ZsimOpt training

Z-set group

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Identification of material coefficients

- Identification of the constitutive equations (Chaboche model)
- Identification of viscoplastic behavior of IN738 for each temperature (20°C, 300°C, 500°C, 700°C, 850°C)
  - Calibration of the viscous effect on monotonic tests
  - Calibration of isotropic and kinematic hardenings on cyclic tests
- Fit analytical functions on the coefficients temperature evolution
- Identification of analytical functions coefficients on the whole database
- Verification on anisothermal tests

Plan

1. Experimental database
2. Material model
3. Calibration strategy

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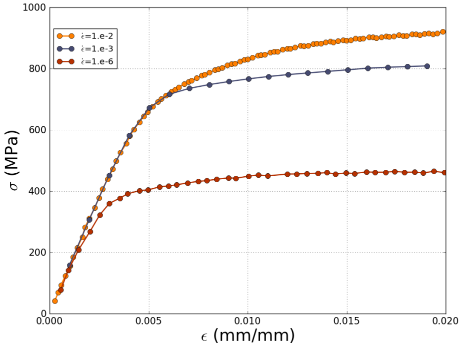
Experimental database

- Tensile tests at various strain rates

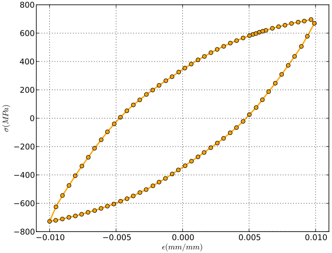


- EXP/tenx2.exp – strain rate 1.e-2 s^{-1}
- EXP/tenx3.exp – strain rate 1.e-3 s^{-1}
- EXP/tenx6.exp – strain rate 1.e-6 s^{-1}

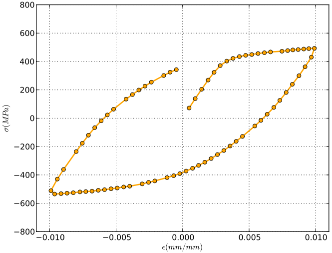
Experimental data base

- Strain controlled cyclic tests, $\epsilon = [-0.01 : 0.01]$

$\dot{\epsilon} = 10^{-3} s^{-1}$



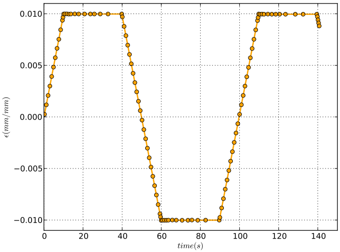
$\dot{\epsilon} = 10^{-5} s^{-1}$

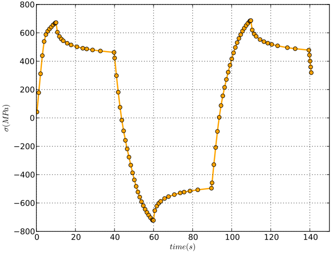


- EXP/lcf1x3.exp – strain rate 1.e-3 s^{-1}
- EXP/lcf1x5b.exp – strain rate 1.e-5 s^{-1}

Experimental data base

- Strain controlled cyclic+relaxation tests, $\epsilon = [-0.01 : 0.01]$

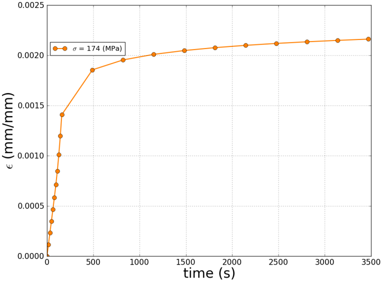


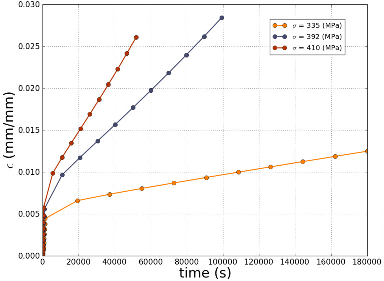


- EXP/frlx3.exp – strain rate 0.001/s

Experimental data base

- Creep tests





- EXP/cr174.exp : σ=174 MPa
- EXP/cr335.exp : σ=335 MPa
- EXP/cr392.exp : σ=392 MPa
- EXP/cr410.exp : σ=410 MPa

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The Chaboche model

- $\underset{\sim}{\epsilon}^{e}$ and $\underset{\sim}{\epsilon}^{vp}$ are the elastic and viscoplastic strain tensors,
- $\underset{\sim}{\epsilon}^{th}$ is the thermal strain,
- $J(.)$ is the von Mises invariant of a second-order tensor,
- υ is the plastic multiplier (cumulated viscoplastic deformation),
- $\underset{\sim}{\boldsymbol{n}}$ is the normal to the yield surface.

