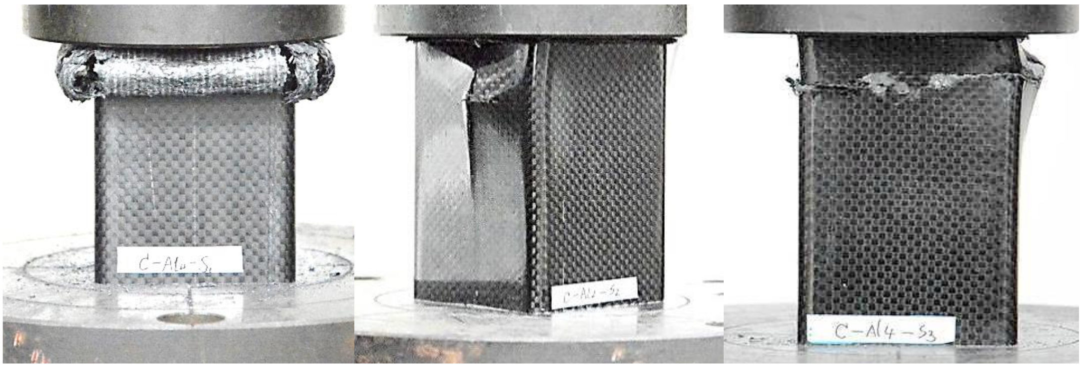
Fig. 4 Typical load-displacement curves of bare/honeycomb-filled CFRP tubes.

Figure 4 shows the typical load-displacement curves for the filled and bare CFRP tubes under the axial crushing. The progressive crushing curves of the filled (blue curve) and bare (red curve) CFRP tubes show the similar trend, which can be divided into two distinct regions, known as the pre-crushing and progressive crushing regions [2]. For the first pre-crushing region, the axial load increased initially when the loading platen contacted with the incident end of the tube, then reached a peak and dropped dramatically to a plateau level. For the second crushing region, crack propagated progressively along the longitudinal axis of the tubes, leading to the alternating drop and rise of load. However, it is evident from the comparison of these two curves (blue and red curves) that the peak and mean loads of the filled CFRP tube are marginally higher than those of the bare tube, indicating the filled tube provided a better buckling resistance under compression.

The unstable crushing curve of the filled CFRP tube (black curve) is also plotted in Fig. 4. Compared to the curve of progressive crushing, their significant difference occurs in the second crushing stage. After the first peak, the load sharply dropped to a lower level as the initiation of fracture occurred on the wall (point A). The crack gradually expanded along the circumference of the tube wall until it reached the whole section, splitting the tube into two separated halves, which is reflected from a plateau for its L-d curve. As the deformation proceeded, the loading platen contacted with the bottom halve and the halves started to crush progressively, leading to a substantial increase in the compression resistance and hence the increase in the load for the curve C-A12-S1? (after point B). An interesting finding is that, for the latter stage, the compression load is slightly higher than that of the other two curves, because of the buckling resistance induced by the two overlapped halves.

3.2 Crushing failure modes

Three distinct modes of brittle collapse, classified as modes I, II, and III, were observed from a series of quasi-static axial crushing tests of the honeycomb filled CFRP tubes (Fig. 5). The brittle collapse of the tested tubes is typical for CFRP tubes fully justified by the nature of the constituent materials i.e. the reinforcing carbon fibers, and thermoset epoxy resin which are tough and highly brittle materials. Mode I is a progressive stable failure, whereas Modes II and III represent two kinds of unstable failure. Details on the failure mode corresponding to each specimen are summarized in Table 1.



(a) (b) (c)

Fig.5 Failure modes: (a) mode I, (b) mode II and (c) mode III.

Mode I is characterized by a progressive end crushing, where the stable brittle fracture started at the incident end of the specimen in contact with the moving loading platen. It was observed in approximately 75 % of the square CFRP tubes filled with 4 and 6 mm cell width of aluminum honeycomb under quasi-static crushing tests, but only happened in 50 % of the tubes filled with 2 mm cell width of aluminum honeycomb. This implies that the CFRP tubes filled with a lower-width honeycomb tended to exhibit unstable crushing in these tests. For mode I, the frond bending, the flexural damage of the lamina bundles, the folding of aluminum honeycomb and their interaction are the most significant sources of the energy absorption in crushing.

