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PROCEEDINGS

Crashworthiness Design of Composite Thin-Walled Structures Manufactured by Additive Manufacturing

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ABSTRACT

To address the increasing demands for lightweight and passive safety in transportation equipment, a series of studies on the crashworthiness design of composite thin-walled structures were conducted. These investigations leveraged the high specific strength/stiffness advantages of carbon fiber-reinforced polyamide composites and the high-formability benefits of fused deposition modeling (FDM) additive manufacturing technology. Compared with traditional composite manufacturing processes, lattice-filled thin-walled structures, integrally fabricated via additive manufacturing, exhibited significant synergistic interactions between their internal lattice and outer walls during compression. This synergy effectively enhanced the energy absorption capacity of the structures and achieved a "1+1>2" synergistic effect in energy absorption. Impact tests at different speeds were performed to investigate the influence of the strain-rate effect of composites on the energy-absorbing characteristics of thin-walled structures. As the impact speed increased, the collapse behavior of the thin-walled structures changed from a stable plastic deformation mode to a brittle crack-to-fracture collapse mode, and their energy absorption capacity first increased and then decreased. Guided by a hierarchical energy management strategy, this study investigated the correlation between cell density and energy absorption capacity in multi-cell thin-walled structures. The stepped and continuous gradient design strategies for their cross-sections were proposed, enabling controlled multistage deformation and the gradual enhancement of energy absorption capabilities. Additionally, inspired by the stem of the bird-of-paradise plant, the staggered diaphragms along the longitudinal direction of the multi-cell thin-walled structures were introduced. These staggered diaphragms induced alternating folding deformations in the thin walls, simultaneously improving energy absorption and reducing load fluctuations. This design effectively reduced the risk of secondary injuries to occupants caused by load fluctuations during collisions. These findings provide a research foundation for the design of additive-manufactured composite thin-walled structures and offer technical support for their applications in transportation equipment.

KEYWORDS

Thin-walled structures; crashworthiness; additive manufacturing; carbon fiber-reinforced polyamide composites

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