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ANISOTROPY INDUCED BY EVOLUTION OF MICROSTRUCTURE IN DUCTILE MATERIAL

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ABSTRACT

The analysis of deformation process of an anisotropic ductile material (mainly metals) subjected to impact loading is presented. The problem is formulated within the theory of continuum mechanics and in the framework of thermodynamics. The macroscopic anisotropy is induced by the evolution of microstructure. Experimental observations show the nucleation, growth and coalescence of microcracks and microvoids. During the deformation process microstructure undergoes the modification in which direction of microvoids and microcracks growth and the direction of new defects nucleation influence then the deformation increment. Anisotropy of microstructure is incorporated in the problem formulation and numerical analysis. The information about direction in evolution of the microstructure is described in the model by second order tensorial field. The microdamage tensor $\boldsymbol{\xi}$ was introduced [1, 3]. The microdamage tensor becomes one of internal state variables defined in constitutive formulation and its evolution is computed in deformation process. The classical volume fraction porosity is related to microdamage tensor, in such a way that the norm of microdamage tensor is the porosity scalar [2, 4]. The microdamage tensor belongs to microdamage tensorial field and all properties of sec-

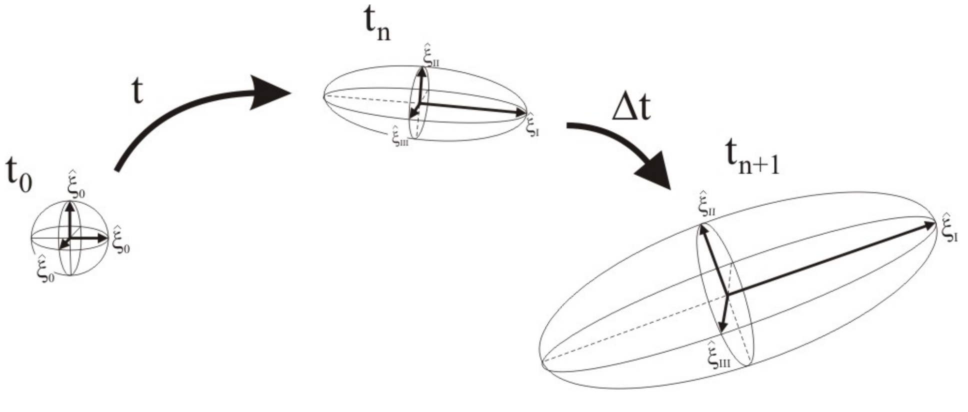

Figure 1: The evolution of the microdamage ellipsoid during deformation

ond order tensorial field constructing tensorial quadric are applied. The microdamage ellipsoid and its evolution characterize the main mechanism of anisotropy evolution in elaborated ductile material [4]. The initial isotropic state, intermediate state of microstructure for evolution time t_1 and the corresponding anisotropic evolution of material defects are presented in Fig.1. The volume change and diameters of ellipsoid reflect the final state of material in time t_n. The critical fracture value of microdamage is introduced.

Solid mechanics state governing equations are formulated and numerically solved. The finite element method and Abaqus code are used to obtain the solution of initial-boundary value problem. The proposed constitutive structure with microdamage is introduced to prepare user defined material subroutine.

The tension of a rectangular prism specimen $(12.7 \times 25.4 \times 0.33\ mm)$ is presented as a numerical example. Initial and boundary conditions are fixed at the one end, while the opposite one is pulled with velocity $10\,m/s$. In Fig. 2 the evolution of the norm of the microdamage tensor and the pattern of fracture are shown. In the process of loading, the direction, and the speed of damage are observed. The final fracture appears when the critical value of the volume fraction porosity coupled with plastic deformations is met. Microdamage field changes directionally and simultaneously enforces the history of fracture.

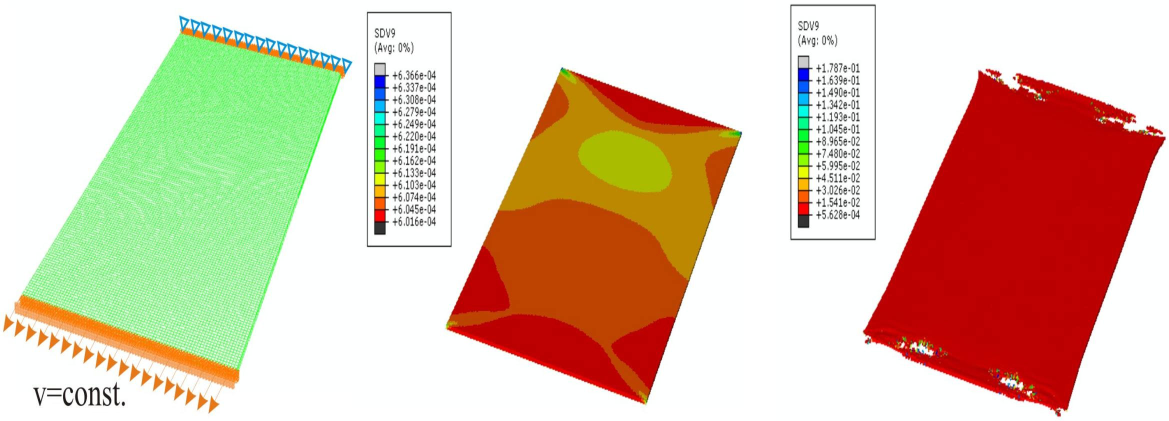

Figure 2: a) geometry and boundary conditions, b) intermediate configuration, c) fracture mode

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