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Corrosion Study in Friction Stir Welded Plates of AA6061 and AA7075

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Abstract: The corrosion behavior of different tempers of two aluminum alloys, AA7075 and an AA 6061 alloy, was studied in NaCl solution. The differences in the microstructure after friction stir welding were correlated. Micro structure analysis enables to provide information about the composition of the solid solution matrix region between the fine-scale hardening particles. The formation of corrosion-susceptible surface layers on as-polished AA7075 and AA6061 are depended on the predominant type of hardening particle. Six month welded plates are taken, cut into three specimens and immersed in NaCl solution for different periods. Then the SEM and EDAX images are taken to study the corrosion.
Keywords: Friction Stir Welding, Corrosion, AA6061, AA7075.

Introduction:

Friction stir-welding (FSW) is a new solid-state joining technique. It was invented by The Welding Institute (TWI) [1]. This technique avoids the formation of solidification cracking and porosity. It significantly improves the weld properties. It has been extensively applied in joining light metals like aluminium and its alloys [2]. FSW is ideal for joining aluminium alloys of the AA2XXX and AA7XXX series [3]. These alloys are difficult to weld using conventional fusion welding and are typically joined though FSW [4]. The corrosion properties of FSW in 2XXX, 5XXX and 7XXX series aluminium alloys have been studied by a number of authors [5, 6]. The surface is the part more exposed to the environment. An analysis was conducted on the welded surfaces instead of the section [7]. The corrosion behaviour of friction stir welded aluminium alloys is being studied in recent years [8]. Recent work on AA2024 T351 showed the correlation between welding parameters on the corrosion behaviour [9]. It has been found that the weld zones are more susceptible to corrosion than the parent metal. The microstructural properties and corrosion properties of friction stir welded 7075 Al alloy have been studied [10]. Recently friction stir processing was developed by as a generic tool for microstructural modification based on the basic principles of friction stir welding technique [11]. Frankel and Xia [12] were first to investigate pitting and stress corrosion cracking behaviors of friction stir welded 5454 aluminium alloy. They also compared them with those of base alloy and gas tungsten arc welded samples. Corral et al. investigated the effect of friction stir welding on the corrosion behavior of a very common heat-treatable aircraft aluminum alloy (6061Al-T4) and a so-called third- generation Al–Li alloy (2195Al) [13]. Zucchi et al. reported that the 5083Al friction stir weld exhibited a higher corrosion resistance in EXCO solution (4 M NaCl–0.5 M KNO3–0.1 M HNO3) and a lower pitting tendency than the base alloy [14]. Meletis et al. investigated stress corrosion cracking behavior of FSW 7075Al-T6, 2219Al-T87, and 2195Al-T87 by two types of experiments: (a) four-point bending at different loading levels under alternate immersion (AI) conditions in 3.5% NaCl solution for 90 days, and (b) slow strain rate tension of specimens pre-exposed (PE) under AI in 3.5% NaCl solution [15]. The investigations by Lumsden et al., Hannour et al. and Paglia et al. demonstrated that friction stir welds of 7075Al, 7010Al, 6061Al, and 7050Al were more susceptible to intergranular attack than the base alloy [16-18], but not studied the pitting corrosion. This requires further research to establish the dominating factors influencing pitting corrosion properties of friction stir welds of aluminium alloys.

Pitting Corrosion:

Pitting is a highly localized type of corrosion in the presence of aggressive chloride ions. Pits are initiated at weak sites in the oxide by chloride attack. Pits propagate according to the reactions

$$A1 \rightarrow A1^{3} + +3e- \quad (1)$$

$$A1^{3+} + 3H_2O \rightarrow A1(OH)_3 + 3H^+ \quad (2)$$

while hydrogen evolution and oxygen reduction are the important reduction processes at the intermetallic cathodes.

$$2H^+ + 2e \rightarrow H_2 \quad (3)$$

$$O_2 + 2H_2O + 4e \rightarrow 4OH \quad (4)$$

As a pit propagates the environment inside the pit (anode) changes.

According to reaction 2 the pH will decrease. To balance the positive charge produced by reaction 1 and 2, chloride ions will migrate into the pit. The resulting HCl formation inside the pit causes accelerated pit propagation. The reduction reaction will cause local alkalinisation around cathodic particles. As previously mentioned aluminium oxide is not stable in such environment, and aluminium around the particles will dissolve (alkaline pits).

The active aluminium component of the particles will also dissolve selectively, thereby enriching the particle surface with Fe and increasing its cathodic activity. Etching of the aluminium matrix around the particles may detach the particles from the surface, which may repassivate the alkaline pits. This may also reduce the driving force for the acidic pits causing repassivation of some in the long run. Figure 2 shows pitting corrosion of an Al alloy.

