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A New Mixed FE-Formulation for Liquid Crystal Elastomer Films

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Liquid crystal elastomers (LCEs) are soft materials, which are capable of large deformations induced by temperature changes and ultraviolet irradiation [1]. Therefore, since many years, these materials are under investigation in experimental researches as actuator materials. LCEs arise from a nematic polymer melt, consisting of long and flexible polymer chains as well as oriented and rigid rod-like molecules, the so-called mesogens, by crosslinking. After this process, the flow ability and the orientation of the mesogens is retained. To date, the alignment of LCEs is primarily achieved in thin films. When the orientational order in the film is lost due to temperature changes or ultraviolet irradiation, the LCE film is capable of length changes of 400 percent.
In order to numerically simulate LCE materials as actuators in multibody system models by using the finite element method, a continuum formulation is necessary, which include in a thermo-viscoelastic material formulation of the polymer chains the orientation effects of the mesogens. This can be performed by introducing a normalized direction vector $\mathbf{n}_t$ as an independent field, and deriving from additional (orientational) balance laws independent differential equations [2]. These differential equations describe the independent rotation of the rigid mesogens connected with the flexible polymer chains. The orientation-dependent stress law of LCEs arises from an anisotropic free energy, comparable with fibre-reinforced materials [3]. But, in contrast to [3], the direction vector of an LCE model has to be independent.
In contrast to [2], we apply a variational principle for deriving a new mixed finite element (FE) formulation, which is based on drilling degrees of freedom for describing the mesogens rotation [4]. This principle leads to an extended set of balance laws which is preserved by an energy-momentum scheme.

REFERENCES

[1] Corbett, D. and Warner, M. Changing liquid crystal elastomer ordering with light–a route to opto-mechanically responsive materials. *Liquid Crystals* (2009) **36**:1263–1280.

[2] Anderson, D.R.; Carlson, D.E. and Fried, E. A continuum-mechanical theory for nematic elastomers. *Journal of Elasticity* (1999) **56**:33–58.

[3] Klinkel, S., Sansour, C. and Wagner, W. An anisotropic fibre-matrix material model at finite elastic-plastic strains. *Computational Mechanics* (2005), **35**:409–417.

[4] Groß, M., Dietzsch, J. and Röbiger, C. Non-isothermal energy–momentum time integrations with drilling degrees of freedom of composites with viscoelastic fiber bundles and curvature–twist stiffness continua. *Comput. Methods Appl. Mech. Engrg.* (2020), **365**:112973.