12th International Conference on Sandwich Structures (ICSS-12) Lausanne - Switzerland, 19–22 August 2018
DOI: 10.5075/epfl-ICSS12-2018-202-204

FATIGUE DAMAGE AND FAILURE ANALYSIS OF HONEYCOMB SANDWICH

Fahmi Alila[1], Pascal Casari[1] and François Bertrand[1]
[1]Université de Nantes, France.
Fahmi.alila@univ-nantes.fr
Pascal.Casari@univ-nantes.fr
Francois.bertrand@univ-nantes.fr

1. ABSTRACT

Fatigue behavior of sandwich structures with honeycomb core and GFRP skins is studied and failure mode is investigated through tomographic observations. The first S/N curves are presented. The second part discusses the failure modes observed during fatigue tests and responsible for stiffness decrease during fatigue tests.

2. INTRODUCTION

Fatigue of composite materials has been less studied during numerous years since these materials were known not to damage under cyclic loading (particularly entrenched reputation for materials-based carbon fiber in the world of aeronautics) [1–6]. Their use is being more and more important in many industries. However the increasingly occurrence of frequent and early failure in composite structure showed the necessity to design and study these structures also in fatigue. Thus the complex aspect of the fatigue phenomenon of composite materials and industrial interest have contributed to the further development of research on the subject over the past two decades [7–9]. In terms of complexity it can be cited for example failure modes and multi-axial stress state. The stress distribution in a composite material is often multi-axial even when subjected to a single load.

In aeronautics, the use of sandwich structures is being increased due to their weight-performance ratio. The challenge nowadays in aeronautics transport field is the reduction of energy consumption by reducing the weight of the airplane [10–12]. For equal reliability and durability and with significant weight savings compared to metal materials, new materials are trying to meet this challenge. Among these materials there may be mentioned the sandwich structures with foam or honeycomb core [13].

In this paper sandwich with GFRP faces and both L and W honeycomb orientations (Fig. 1) was studied in fatigue under 4 point bending test.

Fig. 1: Honeycomb panel sandwich and associate cells orientation.

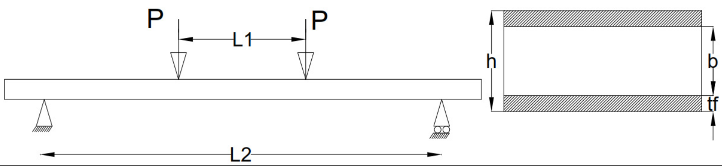
The additional outcome of this study is the analysis of the cell orientation (L and W) effects on the fatigue life of the honeycomb structure and a tomography analysis of the honeycomb sandwich.

3. MATERIALS AND METHODS

The honeycomb sandwich beams are provided by the aircraft industry. Sandwich specimen dimensions are shown in Table 1.

Table 1: Sandwich specimen dimensions and boundary conditions.

L (length) (mm)	l (width)(mm)	h (mm)	b (mm)	tf (mm)	L2 (mm)	L1 (mm)
300	50	12.7	11.26	0.72	250	80



Fatigue tests were carried out through a developed four point bending testing fixture device that can test 3 specimens in the same time (Fig. 2).

Fig. 2: Developed four-point test machine.

4. FATIGUE TEST RESULTS

Fatigue behavior of honeycomb sandwich structure is analysis based on S/N curves and fatigue damage modes. The fatigue tests were performed at conditioned temperature room made at 25°C. The test load frequency was f=2Hz and the load ratio was R=0.1. Fatigue lifetime of specimens is recognized by the number of cycles to ultimate failure. Moreover, the number of cycles from crack initiation to final fracture was in all cases short compared to fatigue life. While monitoring tests, degradation of stiffness was more affirmed due to the crack formation.

S/N curves illustrated in Fig. 3 show a qualitative comparison between the fatigue life-time of sandwich composites made of aramid fibers cores in L and W orientations cells. It appears that for honeycomb sandwich composites the lifetime of the L configuration is greater than in the W configuration at constant load level.

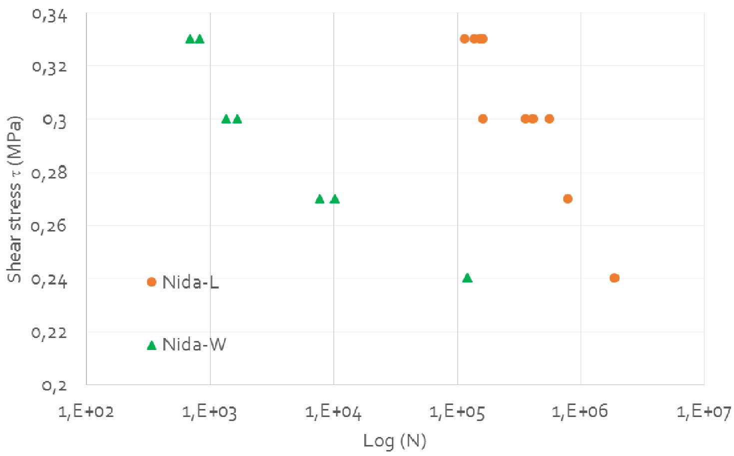


Fig. 3: S/N diagram of fatigue tests at f=2Hz.

During the fatigue test we followed the evolution of Force versus displacement in order to investigate the stiffness loss in the specimen. Different cycles were plotted in Fig. 4.

