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CONSISTENT APPROACH

Context

Mechanisms of ductility loss

Plastic mechanisms of ductility loss

Structural origin: wrinkling, buckling
Material origin: localization, necking
Damage mechanisms of ductility loss

Cavities
Failure

Strain path dependence

Forming Limit Diagram (FLD)

Plastic anisotropy evolution

Textured anisotropy (crystallographic network + morphology)
Structural anisotropy (intragranular microstructure)

Single crystal modeling

Mesoscopic scale - basic slip process

Assumptions

• Elastic-plastic behavior
• Large strain formulation
• Body-Centered Cubic (BCC)
• Plastic strains only due to slip processes (<110) slip direction family and (110), (112) slip plane families

Elasticity

\[ \sigma_i = C_{ijkl} \varepsilon_{kl} \]

Plasticity

\[ \tau^p = \sum_{i,j} k_{ijkl} \varepsilon_{ij} \]

Elastic-plastic tangent modulus

\[ M = (\varepsilon_{ij} + \varepsilon_0 C_{ijkl} C_{ijkl}) \]

Single crystal modeling

Microscopic scale - intragranular microstructure

• The statistically stored dislocations in the cell interior, as well as the cell boundary dislocations, are represented by a single local dislocation density \( \rho \)
• The local density of immobile dislocations stored in the wall \( \rho^{\text{wall}} \) associated with the (110) plane
• The polarity dislocations density \( \rho^{\text{path}} \) associated with the (110) plane

Scale transition

What is the link between local and global strain?

\[ \Sigma, G \]

Volume average

\[ \sigma, G \]

Fourth order localization tensors

\[ a_{ij} = B_{ij}, S_{ij}, \Phi_{ijkl}, \gamma_{ijkl} \]

Relation between A and B

\[ A_{ijkl} = B_{ij}, S_{ij}, \Phi_{ijkl}, \gamma_{ijkl} \]

Ductility loss criterion

Assumption: the onset of localization is along a band (Rice, 1976)

\[ \text{Field equations} \]

\[ \text{Boundary conditions} \]

Ellipticity loss

\[ \text{Multiscale model with intragranular modeling} \]

• Reproduces correctly the intragranular microstructure during monotonic and sequential loading paths
• Gives better results concerning macroscopic behavior during changing loading paths than model without intragranular modeling

Conclusions

• Reproduces correctly the shape and the level of direct FLD for mild steel and dual phase
• Reproduces the strain-path dependence of complex FLD