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MICROBEAM X-RAY DIFFRACTION WITH HIGH LATERAL RESOLUTION AT THE GRENOBLE SYNCHROTRONS RADIATION FACILITY APPLIED TO A NICKEL-BASE SUPERALLOY TURBINE BLADE AFTER SERVICE

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In modern aircraft engines nickel-base superalloys are used as monocrystalline turbine blades of the first stages. In the initial state, their microstructure consists of a high volume fraction of cuboidal γ' particles precipitated coherently in the γ matrix [1-3]. X-ray diffraction line profiles of creep-deformed nickel-base superalloy were shown to be characteristically asymmetric due to long-range internal stresses induced i) partly by plastic deformation of the heterogeneous γ/γ' structure and ii) partly by the difference in the thermal expansion coefficients of these two phases. These internal stresses lead to counteracting tetragonal lattice distortions, cf. [2]. In turbine blades subjected to service, changes of the microstructure and a build-up of internal stresses can be observed [1,3]. The hot regions near the leading and trailing edges are subjected to temperatures up to 1100 ‘C whereas the regions near the cooling channels are subjected to temperatures of about 800 “C. These temperature gradients cause strong inhomogeneities in the local thermal and mechanical loads. An investigation of the local variations of the internal stresses near the surfaces of turbine blades therefore requires a high lateral resolution which can only be achieved by special techniques. In the present paper, measurements of line profiles were performed with a new technique, using the advantages of synchrotrons radiation of the European Synchrotron Radiation Facility (ESRF) at Grenoble applying the Bragg-Fresnel focusing optics [4-6].

The experiments were performed at the optics beam line BL 10 at a bending magnet. The (111) Si single crystal, linear phase-Bragg-Fresnel lens (BFL), cf. [4-6], and the sample were arranged in a double crystal diffractometer mode, as shown schematically in Fig. 1. The BFL was used both to monochromatize the synchrotron radiation and to focus the X-ray beam. The BFL with a focusing distance of 0.6 m was adjusted for the energy of 18.006 keV, determined by the absorption edge of Zr. With a slit system, a spot of 2 µm height and 30 µm and 50 µm length, respectively, was adjusted for the experiments in the present case. The sample to detector distance was selected to be 0.82 m, in order to have a sufficiently high angular resolution for the line profile measurements. A linear position sensitive proportional counter (OED-50, Braun, Munich) with a spatial resolution of about 80 µm has been used for the measurement of the line profiles of the (400) and/or (004) Bragg reflections. The samples were mounted on a high precision goniometer with an x-y-z three dimensional translation stage.

A turbine blade of the nickel-base superalloy CMSX-6 which was subjected to service in an accelerated mission test for several hundred hours was investigated at different positions along several (100) and (001) sections. From the locally measured (004) and (400) line profiles the local lattice parameters of the y and y’ phases were determined. Fig. 2 shows the variation of these lattice constants for the different reflections and phases as a function of the distance from the high pressure side up to the low pressure side in the trailing edge region. The analysis of the data shows that in the region near the surfaces i) a macroscopic compressive stress state exists parallel to the surfaces and ii) the higher Al content in this region measured by energy dispersive analysis causes an increase of the net lattice constant. In the bulk of the material a homogeneous stress state exists which is comparable with the results obtained in the home laboratory. Further details will be published soon [7].

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Figure 1: Set-up of the Microdiffraction experiment with the Bragg-Fresnel lens at Beamline 10.

Figure 2: Lattice parameters in the [100] and [001] directions for they and γ' phases vs. the relative position of the cross section at the trailing edge of the turbine blade.

figure : 1

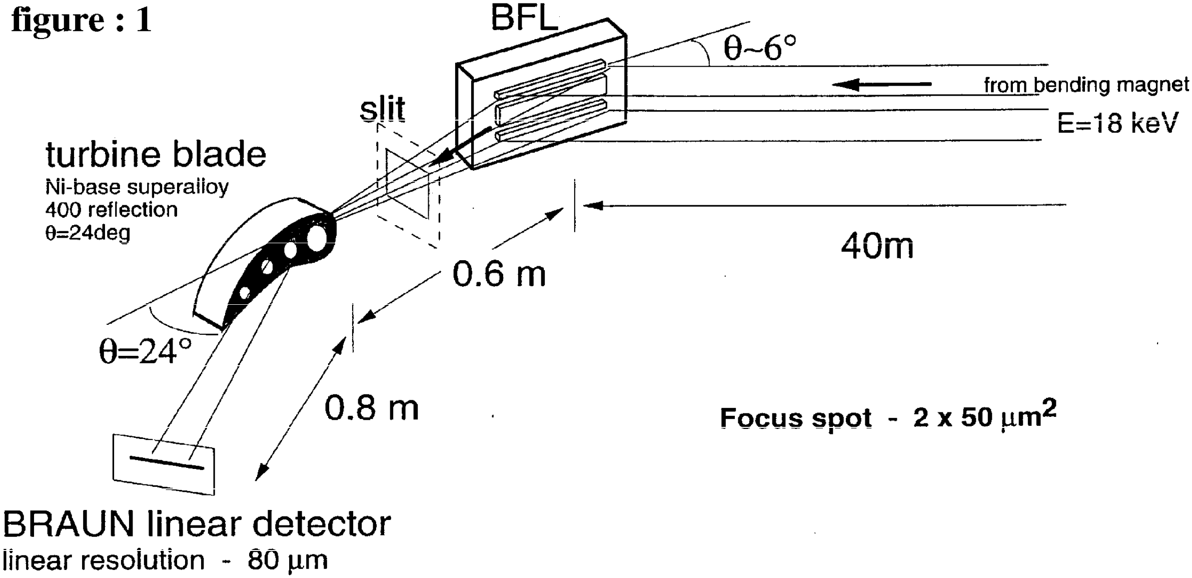

figure : 2