ESRF	**Experiment title:** Three Dimensional Microstructural Measurement of Strain Distributions in Metallic Wires	**Experiment number**: ME-869
Beamline: ID11	**Date of experiment**: from: 17/02/2005 08:00 to: 22/02/2005 08:00	**Date of report**: 04/11/2005
Shifts: 12	**Local contact(s)**: Gavin Vaughan	*Received at ESRF:*

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Report:

The aim of the experiment was to obtain three-dimensional measurements of lattice rotations and elastic strain distributions in annealed stainless steel wire during tensile deformation. The results were intended to validate and refine finite element crystal plasticity models of deformation.Finite element models are frequently used to predict the magnitude of the stresses and strains generated during deformation of metals. However, when the dimensions of the component are similar to the scale of the material microstructure (e.g. grain size), traditional continuum material models are not applicable because of a "size effect".Lack of mechanical constraint, combined with the anisotropic deformation of individual grains of different crystallographic orientations, has a significant effect on the mechanical properties when compared with bulk material. The material can no longer be considered to be truly isotropic. To address this, 3-D micro-mechanical material models based on crystal plasticity theory have been developed. Recently, colleagues of the proposer successfully observed and modelled the size effect in stainless steel stent wires [1]. To continue development and validation of the material models, it is necessary to obtain physical measurements in 3-D of lattice rotations and within individual grains.

EXPERIMENTAL METHODS

The experiment used the 3-D X-ray diffraction (3DXRD) microscope on beamline ID11 at the ESRF [2]. The specimen studied was a 0.71mm diameter wire of 316LVM stainless steel (ASTM F-138), annealed for 10 days at 1177^{o}C to deliberately grow the grains. To check the grain structure, the wire was electropolished, etched (oxalic acid (10g/100ml), electrolytic 6V, 160s) and examined in a scanning electron microscope (SEM). To assist in subsequent specimen set-up and data analysis, the region of interest to be examined by 3DXRD was marked and photographed in the SEM.

The beamline was set up to perform a "box scan" experiment on the wire. The X-ray optics were configured to give a 50 µm x 50 µm beam of 80 keV X-rays. The sample was mounted on a stage giving x, y, z and ω positioning. The box scan was performed by defining a grid of scan points in the y-z plane. Scan parameters were:

Experiment Name	Strain (%)	y_{min} (mm)	y_{max} (mm)	y_{step} (mm)	z_{min} (mm)	z_{max} (mm)	z_{step} (mm)	ω_{min}	ω_{max}	ω_{step}
NCBES_Wire_01_step0_	0	-0.45	0.45	0.05	-0.35	0.35	0.05	-55°	35 °	1 °
NCBES_Wire_01c_step0_	0	-0.39	0.39	0.06	-0.45	0.45	0.06	-45 °	45 °	1 °
NCBES_Wire_01c_step1_	5	-0.39	0.39	0.06	-0.45	0.45	0.06	-45 °	45 °	1 °
NCBES_Wire_01c_step2_	10	-0.39	0.39	0.06	-0.48	0.54	0.06	-45 °	45 °	1 °

The first experiment was attempted using an Instron 25kN axial testing rig, mounted horizontally on the sample positioning stage (Figure 1). Following acquisition of the first set of data at 0% strain, it was found that the ω stepper motor was malfunctioning and it then failed completely. It was thought that the heavy weight of the Instron rig and bending moments induced by its horizontal position had damaged the motor gearbox. For the experiment to continue, a spare rotation motor and y motor were fitted. An alternative, lightweight straining rig was improvised, using a manual leadscrew frame. Simple clamps were manufactured to hold the wire sample in a vertical position (Figure 2). A trial run was conducted to see if the rig could apply tensile strain to a wire without slipping. In the time available to make modifications, it was not possible to fit a load cell to the rig but it did enable a known global strain to be applied to the wire sample.

RESULTS & DISCUSSION

Data reduction and analysis were performed using the ImageD11 software being developed by Dr. Jonathan Wright at the ESRF. Grain orientations for 25 grains in the underformed sample have been determined. Analysis of data from the deformed sample to determine lattice rotations will proceed subject to the availability of personnel. The lack of force data from the experiment, due to the fact that the Instron rig could not be used, may restrict the use of the results in establishing parameters for crystal plasticity models. However, loading information may be inferred from tensile tests performed on similar wires. It is hoped that the information on lattice rotations and lattice break-up will be of sufficient interest.

FIGURES

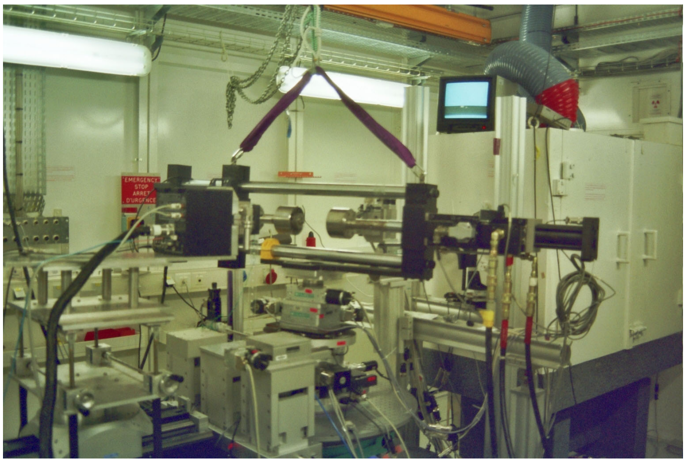

Fig. 1: Instron axial testing rig mounted on the sample positioning stage.

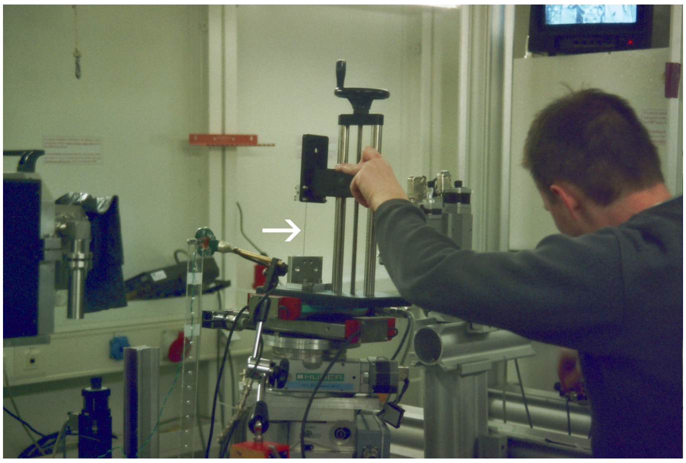

Fig. 2: Manual vertical axial testing rig improvised following failure of the ω motor. The wire sample can be seen (arrowed).

REFERENCES

[1] B. P. Murphy, P. Savage, P. E. McHugh, D. F. Quinn (2003). "The stress-strain behaviour of coronary stent struts is size dependent" *Ann. Biomed. Engng.* 31: 686-691

[2] S. F. Nielsen, E. M. Lauridsen, D. Juul Jensen & H. F. Poulsen (2001). "A three-dimensional X-ray diffraction microscope for deformation studies of polycrystals" *Mater. Sci. Engng.* A319-321:179-181