Mechanical and microstructural response during biaxial load path changes of stainless steel: in-situ neutron diffraction and multi-scale modeling

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Abstract: Engineering materials are often subjected to complex load path changes during their forming processes or under service conditions. Their complex deformation history determines their subsequent mechanical response such as the Bauschinger effect, work hardening rate, etc. The origin of these macroscale phenomena is found at the microscopic scale. At the polycrystalline level, elastic and plastic heterogeneities due to texture result in the generation of intergranular stresses whose nature and evolution depends on the type of loading. At the single grain level, dislocation slip and interactions with other defects result in the generation of intragranular stresses, whose evolution also depends on the type of loading.

Our current understanding of the material behavior, and development of constitutive models, is mainly driven by experimental studies performed under uniaxial loadings and load reversals. However, this may not be sufficient to appropriately capture the material response in complex part geometries subjected to multi-axial load path changes. The present work is relevant to the sheet metal forming and applications during which materials are typically subjected to biaxial load path changes. Recently, with support from the ERC advanced grant MULTIAX (339245), a series of in-situ neutron diffraction tests were performed to study the microstructural response of 316L stainless steel cruciform samples subjected to biaxial load path changes.

To better understand the macroscopic and microstructural behavior of these 316L cruciform samples, a combined approach including the viscoplastic self-consistent finite element (VPSC-FE) scheme and the elasto-viscoplastic fast Fourier transform (EVP-FFT) model was proposed [1]. The passage of information between the experiments and simulations was based on a previous work where the aim was to understand the mechanical and microstructural behavior during monotonic biaxial loading response of 316L steel [2]. At the macroscale, the VPSC-FE model converts experimental boundary conditions to predict the cruciform gauge stresses. These macro-stresses are used as homogeneous boundary conditions to drive the polycrystalline EVP-FFT model. Both models use the same dislocation density based hardening law that accounts for load path changes. Following validation with in-situ digital image correlation and in-situ neutron diffraction experiments, the multi-scale model is applied to quantitatively explain the mechanical response [1], including the Bauschinger effect, and the microstructural behavior [3], including the lattice strain and texture (through diffraction peak intensity) evolution.

[1] Upadhyay et al., *Int. J. Plast.*, 108 (2018) 144 – 168
[2] Upadhyay et al., *Acta Mat*. 118 (2016) 28 – 43
[3] Upadhyay et al., *Int. J. Plast., under review*