The cracks initiated at the incident corner due to local stress concentration, and eventually led to splitting of the tube into four pieces. Subsequent to the splitting, four continuous fronds comprised of lamina bundles were formed at these separated sides, in which some bundles start spreading outwards and inwards along the midline. The lamina bundles were bent and curled extensively (Fig. 6a), leading to delamination, fragment and longitudinal cracking on the curl fronds, which are the significant sources of the energy absorption in crushing. More details were discussed in our previous study on the bare double hat shaped CFRP tubes [2]. By comparison with the crushing of bare tubes[2, 22], the main difference can be found at the deformation of inwards fronds. Due to the inwards folding, the filled aluminum honeycomb was compressed transversely and folded irregularly (Left in Fig.6b), whilst the bent inwards fronds were cut into small pieces. The inwards CFRP fronds continuously extruded the aluminum honeycomb and increased the friction between tube and honeycomb, leading to the other sources of the energy absorption.

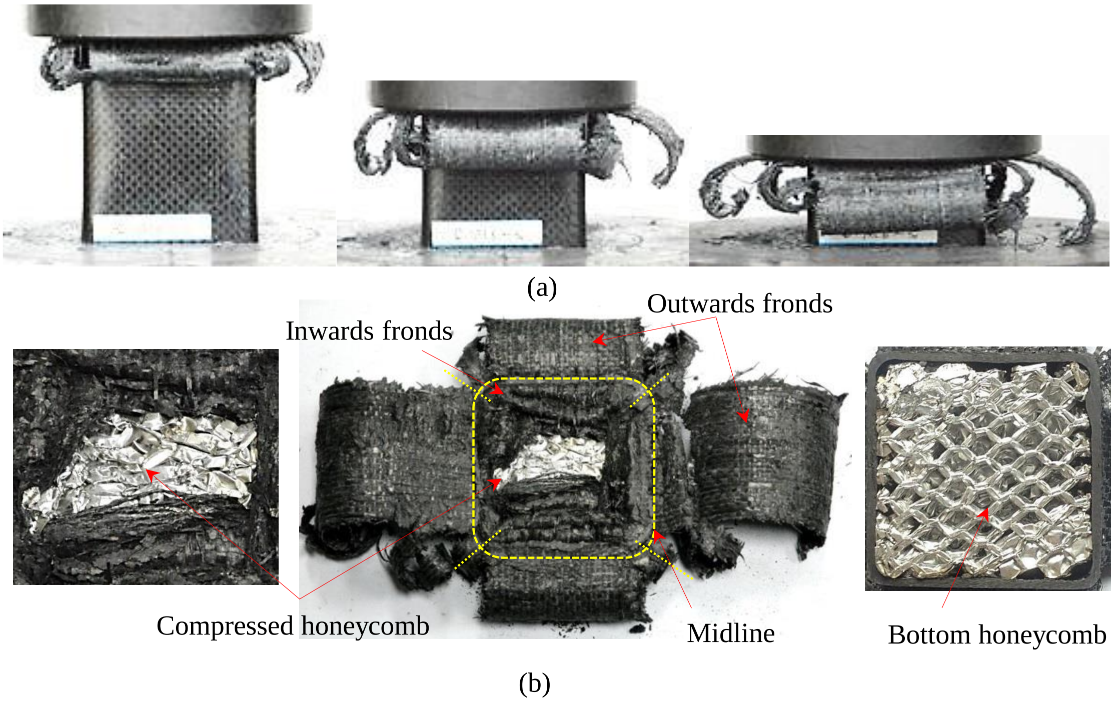


Fig.6 Failure mode I: (a) crushing process and (b) damaged specimen.

Mode II is characterized by an unstable local buckling in a tested tube, and a circumferential crack around the tube wall. It was observed in approximately 25% of the CFRP tubes filled with 2 mm cell width of aluminum honeycomb and the bare CFRP tubes. As shown in Fig.7, the tested tube presented the local wall buckling first, then underwent unstable collapse in the incident end and progressive folding during the last crushing stage.

