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A numerical investigation on the heterogeneous and anisotropic mechanical behaviour of AISI H11 steel using various stress-strain formulations: a multi-scale approach

A. Zouaghi[1,2], V. Velay[2], A. Soveja[1] and F. Rézaï-Aria[2]

[1] Université de Toulouse; INSA, UPS, Mines Albi, ISAE; ICA (Institut Clément Ader), Campus Jarlard, F-81013 Albi cedex 09, France
E-mail: vincent.velay@mines-albi.fr; rezai@mines-albi.fr

[2] Université de Toulouse; INSA, UPS, Mines Albi, ISAE; ICA (Institut Clément Ader), 10 Avenue Edouard Belin, F-31055 Toulouse Cedex 4, France
E-mail: ahmed.zouaghi@isae.fr; adriana.soveja@isae.fr

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During forming and machining processes, metallic structures are experiencing heterogeneous and anisotropic inelastic deformations which can lead to significant changes in the microstructure of the material. Since material properties are in concerns, it is thus important to better get insight into the local mechanical response by the mean of a multi-scale approach, i.e. how a global macroscopic load is accommodated at the local scale of a grain. In this direction, several progresses have been made in the development of multi-scale materials models benefiting from the increase of computational resources [1, 2]. Such approaches have been used to investigate the deformation localization prediction and show a quite satisfactory agreement with experimental observations of the local mechanical field [3, 4]. Nevertheless, the effects of the used stress-strain formulation on the local mechanical behaviour have not been investigated. It is well known that, besides small strain assumption, it is possible to use several finite strain formulations whether in Lagrangian or Eulerian framework for multi-scale modelling.

The aim of this contribution is to investigate the local heterogeneous mechanical response of AISI H11 steel using various stress-strain formulations. For this purpose, the elasto-viscoplastic model of [1] which includes non linear isotropic and kinematic hardenings, is implemented in a finite elements code using the three following formulations: the first formulation concerns the basic small strain assumption where rotation is neglected; the second one is based on finite strain theory in Eulerian framework defined by the Jaumann-Zaremba objective rate of Kirchhoff stress; and the last one is also based on finite strain theory in Eulerian framework but equivalent to the Lagrangian one defined by the Olroyd objective rate of Kirchhoff stress. The parameters of the constitutive equations are identified using macroscopic quasi-static and cyclic material responses and small strains assumption by the mean of a localization rule [5] (Fig1.a). By using a particular Voronoï tessellation [6] (Fig1.b), a virtual realistic microstructure, consisting of laths and grains, is generated considering the specific crystallographic orientations α'/γ relation (i.e. Kurdjumov-Sachs relation).

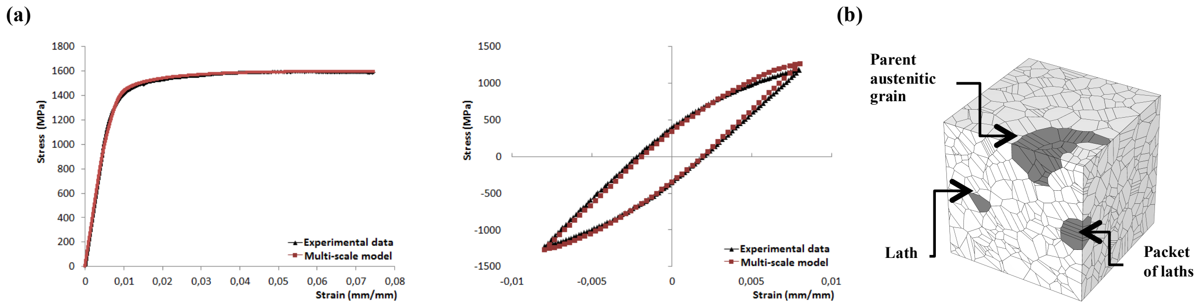

Fig 1. Model identification from experimental data (a) Virtual microstructure of AISI H11 generated by Voronoï tessellation (b)

Finite elements calculations are then conducted on the virtual microstructure of AISI H11 steel and show heterogeneous and anisotropic mechanical response depending on laths orientations, geometries and interactions. The numerical investigation emphasize that stress-strain formulations mentioned above deliver realistic estimates of the local heterogeneous mechanical field, but induce perturbations on it as it is shown in Fig.2.

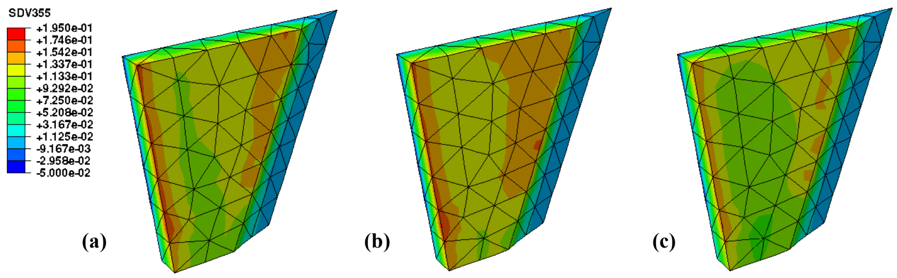

Fig 2. Intragranular equivalent plastic strain in a lath with Euler angles (φ1=114.2°, ϕ=10.5°, φ2=24.2°) using small strain assumption (a) Jaumann-Zaremba objective stress rate (b) Olroyd objective stress rate (c) subjected to uniaxial tension of 10%

These perturbations, which are discussed in this contribution, are dependant on the local microstructure; they can either amplify or reduce the localized mechanical field, which may have consequences on cracks initiation prediction.

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