MA-4228, ID 15A "Mapping of phase transformation in superelastic NiTi polycrystalline wires under tension and torsion - from localization to homogeneous transformation"

Experiment start: 7/9/2018 8:00:00 AM

Experiment end: 11/9/2018 8:00:00 AM

Shifts: 12

Local contact: Stefano CHECCHIA

Report:

The main aim of the experiment was to map martensite phase fraction in the vicinity of martensitic band front in loaded NiTi shape memory alloy wires subject to combine external loading. The samples were prepared from superelastic NiTi wires with diameter 200 μm. The combine tensile-twisting loading was realized by an in–house assembled tension-twisting rig with a manual control of stretching and twisting (Fig.1). The tomography-specific design of the rig assured minimal shading of the incident and diffracted beams by the supporting arms while the whole rig could freely rotate in the diffractometer.

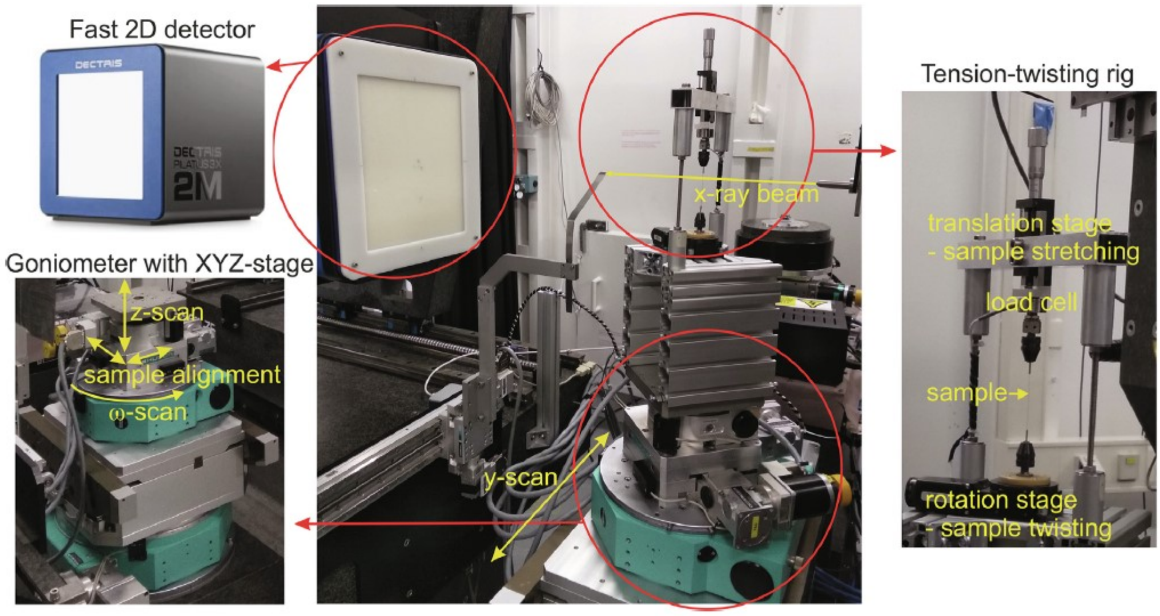

Figure 1: *Sheme of the DSCT experiment with the tension-twisting rig mounted on goniometer.*

Data acquisition and their further processing followed the methodology of the diffraction/scattering computed tomography (DSCT) schematically depicted on Figure 2. The X-ray beam of the wavelength 0.0189 nm was focused to a spot approx. 3 μm by 3 μm at the sample location, the diffracted radiation was detected with acquisition time 30 ms. During the tomographic measurements, the sample was translated along the *y*-direction (Fig.1) within the range of 295 μm by 5 μm-steps (60 scanning positions in total). The rotation, *ω*-scanning, was conducted in the azimuthal range of 189° with 3° per step (64 positions). The translation in *z*-direction was performed in 20 positions with 15 μm spacing.

The data processing required to develop several routines in Matlab to adopt the DSCT method for martensitic transformation in NiTi. The main difficulty in data evaluation was related to a strong texture of strained martensite which, in general loading cases (as torsion or combine tension and torsion) loses rotational symmetry complicating tomographic reconstruction of phase fraction maps. We have found a way to eliminate this problem by both integrations of 2D diffraction patterns and by introducing knowledge of sample geometry into tomographic reconstruction.

