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The evaluation of corrosion rate on welded specimen of low carbon steel

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Abstract

The aim of this work is to study the effect of welding on corrosion rate of low carbon steel in Sabha water. Some of the specimens welded by V joint and the other left without welding. The tests carried out on all the specimens are corrosion test. The corrosion media used in this study was Sabha water. The anti-corrosion paint that was used is undiluted AL- WAHA paint (from local market), according to the paint results, it was found that the drying time for AL- WAHA paint should be more than 24 hours when used without dilution. According to the visual observations, it was seen that the color of the all-exposed areas to the environment was changed to the dark red orange color. Also from the obtained results, it was found that the average corrosion rates for the unpainted heat affected zone areas (HAZ) are less than that for unpainted welded metal areas (fusion region) and higher than unpainted base metal areas for welded specimens, this is because the structure of the HAZ is changed to the carbide (cementite) which is hard and tend to be has more corrosion resistance than welded metal area (fusion region). Moreover, the average corrosion rate for non-welded specimen is less than that for unpainted base metal for welded specimens. Pitting corrosion and Galvanic corrosion were seen on the painted specimens, while, the type of corrosion of the non-welded specimens was uniform corrosion.

Keywords: *low carbon steel, welding, painting, Sebha water, corrosion rate.*

1. Introduction

Today, steel is one of the most commonly used material in the world. Steel is a crystalline alloy of iron, carbon and several other elements, which hardens above its critical temperature. Like stated above, there do exist several types of steels which are (among others) plain carbon steel, stainless steel, alloyed steel and tool steel [1]. Carbon steel is by far the most widely used kind of steel.

The properties of carbon steel depend primarily on the amount of carbon it contains. Most carbon steel has a carbon content of less than 2%. Carbon steel is made into a wide range of products, including structural beams, car bodies, kitchen appliances, and cans [1]. Containing carbon up to 0.35% responds to heat treatment as improvement in the ductility is concerned but has no effect in respect of its strength properties. Low carbon steel has carbon content of 0.025% to 0.35%. Low carbon steel is the most common form of steel as it provides material properties that are acceptable for many applications. It is neither externally brittle nor ductile due to its lower carbon content [2].

Corrosion is the destructive result of chemical reaction between a metal or metal alloy and environment. Metal atoms in nature are present in chemical compounds (i.e. mineral). The same amount of energy needed to extract metal from their minerals are emitted during the chemical reaction that the produce corrosion. Corrosion returns the metal to its combined state in chemical compounds that are similar corrosion has been called extractive metallurgy in reverse [3]. Electrochemical Corrosion occurs in liquids or electrolytes (conductors of electricity). Most liquids, such as ordinary water, seawater, acids, and other chemical are good conductors of electricity [3]. The corrosion reaction is the transfer of metal atoms from the solid to the solution where they exist as ions (i.e., $M \rightarrow M^{m+} + me$). Because there is a loss of electrons from the metal atom in this transfer, the metal has undergone oxidation. The oxidation is sustained by the consumption of the electrons by another reaction, generalized in this case as $X^{x+} + xe \rightarrow X$. The oxidation occurs at a site on the metal surface referred to as the anodic reaction site and is the location of the loss of metal by corrosion. Steel and galvanic steel have long been used to handle hot and cold fresh water. Dissolved oxygen, carbon dioxide, sulfides, and low **pH** all accelerate the attack of steel in fresh water. The corrosion products are usually oxides, hydroxides, or hydrated oxides of the metal components of the alloy in use [4].

Ismail et al [5] have studied the effect of oxygen concentration on corrosion rate of carbon steel in seawater and concluded that the corrosion rates are higher in solutions with oxygen content and the hardness properties of carbon steel reduced after corrosion attack significant to weight loss of the materials. Furthermore, the weight loss value and hardness reduced is directly proportional to corrosion rate.

A weld is made when separate pieces of material to be joined combine and form one piece when heated to a temperature high enough to cause softening or melting. Welding is used extensively in all sectors or manufacturing, from earth moving equipment to the aerospace industry [6]. The welded metal can be divided into three parts: the first part is base metal, heat affected zone, welded area (fusion area) as shown figure 1.

