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A REVIEW OF WELDING PARAMETER ON CORROSION BEHAVIOR OF ALUMINUM

Ervina Efzan M. N.[1]
K.Vigram Kovalan[1]
Suriati G.[2]

Faculty of Engineering and Technology, Multimedia University, Malaysia[1]
Faculty of Chemical and Natural Resources Engineering, Universiti Malaysia Pahang, Pahang[2]
ervina.noor@mmu.edu.my

Abstract

There have been a number of reports highlighting the microstructural changes due to the plastic deformation and frictional heat associated. Dissolution and coarsening of strengthening precipitates as well as the formation of wide precipitate-free zones have been found in the weld region. Mechanical failure of the welds can take place in the nugget, Heat Affected Zone (HAZ) regions depending on the amount of heat input, which is controlled by welding parameters such as rotation and travel speeds. The dependence of weld microstructure on processing parameters also has been observed.

Keywords: welding; corrosion; aluminium; stainless steel.

1. Introduction

Welding often done by melting the work pieces and filler material is added to form a pool of molten material that cools to become a strong joint, with the pressure, sometimes used in conjunction with heat, or by itself, to produce the weld. The history of joining metals goes back several millennia, with the earliest examples of welding from the Bronze Age and the Iron Age in Europe and the Middle East [1].

Welding technology which is a high productive and practical joining method is widely used in modern manufacturing industry such as shipbuilding, automobile, bridge, and pressure vessel industry [2]. It is also a type of fabrication or sculptural process that joins materials, usually metals or thermoplastics, by causing coalescence [1].

Welding is a potentially hazardous undertaking and precautions are required. It releases poisonous gases and fumes which is very harmful to human [3]. Welding as a fabrication method is one of the simplest ways to make a gas or liquid tight joint and laser welding competes favorably with alternative welding processes on the basis of all-round performance. However, welding introduces microstructural and compositional heterogeneities that can result in substantially enhanced corrosion and hence aluminium alloy weldment corrosion has been the subject of considerable research [4].

The common types of welding are such as oxy fuel gas welding, arc welding, and resistance welding [5]. For arc welding there are plasma arc welding and carbon arc welding. Whereabouts, gas welding there are Tungsten Inert Gas (TIG) welding and Metal Inert Gas (MIG) welding. Last but not least resistance welding which has spot and seam welding [5].

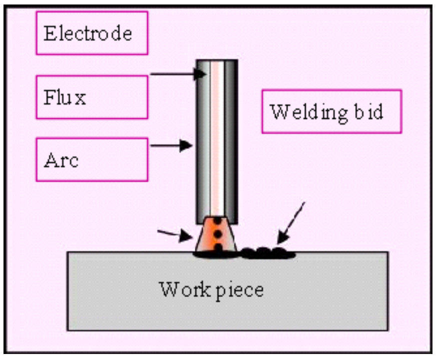

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Figure 1 : Carbon Arc Welding [6]

2. Welding Parameters Effects on Speed

According Jariyaboon, et al, it was found that rotation speed plays a major role in controlling the location of corrosion attack. Localized inter-granular attack was observed in the nugget region for low rotation speed welds, whereas for higher rotation speed welds, attack occurred predominantly in the heat-affected zone. The increase in anodic reactivity in the weld zone was due to the sensitization of the grain boundaries leading to inter-granular attack [7].

In the particular experiment, aluminum alloy plate friction stir welded at a tool traverse speed of 400 mm/min exhibited higher tensile strength with 45 degrees shear fracture, whereas lower tensile strengths with nearly vertical fractures were observed for samples welded at a lower speed of 100 mm/min. The fracture paths corresponded well with the lowest hardness distribution profiles in the joints. The heat indexes cannot be used as parameters to evaluate the thermal input, mechanical properties and fracture mode [7].

