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LOCALIZATION, DAMAGE AND FRACTURE MODELLING IN SHELL STRUCTURES

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Introduction

We consider a problem of damage, localization and fracture in ductile metals from the point of view of large scale structural analysis. Special emphasis is placed on the computational efficiency of the constitutive formulation. In this context we seek the formulation which is both theoretically sound and easily implementable into a large scale explicit dynamic finite element code without precluding vectorization or parallelization. This is achieved through a viscoplastic damage constitutive model for finite-element analysis of thick and/or thin metallic shells and plates defined in the stress resultant space. The formulation features both material and geometric non-linearities, with the latter addressed by means of the Lagrangian method. Rate-dependent elasto-plastic behavior is described using a dynamic yield function, based on the Iliushin's [5] yield function expressed in terms of stress resultants and stress couples. The hardening rule defined by Bieniek and Funaro [1] allows for representation of the Bauschinger effect on a moment-curvature plane. Viscoplastic strain rates are calculated with transverse shears taken into account. The damage effects leading to softening of material due to the growth of microvoids and localization are formulated within the framework of a micromechanical damage model. The evolution equation of the scalar damage parameter, related to the porosity proposed by Gurson [4] and later modified by Duszek-Perzyna and Perzyna [2] will be used to describe the most relevant damage effect for isotropic plates and shells, i.e. the growth of voids as a function of plastic flow. The porosity parameter is incorporated directly into the yield function, resulting in a strong coupling between plasticity and damage, with a generalized, accurate, and convenient loading surface expressed in terms of stress resultants and stress couples. The current damage model is a stress-resultant-based formulation, which obviates the need for through-the-thickness-integration and leads to a computationally efficient and practical scheme. The model is implemented into an explicit dynamic finite element code EPSA.

Localization, regularization and fracture simulation

Localization and softening behavior of ductile materials is a precursor to fracture. These processes are crucial for correct determination of the energy dissipated during the deformation. The constitutive model for failure based on the evolution of damage effects leading to material softening due to the growth of microvoids is formulated.

Modeling of softening, localization and fracture requires a regularization procedure to ensure well-posedness of the solution, i.e. independence of the results of the small changes in initial conditions (mesh and timestep size). Regularization is also necessary for the correct determination of the extent of the localized area of very high strains which influences greatly the assessment of the energy dissipated through inelastic deformation. This assessment is very important in simulations of various structural components subjected to extreme loading. Viscoplastic formulation is used to provide a length scale and regularize the problem ensuring independence of the mesh and timestep size. The material parameters defining the model have been identified by validation of the model through comparison with the experimental test results.

Fracture criterion is postulated based on the critical value of the damage parameter. The element with damage exceeding the threshold damage value is eroded. The fracture criterion proposed here is validated against the experimental test data [3]. Such detailed yet efficient description of mechanics of materials, despite its importance, is not available in any of the major commercial structural solvers. An example of localized area of deformation (shear band) and associated stress-strain curve is shown in Figure 1.

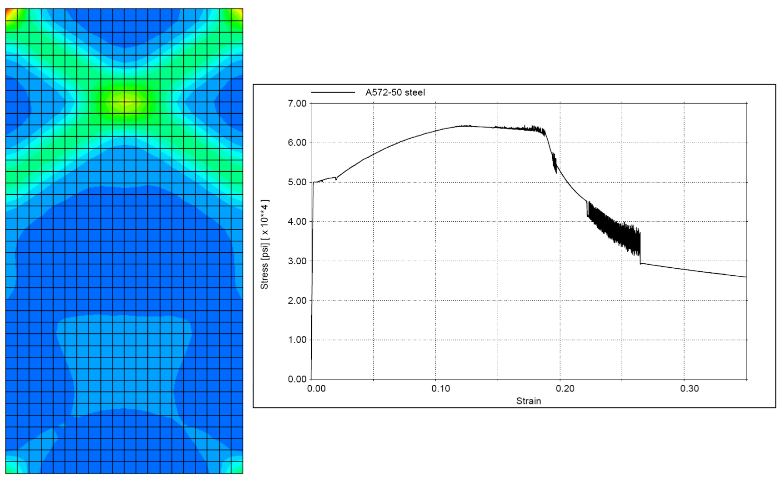

Figure 1 – Localized area of deformation (shear band); steel engineering stress-strain curve

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