Variational-based energy-momentum schemes of higher-order for elastic fiber-reinforced continua

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Variational-based energy-momentum schemes of higher-order for elastic fiber-reinforced continua

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Abstract

This paper contributes to the improvement of recently published higher-order accurate energy-momentum schemes for an anisotropic hyperelastic material formulation based on the concept of structural tensors. These Galerkin-based energy-momentum schemes are developed by means of time finite elements with the focus on improving numerical stability and robustness in the presence of stiffness and large rotations. They show advantages over conventional time stepping schemes in combination with anisotropic materials formulated with polyconvex strain energy density functions. In this paper, higher-order energy-momentum schemes are developed by using a differential variational principle in order to remedy the drawbacks of these Galerkin-based schemes, namely a variationally inconsistent time approximation of the strains in the higher-order case, no coordinate free superimposed stress tensor and an unseparated time approximation of the fibers and the matrix material. These new structure-preserving time integrators preserve all conservation laws of a free flying hyperelastic anisotropic continuum, namely the total linear and the total angular momentum conservation as well as the total energy conservation. Numerical examples demonstrate dynamic behaviour of anisotropic continua, discrete conservation properties of flying continua and the effect of higher-order accuracy subject to transient loads.

Key words: Fiber-reinforced continua, anisotropy, energy-momentum schemes, higher-order accuracy, mixed variational principle.