
Influence of strain hardening and elasticity upon transformation plasticity of metals and alloys

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Abstract

Some recent theoretical works were devoted to Greenwood and Johnson's mechanism of transformation plasticity of metals and alloys, that is, the anomalous increase of plastic deformability during solid-solid transformations. These works used the powerful kinematic approach of the classical theory of limit-analysis, assuming the sole weaker mother-phase to be plastic. The theory is based, by construction, on the hypothesis of absence of strain hardening and elasticity - it thus applies to *rigid-ideal-plastic* materials only. The models derived on this basis were found, on average, to yield acceptable predictions, as evidenced through comparisons with the results of both experiments and micromechanical numerical simulations of Greenwood and Johnson's mechanism.

However, at the temperatures at which transformation plasticity occurs in practice, the hypothesis of ideal plasticity is questionable. Moreover, micromechanical numerical simulations have evidenced a notable effect of elasticity in the daughter-phase, at least in the case of growing nuclei of this phase of elongated shape (as encountered in laminated plates). Theoretical models are therefore prone to improvements pertaining to the effects of both strain hardening and elasticity.

In the present work, we propose to account for the effect of (isotropic) strain hardening by adapting a trick used by Gurson when developing his famous model for porous ductile materials. This trick consists in replacing the true medium with a heterogeneous distribution of hardening through some "equivalent" medium with a uniform hardening ; this "equivalent" hardening being determined by assuming the plastic dissipations in the true and equivalent media to be equal. Comparisons of the predictions of the model thus defined with results of some new micromechanical numerical simulations of Greenwood-Johnson's mechanism evidence a nice agreement, provided some correction is introduced into the model to account for the strong nonlinearity of hardening at the onset of plasticity.

We also propose to model the effect of elasticity by assuming the daughter-phase to now be elastic instead of rigid ; elasticity being still disregarded in the (essentially plastic) mother-phase. This amounts, in the homogenization-based derivation of the model, to modifying the boundary conditions on the plastically deforming RVE of mother-phase. Comparisons of model predictions and results of micromechanical simulations evidence a reasonable agreement, except for relatively high stresses applied and nuclei of daughter-phase of highly elongated shape. The reasons for the discrepancy are discussed.

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