2. Experimental Procedures

Two aluminium alloys namely AA6061 and AA7075 are taken. The FSW is carried on these plates using three different weld parameters listed below, so that three different samples are formed. These samples remain untouched for 6 months so that it has a chance to corrode. After that the welded portion of each sample is taken for testing of corrosion properties. The welded portion of each sample is cut. A NaCl solution of pH 8 is prepared. The welded portions of samples A,B and C are dipped in a 100ml NaCl solution for 1, 2 and 3 hours respectively. Then the solution from the samples are drained and the samples are washed in distilled water .Then the samples are washed with acetone so that the sample gets covered with acetone layer preventing it from further corroding. The SEM images of each sample are taken and the corresponding change in structure is noted. The EDAX of these samples before and after FSW are found out.

Results and Discussion

The base metal surface reveals the presence of micropores in large volume and the tool markings. This shows the fine crystalline structure of Iron, carbon and silica particles. Silica particles are making bleaching effects. The base metal zone (in Fig.4 (a) indicated as “BM”) is tested through Scanning Electron Microscope (SEM). However the detailed magnification shows there is no pitting corrosion effects through the SEM images (BM). But the crack formation is only on base metal, so fracture is suspected more at base metal than nugget zone. The elements of carbon and iron makes the corrosion accelration at a faster rate for a three hour test (Detailed "BM").

The etched surface reveals the presence of micropores in large volume and the tool markings. On the nugget zone area there is no crack found. The friction stir welded nugget zone (in Fig.5 (a) indicated as "A") is tested through Scanning Electron Microscope (SEM). The copper and silica particles are making a bleaching effects on the SEM images (A). It is found that at three hours of immersion it is having more bleaching effects at centre. It indicates more pitting corrosion and needs to have coating to avoid corrosion. Any way this is less compared to bare aluminium pitting corrosion as shown in Fig.2. Oxygen and Aluminium has been tested to be an effective corrosion inhibitor for AA 6061 and AA 7075 in 0.05 M NaCl solution. The elements of copper and silica makes the corrosion accelration at a faster rate for the three hour test (Detailed "A").

As per EDAX analysis shown in Figure 6, the chemical elements present on the welded zone is identified as Aluminium as major element, then Oxygen, Carbon, Cadmium, Copper and magnesium with decreasing weight content. These elements are represented in Figure 7.

Elements of Magnesium, Cadmium and Silicon have the moderate accelerating effects on the corrosion rate, while carbon, copper and iron have extremely severe accelerating effects. In order to achieve good corrosion performance from a Aluminum alloy, only compatible elements are accepted and contaminant elements such as iron, carbon, and copper must be controlled to low levels. The weight percentage of these elements and graphs are shown in Figure 7.

Table1. Weld Parameters of the three samples

Sample	A	B	C
Load(kN)	10	12	16
Rotational Speed(rpm)	400	600	1200
Weld Speed(mm/min)	30	40	90

