3D-MODELLING OF CUTTING PROCESS ON THE BASE OF THE MULTISCALE THERMO SOFTENING DAMAGE MODEL

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ABSTRACT

On the basis of the phenomenological theory of dislocations, a multiscale coupled micromechanical model of thermo elastoviscoplasticity and damage was constructed, which gives a well-posed description of the scale affect, the localization of plastic strains, and the viscous fracture, as in hardening stage of plastic deformation as well as for the softening [1].

The proposed damage model is multiscale and contains the following three time parameters: t_0 - the characteristic time of the problem, τ_p - the stress relaxation time in the damaged material, and τ_d - the relaxation time in the initial viscoplastic material. These time parameters correspond to three different spatial scales, namely, macro-, meso-, and micro-, respectively corresponding to the dimensions of a macro-object, a void, and a dislocation and satisfying the inequalities $t_0 >> \tau_p >> \tau_d$.

At the stage of hardening, the scale effect is determined by a small parameter $\delta_d = \tau_d / t_0$ and at the stage of softening, by a small parameter $\delta_p = \tau_p / t_0 >> \delta_d$. Hence the scale effect in the prefracture state is significantly stronger. In the limit case as δ_p and δ_d tend to zero, the model becomes the GTN-model with kinematic hardening independent of the scale factors [2].

An affective numerically-analytic method for integrating the thermo elastoviscoplasticity equations with internal variables is proposed. An advantage of this splitting method is that integrating a nonlinear system of n constitutive equations $(n = 6 + k)$ for six components of the stress tensor and k internal variables in the case of coupled models of damaged plastic media is reduced to numerically solving a nonlinear system of two equations. The other equations can be integrated analytically, which makes the solution easier and faster (more than twice for the GTN-model) [1, 3].

The numerically-analytic solution of the system of constitutive equations allows easily analyzing the difference schemes for splitting the multiscale elastoviscoplastic problems and

guarantees both the stability and the asymptotic convergence to the solution of the limiting constitutive equations as the small parameters tend to zero.

The proposed coupled thermo elastoviscoplastic multiscale model taking account thermo conduction and thermal softening due to dissipation in plastic shear bands and the splitting method of solution were applied to the 3D modeling of a metal cutting process. A fracture and a deflection of particles of damage material as well as a fragmentation of finite pieces of the chip are considering. 3D-modelling of the process takes into account the lateral movement of piece-wise opposite to plane strain statement, and essentially changes the mechanism of cutting and fracture of the chip and leads to softer regime of cutting and the smooth drug force acting on the tool.

The parametric investigation of different regimes of a tool's speed and angles and depth of cutting as well as plastic properties of cutting piecewise was done and a drug force acting on the tool was determined. In 3D case the formation of continuous chips gives a quasi monotonic reaction force. In the initial stage of cutting the resistance force increases and has a high value and after that it decreases to his stationary value and cutting process becomes quasi monotonous.

In the plane strain state the drag force acting on the tool has jumps when the chip fractures and becomes quasi periodical with minimal values corresponding to times of the failure of the chip due to formation of shear bands.

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