Modeling and Measurement of Residual Macro and Lattice Strains during Four-point Bending of Zircaloy-2

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Zircaloy-2 is an hcp zirconium alloy. It is used to make calandria tubes, which are a structural part of a CANDU nuclear reactor core. We are carrying out a combined modeling and experimental study of the development of internal strains of textured Zircaloy-2 during bending. The bending process is complex due to the highly anisotropic deformation of textured Zircaloy-2. Understanding the residual strains left by the bending process will make direct and significant contributions to the understanding of the material's real-life deformation and design of next-generation components.

Beams were machined in three different directions relative to a parent plate and deformed ex-situ. The residual macroscopic strain field on the beam surfaces were recorded with an image correlation technique. The residual microscopic lattice strains distributed on the cross-section plane in three directions were measured by neutron diffraction.

Residual strains were modeled at two different length scales. Macroscopic strains were determined using finite element modeling (ABAQUS) and lattice strains were determined with polycrystal plasticity modeling, using an elasto-plastic self-consistent (EPSC) model. Material parameters obtained from uni-axial loading were used as the input to the finite element model. Subsequently, the averaged stresses and strains over a group of elements, representative of the diffraction measurement gauge volume, were used as the boundary constraints for the EPSC models, in order to calculate the residual lattice strains as a function of position in the beams. The modeling results are compared with experimental data at both length scales.

Keywords: Bending, Residual strain, Neutron Diffraction, Finite element model, EPSC, Zircaloy-2