Friction **S**tir **W**elding

Strength of FSW-joints. Comparison with MIG and TIG welds. Reference: KTH – Royal Institute of Technology.

FSW joints have higher fatigue strength than MIG and TIG welds. This is the conclusion arrived at by Mats Ericsson, graduate engineer, and Rolf Sandström, professor, both at KTH – Royal Institute of Technology, Institution for Materials Science, in a research report entitled Influence of Welding Speed on the Fatigue of Friction Stir Welds, and Comparison with MIG and TIG, December 2001.

Test material and test methods

This extract from the report gives values for extruded profiles of **SS-EN AW 6082 alloy** (AlSi1MgMn) in **condition T6** and with a material thickness of **4 mm.**

The dimensions of the test pieces were in accordance with SS-EN 284-4.

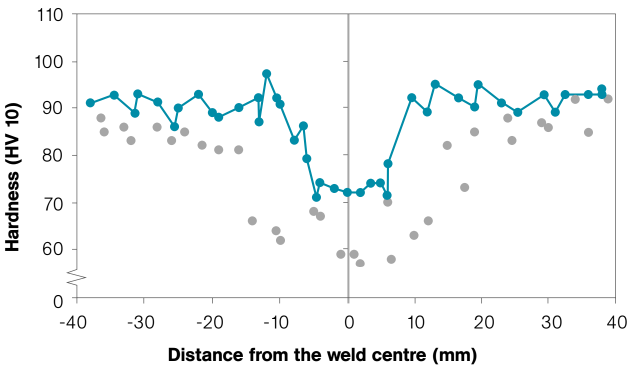
FSW was carried out by Sapa in a plant used for serial production. Test materials welded at two different speeds were included in the experiment.

Fusion welding was carried out by CSM Materials Technology to the same high quality standards as those applicable in the aeronautical industry. TIG and pulsed MIG welding were used.

The Vickers hardness was measured with a load of 10 kg.

Fatigue testing was carried out with a stress ratio $\sigma_{min}/\sigma_{max}$ of 0.5, and the main direction of stress was across the weld.

Hardness profile



The graph above shows the variation in the Vickers hardness at a cross-section of an FSW joint (●) welded at a speed of 1400 mm/min, and an MIG weld (●).

Comments: In both welds, the hardness in the heat affected zone (HAZ) decreases, although clearly more in the MIG weld. The hardness is lowest (just below 60 HV) around the centre of the MIG weld. The reason is that fusion welding involves higher working temperatures, the addition of a 'foreign' filler metal, and a less favourable structure in the weld.

In TIG welding, more heat is supplied than in MIG welding, and the HAZ is therefore somewhat wider.

No significant difference was observed in the HAZ for the two different welding speed using FSW.

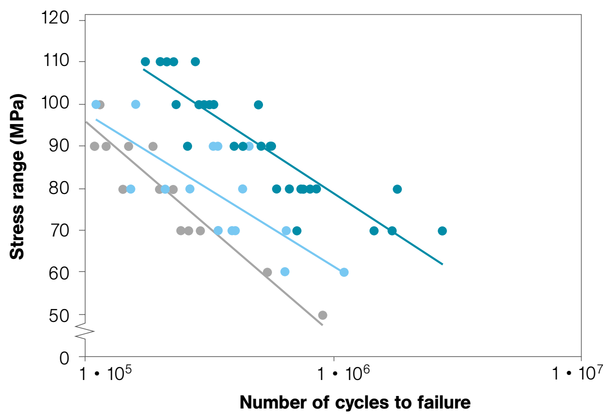
Mechanical properties

SS-EN AW 6082	Yield strength $R_{p0,2}$ (MPa)	Tensile strength R_m (MPa)	Elongation $A_{50\,mm}$ (%)	Reference
T6, parent material	291	317	11.3	ME, RS [1]
Min. values for profile t < 5 mm	250	295	6	SS-EN 755-2
Pulsed MIG	147	221	5.2	ME, RS [1]
TIG	145	219	5.4	ME, RS [1]
FSW, speed A [2]	150	245	5.7	ME, RS [1]
FSW, speed B [2]	150	245	5.1	ME, RS [1]

1) Mats Ericsson and Rolf Sandström, mean values of the results from their research report

2) Speed A: 700 mm/min. Speed B: 1400 mm/min.