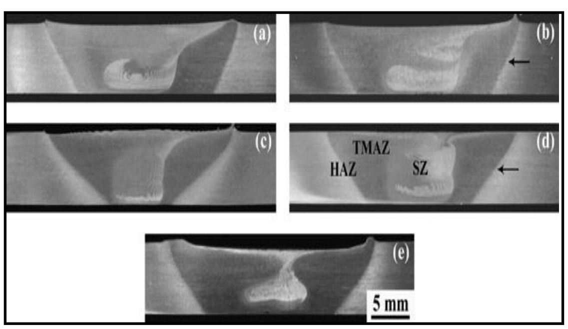

Figure 2: Cross-sectional macrostructures of FSW 6061Al–T651:

(a) Cross-sectional at 400 rpm, 100 mm/min;
(b) Cross-sectional at 600 rpm, 100 mm/min;
(c) Cross-sectional at 800 rpm, 400 mm/min;
(d) Cross-sectional at 1200 rpm, 400 mm/min;
(e) Cross-sectional at 1600 rpm, 400 mm/ min [8].

3. Corrosion

Corrosion is a complex phenomenon that depends on many parameters that are related to the environment or to the metal [9]. Corrosion is an electro-chemical process involving an anode, a cathode and an electrolyte. In the case of steel, when favourable condition for corrosion occurs, the ferrous ions go into solution from anodic areas. Electrons are then released from the anode and move through the cathode where they combine with water and oxygen to form hydroxyl ions [9]. These react with the ferrous ions from anode to produce hydrated ferrous oxide, which further gets oxidized into ferric oxide, which is known as the 'red rust'[9].

There are several types of corrosion. Some of the common types of corrosion are galvanic corrosion, pitting corrosion, and crevice corrosion [10]. These kinds of corrosion are the corrosion that can be identify in daily life. A crevice has to be of sufficient width to permit entry of the corrodent, but sufficiently narrow to ensure that the corrodent remains stagnant [10]. Accordingly crevice corrosion usually occurs in gaps a few micrometers wide, and is not found in grooves or slots in which circulation of the corrodent is possible [11].

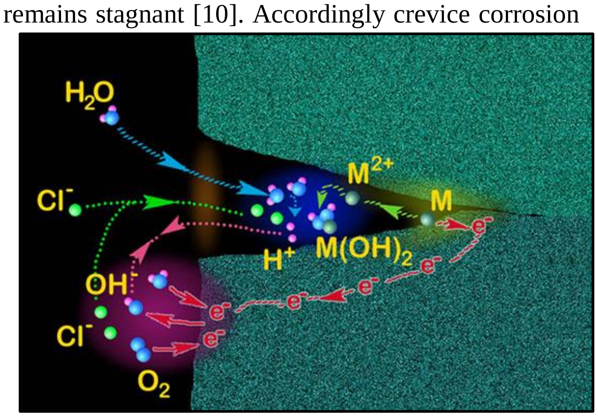

Figure 3:

Chemical Reaction of Crevice Corrosion [12].

Pitting corrosion occurs in materials that have a protective film such as a corrosion product or when a coating breaks down. The exposed metal gives up electrons easily and the reaction initiates tiny pits with localised chemistry supporting rapid attack [10].

Pitting corrosion is essentially due to the presence of moisture aided by improper detailing or

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constant exposure to alternate wetting and drying [13].

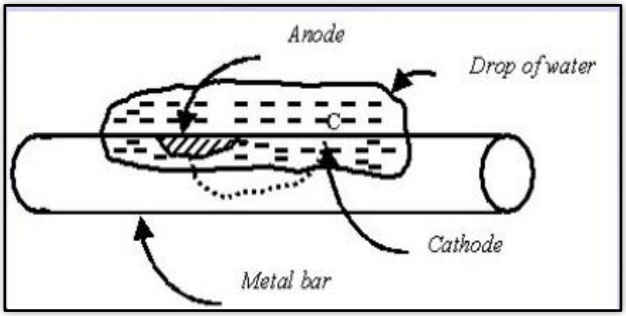

Figure 4: Mechanism of corrosion in steel [14].

Galvanic corrosion occurs when two or more dissimilar metals or alloys are electrically coupled in the same electrolyte [15]. When a galvanic couple forms, one of the metals in the couple becomes the anode and corrodes faster than it would all by itself, while the other becomes the cathode and corrodes slower than it would alone [16].

