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Micromechanics based homogenization of truss lattices with experimental validation

A homogenization scheme has been developed to compute effective elastic properties for truss lattices using an interpolation scheme to develop the required continuum-to-discrete mapping rules for deformation. In the case of bending-dominated truss lattices, for hinged nodes, the lattice reduces to a mechanism for which the individual member rotations in response to deformation at the boundary can be determined from kinematic compatibility alone. For fully rigid nodes, the affine deformation yields fairly accurate results for rotations and axial strains of individual truss members. For a general case, the continuum-to-discrete deformation mapping rule is developed using (a) interpolation between the hinged nodes case and the rigid nodes case and (b) enforcing finite stiffness under axial strain. Using this mapping scheme, strain concentration tensors are developed for individual lattice members in a representative volume element. Subsequently, the granular micromechanics approach is used to homogenize the discrete lattice to an effective classical continuum. The approach has been applied to study different planar lattice microstructures such as diamond, hexagon, re-entrant honeycomb etc. under plane stress condition. It is known that for bending-dominated lattices, affine mapping yields effective elastic properties that differ by orders of magnitude from the true behavior. The scheme developed here is shown to give effective properties that match well with the corresponding full-resolution finite element solutions for both stretch-dominated as well as bending-dominated lattices. Furthermore, in contrast to numerical methods such as finite element approach, it can be used to determine closed form relationships between effective elastic properties and lattice geometry for a given material of construction in a micromechanics framework. Thus, the proposed scheme can be used to identify potential lattice designs for target effective elastic properties. Experimental validation of the interpolation scheme proposed has been performed using monotonic displacement-controlled testing of 3D printed planar truss lattices. The rotational stiffness at lattice nodes was controlled by means of pantographic design.