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Micro material characterization by neutron diffraction

Motivation

The elastic deformation and, accordingly, the spring-back behavior of metal materials are still challenges in sheet metal forming. The steady transition from elastic to elasto-plastic deformation, the strain dependency of the Young's modulus, the nonlinearity of the unloading curve and the early reyielding, respectively the anelastic behavior of the materials lead to difficulties in modelling springback (Figure 1). In the state of the art, these phenomena are explained by the movement and behavior of mobile dislocations, but the microscopic explanations are based on macroscopic experimental results. For a proof of these assumptions and a better understanding of the elasticity, microscopic experiments are necessary.

Neutron diffraction is a non-destructive method and has a high penetration depth for steel materials, which enables the measurement of micro strains and dislocation densities. Within this research project, uniaxial tensile tests with neutron diffraction are conducted to correlate the microscopic with the macroscopic behavior to improve the modelling of elastic deformation.

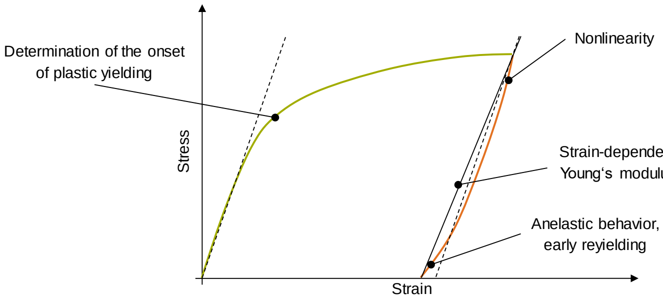

Figure 1: Challenges in the modelling of elastic deformation.

Approach

In cooperation with the FRMII, an experimental setup is developed to perform uniaxial tensile tests in the nuclear reactor (Figure 2). A load cell, a strain gage and a resistance thermometer (PT1000) measure the macroscopic parameters force, strain and temperature. The tensile specimen of an interstitial free material is loaded to predefined loads and unloaded afterwards. Meanwhile, neutron diffraction is performed and the intensity interference pattern shows the individual lattice planes dependent on the diffraction angle (Figure 3).

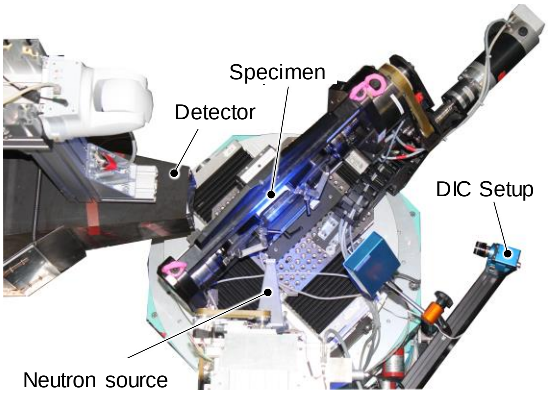

Figure 2: Experimental setup in the FRMII nuclear reactor for uniaxial tensile tests with neutron diffraction.

The lattice distance, respectively the micro strain can be determined by using Bragg's law. The peak broadening is used to determine the dislocation densities throughout the test (Figure 3). Additionally the development of the texture is investigated. These microscopic results are correlated directly with the macroscopic results by a synchronized measurement.

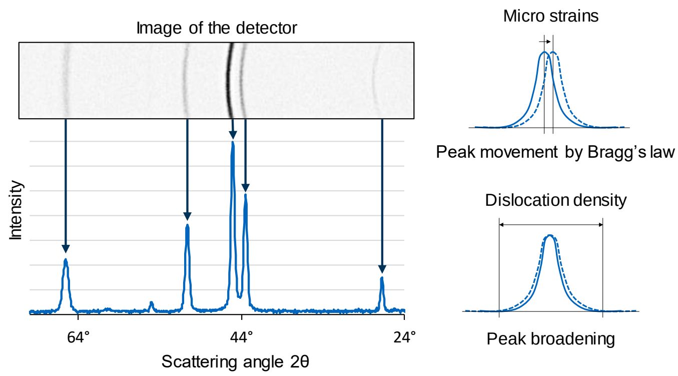

Figure 3: Intensity pattern of the neutron detector and determination methods of micro strains and dislocation densities.

Research objective

With the correlation of the microscopic and macroscopic values, better material understanding is gained and existing assumptions can possibly be proofed. Furthermore, existing macroscopic models, such as the Yoshida-Uemori model, can be extended and improved. This leads to a higher prediction accuracy of the springback in numerical simulations.

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