

## Galvanic corrosion behavior of friction stir welded copper alloy in 3.5% NaCl

Reza Parvizi<sup>1,\*</sup>, Mohammad Hadi Moayed<sup>2</sup>, Ali Davoodi<sup>3</sup>, Mohsen Haddad Sabzevar<sup>2</sup><sup>1,\*</sup>M.Sc, Metallurgical and Materials Engineering Department, Ferdowsi University of Mashhad, Mashhad 91775-11, Iran, Email: [reza.parvizi@stu-mail.um.ac.ir](mailto:reza.parvizi@stu-mail.um.ac.ir),<sup>2</sup>Associate Professor, Materials Science and Engineering, Ferdowsi University of Mashhad, Mashhad, Iran<sup>3</sup>Assistant Professor, Materials Engineering Department, Tarbiat Moallem University of Sabzevar, Sabzevar 391, Iran

Friction stir welding (FSW) is a relatively new solid-state joining process which is energy efficient, environment friendly, and versatile<sup>1</sup>. However, studies on galvanic corrosion of copper alloys joined by FSW are scarcely reported. In the present study, the corrosion behavior of friction welded copper plates is investigated. Identical samples were extracted from base and weld regions. Several DC and AC electrochemical measurements including OCP, potentiodynamic polarization, ZRA and EIS were carried out in conjunction with microstructural examinations.

Severe plastic deformation and forging in weld region results in formation of stir bands<sup>1</sup>. Small round pits, dissolved inclusions (mainly Cu<sub>2</sub>O), with less than 500 nm in size, are accumulated in stir band area. During FSW, the number of oxide inclusions is increased particularly in stir bands, shown in Fig. 1.

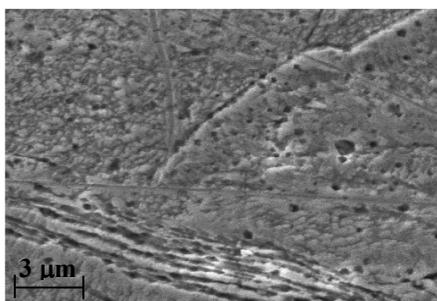


Figure 1. SEM image of an individual stir band and pits in weld zone.

Potentiodynamic polarization in 3.5% NaCl shows that the corrosion potential ( $E_{\text{corr}}$ ) difference between base and weld just after immersion is less than 10 mV where the weld owes higher potential. Near  $E_{\text{corr}}$ , both anodic and cathodic activities for base sample are noticeably higher than the weld. After 4330 minutes, the  $E_{\text{corr}}$  difference increases to 100 mV where the base reaches to a higher potential. This indicates that galvanic corrosion driving force raised up within the exposure time. While  $i_{\text{corr}}$  remains almost constant in pweld, it appreciably decreases in base sample. These facts can be attributed to the formation of additional CuCl on the base surface<sup>2</sup>.

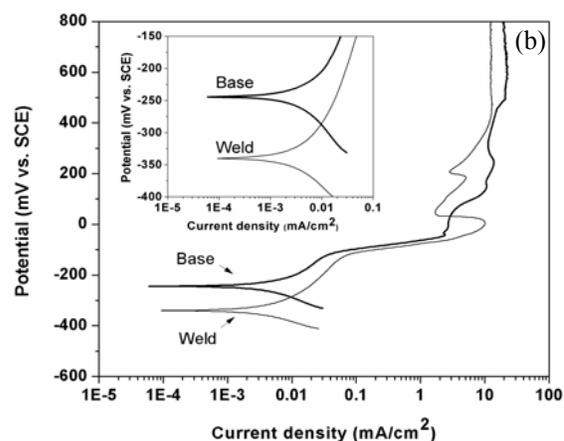
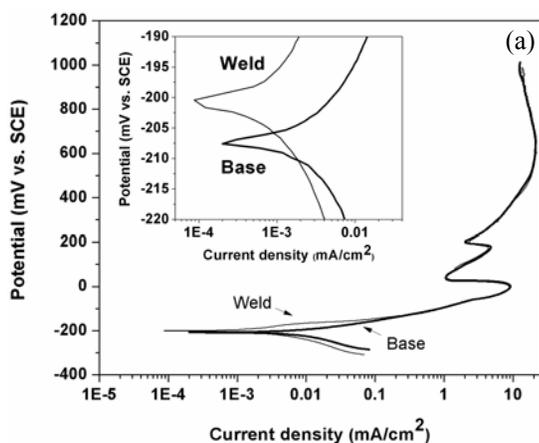


