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Large-deformation analysis of isotropic elastomeric structures by Carrera Unified Formulation

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Owing to their specific mechanical and physical properties, elastomeric structures made of soft materials are constantly employed in various applications, such as in civil and aerospace engineering, seismology, oil prospecting, automotive industry, signal processing, phononic crystals and metamaterials, as well as biomechanics and biomedical devices. Soft materials are usually susceptible to undergoing large deformations under external stimuli such as mechanical loadings. Therefore, accurate predictions of their large-deformation response accounting for both *geometrical and physical nonlinearities* are of paramount importance for their design and failure evaluation.

Based on the well-known nonlinear hyperelasticity theory and by using the Carrera Unified Formulation (CUF) as well as a total Lagrangian approach, the unified theory of slightly compressible elastomeric structures including geometrical and physical nonlinearities is developed in this work. By exploiting CUF, the principle of virtual work and a finite element approximation, nonlinear governing equations corresponding to the slightly compressible elastomeric structures are straightforwardly formulated in terms of the fundamental nuclei, which are independent of the theory approximation order. Accordingly, the internal nodal force vector and the tangent stiffness matrix of the unified 1D beam and 2D plate elements are derived by using the 3D Cauchy-Green deformation tensor and the nonlinear constitutive equation for slightly compressible isotropic hyperelastic materials. A class of nonlinear constitutive equations is implemented where the isochoric strain energy functions are based on the first invariant of the right Cauchy-Green deformation tensor. The Newton-Raphson linearization scheme along with a path-following method based on the arc-length constraint is employed to solve the geometrically and physically nonlinear problem. Several numerical assessments are conducted, including uniaxial tension nonlinear response of rectangular elastomeric beams as well as uniaxial and equiaxial tension response of elastomeric plates. Numerical findings confirm the capabilities of the CUF model to predict the large-deformation equilibrium curves and the stress distributions with high accuracy.

References

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