Abstract

Abstract: Joining Aluminium alloys by Friction stir welding (FSW) results in different weld zones viz, nugget zone (NZ), thermos-mechanically affected zone (TMAZ), heat affected zone (HAZ) and the base metal (BM). Each zone exhibits different microstructures and mechanical properties across the weld leading to poor mechanical attributes for the weldment. An insight in to the creep deformation and fatigue crack growth through these weld zones will enlighten the research community with the usage of these materials for elevated temperature applications as well as for conditions of dynamic loading. The present work was therefore taken up with the objective of joining defect free joints of Aluminium alloys by FSW and investigating the (i) creep behaviour of different weld zones at elevated temperatures by impression creep (IC) tests and (ii) fatigue crack growth (FCG) behaviour through different weld zones of the weldments. The materials chosen for the study are commercial Aluminium alloys viz, AA2014 and AA6061-T6. For obtaining the best quality joints of the two Aluminium alloys based on the mechanical properties the process parameters selected were low tool rotational speed, low welding speed, low plunge depth and moderate shoulder diameter of square pin (SQ) tool profile. The effect of process parameters on the mechanical properties viz, ultimate tensile strength (UTS), yield strength (YS), % elongation, Flexural strength (FS) and bend angles of the weldments were studied. The best AA6061-T6 weldments exhibited 97%, 98% and 98% of the UTS, YS and FS of the base metal respectively. In the case of AA2014 alloy the corresponding properties were 86%, 80% and 90% of the base metal. The results of the microstructure and fractography under field emission scanning electron microscope (FESEM) are studied and discussed.

The creep deformation behavior of different weld zones is investigated by IC tests. IC tests were performed at NZ, TMAZ, HAZ and BM with combination of temperatures 310, 330 and 350 ºC and stresses 21, 24 and 27 MPa. From the experimental data the steady state creep rate (SSCR) for each weld zones were estimated and their respective creep rates $\dot{\varepsilon} = f(T, \sigma, t)$ were established using a power law relationship. The creep rate was the highest for the NZ and decreased in the order of TMAZ, HAZ and BM. The constants in the power law equation such as stress exponents *(n)* and apparent activation energy for the IC deformation *(Q_{ic})* for each weld zone were determined. The power law

constitutive equation for creep deformation at each weld zone was developed. Microstructure of the different weld zones were invested after the IC tests and the creep deformation behavior was discussed with the support of the microstructure.

The fatigue crack growth rate experiments of the best weldment were performed by allowing the crack growth along each particular weld zones using compact tension (CT) specimen. For each weld zone, experiments were performed with three stress ratios, R = 0.10, 0.33 and 0.60. From the FCGR plots, the constants C and m of Paris equation were determined for the steady state crack growth region and compared with the BM. The fracture surfaces of the failed specimen after FCGR tests were investigated using FESEM and correlated to the microstructure and the crack growth behaviour. It is found that fatigue cracks propagated faster at NZ in compared to the other zones due to the finer grain size that was mainly due to the dynamic recrystallization as a result of the stirring action during the FSW process. Though the mechanical properties of the friction stir weldment was lower than the BM, a post weld heat treatment (PWHT) leads to the release of the stored internal energy at the weld zones and restored almost all the mechanical properties back to the BM. The FCGR at NZ was also improved and comparable to the BM after PWHT.

To summarize, the present work highlights the combination of process parameters for FSW of AA2014 Al alloy and AA6061-T6 Al alloy for obtaining the best mechanical properties and discusses the microstructure, hardness, impression creep behaviour and fatigue crack growth behaviour of the four weld zones, viz NZ, TMAZ, HAZ and BM in the two Aluminium alloy weldments.