# Experimental report

17/09/2019

**Proposal:** **1-02-226** **Council:** 4/2017

**Title:** Residual stress analysis for multiphase materials with depth gradients of the strain free / independent lattice parameter d0 (cont.)

**Research area:** Materials

**This proposal is a continuation of 1-02-199**


**Main proposer:** **Jens GIBMEIER**

**Experimental team:** Joana REBELO KORNMEIER
Jens GIBMEIER
Samuel PULVERMACHER
Michael HOFMANN
Michael ZUERN

**Local contacts:** Thilo PIRLING


**Samples:** X3CrNiMoN27-5-2

| Instrument | Requested days | Allocated days | From | To |
|---|---|---|---|---|
| SALSA | 7 | 4 | 29/09/2018 | 03/10/2018 |


## Abstract:

For neutronographic residual stress analysis it is essential to provide correct reference data of the strain free / independent material state, i.e. the lattice parameter d0. As a supplement to laboratory X-ray diffraction approaches using soft X-rays, there exists an increased interest for the non-destructive determination of near surface residual stress gradients for the application of neutron diffraction stress analyses by means of through surface strain scanning. Causal for the residual stress gradients are often processes that induce a chemical gradients of the lattice parameters like e.g. nitriding or case hardening of steel. Moreover, the most technical materials are multi-phase materials. This in total leads for thermal and / or mechanical treatment processes to specific gradients of the phasespecific micro residual stresses. With regards to the preparation of samples to determine the local depth distribution of d0 (typically comb structures, small cubes or pin-like samples) it is mostly unknown if the residual stresses are sufficiently released through the mechanical sectioning for that they can be regarded as being ´stress free´ in the respective measuring directions. Thi

## Experimental Report – Proposal No. 1-02-226

# Residual stress analysis for multiphase materials with depth gradients of the strain free / independent lattice parameter $d_0$

J. Gibmeier[1], J. Rebelo-Kornmeier[2], M. Hofmann[2], J. Šaroun[3]

[1] KIT – Karlsruhe Institute of Technology, IAM, D-76131 Karlsruhe, Germany

[2] TU München, ZWE-FRM II, D-85747 Garching, Germany

[3] Nuclear Physics Institute of the ASCR, Řež, Czech Republic

Abstract/Aim

Aim of the project is to develop a basic understanding on the effect of local phase-specific micro residual stresses on the determination of the strain independent lattice parameter and providing an approach for the reliable modelling of the surface effects for coarse multiphase materials and for materials states with chemical gradients in the near surface region, corporately a measuring and evaluation strategy for non-destructive analysis of near surface residual stress gradients for problematic material states will be developed. In the current research project fundamental investigations on the effect of phase-specific micro residual stresses on the reference value $d_0$ are carried out. For this purpose, defined residual and applied stress states were applied for multiphase materials with variations in the phase contents. For this first approach various fine grained duplex steels were studied, which clearly differ in the amount of the phase contents.

The systematic neutron studies is the centerpiece of a collaborative research project, which is currently granted (for 3 years) by the German research foundation (DFG) with the partners TU Munich and KIT, Karlsruhe in cooperation with the Czech research foundation (GACR) with the partner Nuclear Physics Institute, Řež.

Measurement setup:

In this first approach we focused on the investigation of the two duplex steel types, X2CrNiMoN22-5-3 (1.4462) and X3CrNiMoN27-5-2 (1.4460), which clearly differ in their ferrite/austenite ratio, which is 50/50 (1.4462) and 70/30 (1.4460), respectively. Uniaxial in-situ tensile loading experiments were carried out for cylindrical samples with a 6 mm diameter in the measuring length. The phase-specific lattice strain distributions were determined for purely elastically and defined elasto-plastically loaded states. A nominal gauge volume of 2x2x2 $mm^3$ was used, which was defined by radial collimators at the primary and secondary beam paths. By this means various lattice planes were measured for the phases austenite and ferrite in the longitudinal and radial directions. A neutron wavelength of 1.62 Å was used. Also, 3 free-cut cubes were measured as reference samples, which were elastic-plastically deformed prior to the beamtime. For this purpose, the intrinsic stress release was observed.

Preliminary results

In Fig. 1 the preliminary evaluation for the phase, respectively {hkl} specific lattice strain for an applied tensile stress is shown (first evaluation without proper background correction) as an example for the duplex steel 1.4460 with a ferrite/austenite ratio of 70/30. The change in lattice strain with respect to the initial state is plotted vs. the applied uniaxial stress. The distribution clearly shows that in the elastic regime the change in lattice strain is almost linear follows the expected materials behaviour. Large deviations occur starting with plastic deformation of the ferrite and the austenite phase. From here on plastic anisotropy effects can be observed. Without going into a detailed discussion the data indicate that for the textured duplex steel plastic anisotropy effects can be resolved that are due to intergranular stresses that depend on grain orientations.

