	Experiment title: Residual Stress Field Under Fatigue Loading in MIG Welded Marine Grade Aluminium Alloy	**Experiment number**: ME 282
Beamline: BM 16	**Date of experiment**: from: 31/10/01 to: 4/11/01 and from: 7/12/01 to: 11/12/01	**Date of report**: 2/8/02
Shifts: 24	**Local contact(s)**: Dr Andy Fitch	*Received at ESRF:*

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Report:

This work required the facilities at the ESRF because of the high flux, and the established synchrotron X-ray strain scanning facilities of BM16. These allow multipoint mapping data to be generated in an acceptable time which, in turn, allows meaningful engineering questions to be addresses regarding the residual stress distribution in welded plates, and its modification under fatigue loading to be studied. This is important to predicting fatigue life as it is greatly affected by the residual stresses. Until now, lack of information regarding their magnitude and changes that occur during loading, means that their effects could only be incorporated empirically through assumed changes to mean stress in the fatigue cycle. This is not optimum for use of material resources, or in developing lightweight, fuel-efficient vehicles. Ideally, one requires sufficient data and understanding of residual stresses, their variation and modification, to allow predictive methodologies to be developed and incorporated in life prediction codes, that allow for inclusion of process and load variations.

This experiment was related to the work performed in ME197, which considered solid-state friction stir welding (FSW) which should lead to low levels of tensile residual stress. ME 282 used MIG welded plates, in which residual stress levels were expected to be a higher fraction of the yield stress. There are also significant grain size variations which affect stresses and their reliability of measurement (FSW is very fine grained ~ 10 μm, whilst MIG leads to larger grains > 100 μm in size). Together the two experiments studied two very different, but widely used, industrial methods of joining plates in the transport industry. Significant insights into effects of fatigue loading on residual stresses have enabled some general conclusions to be formed and specific, focussed experiments proposed to answer the questions raised. ME 197 revealed some surprising results in the 5383-H321 aluminium alloy plate used. Firstly fatigue loading can lead to a four-fold increase in residual stresses to a tensile level of around 50% of yield - this is the first observation of this effect known to the investigators, and is contrary to received wisdom on the influence of fatigue cycling on residual stresses. Secondly, plate-to-plate variation in compressive residual stresses is much larger than anticipated. Data for the MIG welds is complementary to these results and of equal interest to fatigue analysis. The results provide the first reasonably comprehensive insight into fatigue effects on residual stresses at welds.

The experimental samples for ME 282 was chosen to correspond with industrially relevant lives of 10^5 to 10^6 cycles of stress, and to elucidate trends in residual stresses as a function of load type. Strain scanning measurements were made both in the as-welded state and after the application of fatigue loads. Applied loads included 1 cycle at R = 0 (zero-tension loading) with a peak stress of 150 MPa (equivalent to a fatigue life of 4 x 10^5 cycles), 1 cycle at R = -1 with a peak stress of 150 MPa (fully reversed loading) and 100 cycles at R = 0.1 with peak stresses of 100 MPa, 150 MPa and 200 MPa. Strains and stresses were mapped through the complete plate cross-section in the as-welded state for selected specimens of both low and high heat input welds, and at surface and mid-plane positions for all specimens.

Figure 1 shows residual stress maps in the as-welded state for the low heat input (LI) and high heat input (HI) MIG welds respectively, where the X-direction is parallel with the weld and the Y-direction in-plane transverse to it. As expected, tensile residual stresses are now at yield strength level with peak values occurring about 10 mm from the weld centreline.

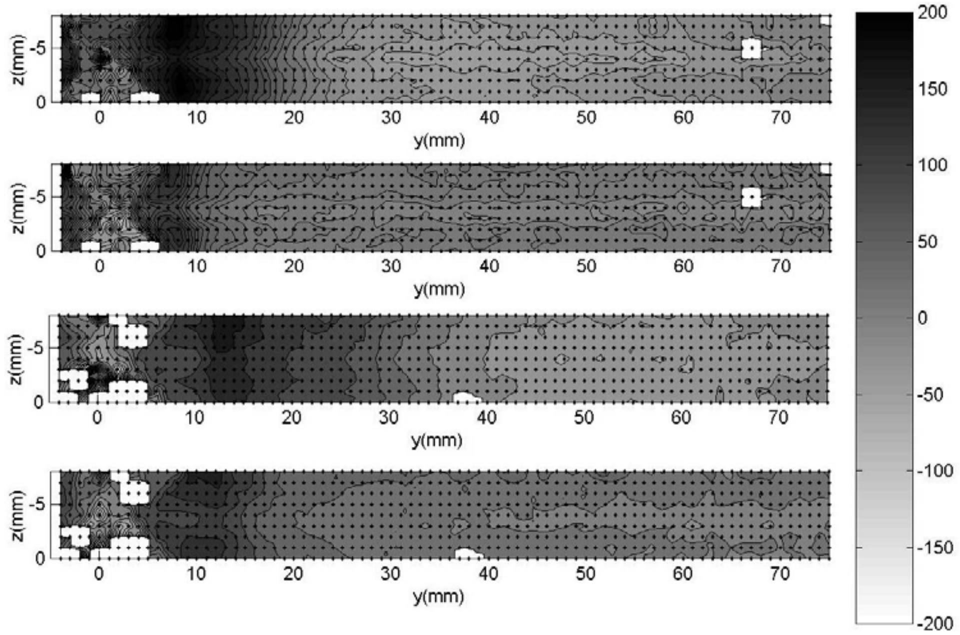

Figure 1 The variation of residual stress in the X and Y directions for LI and HI welds. Residual stresses are shown in units of MPa from top to bottom as:
TOP AA5383 LI X direction
AA5383 LI Y direction
AA5383 HI X direction
AA5383 HI Y direction

