12th International Conference on Sandwich Structures (ICSS-12) Lausanne - Switzerland, 19–22 August 2018
DOI: 10.5075/epfl-ICSS12-2018-115-117

MECHANICAL RESPONSE OF SANDWICH STRUCTURES BASED ON CORRUGATED COMPOSITE CORES FILLED WITH PVC FOAM

Jin Zhou[1], Lei Peng[1], Zhong Wei Guan[1] and Wesley James Cantwell[2]
[1] School of Engineering, University of Liverpool, Liverpool, L69 3GH. United Kingdom. Email: jinzhou@liv.ac.uk
[1] School of Engineering, University of Liverpool, Liverpool, L69 3GH. United Kingdom. Email: sglpeng2@liv.ac.uk
[1] School of Engineering, University of Liverpool, Liverpool, L69 3GH. United Kingdom. Email: guan@liv.ac.uk
[2]Aerospace Research and Innovation Center, Khalifa University of Science Technology and Research, 127788 Abu Dhabi, United Arab Emirates. Email: cantwell@liv.ac.uk

1. INTRODUCTION

Sandwich structures have been used in a number of light-weight aerospace structures. In recent years, there has been a drive to develop sandwich structures based on novel designs, for example truss, lattice and prismatic structures [1, 2]. For example, researchers have developed stretch-stretch hybrid hierarchical cores that include pyramidal lattice sandwich panels in macroscopic truss designs [4]. More recently, researchers have studied the possibility of employing corrugated composite panels in the design and manufacture of morphing structures and energy-absorbing components [3, 4]. Kazemahvazi and co-workers characterized the properties of hierarchical corrugations manufactured from a carbon fibre reinforced epoxy resin [3]. The sandwich structures exhibited different failure mechanisms as the geometry of these novel structures was changed. Rejab and Cantwell [4] used a steel mould with a triangular profile to manufacture a number of corrugated cores with differing wall thicknesses and compared the resulting properties to those associated with a comparable aluminium system. It was concluded that the carbon fiber-based core offer superior properties of that of the metallic system. Malcom et al [5] tested a number of foam-filled and plain corrugated core structures produced from 3D glass fiber fabrics where it was shown that slender struts failed in an elastic buckling mode and thicker struts in a plastic microbuckling mechanism. Finally, Zhou et al [6] a broad range of tests on integrated woven corrugated sandwich composites and showed that the compressive properties of these sandwich structures, offer stiffness and strength characteristics that vary with the relative density squared. The aim of the work presented in this paper is to investigate the mechanical properties of sandwich structures consisting of curvilinear composite cores filled with PVC foam. Here, the effect of density of filled PVC foam and geometrical parameters on the mechanical properties of the sandwich structures is investigated.

2. EXPERIMENTAL PROCEDURE

The corrugated core sandwich structure tested in this study were fabricated using a woven glass fibre reinforced plastic (GFRP), and a woven carbon fibre reinforced plastic (CFRP). The sinusoidal-shaped composite cores with varying diameter and thickness were manufactured by wrapping sheets of composite prepreg around an array of Teflon-coated steel tubes, as shown schematically in Fig. 1. The skins of the sandwich structures were introduced by laying composite plies on the top and bottom surfaces of the uncured tubular array.

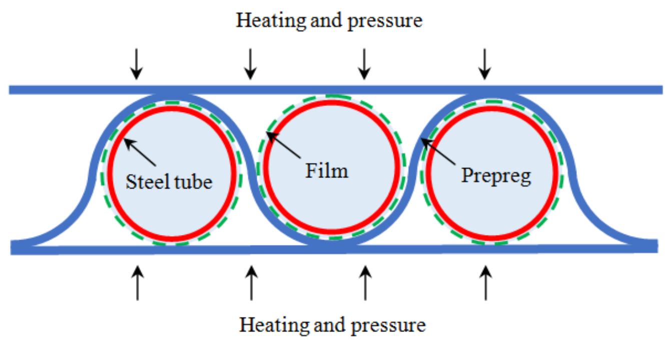

Fig. 1: Schematic of the corrugated core sandwich structure.

Subsequently, the entire structure was cured in a hot press. Here, the panels were heated to 125 ºC at a heating rate of 1.5 ºC/minute. This temperature was then maintained for 90 minutes, before allowing the samples to cool to room temperature. The sandwich panels were then moved to oven and post-cured for 90 minutes at 125 ºC. The PVC foam varying density from 40 to 130 kg/m^3 used in this investigation, were supplied by Airex AG. PVC foams were machined by CNC machine and filled in the curvilinear composite core structures. The specimen investigated in this study is shown in Table 1.

Table 1: Summary of the specimen investigated in this study.