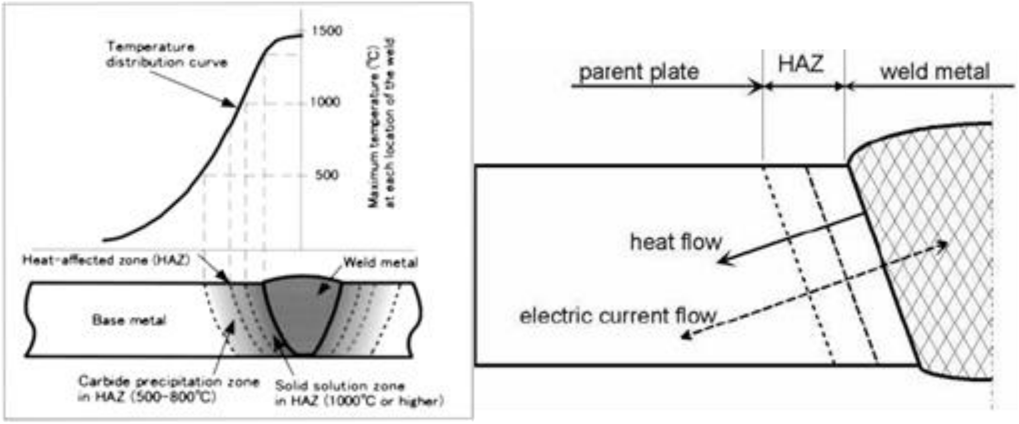

Figure 1. shows the fusion zone, zones of heat affected zone, and unaffected base metal

The concept of placing a protective barrier between materials and their environment is so ancient that its origin is lost in the mist of history. There are three main kinds or compositions of barriers: inert or essentially inert, inhibitive and sacrificial. Various combinations of these types are found in coatings systems designed to use some or all of the several protective advantages provided. Thus, practical coatings are a compromise between the maximum protection that can be extracted from a system and how much is available to pay for them. As the effective life of a coating system increases, its cost usually increases also [7].

Phosphate coatings on steel are produced by brushing or spraying onto a clean surface of steel, a cold or hot dilute manganese or zinc acid orthophosphate solution (e.g., ZnH_2PO_4 plus H_3PO_4). A fast dry coating is preferred because a slow dry coating will fail when humid conditions exist because of the absorption of water and pickup of airborne contamination, which would interfere with adhesion and reduce the resistance of the coating because the coating has not completely cured. A coating when applied should have at least 1.5 mils of dried film thickness per coat [8].

2. Experimental work

Materials

The material used in this work is carbon steel. Carbon steel is a steel with carbon range of 0.025% to 2%. The chemical composition for the material of the carbon steel that was used in the experiment was not available in the local market of Sebha and it was known from the market only that the material is carbon steel.

Coatings

The coating that was used in this work is AL- WAHA paints, its color is grey. Al-WAHA primer is modified alkyd resin-based single component metal primer formulated to contain zinc phosphate, an anti-corrosive pigment. The features of AL-WAHA paint are: suitable for protection of structure steel and corrosive environments, for exterior and interior use, can be over coated with alkyd, drying time 4 hours, exceptional resistance to extreme weather condition and strong abrasion, environment friendly, lead free, and color: (red, grey, and black).

Specimen preparation

Twenty-four (24) specimens were cut from metal sheet with dimension of 60 mm long, 10 mm width and 10 mm thickness as shown in figure (1-a), each specimen from the above specimens was cut from one edge with the angle of 45° as shown in figure (1-b). And another four (4) specimens also were cut from the same previous metal sheet with dimension of 120 mm long, 10 mm width and 10 mm thickness as shown in figure (1-c). All the surfaces of the specimens were ground with 80,400 and 1200 grit papers to remove oxide layer.

