DIFFUSE AND LOCALIZED FAILURE PREDICTIONS OF PERZYNA VISCOPLASTIC MODELS FOR COHESIVE-FRICTIONAL MATERIALS

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Abstract— **Viscoplastic constitutive formulations are characterized by instantaneous tangent operators which do not exhibit degradation from the elastic properties. As a consequence viscoplastic material descriptions were often advocated to retrofit the shortcomings of the inviscid elastoplastic formulations such as loss of stability and loss of ellipticity.**

However, when the time integration of viscoplastic material processes is considered within finite time increments, there exists an algorithmic tangent operator which may lead to loss of stability and loss of ellipticity similar to rate-independent elastoplastic materials.

The algorithmic tangent operator follows from the consistent linearization process. Therefore, the numerical method considered for the time integration of the constitutive equations plays a fundamental role in failure analysis of viscoplastic materials.

This paper focuses on the performance of the conditions for diffuse and localized failure of two Perzyna-type viscoplastic models, one of them based on the classical formulation and the other one based on a new proposal by Ponthot (1995) which includes a constrain condition representing a rate dependent generalization of the plasticity's yield condition. Application of Backward Euler method for time integration of both Perzyna formulations leads to quite different form of the consistent tangent material operators. These stiffness tensors are obtained for Perzyna generalizations of the so called Extended Leon Model which is a fracture energy-based elastoplastic constitutive model for concrete.

The results included in the paper illustrate the strong differences between the failure predictions of both Perzyna-type viscoplastic formulations. In this regard, the classical formulation is unable to reproduce the predictions of the inviscid model when the viscosity approaches zero. This case leads to very small values of both failures indicators and their performance are characterized by strong oscillations and even discontinuities. On the other hand the so-called continuous formulation is associated with algorithmic tangent moduli which signals a smooth transition from the elastic operator to the elastoplastic algorithmic one, when the viscosity varies from very large to very small values.

Keywords— **Viscoplasticity, failure, localization, consistent tangent.**

I. INTRODUCTION

The Perzyna-type viscoplastic models are widely used to characterize rate effects in plastic materials. In the classical form the constitutive equations of Perzyna-type viscoplasticity do not reduce to the rate-independent plasticity formulation as the viscosity parameter approaches zero. This feature had led to some difficulties on the development of efficient time integration algorithm for computational implementation of Perzyna viscoplastic models, both at the local as well as at the global "momentum-balance loop" level. On the local level, the viscoplastic rate equations are numerically integrated for the specified time increment Δt. It is certainly desirable if the integration algorithm employed is unconditionally stable. Therefore, the Backward Euler algorithm is usually considered for the return mapping during Perzyna viscoplastic material processes. On the global or Finite Element level, the use of consistent tangent moduli is crucial in preserving the quadratic rate of convergence of the Newton method in conjunction with nonlinear finite element computations. The lack of a constrain condition in case of the classical formulation of Perzyna viscoplasticity forces the consideration of residual functions for Newton iteration of momentum balance, see Ju (1990) and Etse and Willam (1999). In this way a consistent or algorithmic tangent operator for rate-dependent material formulations is derived which strongly varies from that of the inviscid elastoplastic material when the viscosity tends to zero. In this case the fourth order material operator of the viscoplastic model approaches the fourth order zero ten-