Application to the Lüders behaviour in steels

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Plan

1. Experimental evidence of Lüders band propagation
2. Mesh–dependency of standard FE simulations of Lüders bands
3. Strain gradient plasticity solution

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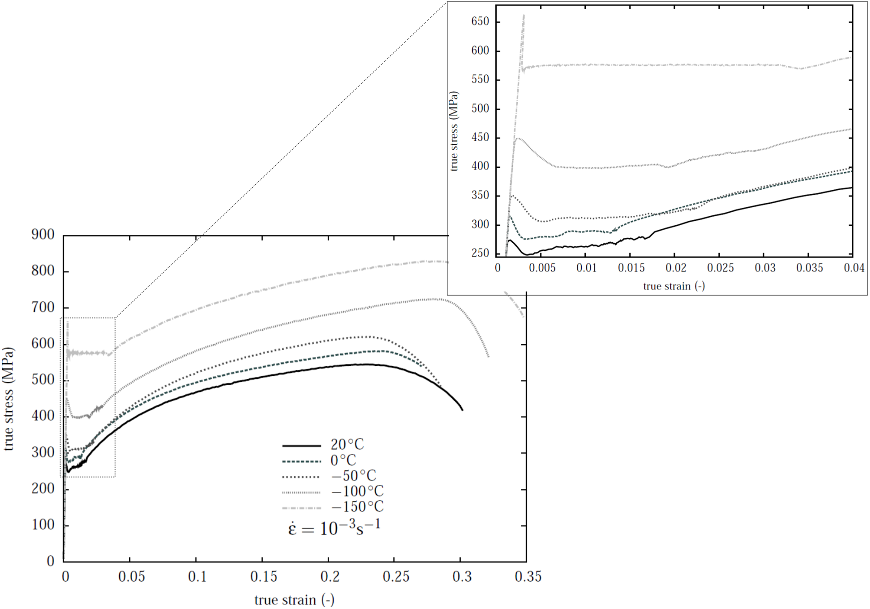
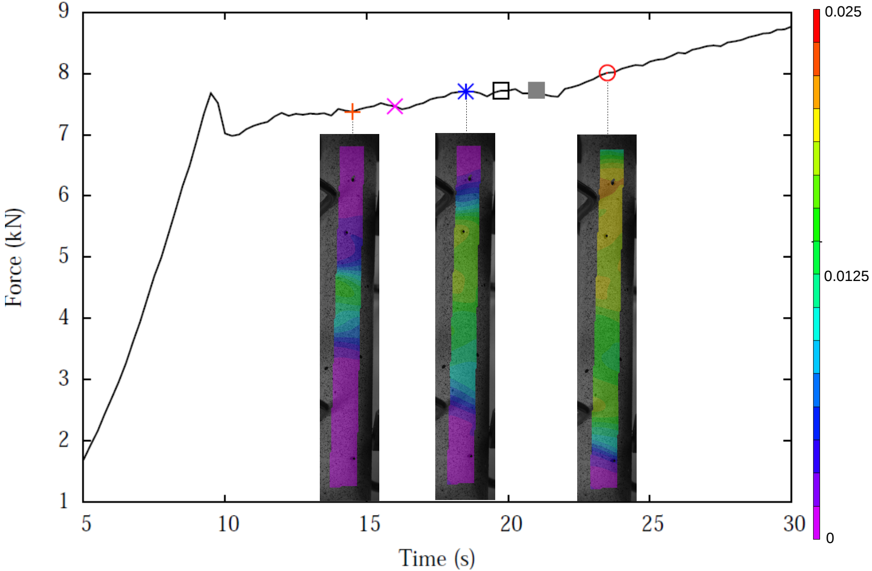
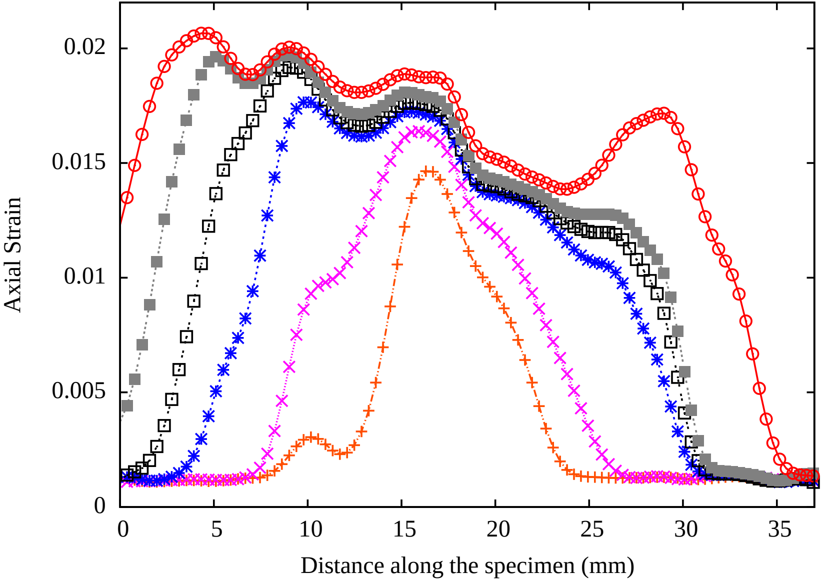


