The 8th European Congress on Computational Methods in Applied Sciences and Engineering
ECCOMAS Congress 2022
5-9 June 2022, Oslo, Norway

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

Iniyan Kalaimani[1,*], Julian Dietzsch[1] and Michael Groß[1]

[1] Technische Universität Chemnitz
Professorship of applied mechanics and dynamics
Reichenhainer Strasse 70, 09126 Chemnitz, Germany
e-mail: iniyan.kalaimani@mb.tu-chemnitz.de,
julian.dietzsch@mb.tu-chemnitz.de,
michael.gross@mb.tu-chemnitz.de,

Keywords: *Fiber reinforced composites, Fiber-bending stiffness, energy-momentum time integration, higher-order finite elements in space and time, Mixed variational principle*

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 capture 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

[1] T. Asmanoglo and A. Menzel, A multi-field finite element approach for the modeling of fiber-reinforced composites with fiber-bending stiffness, *Computer Methods in Applied Mechanics and Engineering*, 1037–1067, 317, 2017.

[2] M. Groß, J. Dietzsch, C. Röbiger, Non-isothermal energy-momentum time integrations with drilling degrees of freedom of composites with viscoelastic fiber bundles and curvature-twist stiffness, *Comput. Methods Appl. Mech. Engrg*, 365, 2020.

[3] J. C. Simo and N. Tarnow, The discrete energy-momentum method. Conserving algorithms for nonlinear elastodynamics, *Z angew Math Phys*, 43, 1992.