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Fracture Toughness of Periodic Beam Lattices

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Abstract

This study addresses fracture modeling in beam lattices, a key challenge in designing robust architected materials. We investigate how lattice microstructure and material properties influence fracture toughness using finite element simulations based on Euler–Bernoulli beam theory, with beam failure triggered by exceeding a critical axial stress. Based on these results, we developed a multi-phase-field fracture model with Cosserat elasticity to provide a consistent and design-oriented toughness framework, which was validated against experimental data. Our results show that the energy release rate remains nearly constant during crack propagation, confirming its suitability as a toughness measure for periodic lattices. Fracture toughness is mainly governed by beam height and material properties such as tensile strength and Young's modulus, while slenderness plays a minor role. Crack paths preferentially follow lattice directions due to stress localization, emphasizing the importance of microstructural architecture. These findings enhance the reliability of fracture modeling and support the optimized design of lattice materials with tailored fracture behavior.

Keywords:

Cosserat elasticity beam lattices fracture toughness homogenization metamaterial