Local buckling initiated at the tube wall after a critical crushing peak load, and followed by a significant drop in the load subjected to continual axial crushing [23]. At this time, a crack was formed in one wall along the axial direction and accompanied by a crisp sound. As deformation proceeded, the wall buckled more serious, and a circumferential crack was formed in the middle of the former grew crack and spread perpendicularly to the direction of the crushing load (Fig.7a). Subsequently, the crack in the first wall would change the shape of

“1” to shape of “┼”, and the circumferential crack continued to grow in the two neighboring walls. Then, the local buckled regions bent and deformed to become in contact with the loading platen. At the latter stage, the bottom tube presented the progressive end crushing, and the failure process was as same as the afore-mentioned mode I failue. Differing from the damaged specimen in Fig. 6b, two interesting features could be observed (second figure in Fig. 7b). One is more fallen fronds around the tube, because the upper wall bucked locally at first stage and bent seriously at the latter stage. The other is formation of five continuous outwards fronds, because one of the outwards frond was divided by the axial crack first exhibited in the wall.

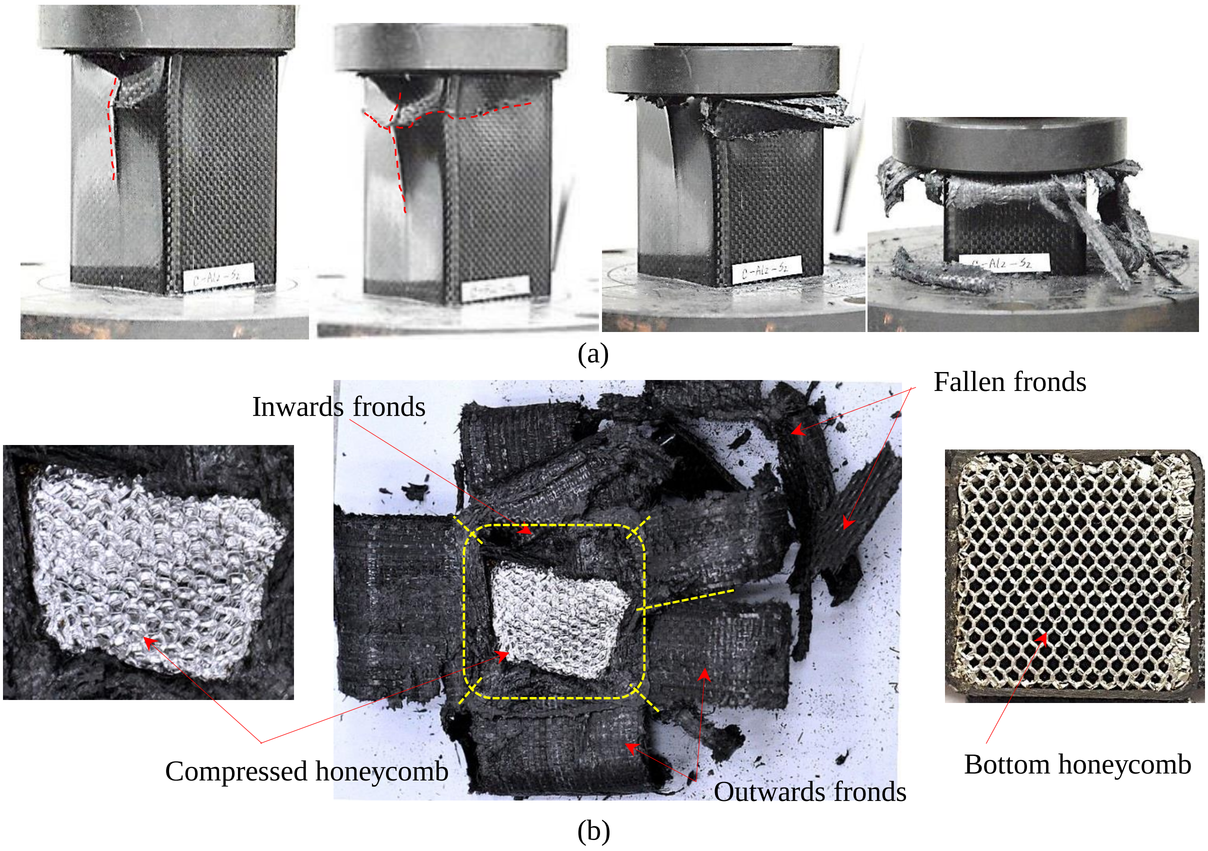


Fig. 7 Failure Mode II: (a) crushing process and (b) damaged specimen.

