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Rigorous framework for modeling plastic anisotropy with applications to predictions of quasi-static and high-rate deformation of textured metals

Abstract: It is presented a rigorous framework developed for formulation of constitutive models incorporating information at multiple length scales. Based on representation theory for tensor functions and scale-bridging theorems, this framework enables the development of constitutive models that account for the influence of crystallographic structures and deformation mechanisms on the macroscopic behavior. The advantage of adopting this framework is that it ensures that the derived constitutive relations automatically satisfy the material symmetries. Moreover, the minimal number of coefficients necessary to describe the anisotropy is specified. For example, it is demonstrated that an orthotropic plastic potential that is quadratic in stresses should involve exactly six independent anisotropy coefficients. For a non-quadratic potential the form-invariance requirements associated with orthotropic symmetries lead to at most seventeen independent anisotropy coefficients.

Next, it is presented a recent formulation which was developed in this framework for face-centered polycrystalline metallic materials ([1]). The capabilities of this 3-D plastic potential to capture the anisotropy in tensile properties for arbitrary orientation of the loading axis are discussed. The predictive capabilities are demonstrated through comparison with data on textured aluminum sheets.

Illustration of the generalized invariants based-approach to modeling both anisotropy and tension-compression asymmetry in yielding and plastic flow is next discussed. Applications of the developed plastic potential to the simulation of the quasi-static and dynamic response of titanium and zirconium are discussed.

Finally, main contributions towards elucidating the role of the plastic deformation on damage evolution are briefly presented. Special attention is given to addressing the open problems posed in the mechanics community in the late 1960's concerning the manner in which the matrix plastic behavior influences damage evolution [2].

References:

[1] Cazacu O. (2018) New yield criteria for isotropic and textured metallic materials. *Int J Solids Struct.* doi: https://doi.org/10.1016/j.ijsolstr.2018.01.036.
[2] Cazacu O, Revil-Baudard, B., Chandola, N. 2018: Plasticity-Damage Couplings:From Single Crystal to Polycrystalline Materials, Springer, ISBN 978-3-319-92921-7.