On Damage Characterization of a Steel Sheet

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Introduction

Ductile damage is a physical phenomena which involves progressive deterioration of mechanical properties of metals, when undergoing high deformations. Compared to plasticity, the physical mechanisms behind damage are more complex and the microscale is not longer negligible. In mathematical damage models, founding an optimal set of material parameters can be a hard task due to the strong coupling and non-linearity of the equations. An identification strategy is then crucial to arrive to a general set of parameters. Therefore, we address the fully characterization of a DC01 steel sheet, involving both the elasto-plastic and damage parameters.

Mathematical model

Yield surface

$$F_p(\boldsymbol{\sigma}, \boldsymbol{X}, H_\alpha) = \frac{\widetilde{q}^2}{{\sigma_Y}^2} - 1 + 2q_1 f^* \cosh\left(-\frac{3q_2\widetilde{p}}{\kappa\sigma_Y}\right) - q_3 f^{*2} = 0$$

Porosity evolution

$$\dot{f} = \dot{f}_g + \dot{f}_n$$
$$\dot{f}_g = (1-f)\mathrm{tr}\left(\dot{\boldsymbol{\epsilon}}^P\right)$$
$$\dot{f}_n = \mathcal{A}(\epsilon_M^P)\dot{\epsilon}_M^P$$

The Gurson-Tvergaard-Needleman model

Plasticity

- Isotropic and kinematic hardening.
- Hill anisotropy: $\widetilde{q} = \sqrt{(\boldsymbol{\sigma}-\boldsymbol{X}) : \mathbb{H} : (\boldsymbol{\sigma}-\boldsymbol{X})}$

Coalescence

$$f^* = \begin{cases} f & \text{if } f < f_{cr} \\ f_{cr} + K_f(f - f_{cr}) & \text{if } f > f_{cr} \end{cases}$$

Material parameters

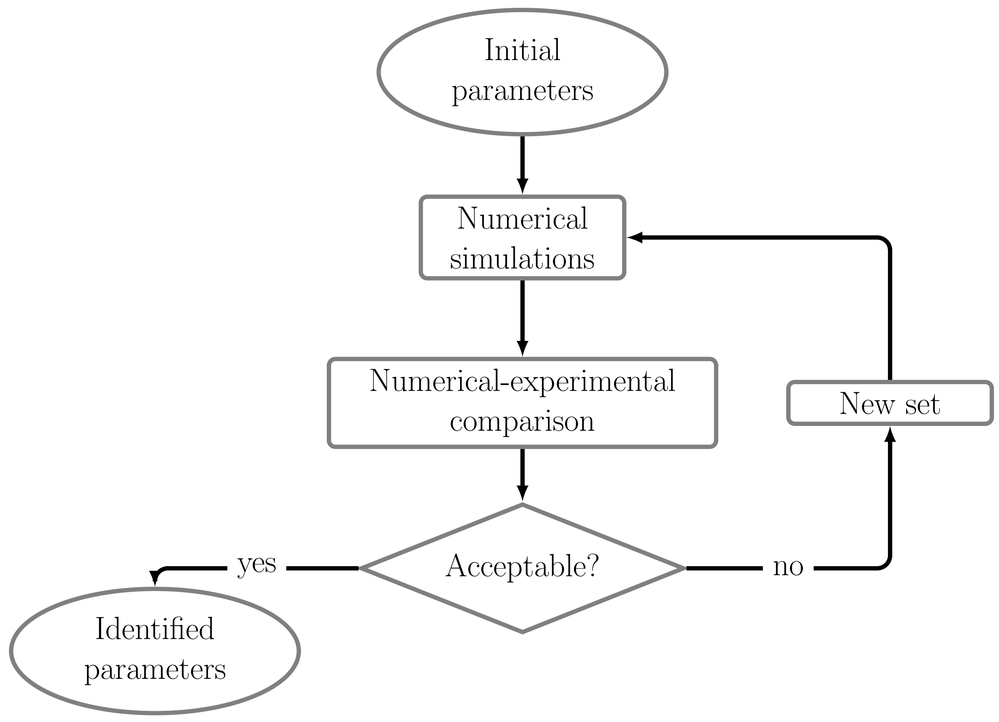
Elasto-Plasticity

- Elasticity: E, ν
- Hardening: K, n, ϵ_0
- Anisotropy: F, G, H, L, ...

Damage

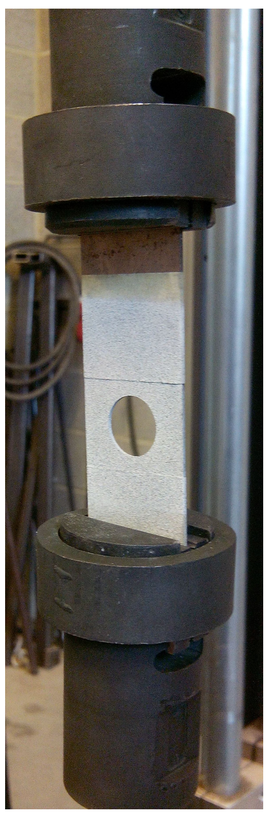
- Initial porosity: f_0
- Nucleation: ϵ_n, S_n, f_n
- Coalescence: f_{cr}, f_F

