Non-Linear Viscoplasticity for Non-Smooth Yield Surfaces

Daniel D. del Pozo*, **Ignacio Romero***†

* IMDEA Materials Institute (IMDEA)
Eric Kandel 2, 28906 Madrid, Spain
E-mail: daniel.pozo@imdea.org, ignacio.romero@imdea.org
Web page: http://www.materials.imdea.org

† Universidad Politécnica de Madrid (UPM-ETSII)
Escuela Técnica Superior de Ingenieros Industriales
José Gutiérrez Abascal 2, 28006 Madrid, Spain
E-mail: ignacio.romero@upm.es, Web page: http://www.etsii.upm.es

ABSTRACT

Numerical methods of the elasto-visco-plastic response in solids are often based on the Perzyna regularisation since its provides a convenient extension of the rate-independent solution [1]. For models based on a rate-independent response with non-smooth elastic regions (e.g., Tresca and Drucker-Prager's model), it is well-known that the latter approach does not provide the correct behaviour. Duvaut-Lions viscoplastic models are more general than Perzyna's and deal correctly with possible non-smoothness of the elastic domain. While this result has been known for several years now [2], the authors are not aware of a general numerical procedure to simulate elasto-viscoplastic solids that is valid for non-smooth yield functions and can be proven to be thermodynamically consistent. In order to arrive to such a formulation, we use the standard theory of non-smooth convex analysis [3]. Once the problem is stated within such a framework, we are able to postulate a large class of elasto-viscoplastic models with guaranteed non-negative dissipation. In contrast with previous models, the ones we present can accommodate power laws for the kinetic potential and other monotonic functions, resulting in elasto-viscoplatic models that strictly satisfy the dissipation inequality. We develop numerical methods that integrate the viscoplastic evolution equation at the material point level. The algorithms, based on the classical return-mapping methods, account for the non-smoothness of the elastic domain in a natural way. In conclusion, the results we obtain show that the model developed provides a general framework for simulating elasto-viscoplasticity, even when the underlying rate-independent model employs a non-smooth yield function.

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