

Mechanical properties and energy absorption capability of functionally graded F2BCC lattice fabricated by SLM

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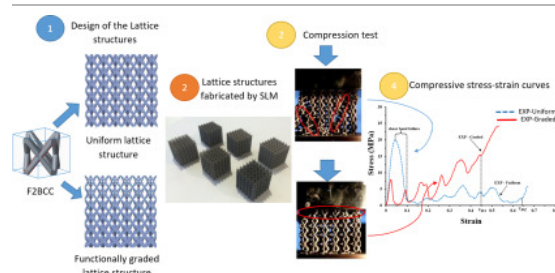
Highlights

- Successful selective laser melting of functionally graded F2BCC lattice structure.
- Comparison of compressive behaviour of uniform and functionally graded lattices.
- Graded F2BCC lattice gives higher energy absorption capacity than uniform lattice.
- Graded F2BCC lattice exhibits distinctive deformation characteristics.

Abstract

Metallic lattice structures with complex internal design can be fabricated using selective laser melting (SLM) additive manufacturing technology. These lattice structures are finding many applications such as in personal protective equipment and packaging due to their distinctive properties, combining the lightweight and high strength. In this study, experimental compression tests and finite element analysis (FEA) were conducted to investigate and compare the mechanical properties and energy absorption capability of functionally graded and uniform F2BCC lattice structures made of Al-12Si aluminium alloy and manufactured by SLM process. The solid struts diameters and surface morphology were examined using scanning electron microscope. The functionally graded lattice structures were found to exhibit distinct deformation behaviour as compared to the uniform lattice structure. Results of finite element analysis were found to be in qualitative agreement with the experimental data and with the predictions of the analytical models for graded lattice structure. The total cumulative energy absorption per unit volume was higher in functionally graded lattice than in uniform lattice. Finally, mechanical characteristics and coefficients of three Gibson and Ashby analytical equations were also determined, which could be used to estimate the mechanical properties of other SLM fabricated functionally graded lattice structures.

Graphical abstract



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Introduction and theoretical background

Three-dimensional lattice structures have numerous applications due to their distinctive properties, in particular combining the lightweight and high strength and that include personal protective equipment, packaging, structural lightweight, thermal insulation, energy absorption, bio-medical implants, and buoyancy [[1], [2], [3]]. Several manufacturing techniques have traditionally been used to produce the metallic porous structures. For example, melt gas injection has been used to form a ...

Design and manufacturing of lattice structures

PTC™ Creo Parametric 3.0 software was used to design the lattice structures in cubes of dimensions 30×30×30mm. The lattice structures were made of repeating unit cells comprising of combined one-unit cell of body centred cubic (BCC) and two-unit cells of face-centred-cubic (FCC), which is defined as F2BCC unit cell. As shown in Fig. 2, the F2BCC lattice unit cell consists of 12 solid struts of circular cross-section by which they intersect at 45° angle to vertical, four at the cell centre, and ...

Finite element modelling and analysis

To simulate the deformation behaviour of the lattice structures, finite element analysis was performed using LS-DYNA code of ANSYS© software. For both uniform and graded lattice structures, 3D solid elements of 4-node tetrahedral type were employed to mesh the lattice models with six degrees of freedom per node. Convergence studies were conducted for a range of mesh sizes in order to determine the proper mesh size. Meshing process of FEA models generated an average of 170,000 elements and ...

Dimensions and morphological characteristics

Fig. 6 shows the SEM and OM images of lattice solid struts. It is clearly shown that the solid struts were found in circular cross section and in different volume fractions, which indicate that the fabricated lattice struts agree well with the CAD model of F2BCC lattice structure in Fig. 2. Table 4 shows the designed and measured dimensions of the uniform and graded lattice structures. It is clear from the table that the dimensions of the solid struts are not identical between designed and ...

Conclusion

This study demonstrated the successful selective laser melting of functionally graded F2BCC lattice structures. Mechanical behaviour of graded structures under compression loads was compared to that of uniform structures. The following conclusions can be drawn from the experimental tests and finite element simulations carried out in this research.

- 1- The SEM and OM images have clearly shown that SLM technology can successfully produce the functionally graded lattice structure such as F2BCC in ...

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