Microstretch beam model with enriched kinematics accounting for variable section

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The beam lattice-type model, such as the Euler Bernoulli or Timoshenko beam, has been very effective in discrete homogenization techniques towards micropolar effective continua in past works [1]. However, in order to develop refined effective continua taking into account the microdilatation, it is needed to formulate a beam element that allows for in-plane cross-sectional dilatation. The kinematics underlying Timoshenko beam is insufficient to account for the so called Poisson's effect accounting for the in-plane deformations. Typical applications of such models include complex yarns made of many intertwined filaments, used in electrical and mechanical engineering, or biomechanics. Enhanced kinematic beam models have been developed beyond Timoshenko beam. The general objective of this work is to construct generalized beam models accounting for Poisson's effect and the occurrence of large deformations. We develop in this work a beam element with 8 degrees of freedom to construct a 3D isotropic microstretch continuum model of the reinforcement in composite structures.

Referring to the theory of Antman (2005), we describe the kinematics of the cross-section of the curved beam by three vector fields; the first vector describes the position of the cross-section along the beam axis, while the two other directors which lie within the section allow modeling the reference cross-section deformations. The equilibrium equations are formulated from the virtual work principle, thus leading to the effective stiffness matrix relating the forces and moments to the conjugated kinematic variables. The powerfulness of the constructed beam model is illustrated by a closed form bending solution; a comparison of the enhanced beam model with Timoshenko beam is done.

Forthcoming developments include the construction of microstretch effective continua for repetitive network materials for periodic reinforcements in composites, consisting of the assembly of enriched beam elements within a repetitive unit cell. Typical applications include fibrous reinforcements in composite materials, trabecular bone microstructure, and any large scale repetitive man-made structure in civil or structural engineering.

References

S. Antman. Nonlinear problems of elasticity. Applied Mathematical Sciences. Vol. 107, 2005.