Simulation of ductile rupture using Zset

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AIMS

• Development of physically based models describing ductile damage: void nucleation, void growth, void coalescence
• Implementation of models in Finite Element codes (Zset, Zmat,...)
• Prediction of crack initiation and propagation in test specimens and actual structures
• Increase the reliability of these predictions
• The methodology can be applied to:
  — nuclear industry (pressure vessel steels, nuclear fuel cladding, ...)
  — GAZ/OIL transportation, offshore engineering
  — Aerospace/Aeronautics

MODELS

• Models derived from the Gurson model (1977)
• One damage variable \( f \): void volume fraction
• Definition (implicit) of a scalar effective stress \( \sigma_e = \sigma_i(\mathbf{f}, f) \)
  \[
  \frac{\sigma^2}{\sigma_e^2} + 2qf \cos h \left( \frac{3f}{\sigma_e^2} \right) - 1 - \eta f \frac{\partial \mathbf{f}}{\partial \sigma} = 0
  \]
  \( \sigma_i \): can be any isotropic (von Mises/Tresca) or anisotropic (Hill, Barlat,...) stress measure (accounting for plastic anisotropy)
• \( \sigma_K \): weighted average stress : \( \sigma_K = \sum_{i=1}^{n} \sigma_i \sigma_{ii} \) (accounting for anisotropic ductility)
• \( f_i \): effective porosity (\( f_i(f) \)) (accounting for void coalescence)
• Plastic yielding \( \dot{\mathbf{f}} = \sigma_e - R(p) \), \( R(p) \): flow stress
• Plastic flow \( \dot{\mathbf{f}} = (1-f)^p \frac{\partial \mathbf{f}}{\partial \sigma} \)
• Damage evolution \( f = (1-f)^p \) trace (\( \varepsilon_i \)) + \( A_n(\ldots) \) \( \Sigma \)
• Kinematic hardening can also be described: \( \dot{\varepsilon} = \dot{\varepsilon} - A \)
• Other models: Rousselier, Lemaitre,...

SIMULATION OF CT AND SENB SPECIMENS (Grade X100 Steel)

- Simulation of \( J \)—\( \Delta a \) curves (anisotropy)

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SIMULATION OF FLAT TO SLANT RUPTURE TRANSITION

- with Lode parameter controlled nucleation
  - \( \dot{\varepsilon}_0 \rightarrow \) eigenvalues: \( p_1 \geq p_2 \geq p_3 \)
  - Lode parameter \( L = \frac{p_2}{p_1 - p_3} \)
  - \( A_n \): function of \( L \) and maximum for \( L = 0 \)

NON-LOCAL MODELLING OF DAMAGE AND CRACKING

- Damage growth leads to softening, localization and consequently to mesh size dependence
- The problem can be addressed using “non-local” models
- Diffuse damaged zone (red), no mesh size dependence, remeshing, crack insertion

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