Mode III is characterized by an unstable collapse along the length of the compressed tube, which was observed in approximately 25% of the CFRP square tubes filled with 2, 4 and 6 mm cell width of aluminum honeycomb, as shown in Fig.8. It is noted that there is a significant decline of compressive load in the crushing process, leading to the lower energy absorption as compared with the failure mode I (black curve in Fig.4).

Fig.8 Failure mode III: (a) crushing process and (b) damaged specimen.

The mid-length collapse was initiated when the displacement of loading platen was approximately equal to 20% of the whole crushing distance, featuring that the small crack occurred at one wall of tube (Fig.8a). The crack gradually expanded along the circumference of the tube shell until it reached the other three sides, splitting the tube into two separated halves, which was reflected from the dramatic drop of load as shown in its L-d curve. As the deformation proceeded further, one half of the tube slid and penetrated into the interior space of the other half. Subsequently, some fronds of the upper half were embedded into compress the honeycomb and some were fallen outside (Figs.8a and b). Whilst the bottom half crushed progressively, but some curled outwards fronds would cut down to become in contact with the upper half.

3.3 Crashworthiness characteristics

3.3.1 Effect of honeycomb filling

The peak load, the absorbed energy and specific energy absorption are the critical parameters extensively used to assess the crashworthiness of structures. Peak load is of strong interest because it measures the capability of a structure to have no permanent deformation under loading [24], which is related to deceleration of structure and injury/damage of occupants; whilst the absorbed energy and SEA represent the capability and efficiency of energy absorption during the structural deformation.

Figure 9 plots the crashworthiness characteristics of bare and honeycomb-filled CFRP tubes under the same crushing failure mode (mode I). The peak load and absorbed energy of filled tubes increase by more than 10% approximately from 12.41% to 27.22% and from 10.49% to 21.83% respectively, when compared with the bare tubes (Fig.9a). However, there is an interesting finding that the specific energy absorption of the filled tube is not always lower than that of the bare tube, as shown in Fig.9b, only the filled tube with 6 mm cell width of aluminum honeycomb resulted in a little higher SEA than bare tube, while the other two types of filled tubes are of lower SEA compared to the bare tube.

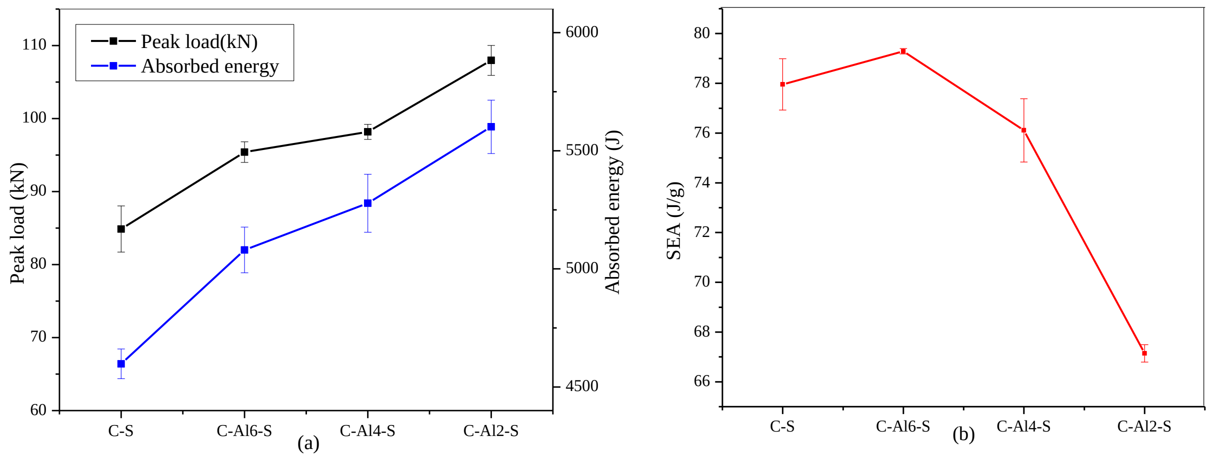


Fig. 9 Comparison of bare and honeycomb-filled tube: (a) peak load and absorbed energy and (b) SEA