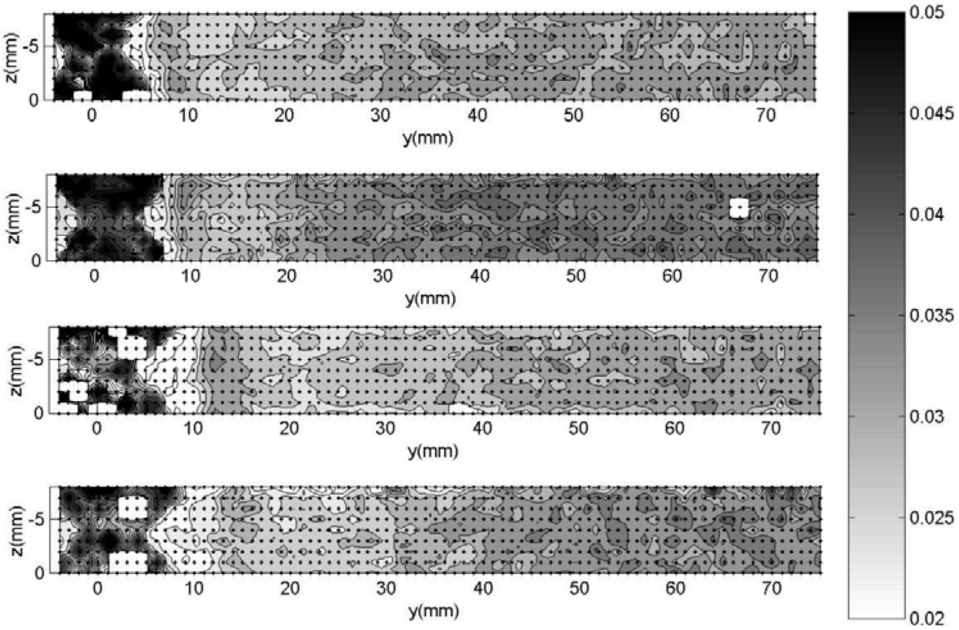

Figure 2 The variation of peak width (FWHM) in the X and Y directions for LI and HI welds. Peak widths are shown in units of degrees two theta from top to bottom as:

TOP AA5383 LI X direction
AA5383 LI Y direction
AA5383 HI X direction
AA5383 HI Y direction

This position approximately corresponds to the boundary between the HAZ and the parent plate for both LI and HI welds. Figure 2 shows peak width variation, which is an indicator of dislocation density within a grain, with narrower peaks indicating lower densities. It provides information on the microstrain level and its variation within grains, and can therefore also indicate microstructural changes such as annealing and tempering. However, the weld filler metal was 5183 alloy, and the grains in the weld metal will have different texture, larger sizes and lower dislocation densities than the HAZ region or the extruded plate. The peak width mapping shows the weld metal very clearly, as well as indicating the extent of the HAZ. This allows one to link residual stress effects to the various weld regions.

Figure 3 shows typical results peak position (2θ) data for the strains transverse to the weld at z = 1 mm, before and after the application of fatigue loading to the specimens. There are clear shifts in residual stress peak positions and magnitudes with the type of load cycle and with amplitude and number of load repetitions.

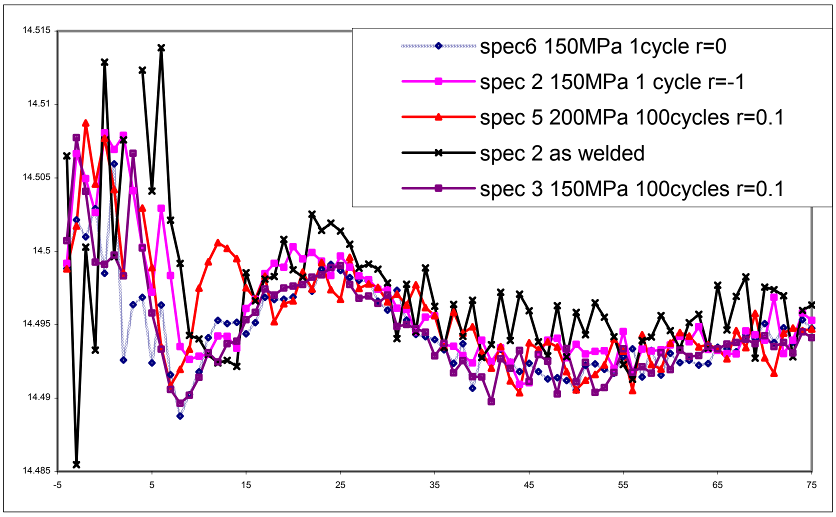

Figure 3 Peak position data for the strains transverse to the weld. The data show clear trends which will assist in understanding the effect of fatigue cycling on weld stress fields.