ESRF	**Experiment title: Residual stresses in AA5083 – AA6082 dissimilar friction stir welds**	**Experiment number**: ME624
Beamline: ID31	**Date of experiment**: from: 23/4/03 to: 25/4/03	**Date of report**:
Shifts: 9	**Local contact(s)**: Michela Brunelli	*Received at ESRF:*

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Report:

Introduction

Friction stir welding (FSW) is a relatively new joining technique developed by TWI, Cambridge, in 1991. Joining is achieved by the translation of a rotating cylindrical tool along the interface between two heavily clamped plates. Friction between the tool and the work-piece rapidly heats the alloy to a plasticised state allowing it to be deformed and mixed by the tool. The process is solid-state and the low temperature compared to fusion welding methods suggests that the subsequent residual stresses may be significantly lower. The method has the additional advantage that the absence of melting makes it possible to join dissimilar materials while avoiding many of the associated problems. The aim of this experiment was to evaluate the residual stress development in a series of AA5083 – AA6082 dissimilar friction stir welds produced with a variety of tool rotation and traverse rates.

Experimental

The welds were manufactured (as part of the European project *Join-DMC*) at the German Aerospace Centre (DLR), Germany, by butt-welding plates 150 mm long and 60 mm wide. The total weld length was around 105 mm from pin entry to pin exit. The short length of these welds means they may not fully represent the conditions within welds of more typical engineering dimensions. However, the small size does allow diffraction experiments to be performed on the entire plate, which would normally have to be cut up in order to fit into the limited space available on ID31. Four welds were produced using a rotation speed of 280 or 840 rpm and a traverse rate of 100 or 300 mm/min. This combination of speeds allows the effects of the two parameters to be analysed separately. In addition these speeds provide two combinations with the same weld speed ratio (2.8 rev/mm) but different speeds.

The beam line was operated at 60 keV, corresponding to a wavelength of approximately 0.21Å. The incident and receiving slits were opened to $1\times1\ mm^2$. The Al-311 reflection, often used in this context due to its relative insensitivity to intergranular strain development, was chosen as a reflection representative of the crystalline ensemble (bulk). The effectively two-dimensional geometry of the thin sample (and thus stress state) permitted the application of the $\sin^2\psi$ technique for the determination of residual stresses and the unstrained lattice parameter d_0.

Results

Fig 1 illustrates the variation of longitudinal residual stress as a function of the lateral distance from the weld line for the four speed combinations used. It can be seen that the stress profiles are characterised by a tensile region around the weld line that is balanced by compressive stresses in the base material. The peak tensile residual stresses are around 150 MPa, which is close to the local yield strength of the weld. There is a clear variation in the stress profile when the rotation speed is altered. At high rotation speeds the peak stresses are associated with the edge of the tool shoulder and drop rapidly as one approaches the weld line forming a plateau of constant stress. The stress within the plateau is noticeably higher in the AA5083 material. At 280 rpm the peak stress within the AA5083 forms around the weld line although the AA6082 material shows similar behaviour to the 'high rpm' weld.

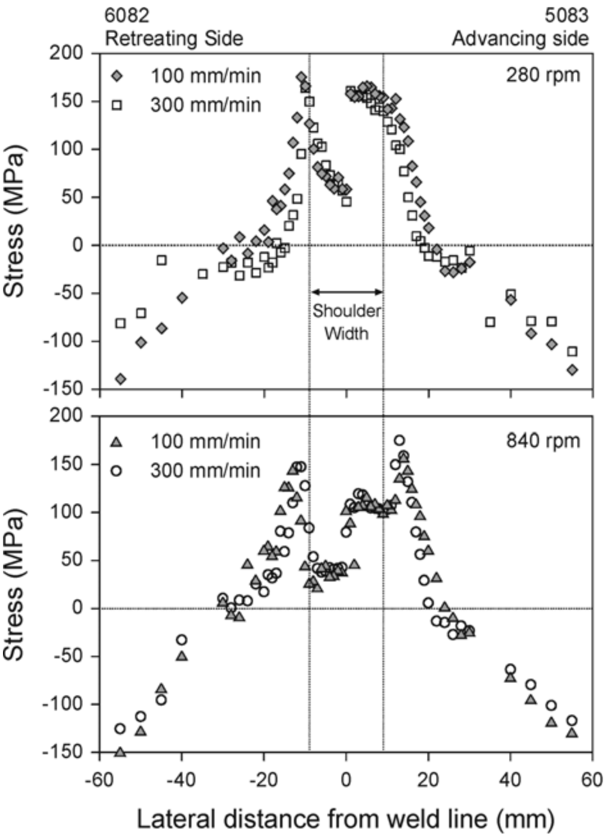

Figure 1. Variation in longitudinal residual stress as a function of distance from the weld

It can be seen that there is a discontinuity in the stress across the weld line. This is an artefact of the experimental procedure used to analyse the data. Within the stir zone and flow arm region (up to ± 9mm depending on the weld) both alloys will contribute to the diffracted beam and, as a result of their different compositions, the diffraction angle will be slightly different for each resulting in a split peak. In fitting the peaks and calculating the strain it was decided to use the peak appropriate to the side of the weld in question. It is apparent that the two phases are under significantly different stresses with the AA6082 taking a noticeably lower load.

The variation of the unstrained lattice parameter d_0 is plotted in fig 2, but only for the AA6082 material since the variation in the AA5083 was significantly smaller. These variations can be attributed to changes in solute content that arise as a result of the impact of the thermal cycle on the precipitate distribution. Also shown is the apparent strain shift that would occur if a single, constant d_0 value were used (in this case an arbitrary value taken from the base material region). It is clear that even small variations in d_0 are sufficient to cause significant changes in the calculated strain and hence in the inferred stresses. The greatest variation is seen in the region relating to that of maximum stress (10-13mm from the weld line). In this area the strain shift is up to 550 $\mu\varepsilon$, which, given a modulus of 70.3 GPa, equates to a potential stress variation of ~60MPa or 40% of the peak measured longitudinal stress.

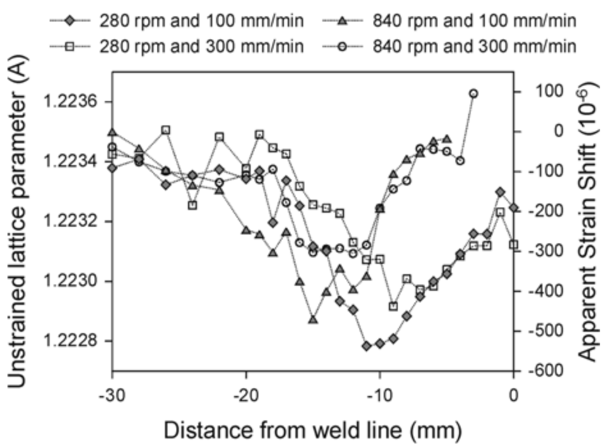

Figure 2. The variation in experimentally determined unstrained lattice parameter within the AA6082 weld material. Also shown is the apparent strain shift if a constant global value is assumed.

Additional results included the production of maps of longitudinal and transverse strain throughout the entire plate. These results will validate and be compared to results from finite element models being developed at Cambridge University. Several publications of the experimental data are currently being prepared.