Fatigue strength



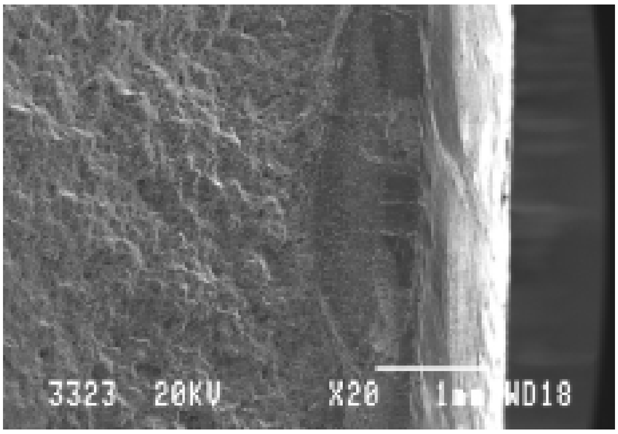
The above figure shows the results of the fatigue tests on MIG welds (●), TIG welds (●) and FSW joints (●).

Comments: The FSW joint yields the best values throughout. In the study, TIG welds gave much better results than MIG welds.

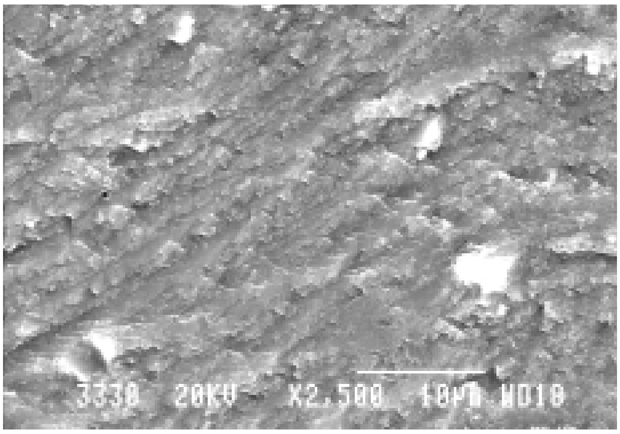
For failure at 500 000 cycles, the stress ranges were:

- Approx. 60 MPa for MIG
- Approx. 70 MPa for TIG
- Approx. 90 MPa for FSW at 700 and 1400 mm/min (slightly higher at 1400 mm/min).

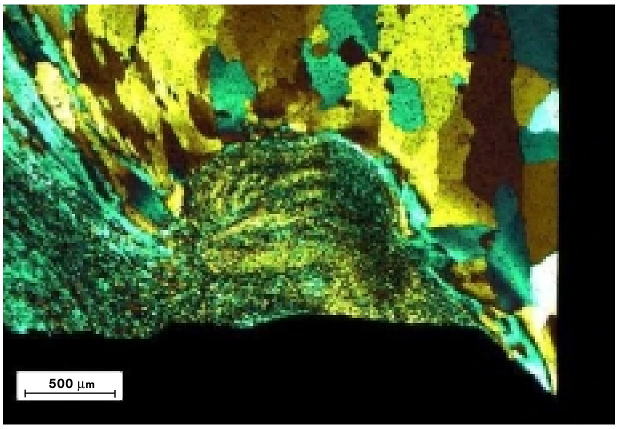
Fractures under the microscope



MIG weld: The SEM micrograph shows the fracture surface. Fracture was initiated in several places in the root (to the right). Magnification: 20X



Same MIG weld as above: Fatigue striations in the area close to the root edge. Magnification: 2500X



FSW: Fracture surface through the fine-grained part of an FSW joint (root to the right). Fracture was probably initiated close to the root.

"FSW offers several benefits"

We quote from the report: "FSW offers several benefits compared to the common fusion welding methods. The relatively low process temperature is below the melting point of the aluminium alloys, which makes it possible to weld alloys that are difficult or impossible to weld by fusion welding.

Since the metal does not melt, no casting structure is formed as in conventional fusion welding, and neither does shrinkage occur in the weld zone due to solidification.

Porosity in the weld zone is a common occurrence in fusion welding, whereas pores of this type cannot occur in FSW joints.

An FSW joint is made by heating to a proper temperature by frictional heat, accompanied by heavy plastic deformation of the material in the weld zone. Oxides and minor impurities are effectively broken up by the rotating tool, and no special pre-treatment is normally necessary prior to welding.

The amount of heat supplied is much lower than in fusion welding, which reduces the thermal deformation. This also reduces the thermal stresses in the material."

Literature

A. Kluken, M. Ranes, *Aluminium bridge constructions – welding technology and fatigue properties.* 'Svetsaren', Vol. 50, No. 3, pp 13-15 1995.

P.J. Haagensen, O.T. Midling, M. Ranes, *Fatigue performance of friction stir butt welds in a 6000 series aluminium alloy.* Computational Mechanics Publications (USA), pp 225-237, 1995.

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