An Eulerian framework for rheological models based on the decomposition of the deformation rate

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In this contribution, a framework for rheological models at large strains is presented. In the past, a lot of concepts were established to model the properties of metals, polymers, or biological tissues. A phenomenological approach is the use of so-called rheological models, which are a composition of particular rheological elements. Each element typically represents an elementary property like elasticity, viscosity, or plasticity. The connection of several elements enables the simulation of more complex behavior. The critical point, in which the particular concepts mainly differ, is the decomposition of the total deformation. Two of the most popular approaches are the multiplicative decomposition of the deformation gradient and the additive decomposition of the deformation rate.

In this work, the basic kinematical assumption is the additive decomposition of the deformation rate tensor. Hyperelasticity is classically modeled by means of a free energy density depending on the deformation of the particular elastic elements. The deformations are obtained by solving the ordinary differential equation connecting the Jaumann rate of the element's left Cauchy-Green tensor with the corresponding deformation rate tensor. Since the relations are formulated in terms of the current configuration, a corotational framework based on the polar decomposition of the relative deformation gradient is used to account for rigid body rotations and to objectively estimate the deformation rate tensor.

The resulting material models as well as the robust numerical implementation based on finite time steps are objective, independent of an isochoric change of the reference configuration and independent of permutations of serial-connected elements. Furthermore, elastic dissipation is completely avoided and the incompressibility of the inelastic flow is exactly preserved.

The properties of this framework and its suitability for challanging finite element analyses in engineering application will be demonstrated.

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