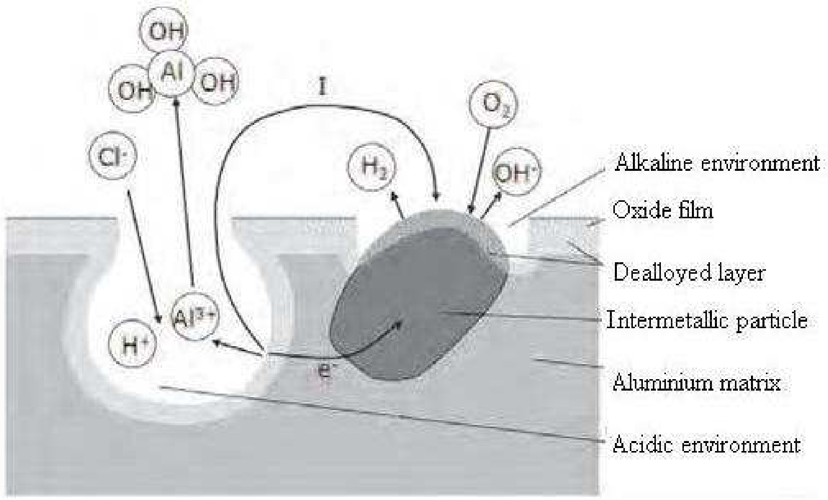


Figure. 1. Pitting corrosion mechanisms for the Aluminium

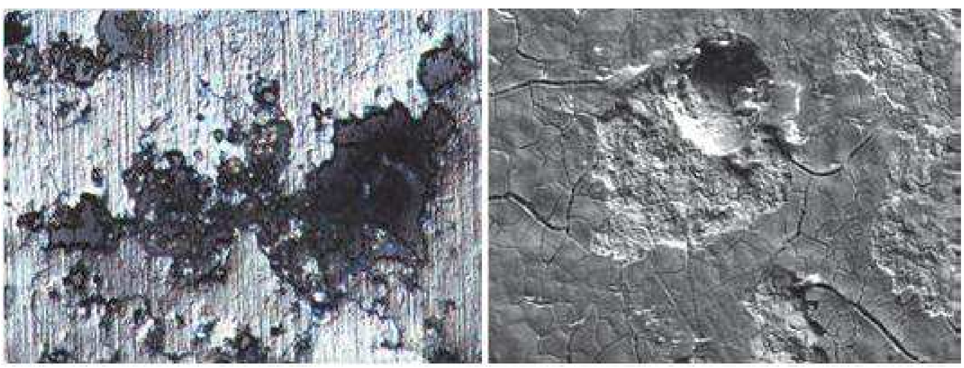
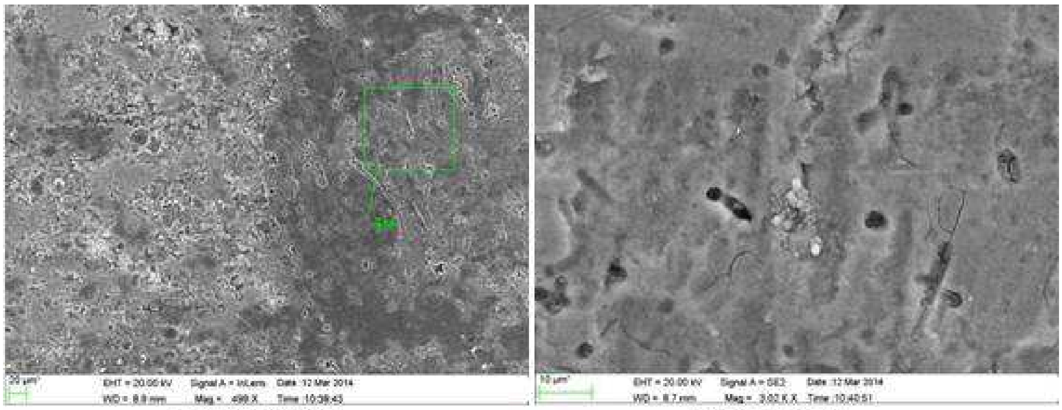


Figure.2. SEM images showing the pitting corrosion for the aluminium

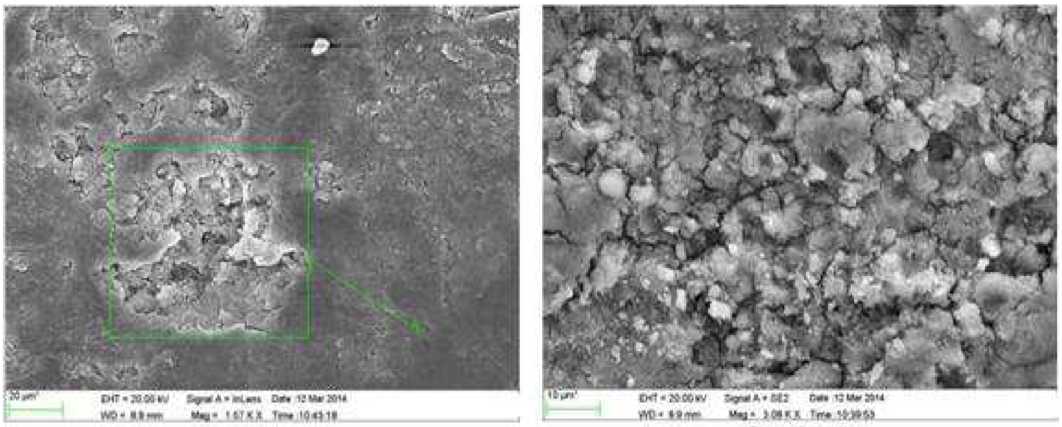
Figure 3. Samples being dipped in NaCl for three different times



Base Metal (BM) Detailed "BM"

(a) (b)

Figure 4 (a) SEM analysis of base metal zone with 20 µm magnification,
(b) SEM analysis of base metal zone with 10µm magnification.



Detail "A"

(a) (b)

Figure 5 (a) SEM analysis of nugget zone with 20 µm magnification,
(b) SEM analysis of nugget zone with 10µm magnification.

