OPTIMIZATION OF FRACTURE BEHAVIOR OF PERIODIC CELLULAR MATERIALS

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Cellular materials modelled as a periodic 2D lattice composed of Euler beam elements are investigated. Four basic layouts: triangular, square, hexagonal and kagome, are considered. Their fracture behavior under tensile, unidirectional or isotropic, loading is examined. The bulk material is assumed to be brittle and a beam is considered to fail when its skin stress resulting from the bending moment and axial force approaches some critical value. Such a fracture event corresponds to the removing of the broken element from the lattice. The analysis of a lattice with several missing elements hinges on the discrete Fourier transform. This enables to obtain an exact closed-form solution for an infinite domain without any simplifying assumptions. The computational efficiency of the employed approach furthers the investigation of different fracture phenomena and provides a firm ground for the solution of optimization problems.

The crack nucleation problem is considered first [1]. The initial defect is introduced by failure of one beam and then the most loaded elements are removed successively until a stable crack path is formed. Somewhat unexpected fracture patterns were observed pointing to a strong influence of the material microstructure on the crack propagation direction. In unidirectional tension, for instance, the crack path was inclined to the loading(hexagonal layout) or even parallel to it(square layout).

The fracture toughness is obtained from the analysis of sufficiently long cracks. For the hexagonal lattice the obtained data meets the results presented in [2] but deviates significantly from [3]. For the optimization problems the fracture toughness for a given lattice layout was maximized subject to an equality constraint on the relative density. In a first instance the material is redistributed between the elements of uniform cross sections composing the periodicity cell. In a second instance the design variables controlled the shape of elements with non-uniform cross section, similar to the approach in [4], and the material is redistributed within the element. It appears that the fracture toughness is rather sensitive to these design parameters. For example, in the case of a lattice with triangular cells under uniaxial tension the fracture toughness can be increased by 25 percent.

References

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