

COMPRESSIVE FRACTURE CHARACTERIZATION OF GFRP/ALUMINUM HONEYCOMB HYBRID LAMINATE BY ACOUSTIC EMISSION

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Introduction

An acoustic emission (AE) technique has been used for monitoring of the status of fracturing in fiber reinforced plastic (FRP) composites. Kostopoulos *et al.* [1] characterized Mode I interlaminar fracture of carbon nanofibers and piezoelectric particles-doped carbon fiber reinforced plastics. The present author investigated the fracture process of FRP/aluminum hybrid composites by an AE frequency analysis and a parametric analysis [2]. This study focused on the characterization of the fracture processes of glass-FRP skin /aluminum honeycomb core hybrid laminates (GF-AH laminates) under compressive load through an AE parametric and frequency approach.

Experimental

Honeycomb sandwich composite

GF-AH hybrid composite plates were made for this study. Composite layups 1mm in thickness with unidirectional glass fiber/ epoxy prepreg (UD-GFRP, UGN 150, SK Chemicals) were prepared for the skin layer. Aluminum (Al 5052) honeycomb plates 5mm in thickness and 0.038 in cell wall thickness (Showa Aircraft Industry Co) were used as the core layer. The adhesive film (Bondex206, HanKook Fiber) was then inserted between the Al5052 honeycomb core and GF prepreg skins using a hand lay-up procedure. GF-AH laminate panels were cured in an autoclave according to the recommended curing conditions. After that, compression test specimens 20 mm wide and 20 mm long were made by sectioning the laminate panels with a low speed diamond wheel cutter (ISOMET, Buehler Co.). Specimens of the Al5052 honeycomb only were also made.

Compression test and acoustic emission measurement

Two AE sensors (micro30, Physical Acoustic Corp.) having a detectable frequency range of 100-600 kHz with a peak sensitivity at 250 kHz were mounted on the upper and lower loading plates using a vacuum

grease couplant and a mechanical fixture. Compression test was performed with a cross-head speed of 0.1 mm/min in the specimen thickness direction using a flat plate indenter. During the test, a traveling optical microscope was used to observe the fracture behaviors. Acoustic emission measurement was carried out to monitor the fracture events in real time. AE measurement conditions were a pre-amp of 40 dB, a threshold level of 40 dB and a sampling rate of 4 MHz. After the test, each stored AE signal was analyzed through a fast Fourier transform(FFT).

Results and Discussion

Aluminum honeycomb plate

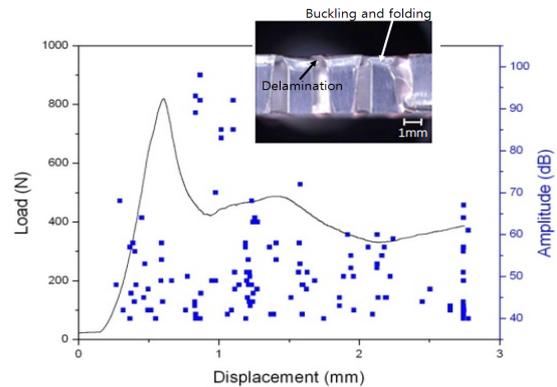


Fig.1 Load and the corresponding AE amplitude distributions for an Al honeycomb plaque specimen under compressive loading.