Figure 2. Potentiodynamic polarization curves after a) 15 minutes and b) 4330 minutes of exposure time in 3.5% NaCl.

Galvanic current density measured by ZRA reveals that although weld acts as a cathode at early stages and lasts for 200 minutes, consuming  $4 \mu\text{A}/\text{cm}^2$ , it switches to anode, generating  $3 \mu\text{A}/\text{cm}^2$  after 4330 minutes. Due to the presence of more Cu<sub>2</sub>O at the weld zone which causes ennoblement of the surface in the beginning, it promotes the corrosion reactions within first hours by CuCl and CuCl<sub>2</sub> formation<sup>3-4</sup>. Later on, an increase in couple potential is associated to more CuCl formation in base surface which causes an increase in base potential (while the weld potential remains constant)<sup>5-7</sup>. EIS measurements showed that Rp (polarization resistance) value increased from 3000 and 3500  $\Omega\cdot\text{cm}^2$  to 8500 and 5500  $\Omega\cdot\text{cm}^2$  in base and weld regions, respectively which is in agreement with above outcomes.

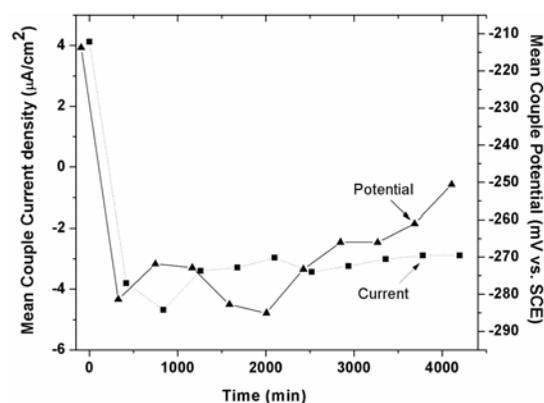


Figure 3. Mean couple current and potential measured by ZRA.

In summery, galvanic current induced by FSW process was gently low in the range of  $3-4 \mu\text{A}/\text{cm}^2$ , associated to the surface microstructural difference between base and weld regions including grain boundaries, stir bands and induced imperfections by FSW process. Both weld and base regions showed similar passivity characteristics with better integrity in base area.

## References

1. R.S. Mishra, Z.Y. Ma, *Materials Science and Engineering R* 50 (2005).
2. M. Keddam, 'anodic dissolution' in corrosion mechanisms in theory and practice by Philippe Marcus, 2<sup>ed</sup> edition, (2002), p. 141-142, Marcel Deckker, Inc.
3. M. Scendo, *Corrosion Science* 49 (2007) 373-390.
4. A.M. Alfantazi, T.M. Ahmed, D. Tromans, *Materials and Design* (2009), in press.
5. E.M. Sherif 1, Su-Moon Park, *Electrochimica Acta* 51 (2006) 4665-4673.
6. El-Sayed M. Sherif, R.M. Erasmus, J.D. Comins, *Journal of Colloid and Interface Science* 309 (2007) 470-477.
7. El-Sayed M. Sherif, A.M. El Shamy, Mostafa M. Ramla, Ahmed O.H. El Nazhawy, *Materials Chemistry and Physics* 102 (2007) 231-239.