Experimental report

24/01/2024

Proposal: **1-02-373** **Council:** 4/2023

Title: Strain behaviour of friction stir welding of dissimilar materials

Research area: Engineering

This proposal is a new proposal

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Experimental team: Halid YILDIRIM

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Samples: Friction stir weld of Al alloy

Instrument	Requested days	Allocated days	From	To
SALSA	8	8	12/09/2023	20/09/2023

Abstract:

Friction stir welding (FSW) is generally used to join aluminium alloys. The present literature available for FSW is mainly based on the experiments at constant amplitude loading (CAL), and there are questions on the verification of the benefits of FSW at variable amplitude loading (VAL), the latter being more realistic of service loadings. In VAL, tensile overloads may interact with other mechanisms such as yielding or fracture while compressive overloads may have significant influence on local buckling, relaxing the stress field or producing secondary bending, and thus shorten the fatigue life. Questions such as: why, how and under what conditions this effect occurs or what damage mechanisms play a dominant role, remain unanswered. The objective of this project aims to solve the damage mechanisms of dissimilar aluminium joints manufactured with FSW by considering fatigue tests at service loading, investigating the microstructures and developing analytical approaches. The scientific approach includes investigations on the development of grain structure size and orientation through the depth of the weld by neutron scattering, and on the relation of stress state at service loading

Strain behaviour of friction stir welding of dissimilar materials – constant amplitude results

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Welds have complex microstructural properties with a large variation in grain size in comparison to the base material, which results in lower fatigue and yield strength than the parent material. It has been shown that friction stir welding (FSW) increases the strength, e.g. by changing the grain shape by elongating it with respect to loading direction, as well as increasing the surface region residual plastic deformation[1,2,3]. For base metal and FSW, highly cold worked microstructure has high hardness, improved surface quality, very good fatigue strength as well as increased resistance to corrosion and wear[3,5]. Therefore, the micromechanical behaviours, particularly the distributions of altered stresses on the grain size before, during and after mechanical fatigue, are crucial to a full understanding of the damage mechanisms. This understanding is vital to characterise the damaging of FSW.

Welding of dissimilar aluminium is one of the challenges and attractive research fields as it involves enormous cost savings in stipulations of minimising the use of high costly materials in aircraft, helicopter blades, and space landing modules. But the implementation is limited in practice due to the weld fatigue cracking. Friction stir welding (FSW) is commonly used to join aluminium alloys but the current literature is limited to testing at constant amplitude loading (CAL)[1]. In reality loads change over the time and therefore there remains questions regarding the use of FSW under such peak loads. Since tensile peak loads may interact with other mechanisms such as yielding or fracture while compressive peak loads may have significant influence on local buckling, relaxing the stress field or producing secondary bending, and thus shorten the fatigue life. In spite of the fact that change of the microstructure and stress state are believed to be the main reason in fatigue cracking, scientific questions such as: why, how and under what conditions this effect occurs or what characterise the damage mechanisms remain unanswered. Based on the above context, the objective has been to characterise the damage mechanisms of dissimilar aluminium joints (AA5056-AA2024) manufactured by FSW. To achieve this, we consider fatigue tests in several conditions, study the microstructures and develop analytical approaches that link to real material response with changing peak load conditions. Our methodology includes investigations on the development of grain structure size & orientation through the weld depth by neutron scattering, and on the relation of grain-orientation-dependent stress state under peak loads in variable amplitude loading (VAL) history. Below figure 1 shows the first fatigue test results under CAL and figure 2 shows the associated stresses change, the latter one was obtained thru ILL. These results[6] will be available soon for the publication.

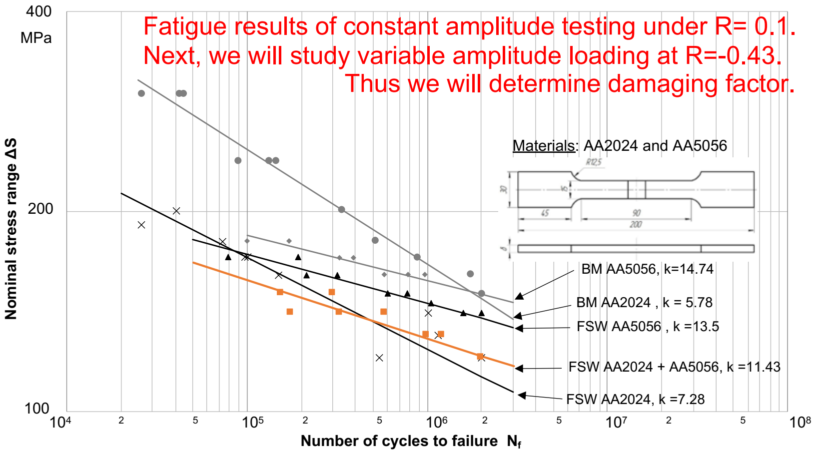

Fig 1. Fatigue testing of the base metal BM, FSW similar and FSW dissimilar joints under CAL R=0.1

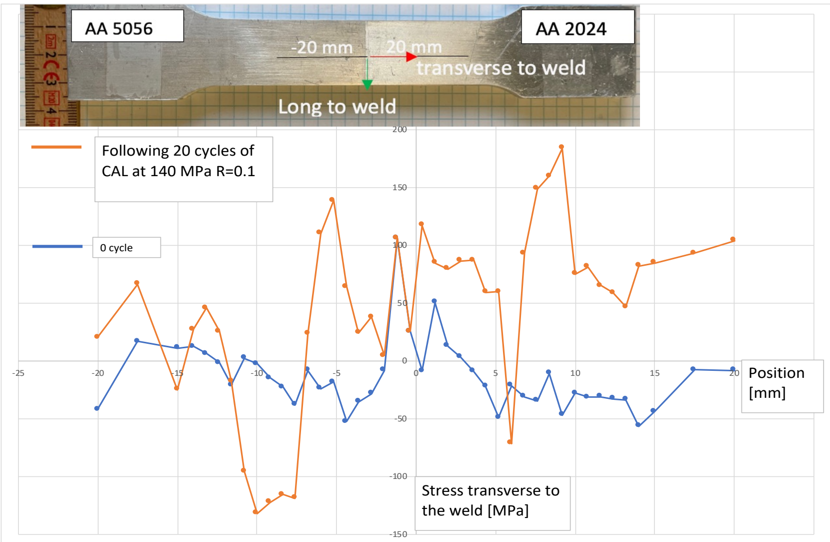

Fig 2. A typical stress behaviour of the dissimilar joint. Measurements were taken at the middle of the sample.

References:

1. Enomoto M., "Friction Stir Welding: research and industrial applications", Welding International, vol. 5, pp. 341-345, 2003.
2. Aval, Microstructure and residual stress distributions in friction stir welding of dissimilar aluminium alloys, 87, 405-13, Mater Des, 2015.
3. Rai R et al. Review: friction stir welding tools, STJW, 16, 325-342, 2013.
4. Steuwer et al. Dissimilar friction stir welds in AA5083–AA6082: the effect of process parameters on residual stress, Mater. Sci. Eng. A, 441 (2006), 187-196
5. Jonckheere et al. Torque, temperature and hardening precipitation evolution in dissimilar friction stir welds between 6061-T6 and 2014-T6 aluminium alloys J. Mater. Process. Technol., 213 (2013), 826-837
6. Yildirim, H. C. (Producer), & PIRLING , T. (Producer). (2023). Strain behaviour of friction stir welding of dissimilar materials.. Dataset, Institut Laue-Langevin. https://doi.org/10.5291/ILL-DATA.1-02-373