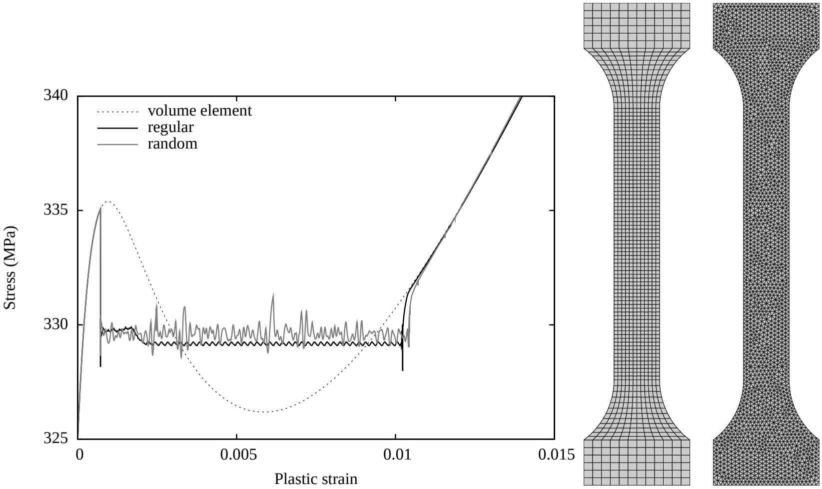
true stress (MPa)
true strain (-)
20°C
0°C
−50°C
−100°C
−150°C
$\dot{\varepsilon} = 10^{-3}s^{-1}$

