Friction stir welding with back-bead to improve fatigue strength

이면비드를 가진 마찰교반용접에 대한 피로강도에 관한 연구

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ABSTRACT The fatigue experiments of friction stir welded Al-6061-T6 alloy with and with out back bead were performed to investigate the variation in fatigue strength and life of the joint. It was found that there were always existed flaws at the roots of friction stir welds for the normal welding parameters and clamping conditions. In order to overcome this root flaws, friction stir welds with optimum back bead has been developed. The test results with root flaws and with back bead were compared. The fatigue life of weld with root flaws was 5-10 times shorter than that of the friction stir weld with back bead.

1. INTRODUCTION

Friction stir welding is a new solid state joining technology developed by TWI in 1991. In FSW a cylindrical shouldered tool with a profiled pin rotating at a high r.p.m is plunged into the faying surface of the joint and moved along the joint line, between two butting plates that are to be joined, at a particular welding speed. Even though the FSW has many advantages there are some defect such as root flaws, kissing bond etc., that are usually been neglected during FSW. More over the relative difficulty of detecting defects in friction stir welds makes it imperative to fully understand the influence and methods to overcome these defects.

Fatigue performance of friction stir welded joint is one of the important properties to estimate the failure behaviors of friction stir welded structures. In the recent years many efforts have been undertaken to optimize friction stir welded processes and to investigate the fatigue properties of friction stir welded joints.

The objective of this investigation is to determine variation in the fatigue strength of the Friction stir welded joint with and without back-bead. In addition SEM of the transverse section of the FSW with back bead and fractured surface of the fatigue specimen has been carried out to study micro-structural and fracture details.

2. EXPERIMENTS

The material used in this experiment is Al6061-T6 aluminum alloy and chemical composition and mechanical properties are shown in Table 1.

Table 1 Chemical composition and mechanical properties of Al 6061-T6

Chemical compositions (wt %)			
Al	Fe	Si	Cr
98	0.7	0.4-0.8	0.04-0.35
Mg	Cu	Mn	Zn
0.8-1.2	0.15-0.4	0.15	0.25

Mechanical properties		
Yield strength	Elongation (%)	Tensile strength
276(MPa)	17	310(MPa)
Density (g/cc)	Thermal conductivity (W-m/K)	Elastic modulus
2.7	153	72(GPa)

All the fatigue specimens are machined from a large butt-welded plate with back bead and without back-bead, which has dimensions of 200mm x 100mm x 4mm.shape and sized if the fatigue test specimens are as shown in Figure 1. The welds of fatigue specimens are transverse to loaded stress axis direction in the S-N specimens.

To encourage failure occurred from the root region, transverse dimension of the specimen near root flaw region has been made smallest as shown in the Fig. 1.

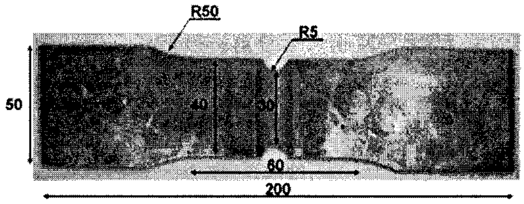

Fig 1. Shape and size of the fatigue test specimens (unit: mm)

For fatigue testing a sinusoidal load-time function was used, with the stress ratio R=0.1. The oscillation frequency was set to 10 Hz. The net section stress was defined as the force divided by the specimen cross sectional area (30mm x 4mm).

The weld transverse sections were mounted in thermoset polymeric mount material. The mounted specimens were ground and polished to a 0.25 탕 finish. Etching procedures were used to expose the underlying micro-structural features including grain boundaries and cracks in the case of FSW with and without back-bead. SEM was used to analyze the grain size variation in the thickness direction of FSW with back-bead. SEM analysis was also used to study the fracture surface after fatigue.

3. RESULTS AND DISCUSSION

FSW made a sound joint without void, crack and distortion in the case of both FSW with back-bead and without back-bead. But there was a formation of root groove at the weld toe in both the cases. Fig. 2 and Fig. 3 show the macrostructure of the weld joints illustrating the details of the root groove at the weld toe in both the cases which is indicated by a dark line on the bottom surface. The macro structure of the weld joint is formally divided into four zones: base material, heat affected zone, thermo-mechanically affected zone, and weld nugget. For majority of the specimen without back bead, the size of the root groove varies from 0.30 to 0.35 mm. They are also defined as root flaws and often referred as kissing bond.

In the case of the FSW with back-bead the variation of grain size in the thickness direction in the weld zone has been studied using SEM.

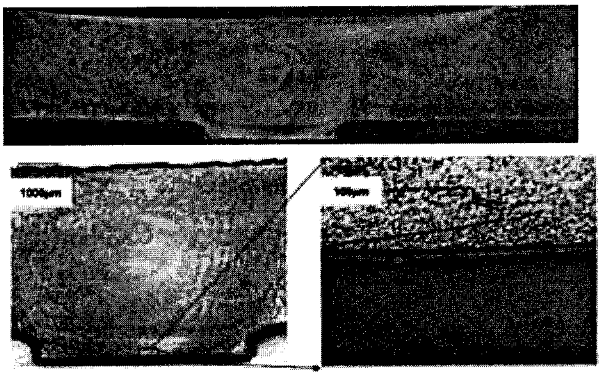

Fig 2. Macrostructure of the Friction stir welded Al6061-T6 with back-bead showing the weld zone and the root flaw after etching.

