

Crack propagation in lattice structures using the AA-FEM

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ABSTRACT

Lattice structures have emerged as a promising class of architected materials due to their lightweight nature, high mechanical performance, and adaptability for energy absorption applications. The advent of additive manufacturing (AM) techniques has further expanded the potential of these architected materials in sectors ranging from civil to biomedical engineering [1].

When used as shock absorbers, the major challenge lies in the choice of both the material and the geometrical characteristics of the lattice so as to maximize the dissipated energy. For a fixed material, the results vary according to the configuration of the unit cells, including cell shape, cell size, and thickness. On the basis of the assembly of the unit cells, the development of damage/plasticity in the weakest zones leads to particular localization mechanisms while absorbing energy. Crack propagation can be simulated using a continuous-discontinuous computational strategy.

In this framework, the Extended Finite Element Method (X-FEM) [2], the Virtual Element Method (VEM) [3], and the Advanced Augmented Finite Element Method (AA-FEM) [4] are examples of proven techniques.

In this work we applied the AA-FEM to the numerical simulation of crack propagation in lattice structures. The methodology introduces a weak discontinuity within the finite element in the form of an interphase element (IPH), thus dividing a non-localized element into two sub-elements and an IPH. A crack-tracking algorithm enables crack evolution simulation without requiring global remeshing. Strain localization criteria are based on an isotropic damage constitutive model and concepts such as critical damage and fracture tensor.

The proposed approach is applied to spatial periodic lattice configurations. Numerical analyses assess the effects of geometric design and material properties on failure mechanisms and energy absorption. A comparison with experimental results is also performed after fabrication and mechanical testing of 3D-printed polymeric lattice specimens using the Fused Deposition Modeling (FDM) technology.

References

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