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# Experimental investigation of grain boundaries deformation behavior in austenitic stainless steels

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## Abstract

InterGranular Stress Corrosion Cracking (IGSCC) is a common failure mode of metal alloys used in industrial applications. This phenomenon is for example observed in the internal structures of nuclear reactors, leading to the intergranular failure of austenitic stainless steel components (1). In the latter case, irradiation affects the mechanical and deformation behavior of the material, resulting in an increased susceptibility to IGSCC due to stronger slip incompatibilities at grain boundaries. In order to predict intergranular cracking, modelling grain boundaries deformation and mechanical behavior – such as slip (dis-)continuity, local stress / stress fields – are thus required. In this study, two experimental campaigns were conducted to gain insights and provide quantitative data relevant for (un)irradiated austenitic stainless grain boundaries for which data in the literature are scarce. First, in-situ Scanning Electron Microscope (SEM) high temperature (320°C) tensile tests were performed on one unirradiated and two proton-irradiated polycrystalline 304L specimens in order to assess slip transfer at grain boundaries. Activated slip systems were determined by coupling Electron Back Scatter Diffraction (EBSD) and slip trace analysis and / or Digital Image Correlation (DIC) coupled with the recently developed Slip System based Identification of Local Plasticity (SSLIP) (2). Among the different model proposed in the literature, slip discontinuity is found to be well predicted considering Luster-Morris (LM) criterion coupled with Residual Burgers Vector (RBV) criterion. Interestingly, the range of parameters for which slip discontinuity occurs is found to be independent of both strain and irradiation levels, and consistent with the criteria reported in the literature for FCC materials (3). Second, in-situ SEM high temperature (320°C) tensile tests were performed on millimeter-sized bicrystalline and oligocrystalline specimens. The material used is a FeCr12Ni26Si3 (wt %) austenitic stainless steel subjected to a high temperature heat treatment promoting grain growth. DIC was used to assess local displacement fields at grain boundary, along with stress – strain curves. The effect of grain boundary type and applied strain was assessed thoroughly on both slip (dis-)continuity and local strain fields. Finally, crystal plasticity constitutive equations accounting for the presence of grain boundaries were used to perform numerical simulations of the experiments, and calibrated using the experimental data. These constitutive equations are then used to perform polycrystalline aggregates simulations aiming at predicting intergranular stresses and thus obtaining an IGSCC fracture criterion for (un)irradiated austenitic stainless steels.

(1) LE. Thomas and SM. Bruemmer. 'Analytical transmission electron microscopy characterization of stress corrosion cracks in an irradiated type 316 stainless steel core component', Technical report, Fontevraud 5 International Symposium, 2002.

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- (2) T. Vermeij et al. 'Automated identification of slip system activity fields from digital image correlation data', *Acta Materialia*, 2023, vol. 243, p. 118502.
- (3) R. Alizadeh et al. 'A criterion for slip transfer at grain boundaries in Al', *Scripta Materialia*, 2020, vol. 178, p. 408-412.