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INVESTIGATION ON CORROSION RATE OF BUTT-JOINT IN GAS METAL ARC WELDING, FLUX CORE ARC WELDING AND SUBMERSIBLE ARC WELDING

Bulan Abdullah*, Syuhada Ismail, Muhammad Hafizuddin Jumadin

Faculty of Mechanical Engineering, Universiti Teknologi MARA (UiTM), 40450 Shah Alam, Selangor Malaysia

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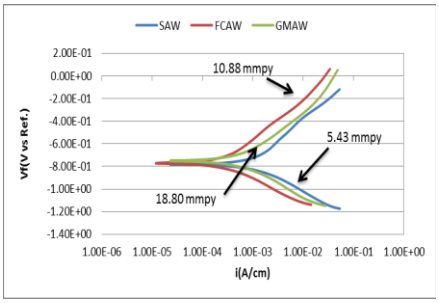
*Corresponding author
bulanabdullah@gmail.com

Graphical abstract



Abstract

Corrosion can be defined as the destructive attack of a metal through interaction with its environment. Different type of welding can be factors that contribute to the corrosion and erosion problems since this type of welding will lead the material to expose with the corrosion and erosion agents like salt, air , water and material composition, dissolved oxygen content in the fluid, pH and fluid's velocity characteristics. Research was carried out in order to investigate the corrosion rate on mild steel at 3 different types of welding which are Gas Metal Arc Welding (GMAW), Flux Core Arc Welding (FCAW) and Submersible Arc after exposed in 3 types of solution; sea water, sodium chloride and reverse osmosis (RO). In each of the types of welding, the parameters were fixed that includes of current, voltage and speed of travel. Immersion and polarisation test using Gamry instruments test were conducted to distinguish the corrosion rate. Results showed SAW had a least corrosion rate than FCAW and GMAW and morphology transformation differences occur during the corrosion process.

Keywords: Corrosion, gas metal arc welding, flux core welding, submersible arc welding, mild steel, butt joint

1.0 INTRODUCTION

Welding was commonly used in joining because the material could stand longer in a period of time and one of the most important processes for joining or combination of metallic structures. Welding is the strongest types of joining, corrosion failures of weld created even the best base metal and filler metal have been selected, industry codes and standard have been followed and weld have been deposited that possess a full weld penetration and have the proper shape and contour [1].

Gas Metal Arc Welding (GMAW) also known as MIG for Metal Inert Gas were types of welding that used wire feed techniques that come out from handguns. The wire electrode was available in numerous coil capacities or spools dependent upon the welder sizing that may contain 100s and perhaps 1000s feet/meter of wire. It can also weld in metals in many metals and several thickness of material [2]. Flux Core Arc Welding (FCAW) consists of flux of the welding wire. This welding process was required wire feed spools and cable shielding gas may or may not use depending on the flux material in the core wire [3]. Submersible Arc welding (SAW) easily produces welds with good process control. For the SAW the used of material were limited. The material that been used were ferrous steels, stainless alloys and a few nickel based metals. It required low skill of welder due SAW welding system were automated and welders are quickly and easily trained. During this process, the flux dust was used [4]. Material that commonly used welding as the joining process is mild steel. Mild steel was very useful and versatile material in industry application because it has

good formability, good weld ability, and lowest cost and should be considered first.

Unfortunately, the corrosion was the crucial for any industry that used metal and using material such mild steel and added to the welding process make the situation worst. Mild steel is among the metal that has lowest corrosion resistance and welding joining that was affected by corrosion changes the microstructures thus decrease the strength of the joining. The microstructure may weaken due to corrosion. Corrosion occurs when material is removed from the surface and changed into rust.

There were many types of corrosion that occur in our daily life, such as uniform corrosion that occur because of the electrochemical process. It is a process of a metal reaction toward the environment and forms an oxide. Another type was galvanic corrosion or known as bimetallic corrosion where 2 different metals immersed in conducting environment which consequential to different corrosion potentials. The types regularly known were pitting, crevice corrosion, stress corrosion, hydrogen embrittlement and intergranular corrosion [3].

There are factors that contribute to the formation of corrosion such as exposure to the salt, air and water, material composition, dissolved oxygen content in fluid, pH level and fluid velocity characteristic. Corrosion was degradation of material properties due to interactions with their environments [2]. The different welding may have different rate of corrosion. In this study were focused into 4 types of welding which were Submersible Arc Welding (SAW), Flux Core Arc Welding (FCAW) and Gas. Weld Metal (WM), Parent Metal (PM) and Heat Affected Zone (HAZ) were the 3 section that available in the welding area.

2.0 EXPERIMENTAL PROCEDURE

2.1 Sample Preparation

The material used for this research was low carbon steel in the form of a plate of 6mm thickness plate x 150 length and 100 mm width with suitable V-groove butt joint preparation. Root face 1 mm and angle of 45^0 were used. During the welding process, the machine that been used was semi-automated gas metal arc welding. 3 types of welding were applied in this welding process; GMAW, SAW and FCAW. The specification of welding parameter as Table 1.

