ESRF	**Experiment title:** DEVELOPMENT OF BM16 and ID11 for STRAIN SCANNING – SECOND PHASE	**Experiment number**: ME-103
Beamline: BM16, ID11	**Date of experiment**: from: November 2000 to: September 2001	**Date of report**: 8/2/2002
Shifts: 30, 30	**Local contact(s)**: Drs A N Fitch, G B M Vaughan, A Terry, J Wright	*Received at ESRF:*

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Report:

The proposal was a combined application from a consortium of three university groups to enable them to continue and to extend, in collaboration with beam-line staff, the development of instruments BM16 and ID11 as strain scanners. The proposers had begun strain scanning at the ESRF in 1996 and were allocated a number of standard beam-time awards up to 1998. During this time they were able to identify the potential of the technique and to make a number of advances. In 1998 their first long-term proposal HS-674 was approved and this enabled significant developments to be started. This second phase allocation ME-103, that began in 2000 has enabled these developments to be substantially advanced.

Technical developments

A new front-end linking for our analysis programmes has been produced so that efficient near real-time analysis of data can now be performed. This, together with the robust and accurate translator system on BM16, now makes it a practical strain scanner for both novice and expert alike. Additionally the provision of positioning and surface location facilities, using CCT cameras attached to fixed theodolites, has speeded up and improved the setting-up procedures. Dead-times have been reduced by a combination of software and hardware developments. These improvements will be particularly beneficial when BM16 is moved to ID31 where count rates will be substantially higher, counting times correspondingly lower, and dead-times will be proportionately more significant. A prototype scanning translator facility has been developed for ID11 so that the benefits of the exceedingly fast rates of data acquisition can be realised. This is of particular benefit when using high spatial resolution or when multiple point mapping of large samples is required.

List of experiments performed

The following studies have been performed, both as part of the development programme and because of their materials engineering significance:

BM16:

1. Ti-6Al-4V – Line profiles across bent bars used in conjunction with polycrystalline modelling
2. Ti-6Al-4V – Line profiles across 2 welds – important aspects of mechanical load transfer and phase interaction identified and highlighted
3. Aluminium alloy cracked sample – strain maps collected through the sample at different depths
4. Residual stress measurements on low-distortion aluminium alloy welds
5. Full strain map around a 4% cold-expanded hole
6. In-situ compression loading of a high volume fraction MMC

ID11:

1. Aluminium alloy casting – Through-thickness profile
2. AlSiC – Line profiles across bent bars
3. Studies of the (100) superlattice reflection in inertia welded superalloys
4. Residual strain measurements of a MMC blade/ring sample
5. In-situ strain mapping of a fatigued Ti-6Al-4V/SCS-6 sample

*6. High-resolution area mapping of a worn railway rail

BM16 was used mostly for measurements on the less dense engineering materials, aluminium alloys, MMCs and some titanium alloys. It was used for both high-resolution studies in the region of cracks and for area mapping of thin plate samples. ID11, with its higher energy and very high count rates and beam intensity was used for thicker samples and denser materials such as nickel-based superalloys, for MMC blade/ring samples and for steel railway rail sections. The figure gives one illustration of the capability that ID11 now has to map, in detail, the residual stress field in sections of steel rail.

