Mechanical Characterization of CFRP Contour Core Panels

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A series of experimental investigations and numerical analyses is presented into the compression response in contour core sandwich panels based on carbon fibre reinforced plastic (CFRP). The contoured-cores were fabricated using a hot press moulding technique and then bonded to face sheets based on the same material, to produce a range of lightweight sandwich panels. The results are compared with the numerical predictions offered by a finite element analysis (FEA).The predictions of the FEA generally show reasonably good agreement with the experimental measurements.

Keywords: CFRP, Contoured Sandwich Panel, Finite element Analysis

1. Introduction

Sandwich panels are continuously being improved by developing new structural geometries with minimum weight and compact volume for automobile, aeroplane, marine and construction industries. Sandwich panels with fiber reinforced plastic skins and cellular core , have been shown to offer superior stiffness ,strength and energy absorption properties compared to their monolithic counterparts

A potential new class of energy absorbing aluminium egg box structure was introduced to understand the collapse mechanism. Experiments suggested that egg-boxes deform by either the rotation of a stationary plastic hinge or by a travelling plastic knuckle, depending upon the in-plane kinematic constraints imposed upon the egg-box (Zupan M, 2002). Egg-box shaped energy absorbing structures made of fabric composites were fabricated to find out the compressive characteristics and energy absorption capacity. The energy absorption per unit mass of composite egg-box panels made of different types of material and stacking sequences was calculated and compared with (Seong Hwan Yoo 2008). Compressive tests on foam-filled composite egg-box panels were carried out to assess their performance as energy absorbers. Material type, number of plies and stacking angle were varied. Collapse trace of the core was used to estimate energy absorption capacity. It was found that the foam-filled composite egg-box sandwich panels had a good energy absorption capacity with a stable collapse response resembling the ideal energy absorber (S.H. Yoo, 2010).

In this paper, the compressive properties of contoured core sandwich panels based on carbon fiber reinforced materials are investigated. Particular focus is placed on identifying the influence of the number of unit cells and the thickness of the cell walls in determining the compression behavior of the panel. The experimental results are compared with the numerical predictions offered by a finite element analysis (FEA).

2. Experimental procedure

2.1 Geometry and fabrication

The geometry of the CFRP contoured core panel are effectively the same as those of composite egg-box panel used in (Chunga J.G 2007).An aluminium mould was used to produce the shaped structure used in ref (Chunga J.G 2007). The mould was manufactured by using a numerically-controlled milling machine. Prepreg carbon/epoxy sheets were used to fabricate the composite cores.

2.2. Sandwich panels

A hot press was used to produce all of the contoured sheets for the sandwich panels. In order to manufacture the composite contour cores, the composite prepreg was placed between the upper and lower moulds, and then cured according to the manufacturer's recommended processing cycle. Once the hot press had cooled to a temperature below 60 C, the sheet was removed from the mould and visually inspected for defects. The contoured sheet was then bonded to the upper and lower skins using a two part epoxy adhesive (Araldite 420 A/B). The contoured sandwich panel was then heated in an oven to a temperature of 120 ^{o}C for approximately 1 h in order to cure the adhesive. Two sizes of rectangular test specimen were prepared. Initially, the effect of increasing the number of cells in the core was investigated for a constant cell wall thickness. Here, (1x1) and (2x2) unit cells were investigated in order to understand the effect of varying unit cell in contoured sandwich panels. Following this, the effect of varying the cell wall thickness 0.50mm, 1.00mm and 1.50mm were investigated for a constant size of (2x2) unit cells specimen.

3. Finite element analysis

The responses of the contoured-core sandwich panels under compression loading were modelled using the ABAQUS/Standard finite element software package. A quarter model was proposed to save the model running time in abaqus, whilst applying the appropriate boundary conditions. In Fig. 1, three-dimensional shell elements (S4R) were used to model the contoured core part. The core and the platten were connected using a contact interaction formulation. The nodes along the upper and lower edges were fully constrained, except in y-direction at the upper edge. Displacements were applied uniformly to the nodes at the apex of the unit cell to simulate compression of the core. Hashin's damage model assuming, an initial linear elastic behavior followed by evolution of damage, was used to predict the behavior of the composite. The models were used to simulate initial failure and to predict the compression strength of the panels. Table 1 Properties of the materials used to produce the contoured-core sandwich panels for Finite element analysis.

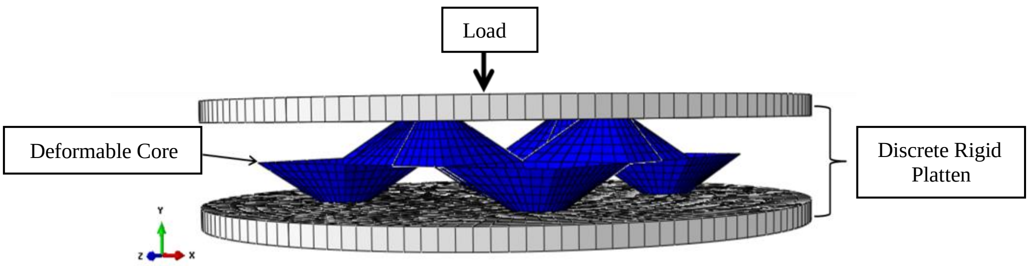

Figure 1. Loading conditions used in the contoured-core model

Table 1. Properties of the materials used to produce the corrugated-core sandwich panels for CFRP.