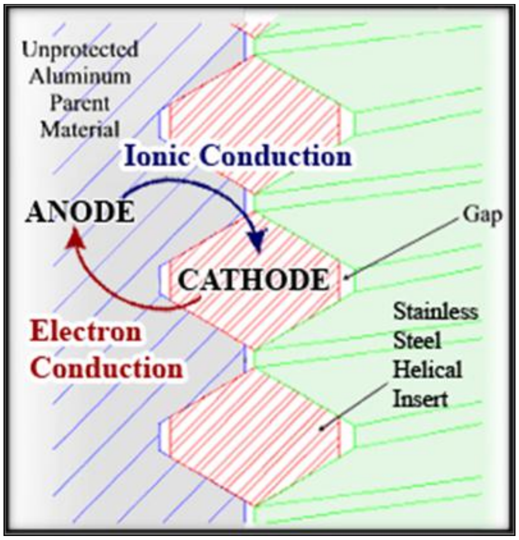

Figure 5: Galvanic corrosion process [17]

4. Aluminium

Aluminum is the most abundant metal and the third most abundant element in the earth's crust, after oxygen and silicon. It makes up about 8% by weight of the earth's solid surface [18].

Aluminum composites have wide applications, e.g. in the aerospace and automobile industries, due to their high specific strength, rigidity, wear resistance and good dimensional stability compared with unreinforced alloys [19]. It is a very reactive metal, and bare aluminum will form an oxide layer in minutes [20].

Figure 6: Aluminum bar surface etched [21]

5. Corroding the Aluminium Using Medium

According to the characteristic of aluminums stated by Jon Perryman, aluminum has high resistant of corrosion. Therefore, to make sure it corrodes in short period, some mediums are selected to be the catalyst [22].

Sodium chloride or better known as seawater is biggest source of natural alkaline. Elements and compounds comprise about 99% of sea salts: chlorine (Cl^-), sodium (Na^+), sulfur (SO_4^{-2}), magnesium (Mg^{+2}), calcium (Ca^{+2}), and potassium (K^+) [23]. Seawater pH is limited to the range 7.5 to 8.4.

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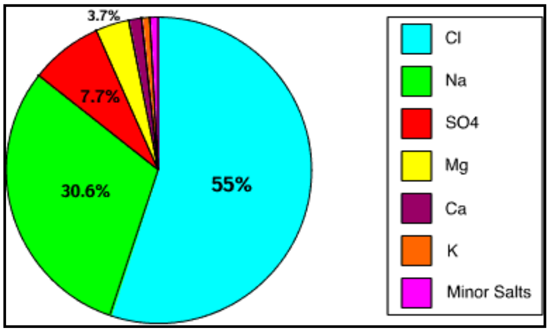

Figure 5: Relative proportions of dissolved salts in seawater [23].

Regarding ferric chloride, it is an orange to brown-black solid, slightly soluble in water and noncombustible. The pH level of ferric chloride depends on the concentration with water. It may vary if the water concentration is different [24].

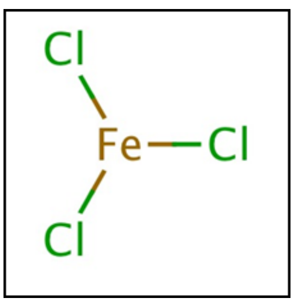

Figure 6: Structure of ferric chloride [25]

4. Corrosion behaviour of aluminium in chloride medium

A research was carried out to study the corrosion behavior of aluminum in chloride medium.

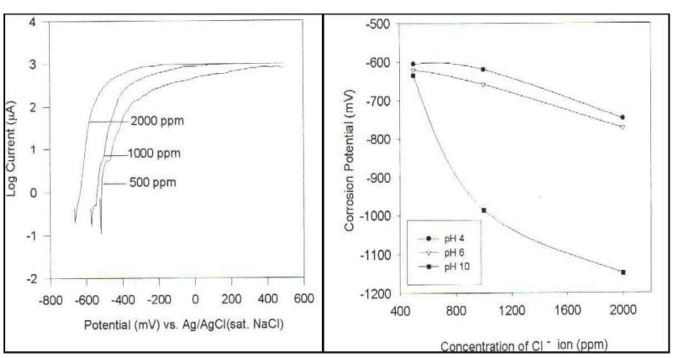

Figure 7: Corrosion behavior of aluminum in different concentration of Cl^- medium at pH 10 (left)

Figure 8 Effect of concentration of Cl^- ion on the corrosion potential of aluminum at different pH (right) [26]

Potential dynamic sweep experiments on aluminum were carried out in chloride ion solutions of different concentrations at different pH values. Aggressiveness of CI- ion on aluminum corrosion is observed at pH 10. Higher current is observed at higher concentration of chloride ion indicating enhancement of corrosion rate.