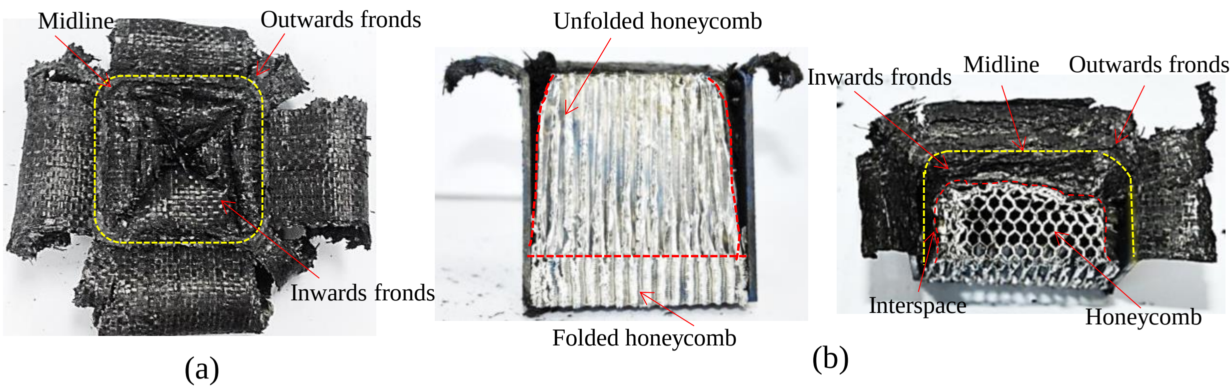


Fig.10 Comparison of damaged tube: (a) bare and (b) filled tubes

In order to further analyze the effect of filling on energy absorption, Fig.10 plots the top view of the damaged bare tube and the cross-sectional view of damaged filled tube. For the bare CFRP tube, the lamina fronds were bent and curled extensively, leading to delamination, fragmentation? and longitudinal cracking on the curl fronds, which were the main source of the energy absorption in crushing [4]. In addition, the fragment wedge remained essentially unchanged during the compression process and penetrated the composite material, resulting in the development of its high frictional resistance with the adjacent fronds, providing another source of the energy absorption [25]. By comparison with the crushing of the bare tubes, the significant difference of filled tubes shows at the deformation of inwards fronds. Due to the inwards folding, the filled aluminum honeycomb was compressed and folded transversely, resulting in the cone shaped of the inner honeycomb, whilst the bent inwards fronds were cut to small pieces. Under crushing, except for the cell buckling, elastic and shear effects within the aluminum honeycomb [26], the inwards CFRP fronds continuously extruded the aluminum honeycomb and increased the friction between the tube and honeycomb, providing other sources of the energy absorption and resulting in a significant interspace between the tube wall and the compressed honeycomb (the area in Fig.10b), thereby causing higher absorbed energy for the filled tubes.

3.3.2 Effect of cell width

The crushing properties of CFRP square tubes filled with three different cell width of aluminum honeycombs are shown in Table 1 and in Fig.9. It indicates that the peak load and absorbed energy of the filled tube increased with the decrease in the cell width, the tube with the 2 mm cell width of the filling has the highest average peak load of 107.97 kN and absorbed energy of 5.60 kJ (Fig.9a). The interspace between the CFRP midline and filled honeycomb decreased under the denser honeycomb, leading to higher deformation resistance and absorbed energy, as shown in Fig. 11.