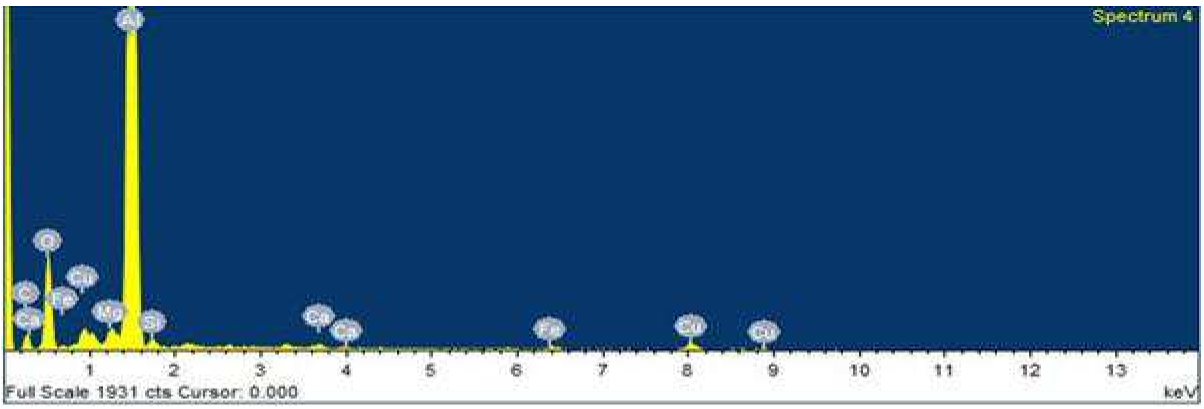


Figure 6. EDAX analysis of AA6061-AA7075 Friction stir welded zone

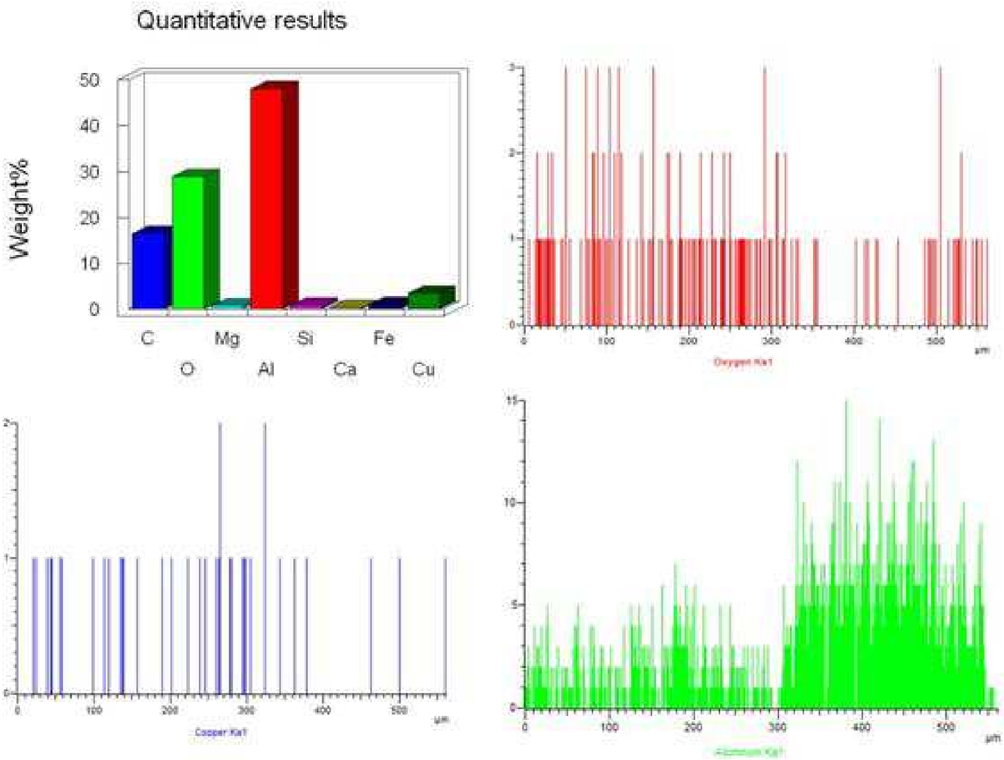


Figure 7. Weight percentage of elements and its varations at different distances of µm

Conclusion

It is found that Aluminum is acting as a good inhibator for corrosion rsistance through the SEM analysis. The combination of two similar alloys AA 6061 and AA7075 on nugget zone makes more pitting corrosion sites than base metal zone of AA 6061. Even though the nugget zone having more bleach effects it does not have crack formation. The base metal zone having crack formations. The EDAX analysis revealed the major portions next to Aluminium as Oxygen, carbon and copper which needs to be controlled by providing suffient coating on the welded zones to prevent corrosion acceleration.

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