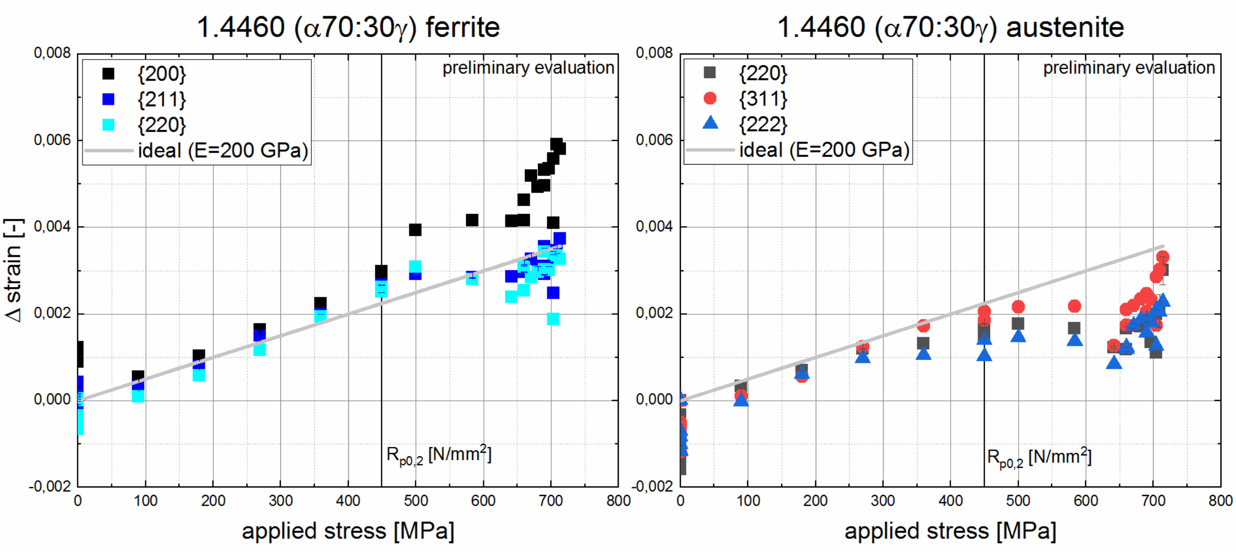


*Figure 1: The phase or {hkl} specific lattice strain distribution vs. the applied tensile stress is shown for one of the two duplex steels, i.e. for the duplex steel with a phase content of 70:30 ferrite to austenite (mat.-no. 1.4460).*

These findings of first data evaluation are supported by the change in lattice strain that is plotted vs. the applied plastic strain for all unloaded states in Fig. 2.

Here, particularly for the ferrite reflections the distributions are strongly dependent on the (hkl) reflections that were monitored during the in-situ loading experiment. Obviously, phase specific micro residual stresses lead to change in the lattice strain for the unloaded states, which is – due to crystallographic texture – strongly deviating for different (hkl)-reflections. In the next step we plan to bring in the local texture information for the further data evaluation to obtain a holistic view on the local anisotropy effects that occur in the elasto-plastic regime.

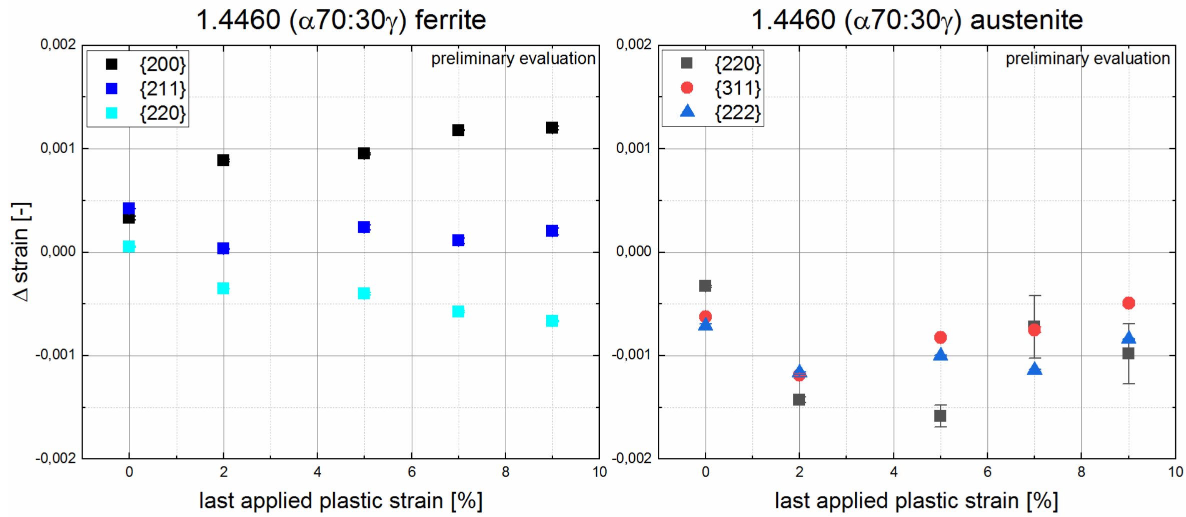


*Figure 2: The phase or {hkl} specific lattice strain distribution vs. the applied plastic strain for the unload state is shown one of the two duplex steels, i.e. for the duplex steel with a phase content of 70:30 ferrite to austenite (mat.-no. 1.4460).*