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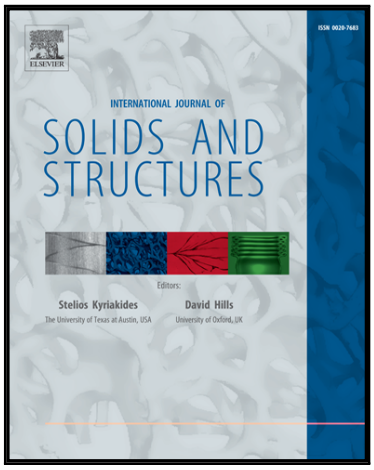

Thermomechanical modeling of distortional hardening fully coupled with ductile damage under non-proportional loading paths

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Thermomechanical modeling of distortional hardening fully coupled with ductile damage under non-proportional loading paths

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A B S T R A C T:

In order to capture, as accurately as possible, the complex physical effects during texture evolution of high strength materials subject to non-proportional loading paths at high temperature, a macroscale thermo-mechanical model is developed. This model accounts, in the framework of large inelastic strains, for anisotropic thermo-elasto-viscoplasticity with isotropic, kinematic and distortional hardenings strongly coupled with isotropic ductile damage. Following the footsteps of François (2001), induced anisotropy is modeled to predict the behavior under complex non-proportional loading paths. The initial plastic anisotropy and tension-compression asymmetry are considered through two different temperature dependent fourth-rank tensors. The full coupling of thermo-mechanical model with ductile damage is considered based on the total energy equivalence assumption. The proposed constitutive equations are implemented into finite element code ABAQUS/Explicit using appropriate user subroutine VUMAT. The local integration algorithm (at each Gauss point) of the developed model is based on a fully-implicit scheme. Applications have been made to three different materials (aluminum alloy AU4G T4 (2024), titanium alloy Ti-6Al-4V and magnesium alloy AZ31) to demonstrate the predictive capabilities of the proposed model.

Keywords: thermomechanical coupling; anisotropy; asymmetry; distortional hardening; damage

Notation

-First-rank tensor or vector: $\vec{x}$, x_i ,

-Second-rank tensor: $\underline{x}$, x_{ij} ,

-Fourth-rank tensor: $\underline{\underline{x}}$, x_{ijkl} ,

-Second rank identity tensor: $\underline{1}$, δ_{ij} ,

-Fourth-rank symmetric identity tensor: $\underline{\underline{I}}$, $I_{ijkl} = \frac{1}{2}(\delta_{ik}\delta_{jl} + \delta_{il}\delta_{jk})$,

-Fourth-rank symmetric deviatoric identity tensor: $\underline{\underline{I}}^D$, $I^D_{ijkl} = \frac{1}{2}(\delta_{ik}\delta_{jl} + \delta_{il}\delta_{jk}) - \frac{1}{3}\delta_{ij}\delta_{kl}$,

-Transpose of 2nd rank tensor: $\underline{x}^T$, $(x_{ij})^T = x_{ji}$,

-Symmetric and skew parts of second-rank tensor: $\underline{x} = [\underline{x}]^S + [\underline{x}]^A$

$[\underline{x}]^S = \frac{1}{2}(\underline{x} + \underline{x}^T)$, $[\underline{x}]^A = \frac{1}{2}(\underline{x} - \underline{x}^T)$,

-Hydrostatic part of second-rank tensor: $[\underline{x}]^H = \frac{1}{3}tr(\underline{x})\underline{1}$,