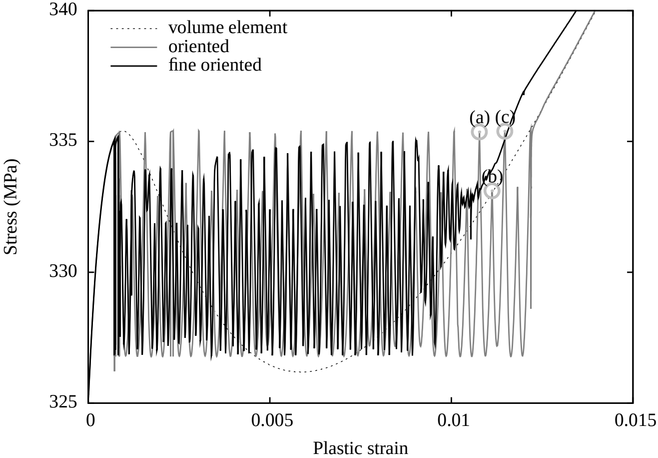
Strain field measurements

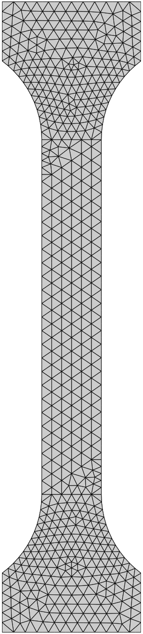


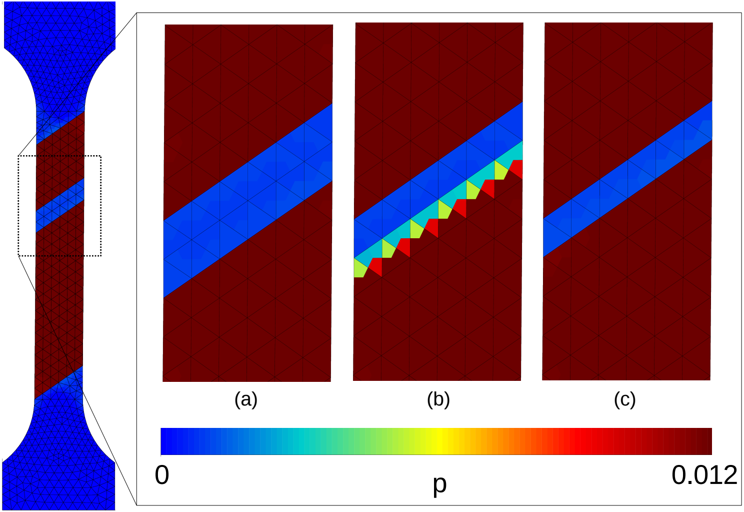
Strain field measurements



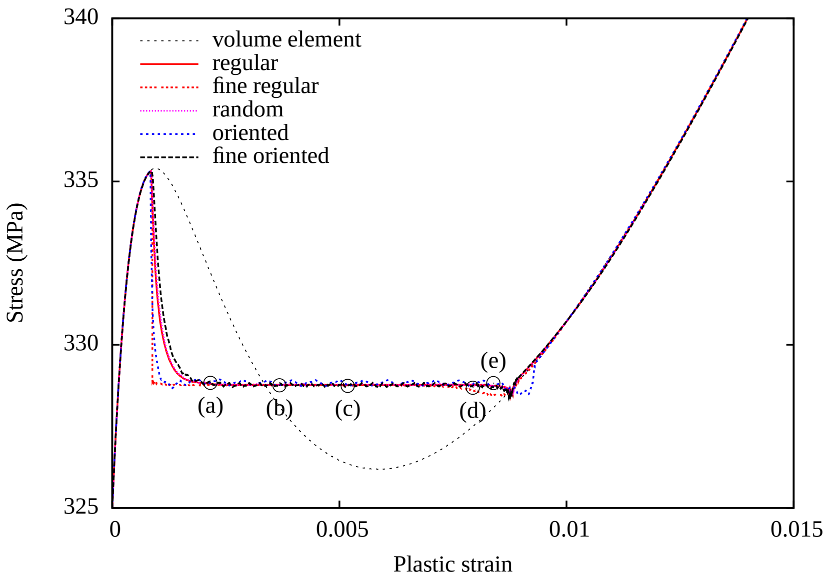

340
335
330
325
Stress (MPa)
0
0.005
0.01
0.015
Plastic strain
volume element
regular
random


340
335
330
325
Stress (MPa)
volume element
oriented
fine oriented
(a)
(c)
(b)
0
0.005
0.01
0.015
Plastic strain



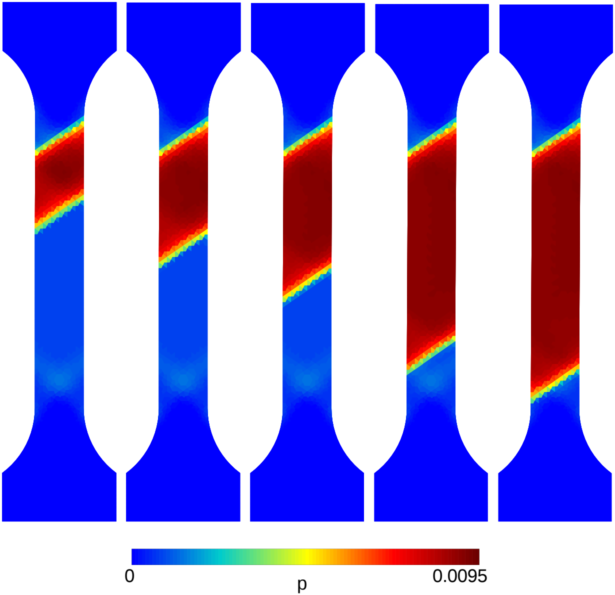


(Ballarin et al., 2009)

