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ON CHOOSING OBJECTIVE TENSOR RATES IN CONTINUUM MECHANICS

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One requirement for the derivation of constitutive relations is to use objective stress and strain tensors and/or their rates [1]. Since, for one second-order tensor, an infinite number of objective rates can be constructed, constructing the rate form of constitutive relations involves the problem of choosing objective rates. In this topic, we show that for media with complex rheology, the most appropriate objective rate for constructing constitutive relations is the d-rate. This rate has several that make it suitable for constructing constitutive relations for inelastic materials with complex rheology:
1. The d-rate belongs to the family of corotational tensor rates, which is a subfamily of the family of convective tensor rates, i.e., this tensor rate satisfies the Prager criterion for choosing tensor rates to derive constitutive relations for inelastic materials.
2. The spin tensor of this tensor rate belongs to the family of continuous spin tensors [2].
3. In the simple shear problem for a hypoelastic material, the shear component of the Cauchy stress tensor constructed using the d-rate of this stress tensor increases monotonically with increasing shear angle.
4. Hypoelastic material of this type is simultaneously hyperelastic.

Note that the better-known Zaremba–Jaumann corotational second order tensor rate has the first two properties but does not have the second two properties. Due to this, the well-known Wilkins scheme for solving high-rate deformation problems for ideal elastic-plastic materials, which uses the Zaremba–Jaumann corotational tensor rate as the objective rate of the Cauchy stress tensor, is not recommended for computer simulations of the deformation of materials with complex rheology. As an alternative, it is proposed to use the d-rate of the Kirchhoff stress tensor as the objective stress tensor rate for this type of problems.

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