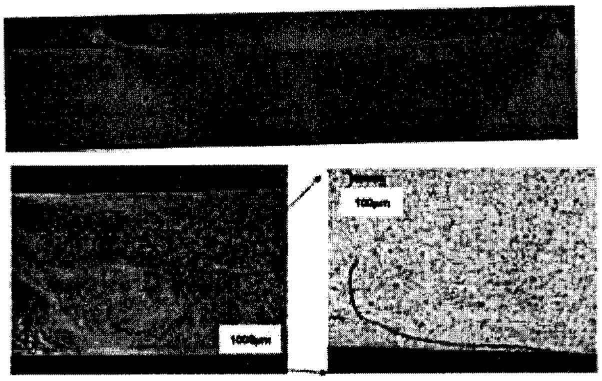

Fig 3. Macrostructure of the Friction stir welded Al6061-T6 without back-bead showing the weld zone and the root flaw after etching.

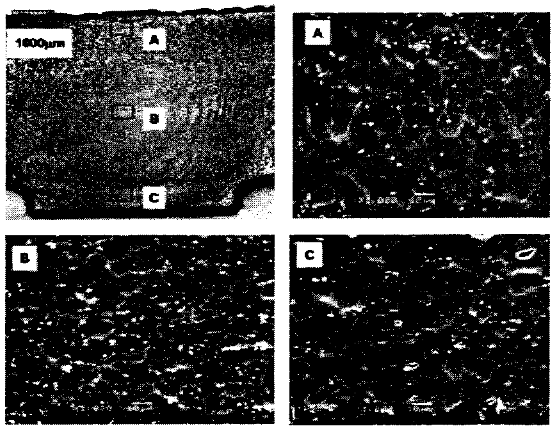

Fig 4. SEM showing the grain size variation in the thickness direction for FSW with back-bead.

It has been observed that the FSW with back bead the grain size is found uniform in the thickness direction. Whereas in the case of the FSW without back bead the grain is smaller below the shoulder, increase in size towards the extrusion zone and again decrease in size towards the vortex swrill zone.

The degree of the root flaw influence on the fatigue property is determined comparing the fatigue test data of the FSW with back-bead and without back-bead. The results are as shown in Fig.5.

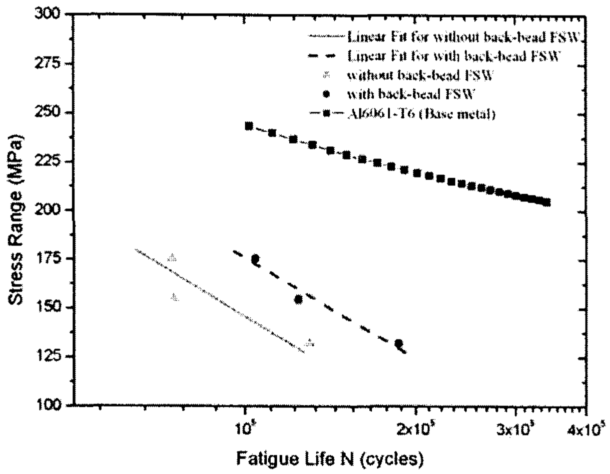

Fig 5. Results of Fatigue testing for Friction Stir butt welding with and without back bead. Compared with the Fatigue of the Al6061-T6 from literature.

In the case of FSW without back-bead fracture during fatigue loading propagated in the weld metal near the toe of weld from the root groove. Fracture surface after the fatigue are transverse to the loading direction. Fatigue is often initiated at multiple positions in the root as shown in Fig 6. Striations are observed in this area.

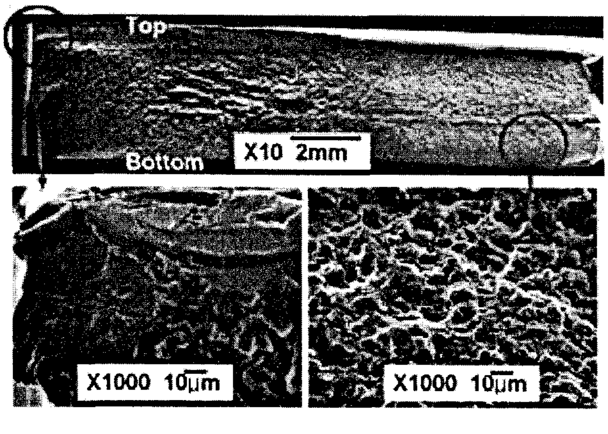

Fig 6. SEM fractrograph of Friction stir welded Al6061-T6 without back-bead specimen, fatigued along weld zone for which the crack initiated at root grove.

4. CONCLUSION

1. The root flaws have an obvious effect on the fatigue performance of the Friction stir welds. The fatigue life of the FSW without back-bead was 5 -10 times shorted than that of FSW with back bead.
2. The grain size of the Al 6061-T6 Friction stir welded plate with back bead is found uniform in the thickness direction
3. In the case of FSW without back bead fracture during the fatigue loading propagated in the weld metal near the toe of the weld from the root grove.
4. The SEM analysis of the Fracture surface evidenced the fracture initiated from the root flaw in the case of the FSW without back bead.
5. The present experiments are limited at low r-ratio and constant amplitude loading; more tests are needed to assign a higher category to assess FSW with optimum back bead.

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