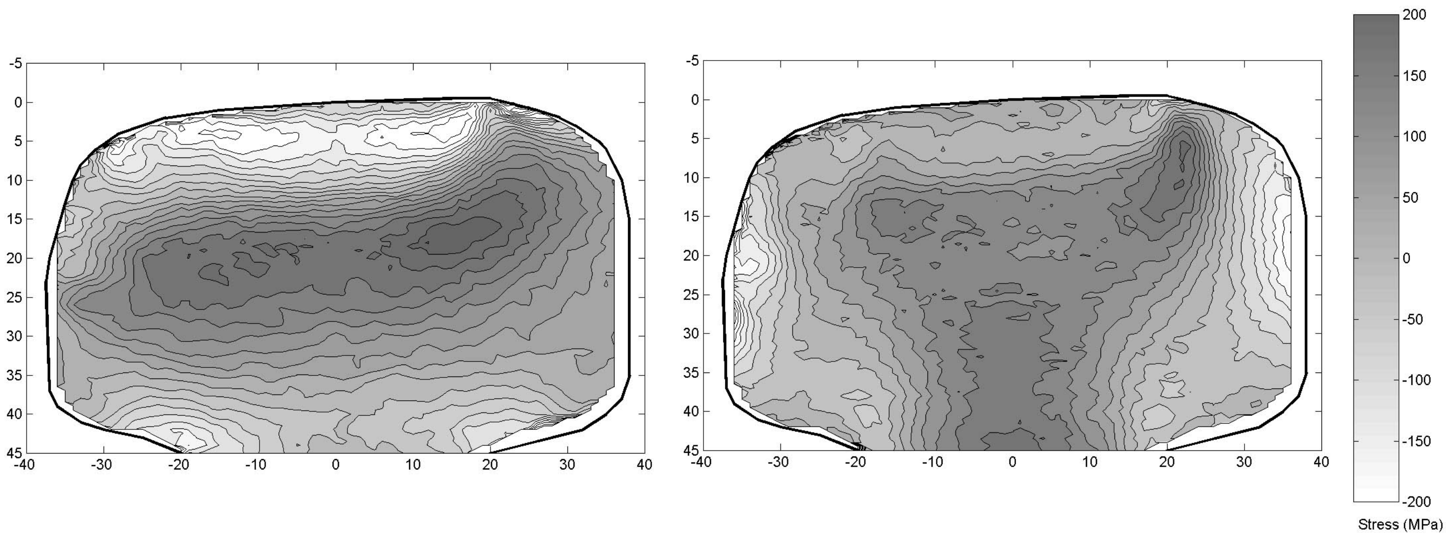

**Figure 1. High resolution transverse (left) and vertical (right) residual stress maps of the head of a 4 mm thick heavily worn US rail section [Scan matrix 1-2 mm, gauge 0.5 mm square, 6000 data points at ~10 seconds per point]*

The sharp features in the pattern, near (x, z), (20, 0), (-30, 5), (-35, 25) are regions at which the wheel running surface or its flange make/lose contact with the rail. They are areas at which internal tensile regions extend towards the surface and are the locations at which fatigue cracks would be expected to form and to propagate. It is intended to continue mapping with higher spatial resolution and higher point density in these critical regions.

ME-103 related publications

The publications listed are those already published, submitted, or in press. A further three papers have been accepted for ECRS6, Coimbra, July 2002. Five theses have resulted from the work.

1. *R A Owen, P J Withers and P J Webster:* 'Synchrotron stress measurements of laser formed aluminium alloy sheet'. Proceedings ICRS6, Oxford 2000, IoM Communications Ltd, 82-89 (2000).
2. *P J Webster, G Mills, P A Browne, D J Hughes and T M Holden:* 'Residual stress around a cold-expanded hole'. Proceedings ICRS6, Oxford 2000, IoM Communications Ltd, 125-132 (2000).
3. *P J Webster, W P Kang, D J Hughes and P J Withers:* 'High resolution synchrotron area strain mapping of a double-V weld'. Proceedings ICRS6, Oxford 2000, IoM Communications Ltd, 743-750 (2000).
4. *P J Webster, D J Hughes, W P Kang, P A Browne, L Djapic Oosterkamp, P J Withers and G M Vaughan:* 'Synchrotron X-ray residual strain scanning of a friction stir weld'. J Strain Analysis **36** 61-70 (2001).
5. *P J Withers and P J Webster:* 'Neutron and synchrotron X-ray strain scanning'. Strain **37** 19-33 (2001).
6. *P J Webster, D J Hughes, P J Withers and A N Fitch:* 'Synchrotron strain scanning on BM16 at ESRF'. MECA-SENS 2000 – Proceedings of Conference on Stress Evaluation with Neutrons and Synchrotron Radiation, Reims, France, December 2000. J Neutron Research **9** 93-98 (2001).
7. *M V R S Jensen, D Dye, K E James, A M Korsunsky, S M Roberts and R C Reed:* 'Residual stresses in a welded superalloy disc: characterization using synchrotron diffraction and numerical process modelling'. Met. and Mats. Trans. A-Physical Metallurgy and Materials Science. In press (2002).
8. *A M Korsunsky, M R Daymond, and K E Wells:* 'The correlation between plastic strain and anisotropy strain in aluminium alloy polycrystals'. Materials Science and Engineering A – Structural Materials, Properties, Microstructure and Processing. In press (2002).
9. *M Preuss, G J Baxter and P J Withers:* 'Inertia welding nickel-based superalloy. Part I: Metallurgical development'. Submitted to Metal. Trans A (2001).
10. *M Preuss, J W L Pang, G J Baxter and P J Withers:* 'Inertia welding nickel-based superalloy. Part II: Residual Stress Development'. Submitted to Metal. Trans A (2001).
11. *R A Owen, R V Preston, P J Withers, H R Shercliff and P J Webster:* 'Neutron and synchrotron measurements of residual strain in TIG welded aluminium alloy 2024'. Submitted to Mat. Sci. Eng. (2002).
12. *P A Browne:* 'Determination of residual stress in engineering components using diffraction techniques'. PhD Thesis, University of Salford (2001).
13. *Z Chen:* 'Determination of residual stresses using synchrotron X-ray techniques'. MSc Thesis, University of Salford (2001).
14. *R V Preston:* 'Modelling of Residual Stresses in Welded Aluminium Alloys', PhD Thesis, Cambridge University, (2001).
15. *K E James:* 'The effect of residual stresses on the deformation of polycrystals', PhD Thesis, University of Newcastle upon Tyne (2001).
16. *R A Owen:* 'Synchrotron Strain Mapping: Aerospace Applications', PhD Thesis, University of Manchester (2002).