CORROSION BEHAVIOUR OF FRICTION-STIR WELDED DISSIMILAR ALUMINUM ALLOY BUTT JOINTS

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Abstract: This paper presents the effect of process variables on micro structure and corrosion behavior of heat affected zone in friction stir welded AA5052H32-AA6061t6 aluminum plates. As friction stir welding process operates at well below the melting temperatures of base metals, often the grain structure is not much affected. This may lead to poor corrosion behavior in some instances. Some methods to improve corrosion resistance are proposed in this paper for dissimilar aluminum alloy joints. Initially, the experimental procedure is explained and output parameter measurement tests are given. Tensile and impact tests are also conducted along with microscopic examination of samples. The weld velocity and tool rotation are varied in three levels and some set of samples are prepared. Microscopic examination of samples using SEM revealed that the accumulated copper at the nugget zone in all the cases is cause of corrosion behavior of samples.

Keywords: Butt welding Dissimilar aluminum alloys; Tensile test; Corrosion examination.

1. **Introduction**

Friction Stir Welding (FSW) is a solid-state joining technique widely employed in ship building and aerospace industries. This technique is suitable for high-strength aluminium alloys (2XXX to 7XXX series). In FSW, defect-free joint is created by a non-consumable rotating tool advancing with certain weld speed. The frictional heat and intense plastic deformation softens the base materials and the stirring produces the joint, without reaching the melting temperatures. Recently, the studies on FSW of dissimilar aluminum alloys have become more popular [1]. FSW region consists of (i) a central nugget zone in recrystallized configuration (ii) thermo-mechanically affected zone (TMAZ) with only plastic deformation and (iii) heat affected zone (HAZ) where heating without even plastic deformation takes place. The heat generated during FSW in each zone is responsible for different corrosion behaviour. Multitude of works reported the corrosion phenomena in these regions of aluminium welds. For instance, Jariyaboon et al. [2] presented the effect of weld parameters on corrosion behavior of FSW in AA2024 alloys. Xu and Liu [3] performed potentio-dynamic polarization and electrochemical impedance spectroscopy test for corrosion analysis of friction stir welding in AA2219-O aluminum alloy. Bousquet et al. [4] found that for AA2024 alloy friction stir welded joint, corrosion at HAZ was found to be due to intergranular precipitation. Lumsden et al. [5] identified the region near the interface between nugget and TMAZ in friction stir welded AA7050-T7651 results in intergranular stress corrosion cracking under slow strain rate. Long-Qin et al. [6] studied the corrosion behavior of friction stir welding of AA2A14 aluminum alloy in exfoliation corrosion solution using various electrochemical measurements. Gharavi et al. [6] analyzed the lap joint corrosion behavior of AA6061 alloy by cyclic polarization and electrochemical impedance spectroscopy tests. It was found intergranular and pitting corrosions have dominance in weld regions. Rasouh et al. [7] illustrated the improvement of corrosion resistance of AA5083 alloy with friction-stir processing. Microstructure and immersion corrosion behavior of AA7020 alloy plates using friction stir welding was shown by Mosieh et al. [8]. Rajesh and Badheka [9] presented the effect of post weld treatment in friction stir welding of dissimilar aluminum alloys on the corrosion behavior. Ma et al. [10] given the effects of laser surface melting on corrosion behavior in friction stir welding of AA2219 alloy plates. More recently, Sinhmar and Dwivedi [11] employed AA2014 plates to study the comparative corrosion behavior in FSW and TIG welding operations. They utilized electrochemical impedance spectroscopy and potentiometric polarization tests and found that the HAZ as the most corrosion susceptible region. Argadi et al. [12] conducted corrosion characterization of friction stir lap welding of stainless steel and plain carbon steel samples in 3 to 5 weight percent of NaCl solution. Positive corrosion potentials were observed in potentiodynamic polarization. There several other works also reported recently the corrosion behavior of friction-stir welded alloy joints. In the present study, a FSW butt joint between AA5052-H32 and AA6061T6 plates is illustrated. The weld parameters like spindle rotation, weld velocity etc are varied in three levels and the weld samples are prepared for tensile, impact and hardness tests. The Rockwell hardness (RH) is measured for different samples. After all these conventional tests, the samples are dipped in 3% sodium chloride solution for 6 hours and the corrosion behavior is observed via the microscopic examination. It was found different levels of corrosion occurring in all test samples.

2. Experimental

Plate samples of 100 mm × 50 mm dimension of dissimilar aluminum alloys (AA5052 and AA6061) are selected with each having thickness 5 mm. A MS plate of 25 mm thick is used as backing material and SS-H13 material is used as a tool. Cylindrical pin with square head profile is employed. The tool is of 9 mm shoulder diameter and 24 mm in length. The composition of alloy materials are given in Table 1.

Table-1 Chemical compositions (%wt) of the studied alloys

Alloy	Si	Fe	Cu	Mn	Mg	Zn	Ti	Cr	Al
AA5052H22	0.4	0.5	0.15	0.1-0.5	1.7-2.4	0.15	0.15	0.15	Balance
AA6061T6	0.2-0.6	0-0.35	0-0.1	0-0.1	0.45-0.9	0 -0.1	0-0.1	0.1 max	Balance

A column and knee type vertical milling machine is used for joining operation. In all the experiments, AA6061T6 was kept on the advancing side. The weld speeds are taken as 18, 22 and 25 mm/min, while the tool rotations are taken as 760 rpm, 1130 rpm and 1340 rpm based on the availability over the machine. Fig.1 shows the experimental set-up.