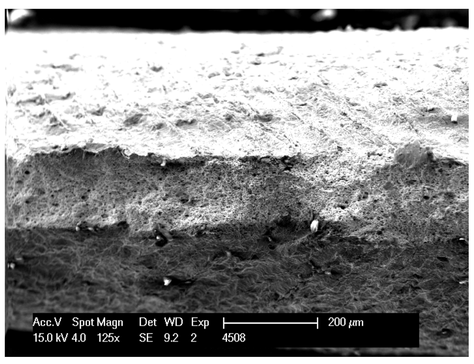
Inverse optimization



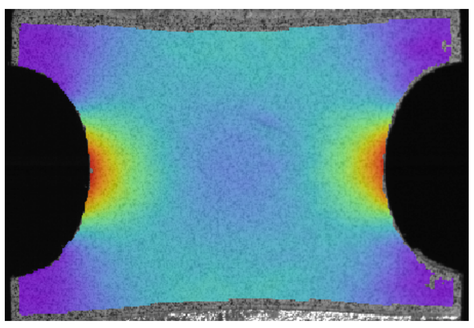
Experimental results

Tensile test

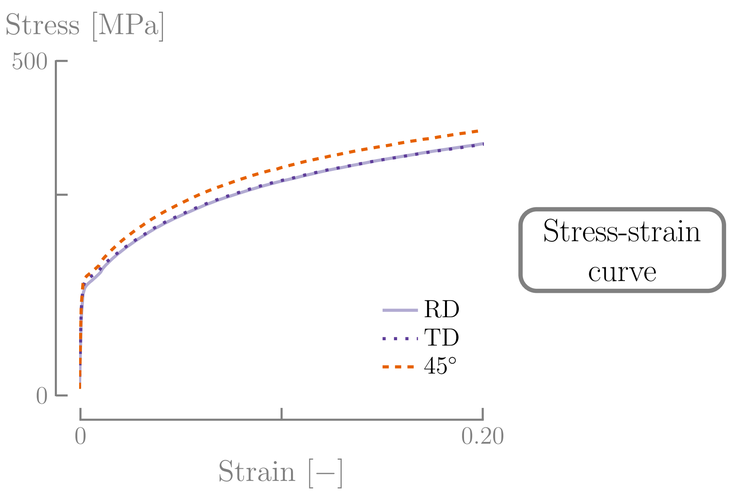




Microscopic measurements

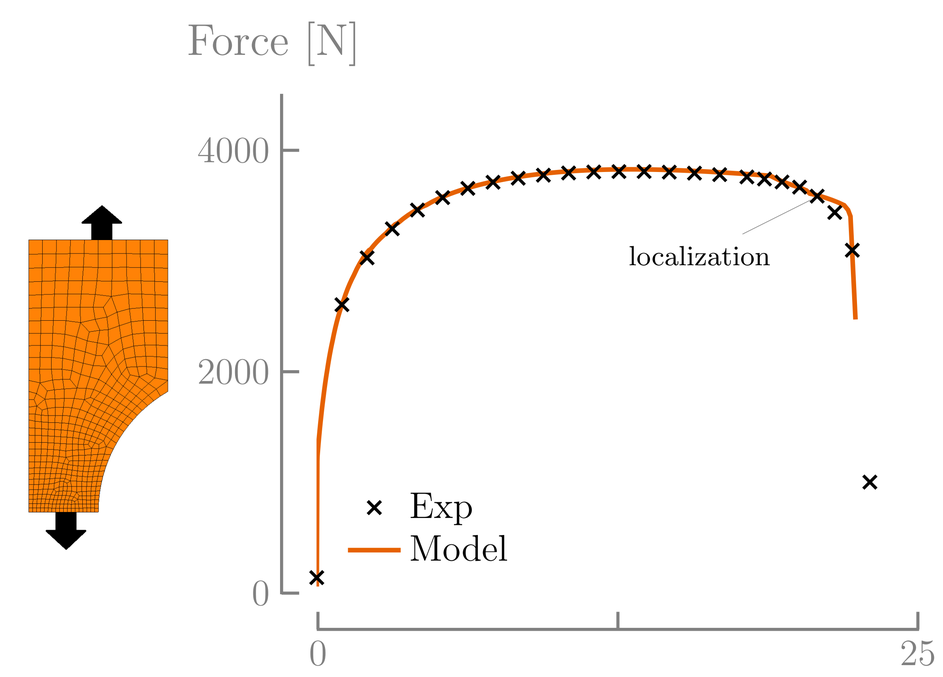


Digital image correlation



Stress-strain curve

Numerical predictions



Comments

- This poster presents an hybrid experimental-numerical procedure, coupling numerical simulations, optimization algorithms and digital image correlation.
- Due to the small thickness of the sheet, the constitutive model is very prone to localization difficulting the parameters identification.
- It is found that a porosity induced inhomogeneity plus a mixed hardening can delay localization and represent the entire deformation range.
- This localization phenomena should be carefully considered in applications involving complex strain paths.

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