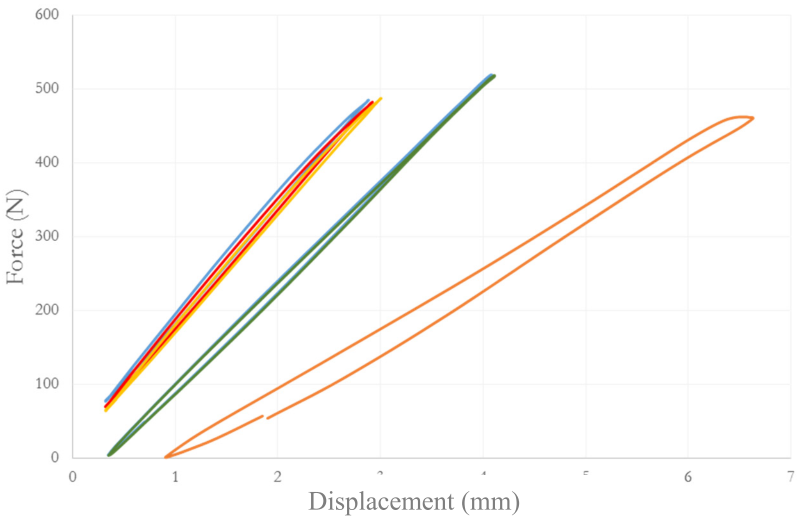


Fig. 4: Force versus displacement loops at different times during fatigue test of L type sandwich.

The loops or the hysteresis plotted in Fig. 4 demonstrate the stiffness loss of the sandwich structure during the fatigue tests. The hysteresis surface area is different from the first cycles to the last ones. This could help quantify the stiffness loss amount and also to predict the failure. The following discussions regarding the fatigue failure processes were only based on visual inspection of the damaged sections of the specimens. For our honeycomb sandwich specimens, both W and L configurations failed in shear with a crack propagation through the thickness of the core (Fig. 5) .The crack propagation in cells walls is always in the diagonal direction in the case of the L configuration and horizontal for the W one. In both cases, cracks or micro defects appear before any macro size crack is formed.

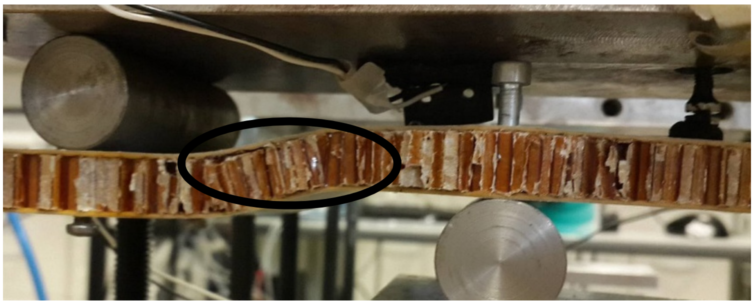


Fig. 5: Core shear failure in honeycomb sandwich at f=2Hz and 0.30 MPa.

Shear failure mode has been analysed with tomography images. 3D views are showing honeycomb cells before and after failure. One can notice cracks in the walls of the failed cell (Fig. 6).

Fig. 6 : (a) 3D view of honeycomb cell before failure. (b) 3D view of honeycomb cell after failure.

5. CONCLUSION

In this paper, fatigue tests in four point bending were performed on two different honeycomb sandwich configurations. One in L cells orientation and the other in W cells orientation. The fatigue tests results were illustrated in standard S/N diagrams. It was concluded that the fatigue life time of L cells orientation is greater than W cells. Most of the specimens' failure mode was core shear failure based on cell walls cracking.

REFERENCES

[1] Jollivet T, Peyrac C, Lefebvre F. Damage of Composite Materials. Procedia Eng 2013;66:746–58. doi:10.1016/j.proeng.2013.12.128.
[2] Gibson LJ, Ashby MF. Cellular Solids: Structure and Properties. 2 edition. Cambridge University Press; 1999.
[3] Fatigue of Composite Materials: A Symposium Presented at December Committee Week, American Society for Testing and Materials, Bal Harbour, Fla., 3-4 Dec. 1973. ASTM International; 1975.
[4] An H, Chen S, Huang H. Optimal design of composite sandwich structures by considering multiple structure cases. Compos Struct 2016;152:676–86. doi:10.1016/j.compstruct.2016.05.066.
[5] Alila F, Fajoui J, Kchaou M, Casari P, Wali N, Gerard R. Mechanical characterization of sandwich composite structure using a new experimental approach. Adv Compos Lett 2016;25:117–20.
[6] Gerard R, Alila F, Fajoui J, Jacquemin F. Updated fatigue test methods for structural foams and sandwich beams. 5th High Perform Yacht Des Conf Auckl 2015.
[7] Allen HG. Analysis and Design of Structural Sandwich Panels. The Commonwealth and International Library: Structures and Solid Body Mechanics Division. Pergamon; 1969.
[8] Zenkert D. The handbook of sandwich construction. Engineering Materials Advisory Services Ltd; 1997.
[9] Dai J, Thomas Hahn H. Flexural behavior of sandwich beams fabricated by vacuum-assisted resin transfer molding. Compos Struct 2003;61:247–53. doi:10.1016/S0263-8223(03)00040-0.
[10] Carlsson LA, Kardomateas GA. First-Order Shear Analysis of Sandwich Beams. Struct. Fail. Mech. Sandw. Compos., Springer Netherlands; 2011, p. 85–101. doi:10.1007/978-1-4020-3225-7_4.
[11] Russo A, Zuccarello B. Experimental and numerical evaluation of the mechanical behaviour of GFRP sandwich panels. Compos Struct 2007;81:575–86. doi:10.1016/j.compstruct.2006.10.007.
[12] Sharma N, Gibson RF, Ayorinde EO. Fatigue of Foam and Honeycomb Core Composite Sandwich Structures: A Tutorial. J Sandw Struct Mater 2006;8:263–319. doi:10.1177/1099636206063337.
[13] Davies JM. Lightweight sandwich construction 2001:245.