Table 1 Welding parameter of GMAW, SMAW and FCAW

Parameter	GMAW	SMAW	FCAW
Current	240A	140A	240A
Voltage	25V	28V	25V
Speed	6m/s	2m/s	6m/s

2.2 Experiment Preparation

Corrosion rate was determined through immersion test when weight before and after was taken. The specimen was soaked on the sodium chloride 3.0M NaCl, sea water and reverse osmosis (RO) solution with a different timeline of 10 days, 20 days and 30. Polarization observation was conducted using Gamry instrument. Corrosion rate was calculated with the formula :

Corrosion rate =

$$\frac{8.74 \times 10^4 \times (weight\ before - weight\ after)}{exposed\ surface\ area \times density of\ specimen \times time\ of\ exposure}$$

W=Weight loss (gram)

A= Total area of exposure (cm^2)
T = Exposure time in hours
g/mm^2/yr. = gram per square mm per year (corrosion rate units) [5]

3.0 RESULTS AND DISCUSSION

3.1 Macrostructure

From macrostructure observation in Table 2 it is shown the macrostructure test after immersion test A GMAW type was the most that contain of yellow rust then FCAW and SAW after 30 day exposed in different solution.

Table 2 Macrostructure observation of SMAW, SAW and FCAW immersed for 30 days in sea water, NaCl and RO water

	Types of welding		
	GMAW	**SAW**	**FCAW**
Immerse in Sea water			
Immerse in Sodium chloride (NaCl)			
Immerse in Reverse Osmosis (RO) water			

3.2 Immersion Test

Immersion test was conducted to observe the corrosion rate of the specimens. From the Figure 1, it showed the weight loss in sea water 3.0 M sodium chloride (NaCl) were higher than reverse osmosis (RO) due to differences of pH value.

The pH concentration was the one factor of decreased in corrosion rates of the specimens in the salt and alkali environment. The other factor may due to the increasing exposure time toward the electrochemical behaviour of different type of welding process in the different environments. Previous study shows that corrosion attack becomes slower due to alkaline environment. Higher value number of rate in alkalinity, the slower the chemical reaction of materials [5]. Corrosion was occurring due to reaction material and its surrounding.

The chemical reaction oxygen and water make the loss of electron. There are many factors that influencing corrosion of weld section such as incomplete weld penetration, improper choice of filler metal and etc. [6]. GMAW took the higher weight loss followed the FCAW and less was the SAW when specimens were exposed to the liquid environment in salt and alkali solution. Longer time taken of immersion donated to the increasing of weight loss. Metals in seawater corrode by releasing metal ions into the water around them. Different environment, acid and salt environment with increasing exposure time effect due to electrochemical behaviour. The weight will loss due the corrosion.

