Identification of the multiscale material model based on a stochastic internal variable

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ABSTRACT

Internal variable method (IVM) is an alternative for conventional models describing processing of materials. When the latter are used the history of the process is not accounted for. Change of the process conditions moves the model to a new equation of state without delay, which is observed in experiments. When external variables are replaced by internal ones, this disadvantage is eliminated. An approach based on works [1,2], which uses dislocation density as the independent variable, was considered. The differential equation describing evolution of dislocation populations (ρ) is:

$$\frac{d\rho(t)}{dt} = A - B\rho(t) - C\rho(t - t_{cr}) \tag{1}$$

$$A = \frac{a_1 Z^{a_3} \dot{\varepsilon}}{b} \qquad B = a_2 \dot{\varepsilon}^{1-a_9} \exp\left(\frac{a_3}{RT}\right) \qquad C = \begin{cases} 0 & \text{for } t \le t_{cr} \\ a_4 \exp\left(\frac{a_5}{RT}\right) \rho(t)^{a_8}\, \rho(t - t_{cr}) & \text{for } t \le t_{cr} \end{cases} \tag{2}$$

where: b – Burger vector, Z – Zener-Hollomon parameter, T – temperature in K, R – gas constant, t_{cr} – time at which critical dislocation density is reached, a_1 – a_{13} - coefficients.

Solution of equation (1) gives variations of the dislocation density in a deterministic form. On the other hand, information about distribution of parameters is often needed. Therefore, equation (1) was written assuming stochastic function of dislocation density:

$$\frac{dG(\rho,t)}{dt} = A - BG(\rho,t) - CG(\rho, t - t_{cr}) \tag{3}$$

$G(\rho,t)$ represents volume fraction of the material with the dislocation density between ρ and $\rho + d\rho$ in the time t. Solution of (3) gives distribution of the dislocation density. When this solution is implemented in the FE code and equation (3) is solved in each Gauss integration point, an information about distribution of the dislocation density is obtained for the computational domain. Proper identification of the coefficients in equation (3) is crucial for the accuracy of the method. Since measurement of the distributions of dislocation density is not trivial, identification of the stochastic model is complex. This problem was the objective of the present work. An inverse analysis was applied, see [3] for Authors' algorithm. Identification was based on the flow curves during two step deformation. Dynamic phenomena were investigated accounting for the drop of the flow stress during the first step of deformation. Static part was identified on the basis of measurement of this stress during the second step. The model with optimal coefficients proved its capability to reproduce the response of the material involving oscillations, which is characteristic for pure metals.

REFERENCES

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