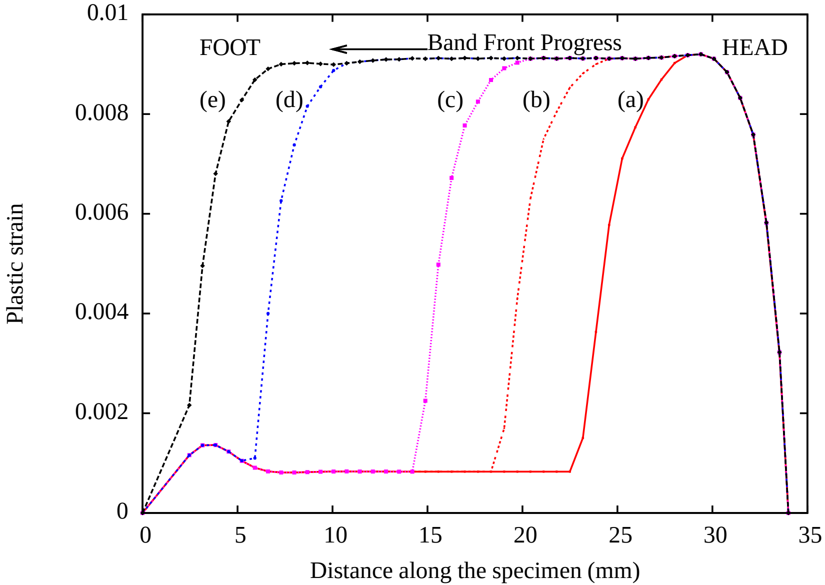


volume element
regular
fine regular
random
oriented
fine oriented
Stress (MPa)
Plastic strain
340
335
330
325
0
0.005
0.01
0.015
(a)
(b)
(c)
(d)
(e)

