The micromorphic approach to gradient plasticity and damage

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A unifying thermomechanical framework is presented that reconciles several classes of gradient elastoviscoplasticity and damage models proposed in the literature during the last 40 years. It is based on the introduction of the micromorphic counterpart of a selected state or internal variable in a standard constitutive model. In addition to the classical balance of momentum equation, a balance of micromorphic momentum is derived that involves generalized stress tensors. The corresponding additional boundary conditions are also deduced from the procedure. The power of generalized forces is assumed to contribute to the energy balance equation. The free energy density function is then chosen to depend on a relative generalized strain, typically, and the microstrain gradient. When applied to the deformation gradient itself, the method yields the micromorphic theory of Eringen and Mindlin together with its extension to finite deformation elastoviscoplasticity by Forest and Sievert. If the selected variable is the cumulative plastic strain, the theory reduces to the so-called “nonlocal implicit gradient-enhanced elastoplasticity model” by Engelen, Geers, and Peerlings, provided that simplified linear relationships are adopted between generalized stresses and strains. The same holds if the micromorphic variable coincides with a microdamage variable. If the internal constraint is introduced that the micromorphic variable remains as close as possible to the macroscopic variable, the micromorphic model reduces to the second gradient or gradient of internal variable approach as defined by Maugin. If the selected variable is the cumulative plastic strain or the full plastic strain tensor, the constrained micromorphic theory delivers Aifantis-like strain gradient plasticity models. The advantage of the micromorphic approach is that it provides the generalized balance equation under nonisothermal conditions and offers the setting for anisotropic nonlinear constitutive relations between generalized stress and strains in contrast to most existing models. In rate-independent plasticity, it is shown that there is generally no need for a variational formulation of the yield condition.

References.

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