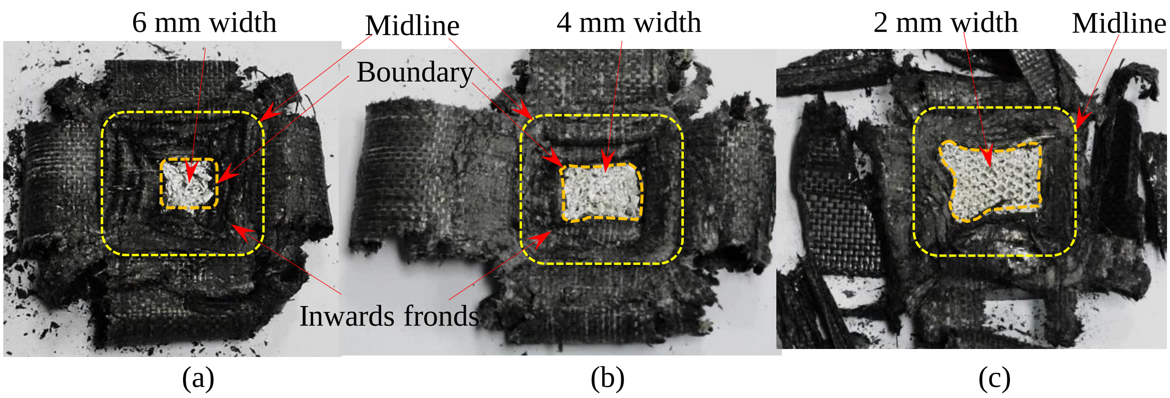


Fig.11 The damaged tube filled with honeycomb width of: (a) 6, (b) 4 and (c) 2 mm.

Whereas the SEA of filled CFRP tubes decreased with the decrease in the cell width, the tubes with the 2 mm cell width of the filling has the lowest SEA of 67.14 J/g (Fig.9b). This opposite trend indicates that the honeycomb filling does not always end to the efficient and light energy absorbers. For the case of the denser honeycomb, higher strengthening effect could be achieved but the structures may lose its weight efficiency [2, 22]. Therefore, selection of appropriate honeycomb density for CFRP tube is critical to achieve a higher energy absorption and weight efficiency in practical lightweight structure design.

The strengthening effect of the aluminum honeycomb with different cell width can be further analyzed on the absorbed energy of each part in the filled tube, as shown in Fig.12. It clearly indicates that the energy absorption capability of honeycomb-filled tube is somewhat higher than that of the combined effect of the bare tube and the aluminum honeycomb alone, which is attributable to the interaction or coupling effect [27, 28]. During the crushing process, the filled honeycomb suffered from the combined shear-compression as the combination of axial loading and lateral resistance by inwards fronds of tube walls, leading to a higher loading capacity and more absorbed energy due to the interaction effect [29-30]. The absorbed energy of the CFRP tube alone equals to 4597.8 J and the absorbed energies of aluminum honeycombs with the cell width of 6, 4 and 2 mm equal to 122.9 J, 208.8 J and 944.4 J respectively. The increasing absorbed energies of the filled tubes with the cell width of 6, 4 and 2 mm equal to 359.4, 471.4 and 59.2 J respectively, which are approximately 7.07, 8.93 and 1.06 % of the corresponding total absorbed energies. It is interesting to note that the honeycomb with the cell width of 4 mm resulted in the highest absorbed energy increment, which was also identified in Ghamarian et al.'s [12] crush test on the three foam filled specimens that the aluminum conical tube filled with the medium-density foam present the highest energy absorption increment.

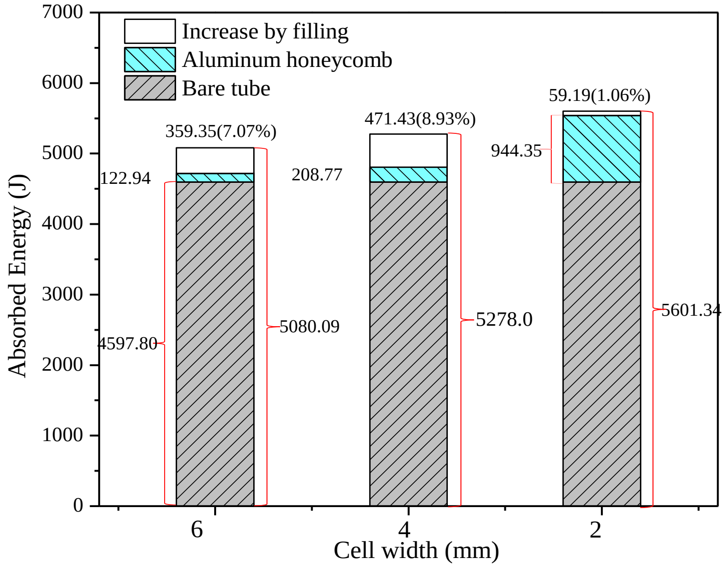


Fig. 12 Comparison of the energy absorption of each part in different filled tube

