Tensile response of elastoplastic lattices at finite strain

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Abstract

The finite strain, uniaxial tensile response of two-dimensional (2D) elastoplastic lattices is investigated using finite element simulations and analytical models, taking into full account the macroscopic stiffening due to cell wall alignment. Four morphologies of 2D lattice are considered: triangular, Kagome, hexagonal, and diamond. The cell walls are treated as Timoshenko beams made from an elastoplastic solid with a strain hardening characteristic that resembles Ramberg-Osgood at low strains and exponential hardening at large strains. This description captures the response of metallic lattices at small strain and selected polymeric lattices at large strain. The use of beam theory is validated by additional continuum element simulations. The dependence of macroscopic ductility and tensile strength of each lattice is determined as a function of relative density, cell wall rupture strain and cell wall strain-hardening. Two failure criteria are invoked: (i) maximum value of local tensile strain anywhere in the lattice attains a pre-defined failure strain, or (ii) maximum value of average tensile strain across any section of the lattice attains the failure strain. The sensitivity of macroscopic ductility and ultimate tensile strength to geometric imperfection is explored by considering: (i) random topologies in which the joints are randomly perturbed in position, and (ii) a finite crack formed by an array of broken cell walls. The notion of a transition flaw size for the lattices is validated by means of a notch sensitivity analysis, and the significance of crack-tip blunting by cell wall alignment is highlighted for the hexagonal honeycomb.

Keywords: lattice materials, ductility, strain hardening, transition flaw size, finite strain

1. Introduction

The existing literature on polymeric and metallic foams and lattices is focused on their in-plane macroscopic compressive and shear response (Papka and Kyriakides, 1994; Grediac,