A large strain thermodynamically-based viscoelastic-viscoplastic model applied to two-dimensional finite element analysis of solids

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Abstract. In this work, we propose a large strain viscoelastic-viscoplastic constitutive model applied to two-dimensional finite element analysis of solids. The model is developed in a thermodynamic framework, based on the multiplicative decomposition of the deformation gradient into elastic, viscous and plastic components. The viscoelastic part is represented by Zener's rheological model, and is formulated with an internal variable approach, with evolution law in terms of the viscous deformations gradient rates. For the viscoplastic part, we apply a Perzyna-like model, including a large strain generalization of the classical Armstrong-Frederick kinematic hardening. In order to characterize the proposed constitutive model, we present results of uniaxial relaxation and creep tests under different analysis conditions, as well as more complex examples showing the potentialities of the developed framework.

Keywords: Large strain, viscoelastic, viscoplastic, finite element method

1 Introduction

Viscoelastic-viscoplastic materials are known for exhibiting rate-dependent behaviour both in the elastic and plastic stages, as shown in experimental results such as [1, 2] for polymeric materials and [3] for asphalt. In the context of large strain models, some of the earlier works is due to [4, 5], who proposes two different methods of coupling viscoelastic and viscoplastic effects, and [6], who developed a generalized constitutive modelling framework. For a more detailed state of the art review in that regard, one can refer to [7].

In this work, we present a thermodynamically-based viscoelastic-viscoplastic constitutive law based on the rheological model shown in Fig. 1, and using the concept of multiplicative decomposition [8, 9], commonly adopted in large strain formulations. The viscoelastic part is represented by a Zener model [10, 11], while the viscoplastic part is represented by a slider, connected in parallel with a rate-dependent component reproducing the Perzyna model [12], and a kinematic hardening component reproducing the Armstrong-Frederick model [13, 14].

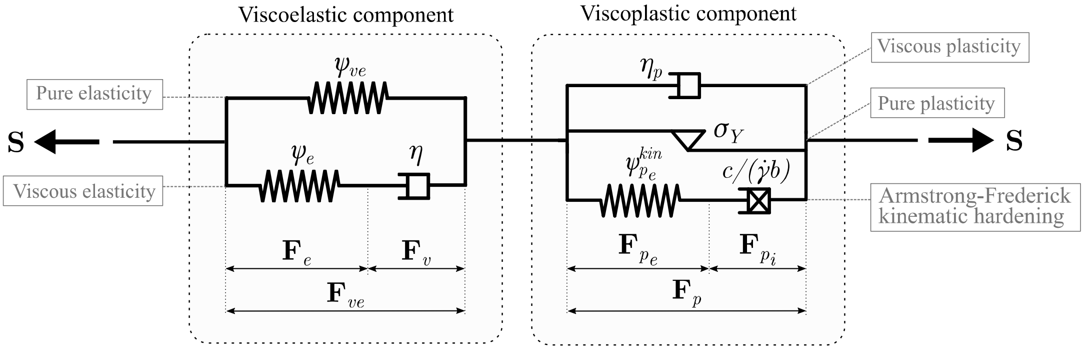

Figure 1. Rheological model