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Dynamic compressive response of additively manufactured AlSi10Mg alloy hierarchical honeycomb structures

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Abstract

Periodic honeycombs have been used for their high strength, low weight and multifunctionality. The quasi-static and dynamic compressive responses of three types of additively manufactured AlSi10Mg honeycomb structures, specifically a single-scale honeycomb and two hierarchical honeycombs with two and three levels of hierarchy, respectively, have been investigated using experimental measurement and finite element (FE) simulations. The validated FE simulation has been employed to investigate the effects of relative density of the honeycombs and the key experimental parameters. The following failure modes of the three types of honeycombs have been observed both under quasi-static and dynamic compression: (1) the single-scale honeycomb experienced a transition of failure mechanism from local plastic buckling of walls to local damage of the parent material without buckling with the increase of the relative density of the honeycomb; (2) the hierarchical honeycombs all failed with parent material damage without buckling at different relative densities. For both quasi-static and dynamic compression, the hierarchical honeycombs offer higher peak nominal wall stresses compared to the single-scale honeycomb at low relative density of $\bar{\rho} = 0.19$; the difference is diminished as relative density increases, i.e. the three types of honeycombs can achieve similar peak wall stresses when $\bar{\rho} \geq 0.26$. Numerical results have suggested the hierarchical honeycombs can offer better energy absorption capacity than the single-scale honeycomb. The two-scale and three-scale hierarchical honeycombs achieved similar peak nominal wall stresses for both quasi-static and dynamic compression, which may suggest that the structural performance under out-of-plane compression is not sensitive to the hierarchical architecture. This work indicates that the structural advantage of hierarchical honeycombs can be utilised to develop high performance lightweight structural components.

Keywords: honeycomb; mechanical properties; impact behaviour; finite element analysis (FEA); additive manufacturing