Energy-momentum conserving dynamic variational modeling of fiber-bending stiffness in composites

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We propose a new variational formulation for large deformations in dynamical systems made of 3D-fiber-reinforced composites. The formulation emanates from the dynamic variational approach based on the principle of virtual power. The use of higher-order gradient theory along with multi-field mixed-finite element method enables us to model the fiber-bending stiffness in fiber reinforced composites for numerical simulations accurately. Our proposed model captures higher-order energy contributions exhibited by fibers that influence the fiber-bending curvature, and consequently the fiber-bending stiffness behaviour. For this, in line with [1], we introduce a higher-order gradient of the deformation mapping as an independent field in the internal energy functional formulation. Along with the energy-momentum scheme demonstrated in [2], our new time integrator makes possible to perform long-term dynamic simulations with larger time steps and efficient CPU-time. We demonstrate our model using transient dynamical simulations on two geometrical examples that exhibit hyperelastic, transversely isotropic, polyconvex gradient material behaviour. In the first example, a L-shaped block tumbles free in the ambient space after an initial loading phase similar to [3] and in the second, a cantilever beam is self-excited due to its body weight. It is observed that our model conserves total momenta and total energy in both these examples along with spatial and temporal convergence.

REFERENCES

