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Experimental identification of thermo-mechanical cohesive zone models for complex loading

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Methodology: Inverse method

Motivation

Objectives: Identification of cohesive zone models for heterogeneous materials

Step 1: identify the stress field from the strain field.

Determine the mechanical properties of a material by minimizing the energy difference between the “measured” (U_m) and a “computed” (U_c) displacement fields.

\[ E(U_c, B(p)) = \frac{1}{2T} \int_{0}^{T} (B(p) \cdot \varepsilon(U_c) - B(p) \cdot \varepsilon(U_m)) \cdot (B(p) \cdot \varepsilon(U_c) - B(p) \cdot \varepsilon(U_m)) \, dv \, dt \]

\[ \min E(U_c, B(p)) \]

\[ U_c \to \varepsilon_c \to \sigma_c \]

and

\[ p = \{E, \nu, G, \sigma_b, k\} \]

Step 2: summarize the “volume” damage as a “surface” damage.

Constitutive Equation Gap Method (CEGM)

\[ B(p) \]

Independent of loading, Explicit estimate of the elastic parameters (cubic):

\[ \frac{1}{E} = \frac{1}{2} \left( \frac{1}{E_{xx}} + \frac{1}{E_{yy}} + \frac{1}{E_{zz}} \right) \]

\[ \nu^{(i)} = \frac{G^{(i)}}{2} = \frac{1}{2} \left( \frac{1}{G_{xx}} + \frac{1}{G_{yy}} + \frac{1}{G_{zz}} \right) \]

\[ G^{(i)} = \frac{1}{2} \left( \frac{1}{G_{xx}} + \frac{1}{G_{yy}} + \frac{1}{G_{zz}} \right) \]

\[ B(p) \]

depends on the Von Mises stress \( \sigma^m \):

\[ B(p) = \begin{cases} E(1 + 2K) & \sigma^m < \sigma_b \\ E(1 + 2K) - K \frac{\sigma^m - \sigma_b}{\sigma^m - \sigma_s} & \sigma_b \leq \sigma^m \leq \sigma_s \\ E(1 + 2K) - K & \sigma_s < \sigma^m \end{cases} \]

Resolution of the non-linear system obtained by the stationarity condition with respect to \( \alpha \) and \( \beta \),

- Computation of \( \sigma_b \) and \( k \) by a linear fit of the data

\[ k = \frac{\text{intersection of the curve with the y axis}}{\text{slope of the curve and } \sigma_s} \]

\[ a = \frac{\sigma^m}{2} \]

\[ b = \frac{\sigma^m}{k} \]

Plastic identification

\[ \alpha^2 = (\sigma - X)^2 P(\sigma - X) \]

Rewrite \( K \)

\[ K = \frac{\Delta Y}{3 + 2 \Delta Y} \]

with \( a = \frac{1}{2K} \) and \( b = \frac{\sigma_b}{k} \)

Results: Polycrystalline structure

Distribution of transversal stress fields, mesh perfectly consistent with the material heterogeneity:

- Identification of heterogeneous fields (stress, ...) for elasto-plastic behavior: linear and non-linear hardening,
- Application of this method to real full-field measurements.

Prospect:
- Extend the constitutive equation gap method to softening behaviors.
- Identification of Cohesive Zone Models.
- Introduction of a calorimetric gap in the identification functional.

Conclusions:
- Identification of heterogeneous fields (stress, ...) for elasto-plastic behavior: linear and non-linear hardening,
- Application of this method to real full-field measurements.