Evaluation of mechanical properties of 3D lattice structures for sandwich panels cores

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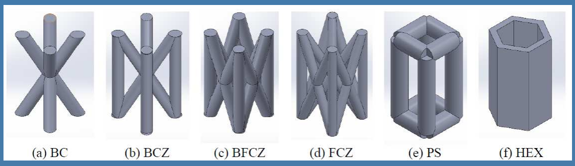
- Sandwich structures are frequently used in automotive, aerospace and marine industries, as they provide adequate functional properties.
- Recently, a new type of cellular structures composed of lattice struts has been proposed, as they combine high stiffness, strength and energy absorption with low weight.
- The main purpose of this research is to investigate the effect of the lattice topology on the flexural behaviour of sandwich panels.
- Five lattice geometries inspired in crystalline structures were designed. The relative density of all the lattices was kept constant as 0.3.
- Additive manufacturing method material extrusion was used to produce polylactic acid panels composed by a single layer formed by the lattice core and two thin plates, at the bottom and top.
- Numerical and experimental approaches were used to evaluate the flexural properties and failure behaviour of the sandwich structures under three-point bending tests.
- The numerical analysis was undertaken with the finite element software NX Nastran.

MATERIAL AND METHODS

1. Sandwich panel design

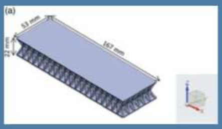
3D CAD program SolidWorks



Lattice unit cells: (a) body-centred parallelepiped (BC), (b) body-centred parallelepiped with struts in z axis (BCZ), (c) body and face-centred parallelepiped with struts in z-axis (BFCZ), (d) face-centred parallelepiped with struts in z-axis (FCZ), (e) parallelepiped simple (PS) and (f) hexagonal honeycomb cell (HEX).

2. Manufacturing

The composite panels were obtained by additive manufacturing (Ultimaker 3).
The material was polylactic acid (PLA).

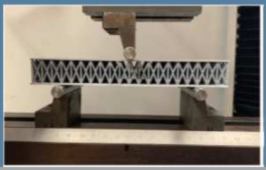


3. Finite element modelling

- NX Nastran software using Siemens NX as pre and post-processor
- Mesh refinement was conducted and the convergence criterion was set as less than 5% changes in the highest von Mises stress

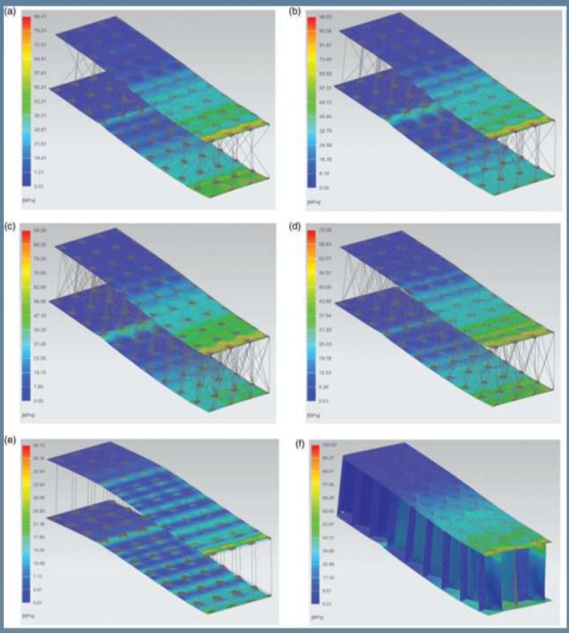
4. Experimental three point bending tests

Instron 3369 universal testing equipment



RESULTS

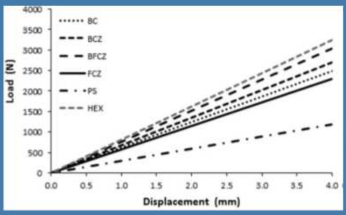
FE analysis

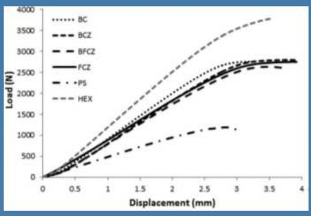


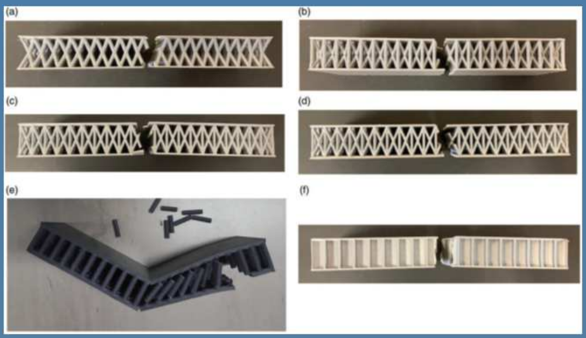
von Mises stress (MPa) in the skins of all the sandwich structures under 3PB loading after a vertical displacement of 4 mm.(a) BC, (b) BCZ, (c) BFCZ, (d) FCZ, (e) PS and (f) HEX.

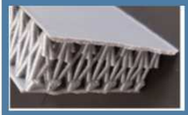
RESULTS

Load-displacement curves obtained by finite element modelling and by experimental tests allow to obtain stiffness and absorbed energy. Strength was evaluated by von Mises stress.









Fractured specimens after 3PB test. (a) BC, (b) BCZ, (c) BFCZ, (d) FCZ, (e) PS, and (f) HEX.

FE and experimental results for bending tests: maximum von Mises stress σ_{max}, stiffness K, and absorbed energy E_a, until dl=3mm.

	Finite element			*Experimental*	
Geometry	σ_{max} [MPa]	K [N/mm]	E_a [J]	K [N/mm]	E_a [J]
BC	86.39	622.44	2.80	821.32±11.39	4.11±0.03
BCZ	98.25	676.61	3.04	820.50±78.49	4.06±0.05
BFCZ	94.20	760.43	3.42	828.56±57.98	4.03±0.15
FCZ	75.08	574.99	2.59	862.84±41.28	3.87±0.14
PS	42.73	297.07	1.34	491.51±24.94	1.73±0.05
HEX	103.93	812.34	3.65	1037.00±25.43	4.87±0.74

CONCLUSIONS

- Good agreement between experimental results and simulations.
- Higher strength is observed in topologies BCZ (body-centred parallelepiped with struts in z-axis) and BFCZ (body- and face-centred parallelepiped with struts in z-axis).
- Higher stiffness and higher energy absorption for BFCZ (body- and face centred parallelepiped with struts in z-axis).
- Values that do not differ much from the ones obtained with a two-dimensional hexagonal cellular structure, with the same relative density.
- Some of the geometries studied may have the potential to be considered as alternatives to conventional structures in the design of sandwich structures.

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