Thickness of corrugation.	C40 PVC	C80 PVC	C130 PVC
CF1	C40CF1	C80CF1	C130CF1
CF2	C40CF2	C80CF2	C130CF2
CF3	C40CF3	C80CF3	C130CF3
CF4	C40CF4	C80CF4	C130CF4
CF5	C40CF5	C80CF5	C130CF5
GF1	C40GF1	C80GF1	C130GF1
GF2	C40GF2	C80GF2	C130GF2
GF3	C40GF3	C80GF3	C130GF3
GF4	C40GF4	C80GF4	C130GF4
GF5	C40GF5	C80GF5	C130GF5

Compression tests were undertaken at a crosshead displacement rate of 1 mm/min using a universal Instron 4045 test machine. A crosshead displacement rate of 1 mm/min was employed during testing. Potential changes in failure mode were photographed at regular intervals during testing in order to elucidate the modes of failure and fracture. The dynamic impact response of the sandwich structure was investigated through a series of drop-weight impact tests on foams had nominal densities of 40 and 130 kg/m^3. During impact loading, the displacement and force of the impact head were measured using a high speed video camera and a piezoelectric load cell respectively.

3. RESULTS AND DISCUSSION

The Influence of Corrugation Thickness

Typical stress-strain traces following compression tests on GFRP and CFRP samples with corrugation thicknesses ‘t’ between 0.25 and 1.25 mm. An examination of the response of those structures, indicates that increasing the value of ‘t’ serves to increase the compression strength of the core. Further increases in thickness precipitated a change in the shape of the stress-strain trace, with the curves exhibiting stable plateau before the onset of final densification.

The Influence of Foam Density

The comparison of the failure modes in GFRP samples with web thicknesses of 1.25 mm filled with 40 and 130 kg/m^3 PVC foams are shown in Fig. 2. Failure in the 40 kg/m^3 foams samples involved initial buckling and creasing close to the upper skin, followed by a buckling failure of the webs at their mid-points. Failure in the 130 kg/m^3 foams samples involved the formation of a hinge at the vertical alignment of the webs and the top surface. These re-aligned webs were capable of supporting significant load before failing, leading to distinct peak in the stress-strain trace. The filled PVC foam enhance the mechanical performance.

Fig. 2: Typical failure of GFRP samples for C40GF3 and C130GF5.

4. CONCLUSIONS

The mechanical response of sandwich structures base on corrugation core filling with PVC foam have been investigated experimentally and numerically. The mechanical response of the sandwich structures was modelled using finite element model. Sandwich structures based on varying thickness of corrugated core have been manufactured by compression molding an array of wrapped metallic cylinders. Tests on the resulting samples indicated that the compression strength increased with the thickness of the corrugation and density of filled PVC foam. The stress-strain traces for the PVC foam filled c samples exhibited less peak, failure mechanisms that were associated with buckling of the web. It indicates that the carbon fiber reinforced corrugated structures offered superior compressive properties to its glass-based counterpart. It also clears that compression strength increased rapidly with the thickness of the corrugation and foam density. The final part of this study focused on investigating the dynamic response of the glass and carbon/epoxy structures. This study suggests that the mechanical response of the hybrid sandwich structures can be predicted by using FE modelling.

REFERENCES

[1]. J. Xiong, B. Wang, L. Ma, J. Papadopoulos, A. Vaziri and L. Wu, "Three-dimensional composite lattice structures fabricated by electrical discharge machining" Experimental mechanics, 2013;54:405–412.

[2]. S. Yin, L. Wu and S. R. Nutt, "Compressive efficiency of stretch-stretch-hybrid hierarchical composite lattice cores", Materials and Design 2014; 56:731–739.

[3]. S. Kazemahvazi, D. Tanner and D. Zenkert, "Corrugated all-composite sandwich structures. Part 2: Failure mechanisms and experimental programme", Composites Science and Technology 2009;69:920-925.

[4]. M. R. M. Rejab and W. J. Cantwell, "The mechanical behaviour of corrugated-core sandwich panels", Composites. Part B Engineering 2013;47:267–277.

[5]. A.J. Malcom, M.T. Aronson, V.S. Deshpande and N.H.G. Wadley, "Compressive response of glass fiber composite sandwich structures", Composites Part A – Applied Science and Manufacturing 2013;54:88-97.

[6]. F.N. Jin, H.L. Chen, L. Zhao, H.L. Fan, C.G. Cai and N. Kuang, "Failure mechanisms of sandwich composites with orthotropic integrated woven corrugated cores: Experiments", Composite Structures 2013;98: 53-58.

[7]. Z. Hashin, "Failure criteria for unidirectional fiber composites", Journal of Applied Mechanics 1980;47:329-334.

[8]. E. Sitnikova, Z.W. Guan, G.K. Schleyer, W.J.Cantwell, "Modelling of perforation failure in fibre metal laminates subjected to high impulsive blast loading", International Journal of Solids and Structures 2014; 51: 3135-3146.

[9]. T. P. Vo, Z. W. Guan, W. J. Cantwell, G. K. Schleyer. "Modelling of the low-impulse blast behaviour of fibre–metal laminates based on different aluminium alloys", Composites: Part B 2013;44: 141–151.

[10]. J. X. Zhang, Q. H. Qin and T. J. Wang, "Compressive strengths and dynamic response of corrugated metal sandwich plates with unfilled and foam-filled sinusoidal plate cores", Acta Mechanica 2013;224:759–775.