

PROCEEDINGS

Design of Ultralight and Ultra-Strong Shell Lattices via Imperfection Strengthening and Rib Reinforcement

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ABSTRACT

Shell lattices are promising candidates for lightweight multifunctional applications for their geometric uniqueness and distinct mechanical properties. However, due to the transition from yield-to-buckling failure mode, shell lattices exhibit notably reduced strength at low relative densities (RDs), making the design of ultralight and ultra-strong shell lattices challenging. Herein, a novel imperfection-enabled strengthening strategy is proposed to enhance the strength of ultralight triply periodic minimal surface (TPMS) shell lattices. It is shown that increasing the bending strain energy ratio in lattices through imperfections such as slightly corrugated geometries can significantly enhance the stability and strength of ultralight shell lattices by suppressing their microarchitecture buckling deformation. Based on this, a novel design method of rib-reinforced shell lattices is further proposed to achieve more exceptional strength. By revealing the relation between the curvature and stress direction of TPMS thin shell lattices, two groups of ribs are orchestrated along the representative curvature directions: the line of asymptotes (LOA) and the line of principal curvatures (LOC). Through physical realization and numerical simulations, incorporating ribs along the LOAs and LOCs that pass through the shell umbilical points is shown to enhance strength by 112.3%, with an RD around 1.28%. Incorporating ribs can redistribute the stress and selectively strengthen thin shells to suppress their buckling deformation, especially at the umbilical region. The continuous ribs also provide additional load paths, thereby resulting in improved load-bearing efficiency. These findings provide a practical method for devising ultralight and ultra-strong shell lattices against micro-architecture buckling failure.

KEYWORDS

Ultralight and ultra-strong shell lattices; imperfection-enabled strengthening; triply periodic minimal surfaces; rib-reinforced shell lattices; curvature directions; buckling-resistant design

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