ESRF	**Experiment title:** Comparison of Residual Stresses in Single- and Double-Pass Friction Stir Welding Ferritic Steels	**Experiment number**: ME-1047
Beamline: ID15A	**Date of experiment**: from: 06 July 2005 to: 10 July 2005	**Date of report**: 28/02/06
Shifts: 12	**Local contact(s)**: Dr T. Buslaps	*Received at ESRF:*

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Report:

Friction stir welding is a relatively new concept in metal joining, where a rotating tool is forced into solid material and then traversed through it. The frictional heat developed by the tool periphery interacting with the material being welded softens the latter into a plasticised state, while the rotating tool then transports this material around the tool. While the tool is traversing along a joint line, the annulus of material adjacent to the tool it is capturing material from both sides of the joint line and intimately mixing them together, resulting in the formation of a sound weld. One of the main attractions is the low distortion seen in aluminium welding, which, if repeated in steel, could translate into a reduced requirement for post-weld straightening of plates before the next weld seam can be processed, in the shipbuilding industry for example.

Nearly all the previous work on friction stir welding has focused on Al alloys, although a little work has recently been carried out on stainless steels [1]. The knowledge and quantification of residual stresses around welds is particularly important in ferritic steels, and to a lesser extent in austenitic stainless steels. High residual stresses can lead to stress-enhanced corrosion problems that are not present in low-stressed joints, and it is important to avoid very high stresses that could complicate the use of welded steels in service. The comparison of single-sided and double-sided welds is important in determining if there are any advantages in using higher processing speeds for each half-penetration weld with the second weld modifying the stress distribution of the first welding pass in a beneficial way.

Experimental results:

Both the single and double pass welds were investigated giving excellent strain resolution in both cases. As expected the residual strains (stresses) were largest and most tensile beneath the FSW tool in the longitudinal direction. The residual strains were similar in the two cases. 2D maps of the strains for the three perpendicular directions measured using the {111} planes are shown in Figure 1 for the 12.5mm thick double pass friction stir weld.

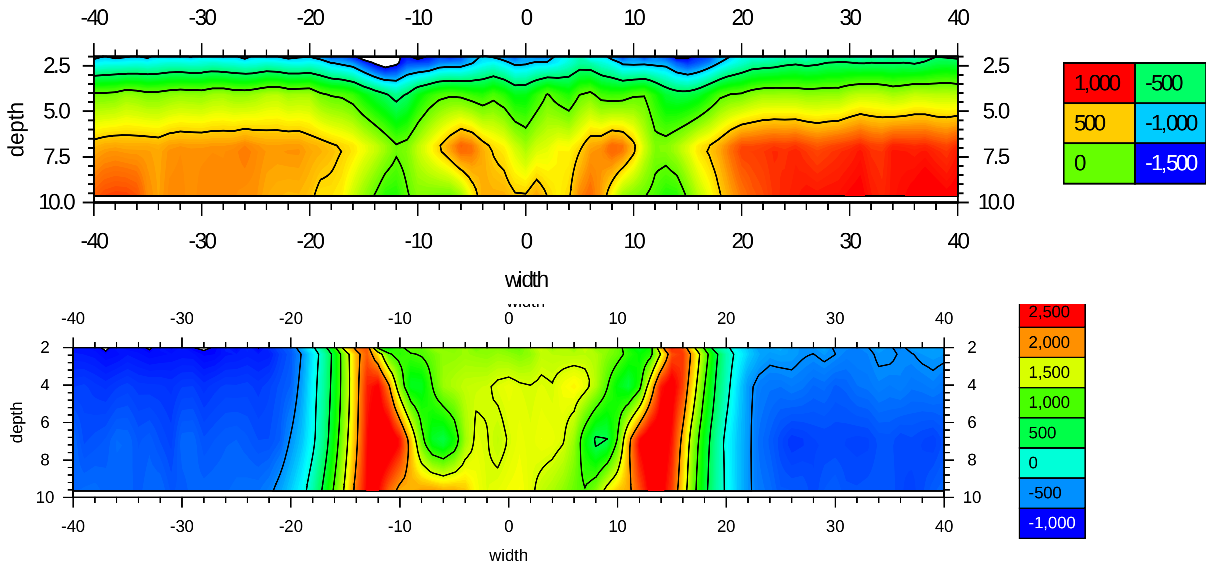

Figure 1: Transverse (above) and longitudinal (lower) residual strains over the central region of the double pass friction stir weld.

As for Al friction stir welds the maximum tensile strains are not acheived in the nugget zone but at a distance of 12-14mm from the weld centreline. this corresponds to the edge of the shoulder of the FSW tool. This is because it is the steep thermal gradients which dominate the final residual stress state rather than the mechanical deformation of the joint. In the far-field region the transverse stresses vary from top (compressive) to bottom (tensile) of the plate; this is not easily explained by the FSW process and is more likely to have been introduced into the plate prior to the joining operation. It is clear that the parent is left in balancing compressive longitudinal strain.

In our work to date the double pass welds have shown that the longitidnal stresses are relatively constant through the depth. The biggest difference is at the weld-line where the tensile strains on the top surface are approximately $750x10^{-6}$ whereas they are around $1500x10^{-6}$ on the bottom surface where the second pass has been made.

Further work

The results are currently being compared against hardness mapping and microstructural observations. In addition some evidence was found in the diffraction profiles for the martensite phase in the weld zone. This peak is currently being assessed and the level of martensite compared directly with our microstructural observations. Once this work has been completed the entire work will be published as a journal paper.