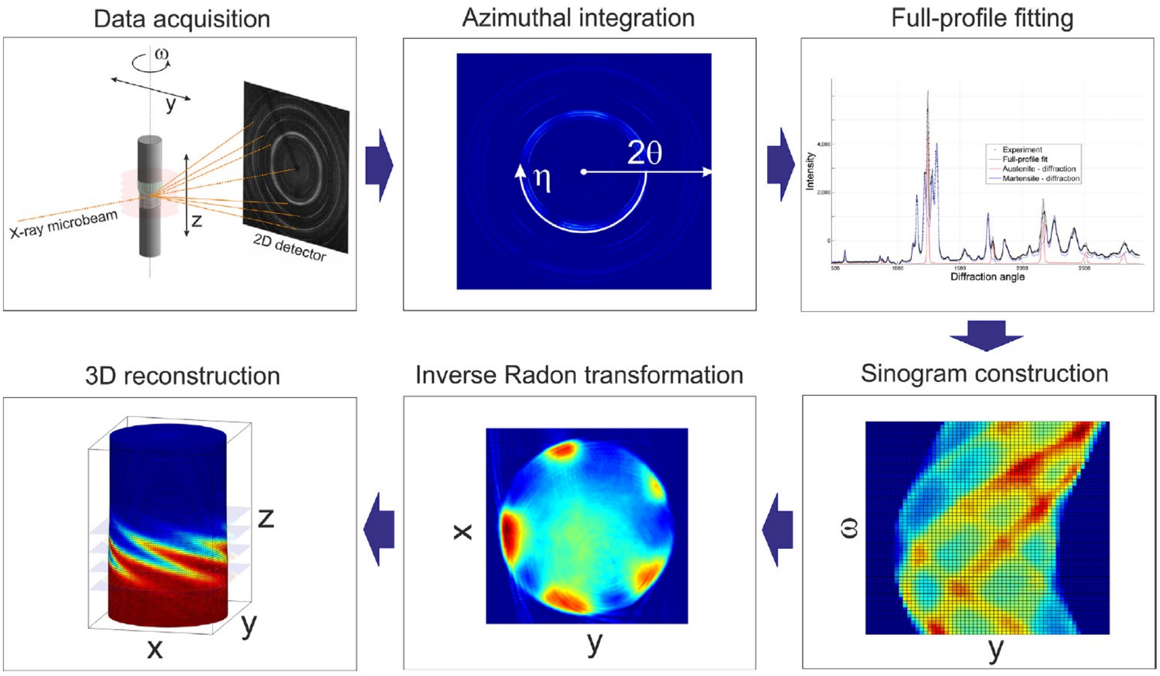

Figure 2: *A simplified workflow scheme of the DSCT technique.*

The most interesting obtained results were:

1) Reconstruction of phase distributions in loaded NiTi helical spring. The results were described in details in the paper [Frost2020].
2) 3D spatial reconstruction of macroscopic austenite–martensite transition zones in NiTi wires induced by tension and twisting. The results confirmed suitability of the chosen experimental approach and brought detailed picture of morphology of transformation fronts in NiTi and their dependence on loading mode (Fig. 3). The results were described in details in the paper [Sedlak2021].
3) Description of localized deformation in NiTi in tension at elevated temperatures, mainly confirmation of appearance of plastically deformed austenite within martensitic bands. The results were described in details in the paper [Chen2019].

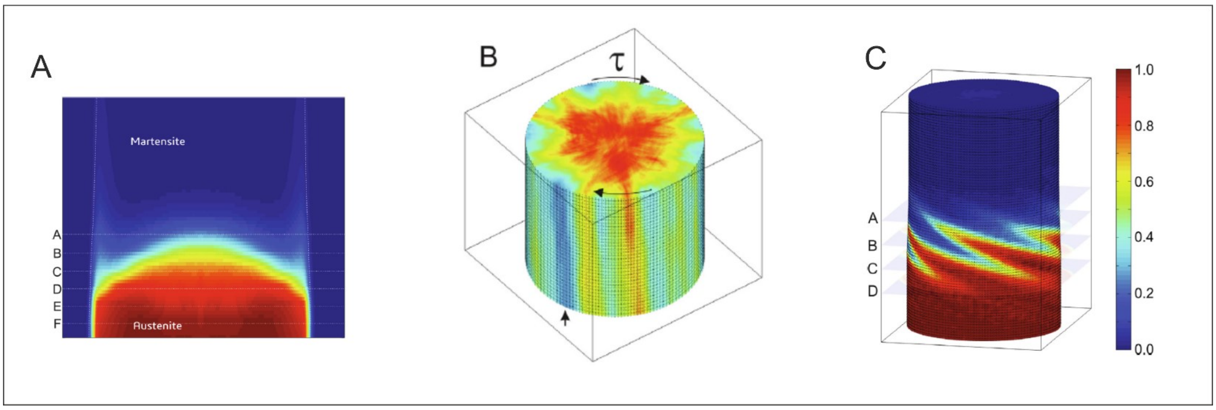

Figure 3: *Martensitic band front for different loading modes: A-pure tension (with rotational symmetry), B- pure twist, and C- combine tension-twist.*

References:

[Frost2020] Frost, M., Ševčík, M., Kadeřávek, L., Šittner, P., Sedlák, P., Reconstruction of phase distributions in NiTi helical spring: Comparison of diffraction/scattering computed tomography and computational modeling (2020) Smart Materials and Structures, 29 (7), art. no. 075036.

[Sedlak2021] Sedlák, P., Frost, M., Ševčík, M., Seiner, H., 3D spatial reconstruction of macroscopic austenite–martensite transition zones in NiTi wires induced by tension and twisting using diffraction/scattering computed tomography (2021) International Journal of Solids and Structures, 228, art. no. 111122.

[Chen2019] Chen, Y., Tyc, O., Kadeřávek, L., Molnárová, O., Heller, L., Šittner, P., Temperature and microstructure dependence of localized tensile deformation of superelastic NiTi wires (2019) Materials and Design, 174, art. no. 107797.