Integration of elasto-plastic constitutive models in finite deformation: an explicit approach

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ABSTRACT

The robustness and accuracy of large deformation finite element analysis relies on the local integration scheme of the elasto-plastic constitutive equations. In the past, two main families of schemes have been proposed. The first one is based on an additive decomposition of the plastic and elastic strain and the use of a hypoelastic rate constitutive model. With respect to the usual small strain formulations, additional terms are added in order to deal with the rigid body rotation and ensure the objectivity of the resulting stress increment [1]. These schemes are usually integrated explicitly in time. In the second family, a hyperelastic response is assumed along with a multiplicative decomposition of the deformation; stresses are integrated implicitly in time, leading to the return mapping algorithms [2].

In this work, a novel explicit stress integration scheme for multiplicative hyperelastic-based finite strain plasticity is presented. Using the Hencky logarithmic strain measure and assuming an exponential approximation of the flow rule, the usual small strain algorithms are recovered. In addition, the large deformation formulation is only reflected on the global stiffness matrix through the geometrical stiffness term. Stresses are integrated using an adaptive explicit Runge-Kutta method in which two different order approximations are computed in order to obtain an error indicator [3]. Special procedures are considered to detect the transition from elasticity to elasto-plastic regime and to correct the yield surface drift violation that may arise in explicit methods.

The proposal is applied to the Modified Cam Clay plastic model. Two different hyperelastic models are tested: in both models the bulk modulus is pressure dependent; however, in one of them the shear and volumetric behavior is coupled, whereas in the other the shear modulus is considered constant.

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