ESRF	Experiment title: MICROBEAM X-RAY DIFFRACTION WITH HIGH LATERAL RESOLUTION APPLIED TO A NICKEL-BASE SUPERALLOY TURBINE BLADE AFTER SERVICE	**Experiment number:** HS - 435
Beamline: BM 5	**Date of experiment:** from: 22-Oct-97 to: 26-Oct-97	**Date of report:** 24-Feb-98
Shifts: 12	**Local contact(s):** A. Souvorov and A. Snigirev	*Received at ESRF:*

Names and affiliations of applicants (* indicates experimentalists):

H. Biermann*, B. v.Grossmann*, S. Mechsner*, H. Mughrabi and T. Ungár*[+]

Institut für Werkstoffwissenschaften, Lehrstuhl I, Universität Erlangen-Nürnberg
Martensstr. 5, D-91058 Erlangen, Fed. Rep. Germany

[+] Institute for General Physics, Eötvös University Budapest, Muzeum krt. 6-8,
P.O. Box 323, H-1445 Budapest VIII, Hungary

Report:

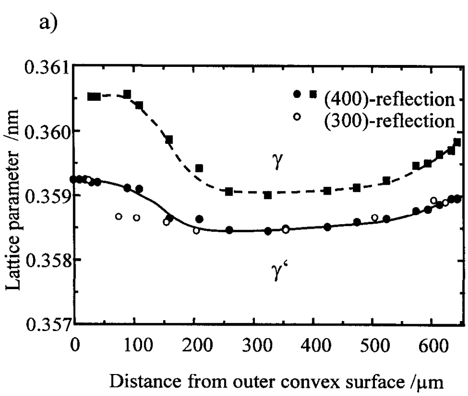
Single crystalline nickel-base superalloys, consisting mainly of the γ- and the γ'-phase, are used in modern aircraft engines for the turbine blades of the first stages. Due to the high temperatures and the high centrifugal stresses acting in the [OOl]-direction severe micro-structural changes occur during service. In addition to the microstructural changes a characteristic variation of the local lattice parameters of the two phases caused by long-range internal stresses can be found. These internal stresses are induced by (i) plastic deformation of the y-phase and (ii) different thermal expansion coefficients of the two phases. They lead to a counteracting tetragonal distortion of the two phases γ and γ'. In a preliminary experiment at the ESRF (HC-495) local changes of the internal stresses in a turbine blade after service were measured by microbeam X-ray diffraction, which were caused by the large temperature and stress gradients under service conditions [11. Especially in the regions near the surfaces a complex three-dimensional stress state was found.

The aim of this experiment was the measurement of the full 3-dimensional stress state in the near-surface regions of the blade with transmissionmicrobeam X-ray diffraction of a thin foil, prepared from a longitudinal section of the trailing edge. In combination with the {300} -superlattice reflections, the characterization of the complex lattice parameter changes in the microstructure is shown to be possible with high lateral resolution.

The experiments were performed at the optics beamline BM 5 with a (111)-silicon linear Bragg-Fresnel lens (BFL). The BFL and the sample were arranged in a double-crystal diffractometer mode. The monochromatized beam had an energy of 18.006 keV, determined by the absorption edge of Zr. The focal spot on the sample had a height of 2 μm and could be adjusted by a slit system in front of the sample to a length between 20 μm and 50 μm according to the intensity of the reflected beam. The samples were prepared as longitudinal and perpendicular sections of some selected parts of a turbine blade which has been subjected to a so-called accelerated mission test for several hundred hours. In addition, a thin foil with 40 μm thickness of a longitudinal section was prepared for transmission diffraction experiments.

Figure 1 shows the variation of the evaluated lattice constants from (400)/(300)- reflections (figure la) and (004)/(003)-reflections (figure lb) for the two phases γ and γ' as a function of the distance from the outer convex surface. The measurements were performed at the trailing edge of the turbine blade. The two figures reveal the counteracting tetragonal distortion of the two phases. In [1 00]-direction the lattice parameters of the y-phase have larger values than those of the γ'-phase. In [001]-direction the values are smaller than those of the γ'-phase. The analysis of the data shows in both cases an increase of the lattice parameters especially for the y-phase near the surfaces. This increase could be correlated with a higher Al content in these regions caused by diffusion from the aluminide protective coating. With increasing distance from the surfaces the effect of the Al-diffusion becomes negligible, and an almost homogeneous stress state exists in the middle of the blade. In both figures the values for the γ'-lattice parameters measured by the {300}-superlattice reflections are in very good correlation with lattice parameters evaluated by the profile analysis of the {400}-reflections.

[l] Biermann, H., v. Großmann, B., Mechsner, S., Mughrabi, H., Ungár, T., Snigirev, A., Snigireva, I., Souvorov, A., Kocsis, M., Raven, C., Scripta mater. 37 (1997), 1309-13 14.



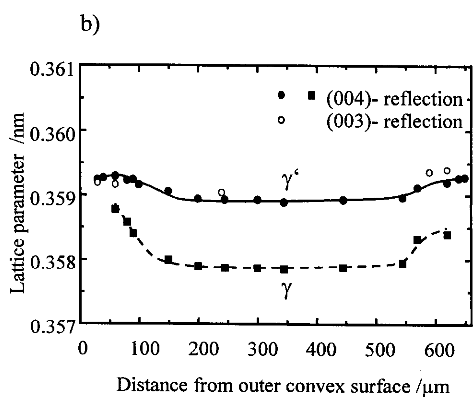


Figure 1: Lattice parameters. a) In [100]-direction and b) in [001]-direction for the γ and the y'-phase. The distance of 700 pm is equivalent to the inner concave surface of the turbine blade.