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MECHANICAL PROPERTIES OF ADDITIVE MANUFACTURED ALUMINUM PERIODIC CELLULAR STRUCTURE (PCS) FOR SPACE APPLICATIONS

Abstract

Combining cellular materials properties and metals characteristics, cellular metals are becoming a main focus of space applications. When the material is highly porous, periodic structures are stronger by one order of magnitude compared to stochastic microcellular metal structures, and feature also a reduced spread in values of mechanical properties. The rapid development of additive manufacturing processes has greatly facilitated the production of such materials, thus opening new possibilities for conceiving and manufacturing lightweight strong structures. In this work, four different types of PCS (body-centered, face-centered, octet-truss and diamond) were manufactured by selective laser melting of the eutectic aluminum-silicon alloy (Al-12wt.pct.Si) with a relative density of 30% (0.8 g/cm^3) and under two different conditions, with and without heat-treatment (2h at 240C). 3D-Tomography recordings were performed to investigate the deviations in dimension from the CAD models as well as topology, porosity and inclusions of the dense struts. Mechanical properties of PCS were evaluated by quasi-static compression with stereo cameras allowing 3D in-situ strain mapping. Bulk materials properties and microstructures were also investigated through tensile tests, their results being used in finite element calculations. Due to its fine microstructure, the printed AlSi12 is 100% stronger in its yield stress (300 MPa) and 33% in its UTS (430 MPa) compared to the standard cast alloy in its F-state. Anisotropy was observed for the non-heated bulk materials, this disappeared with the heat-treatment. Concerning the PCS, the relative density ranges from 29.8 to 32.3%, compressive modulus from 3 to 4 GPa, yield stress from 28 to 38 MPa and peak stress from 46 to 66 MPa. Deformation and failure modes were studied for each structure, the comparatively brittle behavior of the base alloy inducing mainly brittle fracture of the periodic structure itself. The evolution of the compressive modulus with increasing plastic strain was measured through loading-unloading cycles and was fitted to a second order polynomial law. Finite element analysis are in a good agreement with the experimental data. Such a process has the potential of being relatively low-cost and could, in certain cases, replace the core of honeycomb panels adding the possibility to integrate heat exchanger, impact absorption or micro-meteoroid shielding in multifunctional structures. Additive manufacturing induced a new way of thinking, designing and fabricating but care as to be taken for its use in space applications, particularly the risk of cross-contamination from other metals during the printing process, as has been observed in this work.