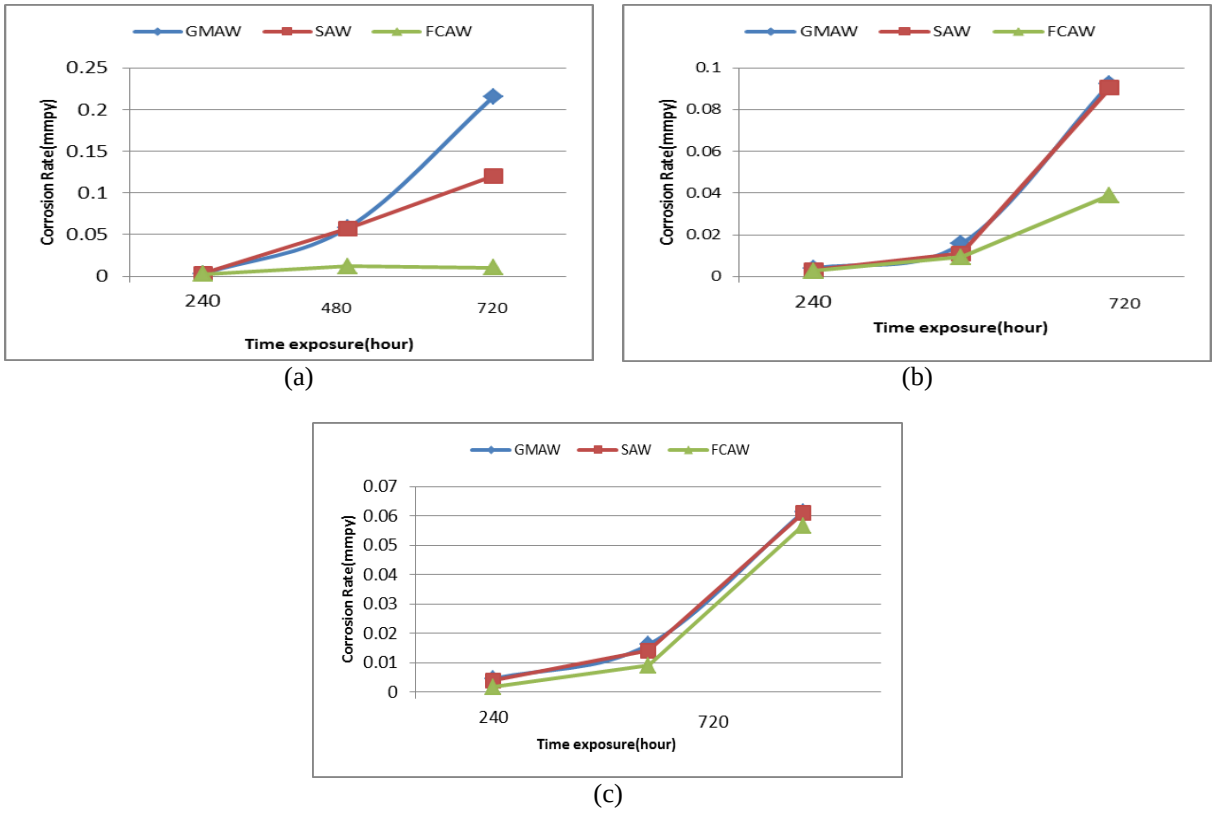


Figure 1 Cummulative weight loss with time of exposure: (a) sea water; (b) sodium chloride; (c) reverse osmosi (RO)water

3.3 Polarization Test

Polarization test was conducted to obtain the corrosion rate in polarization curved plot. There are three types of solution used in this weight loss measurement which were 3.0 M Sodium Chloride (NaCl), sea water and distilled water. For the 3.0 M Sodium Chloride (NaCl) was dissolved with distilled water.

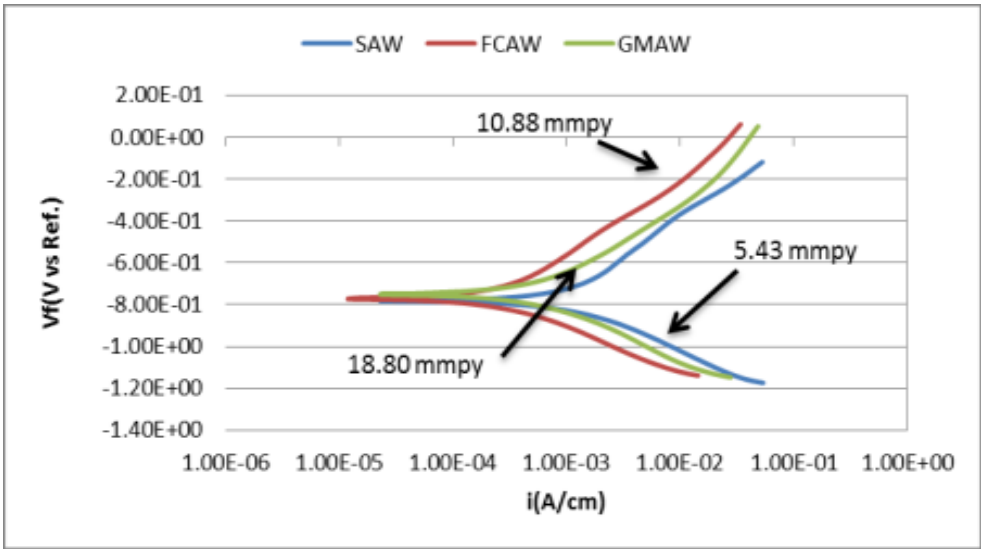


Figure 2 Polarization curves 3 types of welding (GMAW, SAW and FCAW) 3.0M NaCl at a scan rate of 0.5 mV/s

The polarisation test was conducted to determine chemical reaction of the materials with 3.0 M sodium chloride (NaCl) under room temperature. The result of tafel plot is shown in Figure 2. Through Tafel calculation and the result were obtained, GMAW has the least corrosion resistance among other types of welding with corrosion rate 18.80 mmpy followed by FCAW with corrosion rate 10.88 mmpy and SAW with corrosion rate 5.436 mmpy. In the joining the tendency of the intergranular corrosion was the limiting the lifetime of the weldments, localized corrosion like pitting has happened on the surface of the specimens immersed in a solution [4] and the dissimilarity of the material base and also the weld pair which lead to galvanic corrosion [9, 10]. Different types of welding process shifts different corrosion potential. The transition tends to move from lower to higher anodic potentials. The corrosion and passive current densities also increased by the different type of welding effect. This effect was aggravated by the increasing temperature [9].

4.0 CONCLUSION

- GMAW loss higher weight during the immersion test while SAW had the least loss weight and corrosion rate. Another contribution to the corrosion rate was the pH concentration between acidic, salt and alkali environment. The exposure time leads to the process of rusting metal from the chemical reaction oxygen and water make the loss of electrons.
- From polarization results, the rapid moved of the atom to move to a higher anodic potential make GMAW has the least corrosion resistance. The highest corrosion resistance was SAW.

Acknowledgement

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