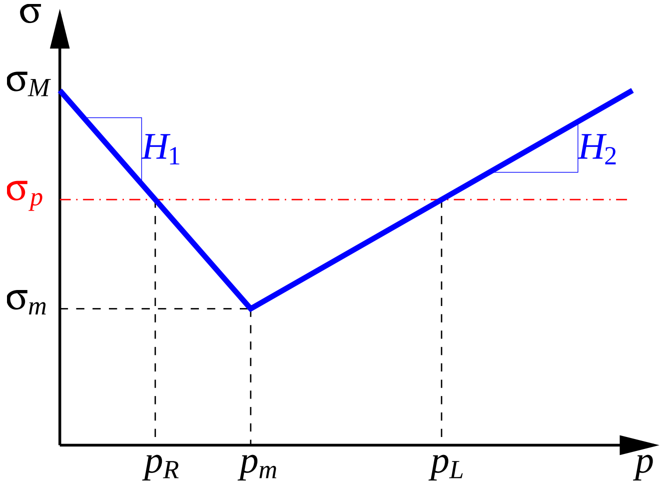
Smooth propagation of the front



Smooth propagation of the front

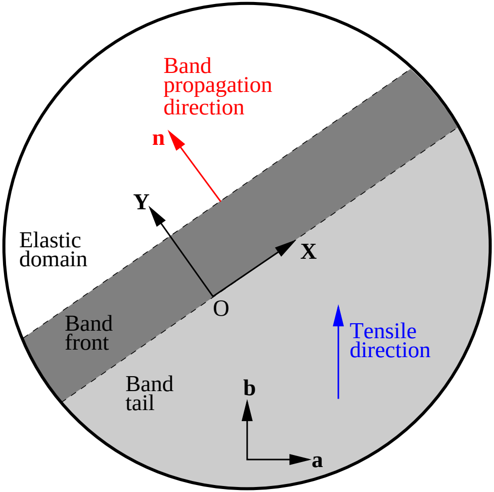


Multi–linear softening-hardening material



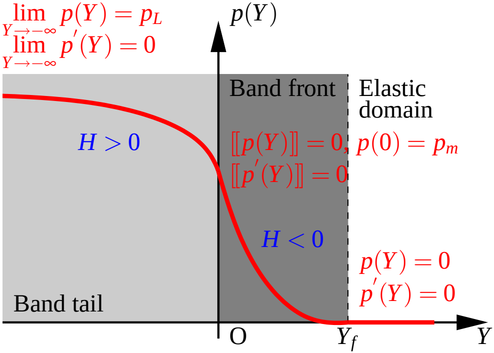
peak stress: σ_M, minimal stress: σ_m, plateau stress σ_p, Lüders strain p_L, hardening moduli $H_1 < 0, H_2 > 0$.

Bifurcation analysis



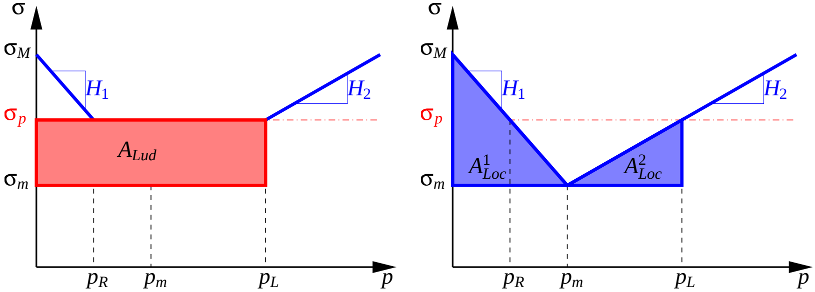
Homogeneous tensile stress state. The strain localization band in 2D (Rice's criterion) is inclined at 54.7° from the the tensile axis

Description of the band front

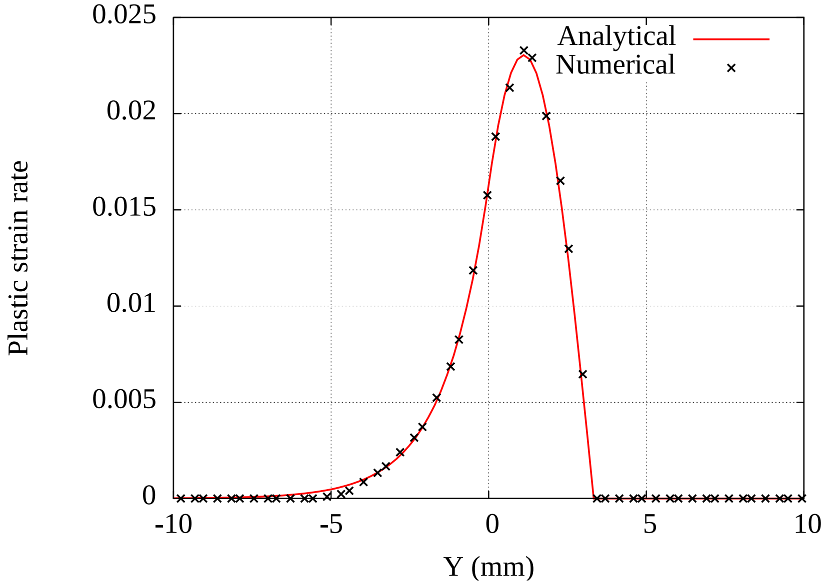


- $\sigma_p = \sigma_m + H_2(p - p_m) - Ap''$, $\quad l_2^2 = \dfrac{A}{H_2} \Longrightarrow$ hyperbolic
- $\sigma_p = \sigma_m + H_1(p - p_m) - Ap''$, $\quad l_1^2 = -\dfrac{A}{H_1} \Longrightarrow$ sine branch
- interface conditions

Maxwell's rule



determination of the plateau stress and Lüders strain



Analytical and finite element plastic strain rate profiles $\dot{p}$

Ballarin V., Soler M., Perlade A., Lemoine X., and Forest S. (2009).

Mechanisms and Modeling of Bake-Hardening Steels: Part I. Uniaxial Tension.

Metallurgical and Materials Transactions A, vol. 40, pp 1375–1384.