Strain partition: $\underset{\sim}{\epsilon} = \underset{\sim}{\epsilon}^{e} + \underset{\sim}{\epsilon}^{th} + \underset{\sim}{\epsilon}^{vp}$

Elasticity: $\underset{\sim}{\boldsymbol{\sigma}} = \underset{\approx}{\boldsymbol{E}} : \underset{\sim}{\epsilon}^{e}$

Plasticity criterion: $f(\underset{\sim}{\boldsymbol{\sigma}}) = J(\underset{\sim}{\boldsymbol{\sigma}}_{eff}) - R \quad \textit{with} \quad \underset{\sim}{\boldsymbol{\sigma}}_{eff} = \underset{\sim}{\boldsymbol{\sigma}} - \underset{\sim}{\boldsymbol{X}}$

Norton flow rule: $\dot{\upsilon} = \left\langle \frac{f(\underset{\sim}{\boldsymbol{\sigma}})}{K} \right\rangle^{n}$

Normality rule: $\dot{\underset{\sim}{\epsilon}}^{vp} = \dot{\upsilon}\, \underset{\sim}{\boldsymbol{n}} \quad \textit{with} \quad \underset{\sim}{\boldsymbol{n}} = \frac{3}{2} \frac{dev\left(\underset{\sim}{\boldsymbol{\sigma}}_{eff}\right)}{J\left(\underset{\sim}{\boldsymbol{\sigma}}_{eff}\right)}$

Non-linear kinematic hardening: $\underset{\sim}{\boldsymbol{X}} = \frac{2}{3}\, C\, \underset{\sim}{\boldsymbol{\alpha}} \quad , \quad \dot{\underset{\sim}{\boldsymbol{\alpha}}} = \dot{\upsilon}\, (\underset{\sim}{\boldsymbol{n}} - D\, \underset{\sim}{\boldsymbol{\alpha}})$

Constant isotropic hardening: $R = R_0$

5 coefficients for each temperature : K, n, R_0, C, D

The Chaboche model

- Additional visco-plastic potential for creep behavior (slow evolutions)

Strain partition: $\underset{\sim}{\epsilon} = \underset{\sim}{\epsilon}^{e} + \underset{\sim}{\epsilon}^{th} + \underset{\sim}{\epsilon}^{vp} + \underset{\sim}{\epsilon}_{s}^{vp}$

Norton flow rule: $\dot{v}_s = \left\langle \frac{f(\underset{\sim}{\sigma})}{K_2} \right\rangle^{n_2}$

Normality rule: $\dot{\underset{\sim}{\epsilon}}_{s}^{vp} = \dot{v}_s \, \underset{\sim}{\boldsymbol{n}} \quad with \quad \underset{\sim}{\boldsymbol{n}} = \frac{3}{2} \frac{dev(\underset{\sim}{\sigma}_{eff})}{J(\underset{\sim}{\sigma}_{eff})}$

Constant isotropic hardening: $R = R_{02} = 0$

2 more coefficients for each temperature : K_2, n_2

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Z-set | Material & structure analysis suite

Calibration strategy

- load Chaboche model (create template)
- load experiments
- optimization on tensile tests, first potential
  - create simulations
  - create optimizations
  - no kinematic hardening (C=1.), optimize K, n, R_0
- optimization on cyclic tests (including cyclic+relaxation tests), first potential
  - create simulations
  - create optimizations
  - n - fixed, optimize K, R_0, C, D
  - release n and optimize n, K, R_0, C, D
- optimization on creep tests, second potential
  - create simulations
  - create optimizations
  - n, K, R_0, C, D - fixed, optimize n_2, K_2