3.3.3 Effect of failure modes

Figure 13 plots the failure modes and the SEA values of the tested filled CFRP tubes. Modes II and III failures were observed in approximately 8.33 % and 25 % of the tested filled tubes, whilst the Mode II failure was observed in approximately 25 % of the tested bare tubes. It seems that the aluminum honeycomb filling was ineffective in improving crush stability in this study. These distinct modes were also observed in our previous investigations of the bare

CFRP tubes [2, 23]. Interestingly, the slight difference was that the local buckling and an axial crack initiated at the wall of the filled tube, and the shape of crack changed from “1” to “┼” (Fig.7), whereas the crack initiated near the end of bare CFRP tubes and caused the local buckling [2, 23].

Moreover, the same as abovementioned literatures, Modes II and III failures resulted in lower energy absorption capability as compared to the Mode I. The average SEA of the filled tube specimens with unstable modes II and III are 48.63 and 50.32 J/g respectively, representing 65.56% and 67.83% of that for the filled tubes with the more stable mode I.

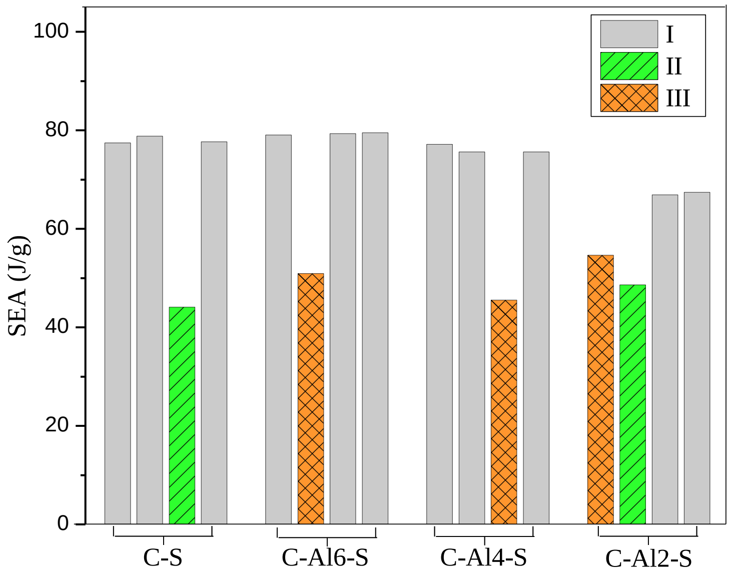


Fig.13 Effect of failure modes on SEA

4. Conclusions

This study presented an experimental investigation into the quasi-static crashworthiness characteristics of the CFRP square tubes filled with aluminum honeycomb. The typical load-displacement curves, failure modes and effect of the varying cell width on the crushing properties were explored. The differences between the bare CFRP tube and filled tube were quantified by comparison. Within the limitation of the study, the following conclusions can be drawn:

(1) Three distinct failure modes, classified as the stable progressive end-crushing (I),

unstable local buckling (II) and collapse in the mid-length (III), were observed in the crushing tests of the filled CFRP tubes. For the modes II and III, representing two unstable failure modes, the average SEA were 48.63 and 50.32 J/g respectively, which were lower than 70% that of the filled tube as compared with the stable mode I.

(2) The peak load and absorbed energy of the filled tubes increased by more than 10 % when compared to the bare CFRP tubes, ranging approximately from 12.41% to 27.22% and from 10.49% to 21.83% respectively. Whilst only the filled tube with 6 mm cell width of the aluminum honeycomb resulted in a little bit higher SEA than the bare tube, the other two types of the filled tubes had lower SEA when compared to the bare tube.

(3) The energy absorption capability of the honeycomb-filled CFRP tube was higher than that of the combined effect of the bare CFRP tube and aluminum honeycomb alone, which was attributable to the interaction effect. The filled tube with a medium-density filling (4 mm cell width) showed the greatest filling effect with the increased absorbed energy of 471.4 J equivalent to 8.9% of the whole absorbed energy.

(4) The cell width was a critical parameter affecting crashworthiness characteristics. The peak load and absorbed energy increased with the decrease in the cell width, whilst the specific energy absorption decreased.

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