Figure 8 represents the effect of chloride ion concentration (aqueous 500, 1000 and 2000 ppm aqueous chloride solution) on the corrosion potential of aluminum at pH 4, 6 and 10. For all the pH values the lowest potential (more negative) was observed for 2000 ppm chloride medium. In general, more negative potential indicates more corrosion of the metal.

The result showed more negative potential at higher pH then those at lower pH values. At pH 10 (the highest pH used in this study) the corrosion potential decreases significantly with the increase of chloride concentrations. This means that at relatively stronger alkaline media the surface oxide layer was more soluble as aluminates in the chloride medium than those in acidic medium. As a result, the metal surface exposed to the aggressive medium corroded severely [26].

The dissolution of aluminum oxide in alkaline medium can be presented as: [27]

$Al2O_3 + 2OH^- = AlO_2^- + H_2$-------------------1
$Al + O_2 + 2H2O = Al_3^+ + 4OH^-$----------------2
$Al_3^+ + 3Cl^- = AlCl_3$-------------------------------3

In acidic condition, the reaction can be represented as: [27]

$ɣ.Al_2O_3.H_2O = Al(OH)_3$-------------------------1
$Al(OH)_3 + HCl = Al(OH)_2Cl+H_2O$-------------2
$Al(OH)_2Cl + H+ = Al(OH)Cl+ + H_2O$---------3
$Al(OH)_2Cl + 2H+ = AlCl^{++} + 2H_2O$------------4

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6. Corrosion behaviour of steel in chloride medium

The single most important property of stainless steels, and the reason for their existence and widespread use, is their corrosion resistance [28].

The stainless steels possess an especially useful characteristic in resisting corrosion in that they perform best under those oxidizing conditions which are most harmful to ordinary steel and too many of the non-ferrous metals and alloys [29].

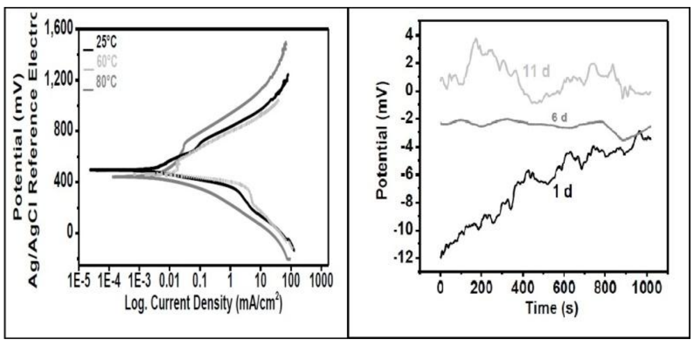

Figure 9: Polarization Curves of Carbon Steel (right)

Figure 10: Potential time series of carbon steel (left) [30]

Figure 9 shows the potentiodynamic polarization curves at all the studied temperatures. These plots show that corrosion potentials (Ecorr) are very close each other, became more active with temperature. The temperature had an effect over the corrosion activity of the material [30]. The polarization curves show that both the anodic and cathodes polarization curves were shifted to higher current densities and the corrosion potential [31].

Figure 10 which is the potential times series shows their behavior has that there are no transients, showing high frequency and low amplitude transients [30]. Value is shifted to more positive potentials with increasing HCl concentration, indicating that the polarization occurs mostly at the anode, hence the corrosion rate is said to be anodically controlled [31].

7. Conclusion

Corrosion occurs widespread on steel. More experiments are conducted on steel weigh against to aluminum. The corrosion may give major impact at the heat affected zone which may weaken the microstructure. The heat affected zone initially undergoes microstructure changes during welding process.

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