

Modeling plastic anisotropy and its influence on damage in polycrystalline materials

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Abstract:

It is presented a unified treatment of plastic anisotropy and damage and a rigorous methodology 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 ([1]).

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 [2]. The capabilities of this 3-D plastic potential to capture the anisotropy in tensile properties for arbitrary orientation of the loading axis (e.g. loading axis belonging to either of the plane of symmetries of the material i.e. in either in (RD, TD), (RD, ND), or (TD, ND) planes where RD, TD, ND denote the rolling, transverse and normal direction, respectively) are discussed. The physical significance of the parameters involved in the formulation, and the strategy for identification is outlined. The predictive capabilities are demonstrated through comparison with data on textured aluminum sheets.

Illustration of the approach to modelling both anisotropy and tension-compression asymmetry in yielding and plastic flow is next discussed. Applications of the developed plastic potential [3] to the simulation of the quasi-static and dynamic response of titanium and zirconium are discussed.

Key contributions toward elucidating the role of the plastic deformation on damage evolution are introduced. Special attention is given to addressing the open problems posed in the mechanics community in the late 1960's the manner in which the matrix plastic behavior influences the rate of damage evolution under given loading conditions. In view of their importance for the prediction of plasticity-damage couplings in hcp-Ti, recent models developed that account for both anisotropy and tension-compression asymmetry on yielding and damage evolution is presented.

Finally, very recent contributions to modeling polycrystalline behavior based on the plastic deformation of the constituent grains, and their abilities to capture the effect of various texture components on the plastic anisotropy in yield stresses and Lankford coefficients (see [1]).

References:

[1] Cazacu O, Revil-Baudard, B., Chandola, N. 2018 *Plasticity-Damage Couplings: From Single Crystal to Polycrystalline Materials*, Springer. <https://www.springer.com/gb/book/9783319929217>

[2] 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>.

[3] Cazacu O, Plunkett B, Barlat F. 2006 Orthotropic yield criterion for hexagonal closed packed metals. *Int. J Plast* 22:1171–1194.

Oana Cazacu-Short Bio

Oana Cazacu graduated from University of Bucharest (Romania) with a joint B.S. and M.S. in Applied Mathematics in 1990, and earned a Ph.D. and Habilitation degree (HDR) from University of Lille (France) in 1995 and 2004, respectively. She is currently Charles E. Taylor Professor in the Dept. of Mechanical and Aerospace Engineering of the University of Florida's graduate research engineering and education center (REEF) in Shalimar, Fl. She is also Associated Editor of *International Journal of Material Forming* (Springer) and *Mechanics Research Communications* (Elsevier)

Her main research interests lie in theoretical and computational solid mechanics with focus on multi-scale modeling of plasticity and damage in textured metals. Major contributions include the development of the most widely used anisotropic criteria for lightweight metals, now included in the built-in materials library of commercial and academic finite-element codes.

She has authored a monograph, 12 book chapters, edited and co-edited 3 books, and she has 85 papers in refereed international journals, over 100 articles in proceedings of international conferences, 90 invited lectures in international conferences and research institutions (18 plenary or keynote lectures). She has been recipient of visiting chair professorships in Europe (e.g. University Pierre and Marie Curie, University of Lille; France), and Australia (Swinburne University).