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Fractional viscoplasticity for metallic materials under dynamic loading

Abstract

Rate-dependent material models are used in civil engineering when a dynamic response of structure has to be examined. These models, used in conjunction with, e.g. software suites for finite element analysis, provide a powerful tool for solving dynamic problems. An effective approach should include material properties such as anisotropy, non-locality and non-normality of the inelastic flow. The goal of this treatise is to develop a comprehensive mathematical model that could be successfully applied for special cases when high-strain-rate deformations in metals, are considered.

The Perzyna viscoplastic model in its extended constitutive form, which accounts for strain-rate hardening, microdamage mechanism, thermo-mechanical coupling and the fracture criterion, was chosen for this research. Fractional derivatives were used for the aforementioned model to introduce the non-local and anisotropic properties. The numerical analyses were conducted at the material point level to evaluate the impact that the fractional parameters have on the dynamic material response. Next, the dynamic tests were carried out for a full three-dimensional dog-bone specimen for various parameters and loading velocities. In this last case, the strain localization was observed and studied. Moreover, the evolution of the state variables in the Perzyna formulation was closely examined.

Results of the numerical analysis have shown that the fractional viscoplastic model exhibits non-locality, as well as, the anisotropy in the level and direction of deformation. Moreover, the directional behaviour was also found in the dissipation of mechanical wave energy. The anisotropy was also observed in the strain localization and deformation modes of the dog-bone specimen. The non-locality and directional dependence had an impact on the evolution of the state variables of the Perzyna model. In conclusion, the results reflect the one obtained in the available experimental studies.

Based on the above, the thesis of this dissertation, which stated that *the fractional formulation of the viscoplastic model improves the description of metals behavior under dynamic loading*, can be assumed to be valid.