Local residual stresses in steels

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Local stresses distributed on the microstructural scale develop heterogeneously in all metals both during manufacturing and in service [1,2]. However, due to a lack of knowledge about their magnitude and distribution, their significance for microstructural evolution and mechanical properties is largely unknown, such that the current generation of materials models and lifetime assessment methods lack sufficient predictive power.

With the recent development of advanced synchrotron X-ray techniques, such as dark field X-ray microscopy (DFXM) and three-dimensional X-ray Laue micro-diffraction, local lattice strains/stresses can be characterized in detail at a spatial resolution of 100-200 nm (see Fig. 1). In this work, local residual stresses developed within individual grains in several (both single and dual-phase) steel systems are reported [3-6]. The results are analyzed in relation to both manufacturing parameters, e.g. plastic strain, annealing temperature and cooling rate, as well as to microstructural parameters, e.g. phase distribution, interface characteristics, grain size and dislocation density. Breakthroughs have thereby been achieved in understanding the origin of local residual stresses, e.g. in relation to differences in thermal expansion coefficients between phases, phase transformation, plastic deformation, or a mixture of any of these. Also, results from in-situ investigations of the development of local residual stresses upon external loading will be presented, with a view to understanding their impact on microstructural evolution and mechanical properties. Altogether, these types of study provide valuable inputs for future development of models that not only take into account the microstructural evolution, but that also can include the role of these important local stresses in this evolution.

Future experiments essential for further advancing the current understanding of the critical role that local residual stresses play in materials design will finally be suggested.

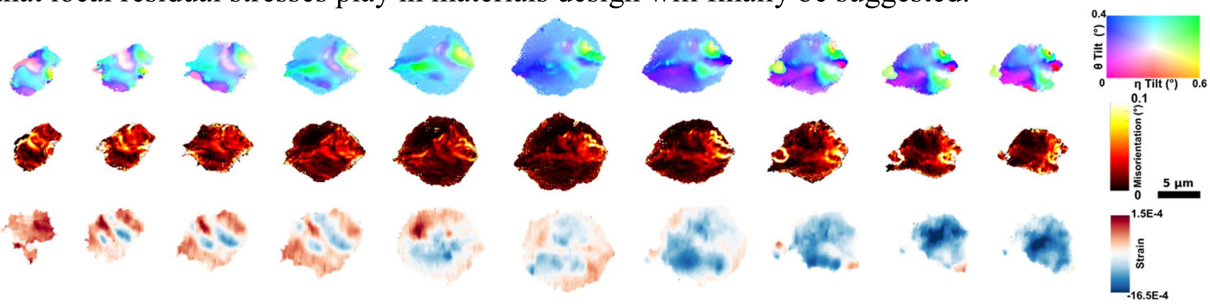

Figure 1: Microstructure and strain maps for all the scanned 2D sections of a 3D ferrite grain in a pearlitic steel sample, characterized using DFXM. From top to bottom rows: mosaicity, misorientation and strain maps. The distance between each section layer is about 600 nm. [5]

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