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Multiscale Experiments and Predictive Modeling for Failure Mitigation in Additive Manufacturing of Lattices

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Additive Manufacturing (AM) empowers the creation of high-performance cellular materials, underscoring the increasing need for programmable and predictable energy absorption capabilities. This study evaluates the impact ofa precisely tuned fused filament fabrication (FFF) process on the energyabsorption and failure characteristics of 2D-thermoplastic lattice materialsthrough multiscale experiments and predictive modeling. Macroscale in-planecompression testing of both thick- and thin-walled lattices,along with theirμ-CT imaging,reveal relative density-dependent damage mechanisms and failure modes, prompting the development of a robust predictive modeling framework to capture process-induced performance variation and damage.

For lower relative density lattices, an FE model based on the extended Drucker–Prager material model, incorporating Bridgman's correction with crazing failure criteria, accurately captures the crushing response. As lattice density increases, interfacial damage along bead-bead interfaces becomes predominant, necessitating the enrichment of the model with a microscale cohesive zone model to capture interfacial debonding. The predictive modeling introduces an enhancement factor, offering a straightforward method to assess the impact of the AM process on energy absorption performance, thereby facilitating the inverse design of FFF-printed lattices.

This approach provides a critical evaluation of how FFF processes can be optimized to achieve the highest attainable performance and mitigate failuresin architected materials.

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