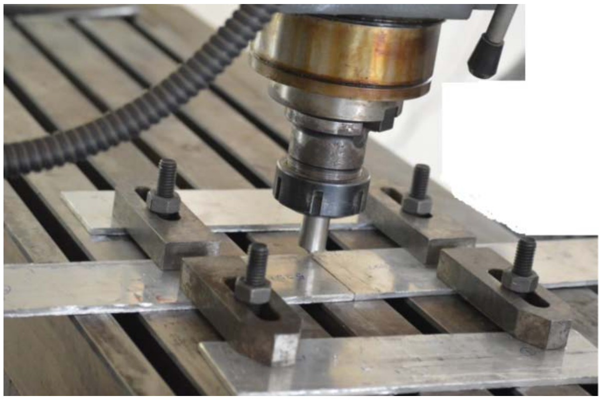


Fig.1. Experimental arrangement on vertical milling machine

Tensile, impact and hardness tests are conducted respectively on 100 tonne Instron machine, Charpy machine and Rockwell hardness tester. The samples prepared from cross-section of weld are shown in Fig.2

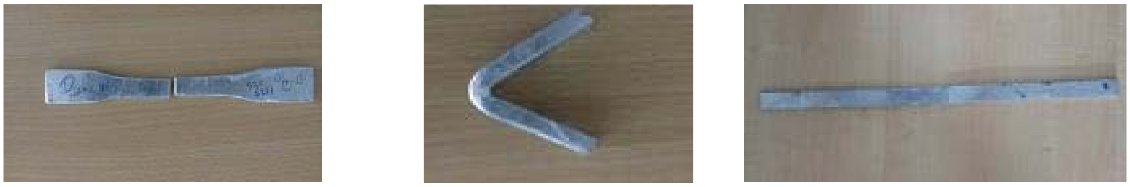


Fig.2. Test samples in one condition (22 mm/min, 760 rpm, 2.2 mm depth)

The stress-strain curve obtained from UTM test is shown in Fig.3 and ultimate tensile strength was found to be 49.15 MPa.

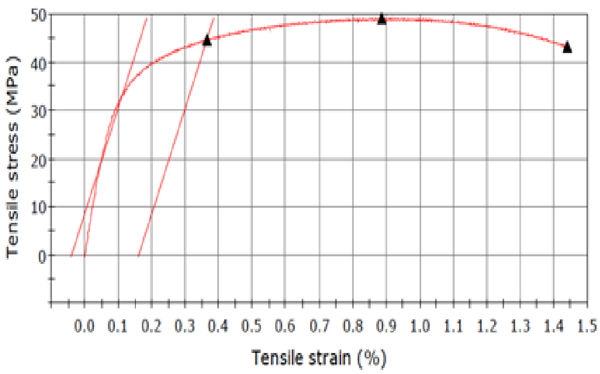
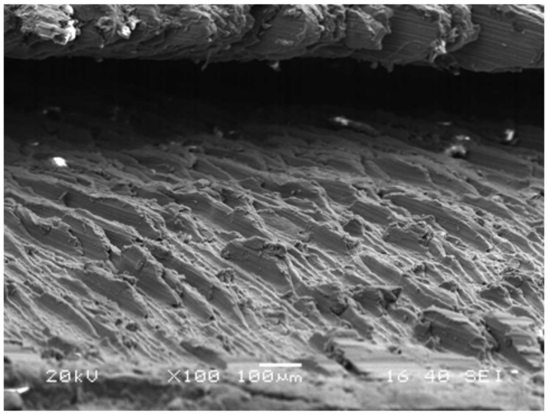
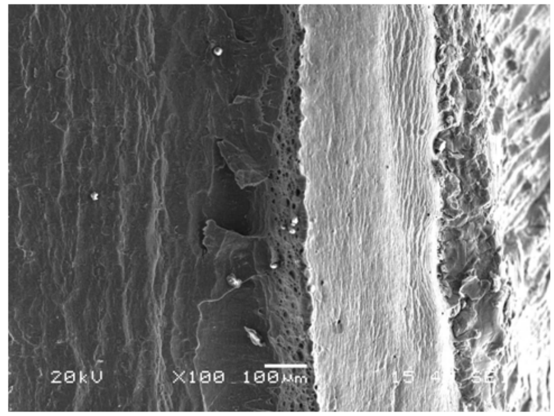


Fig.3 Tensile test output.

The microstructure analysis is also conducted on the cross-section of the welds. In order to investigate the grain structure, the samples were electro-etched. The grain structure was observed using scanning electron microscope. Fig.4 shows the surface morphology at nugget zone and heat affected zones.



(a) Weld nugget zone



(b) heat affected zone

Fig.4 Surface morphology in normal conditions

In the next step, the weld samples are dipped in 3% NaCl solution for 6 hours to induce corrosion on the surface.

3. Conclusions

In this work, the effects of operating parameters like weld speed and tool rotations were primarily focused on the tensile, impact and hardness behavior. Further, as hardness indirectly affects the corrosion behavior of weld samples, microstructure examination was also conducted. Initially, the corrosion medium (aqueous NaCl solution) has not affected much the microstructure of the surfaces. As the time of dissolution increased, some changes in the microstructure were noticed.

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