Symbol	Values (CFRP)	Property
E_{11}	48 GPa	Young's modulus in longitudinal direction
E_{22}	48 GPa	Young's modulus in transverse direction
E_{33}	1 GPa	Young's modulus in thickness direction
G_{12}	9 GPa	In-plane shear modulus
G_{13} ,G_{23}	9 GPa	Through-thickness shear modulus
ν_{12}	0.1	In-plane Poisson's ratio
ν_{13}, ν_{23}	0.1	Through-thickness Poisson's ratio
X_t	550	Longitudinal tensile strength
X_c	150	Longitudinal compressive strength
Y_t	550	Transverse tensile strength
Y_c	150	Transverse compressive strength
S_t	120	Transverse shear strength
S_L	120	Longitudinal shear strength

4. Results and discussion

4.1. The effect of varying the number of unit cells

The effect of varying the number of unit cells on the compression strength of the CFRP sandwich panels is shown in Fig.2.A comparison of the finite element predictions and the experimental measurements indicates that the influence of the cell number is accurately predicted.

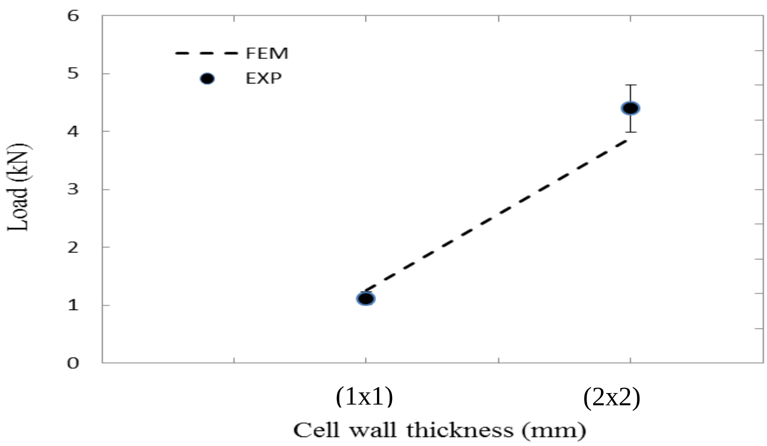

Figure 2. Comparison between measured and FE predictions for compression strength for CFRP as a function of number of unit cells

4.2. The effect of cell wall thickness

The final part of this study investigated the influence of varying the thickness of the cell wall on the compressive properties of the contoured panels. Fig.3 shows the variation of strength of the CFRP contoured panels as a function of wall thickness. As expected, the strength increases highly with wall thickness. The compression strength of the CFRP contoured panel with a wall thickness of 1.50 mm is impressive, with a value in excess of 15.98 MPa being recorded. A comparison of the finite element predictions and the experimental measurements indicates the good agreement.

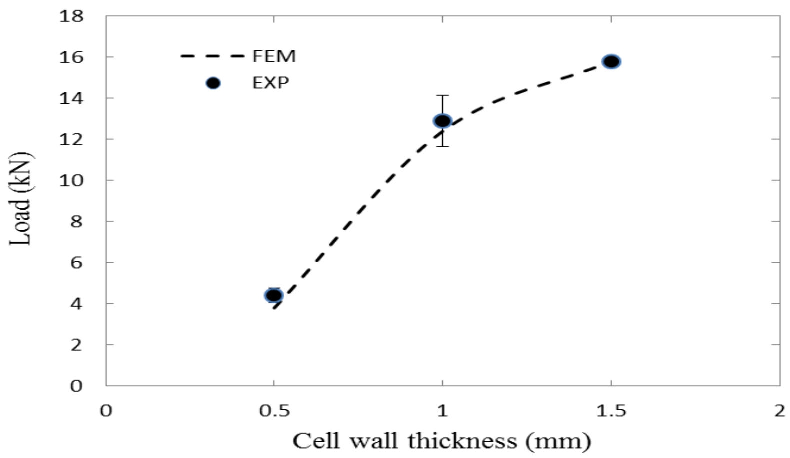

Figure 3. Comparison between measured and FE predictions for compression strength for CFRP as a function of cell wall thickness

5. Conclusion

Contoured-cores, manufactured using an aluminium profiled mould, have been used to produce a range of lightweight sandwich structures. The compressive behavior of carbon fiber reinforced composite material has been investigated both experimentally and numerically. The predictions offered by the numerical models were found to be in reasonably good agreement with the experimental data.

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