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Numerical implementation of a micromechanical elastoviscoplastic homogenization model for austenitic-ferritic stainless steels

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Cast duplex austenitic-ferritic (AF) steels are widely used in primary loop of Pressurised Water Reactors. They offer a good combination of mechanical properties and corrosion resistance. However, at service conditions (about 320°C) and during long times of exposure (more than 10 000 h), the ferrite phase embrittles. This is due to a well-known phenomenon called '475°C embrittlement'. The mechanical resistance of the material is then strongly affected.

Regarding the microstructure of this material, three scales of interest can be pointed out: monocrystalline laths of each phase (1), the "bicrystals" (2) and the "poly-bicrystal" representing the macroscopic behaviour (3). At the second scale, the two phases are bipercolated and tend to have some crystallographic orientations relationships such as Kurdjumov-Sacks (KS) and Nishiwama-Wasserman (NW). This scale represents the complexity of the microstructure of this material and the main challenge to the scale transitions.

In this present work, at scale (1), the behaviour of the single crystals for both phases are modelled using the Meric-Cailletaud's crystal plasticity law [1]. Then, we integrate the lamellar austenite/ferrite structure observed for this microstructure by considering the intermediate scale of austenitic laths colonies as laminated domains. The bicrystal is then modelled as an aggregate of different laminate domains. We then apply the self-consistent scheme through translated fields (TF) homogenization approach (mean field model) [2]. An affine linearization is applied to the inelastic part of the deformation.

For the "poly-bicrystal" (transition from scale 2 to 3) representing the behaviour of an aggregate of "bicrystals", the self-consistent TF homogenization model is implemented. This model is coupled with the code generator MFront in order to perform FE simulations with code_aster of EDF R&D. The full field simulations - FE and FFT - and experimental data are used to validate the mean field model.

Keywords: nonlinear homogenization – austenitic-ferritic steels – multi-scale modelling.

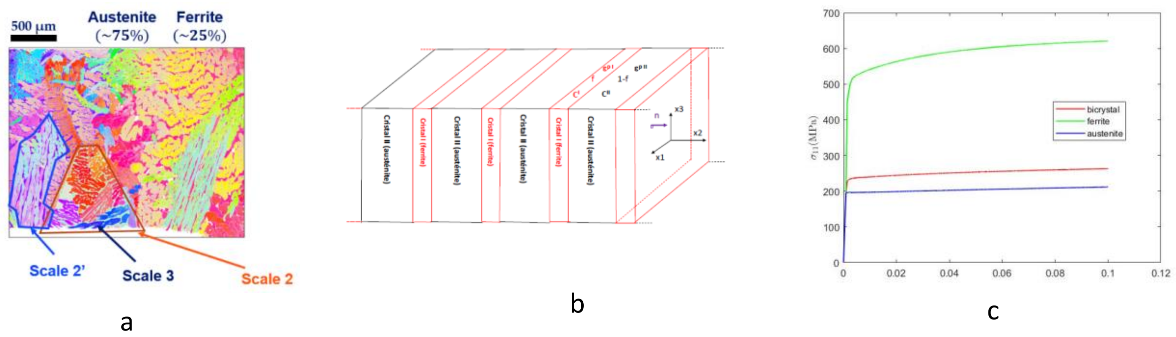

Fig.1 a) Map of cristallographic orientations of the austenitic phase and the three sclare of interest:Scale 2: the bi-crystal; Scale 2' : Lath colony and Scale 3 : Single crystal
b) Lamellar structure representing the scale 2' considering the lath colonies
c) Incompatibility stresses of a austenitic-ferritic bicrystal under imposed tension along x1-axis

References

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