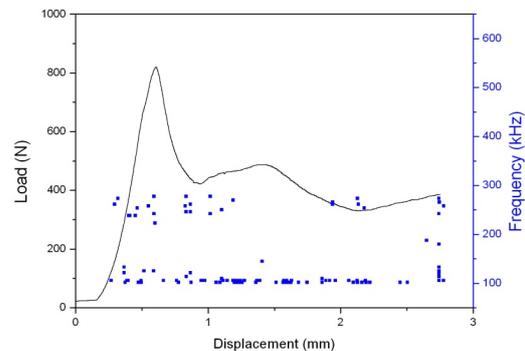


Fig.2 Distributions of the peak AE frequencies in Fig.1

Fig. 1 shows the typical load behavior and the accompanying AE amplitude distributions as a function of displacement for an Al honeycomb core plaque specimen under a thickness-wise compressive load. After arrival at the maximum load, the load reduced drastically with the 1st plastic buckling deformation of the cell wall. The load increased again and then a bit decreased keeping up a constant level of crushing load, and induced the secondary buckling deformation. During the compressive deformation, buckled bending and plastic folding of the cell walls as well as delamination in the bonded cell walls occurred (see the photo in Fig.1). A burst type of several AE events initiated at a displacement of 0.3mm. In the post stage of the 1st buckling around displacement 0.7-1.1mm, high amplitude emissions above 80dB were generated. About 80% of the total events corresponded to the low amplitudes below 60dB. Distributions of the peak frequencies shown in Fig.2 indicated two different groups of peak frequency band: low frequency band 90-140kHz and high frequency band 180-300kHz. The high frequency events represented the high amplitude. Most of the high amplitude events seemed to be originated from the rapidly delaminated fracture of the bonded cell walls. However the low frequency band events originated from slow microfracturing of the resin adhesive and/or plastic deformation of Al thin wall.

GF-AH hybrid composite plate

Load behaviors and accompanying AE peak frequencies of an GF-AH hybrid composite plate specimen under a compressive load are shown in Fig.3. Drastic load decrease similar to the behavior of only the Al honeycomb plaque arose simultaneously with the buckling collapse of the cell wall. Distributions of the peak frequencies shown in Fig.3 split into basically two different groups similar to the case of Fig.2. As shown in Fig.4, only the 1st-mode folding in the central region of the cell wall height was induced by the buckling, without forming the 2nd-mode folding. After the cell wall collapse, the load increased gradually due to a pure compressive deformation in the specimen thickness direction. The progress of only the 1st mode folding of the cell wall caused some large delamination in the bonded cell walls and some microfractures between the GF skin layer and the edge of cell walls. (see Fig.4). Five times in AE hit events for the GF-AH hybrid composite in comparison with the honeycomb plaque indicated a large amount of microfracturing and delamination. Various levels of AE amplitudes including high amplitudes above 70dB appeared frequently around the 1st maximum load. The low peak frequency band 90-140kHz corresponded to about 70% of the low amplitude events below 60dB. This originated from the slow microfracturing in the resin adhesive between cell walls, between the fiber

skin and the honeycomb core, and/or from the plastic deformations of Al cell walls which was similar to the case of honeycomb only as stated in the above. However the events of high frequency band 180-300kHz were from some large, rapidly progressing delamination in the bonded cell walls and/or between the skin and the core layers.

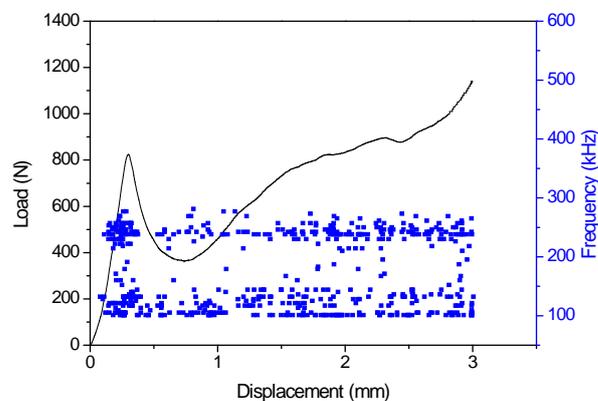


Fig.3 Load and accompanying peak AE frequencies of an GF-AH hybrid composite plate specimen under a compressive load

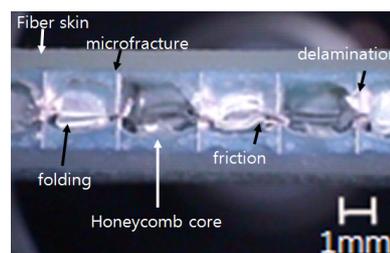


Fig.4 Deformation and failure of the GF-AH

4. Conclusion

Various failure modes of glass fiber reinforced plastic skin/ aluminum honeycomb core (GF-AH) hybrid composites under compressive loads were classified through the fracture identification in association with the AE frequency and amplitude analysis. The fracture behaviors of GF-AH hybrid composites were comparable to those of honeycomb core only.

References

1. Loutas TH, Kostopoulos V, Ramirez-Jimenez C, Pharaoh M, Damage evolution in center-holed glass/polyester composites under quasi-static loading using time/frequency analysis of acoustic emission monitored waveforms, *Compos. Sci. Tech.*, 66(2006) 1366-75.
2. Woo, S.-C., Choi N.-S., Cho N., Characterization of the fracture process of notched glass fiber/aluminum hybrid laminates by acoustic emission, *Compos. Sci. Tech.*, 68(2008) 1521-1530.