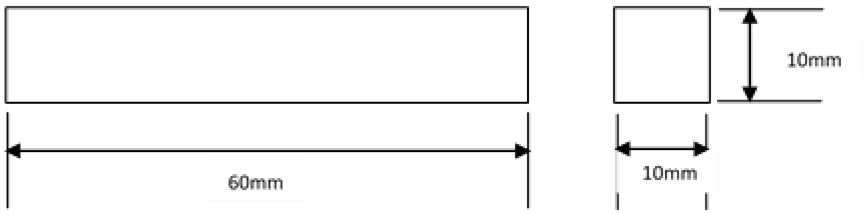

Figure 1-a. The dimensions of specimen

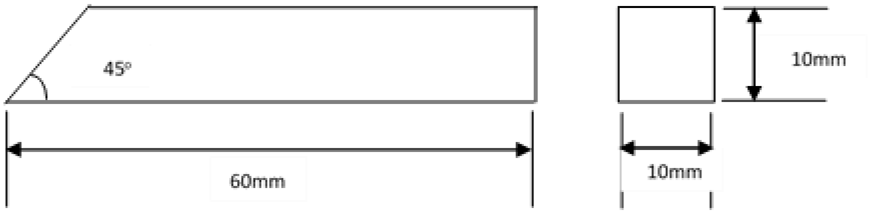

Figure 1-b. The dimensions of specimen

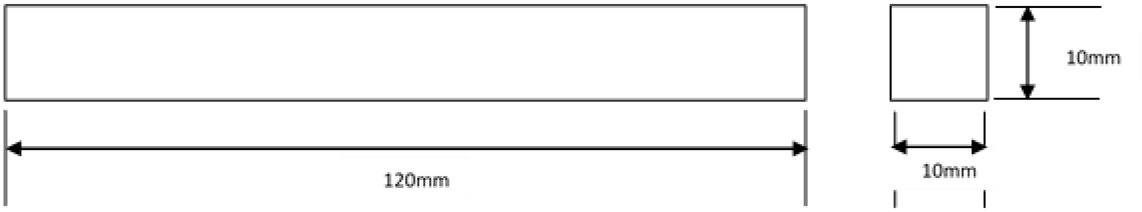

Figure 1-c. The dimensions of specimen

Every two specimens with dimension of 60 mm long, 10 mm width and 10 mm thickness were joined together by welding, by using electric arc welding technique, as shown in figure 2. Then the welded specimens were painted at different positions by using an anti-corrosion paint (Alwaha paint). The painted specimens were divided into three groups: the first group were painted except the welded areas, the second group were painted except the heat affected zone areas, and the third group were painted except the base metal areas, as shown in the following figure 3, 4, 5, respectively.

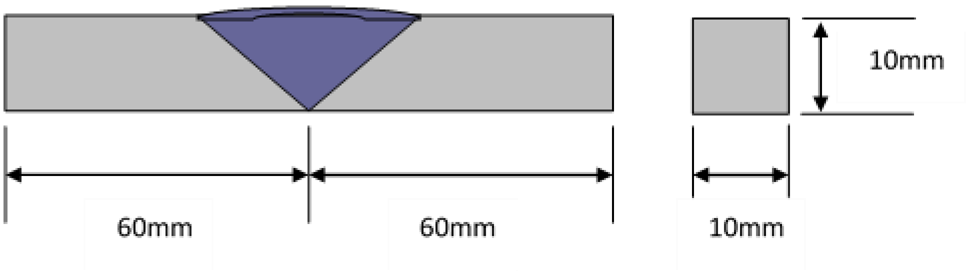

Figure 2. Shows sketch for the welded specimens

Figure 3. Shows the painted specimen except the welded area

Figure 4. Shows the painted specimen except the heat affected zone area

Figure 5. Shows the panted specimen except the base metal area

Corrosion test

The solution that was used in the experiments was Sebha's water, the following table (1) show the analysis of Sebha's water:

Table 1. Shows the analysis of Sebha water

Ph	8.26
Calcium	68 mg/L
Chlor	32 mg/L
TDS	1254 mg/L
Total Alkalinity (Talk)	15 mg/L
Conductivity (Ec)	2558 µs/cm
Salinity	1.3 ptt

There is no complicated equipment used in the experiments. The two letter flasks were used and filled by the Sebha water and then each specimen was vertically immersed separately inside one flask, all experiments were carried out at room temperature.

In order to predict the tendencies of water to precipitate or dissolve calcium carbonate, the Langelier Saturation Index (LSI) was designed to measure calcite formation and used as a measure of corrosion. Also, this index indicates the driving force for scale formation and growth in terms of pH as a master of variable.

In order to calculate the LSI, it is necessary to know the alkalinity (mg/L, as $CaCO_3$, or calcite), the calcium hardness (mg/L Ca^{+2} as calcium carbonate), the total dissolved solids (TDS) (mg/L TDS), the actual pH, and the temperature of water (^{o}C) [9].

LSI is defined as the following equation [9]:

LSI = pH - pHs …………(1)

Where:

pH is the measured water pH.

pHs is the pH at saturation in calcite or calcium carbonate and is defined as[9]:

pHs = (9.3+A+B) – (C+D) ……………………. (2)

$A=\{\log_{10}[TDS]-1\}/10$

$B=13.12\times\log_{10}(^{0}C+273)+(34.55)$

$C=\log_{10}[Ca^{++} \text{ as } CaCO_3]-[0.4]$

$D=\log_{10}[\text{alkalinity as } CaCO_3]$

The LSI indicates three situations [9]:

If LSI is negative: No potential to scale, the water will dissolve $CaCO_3$.

If LSI is positive: Scale can form and $CaCO_3$ precipitation may occur.

If LSI is close to zero: Borderline scale potential.

1. Results and Discussion

Corrosion test

Corrosion action on the test specimens were assessed by visual observations and corrosion rate measurement.

By using and calculating the Langelier Saturation Index (LSI), the result obtained is :

LSI = -0.761. According to this result obtained from the Langelier saturation index (LSI), it was found that the LSI for Sebha water samples is negative; this result indicates that no tendency to scale and the water will dissolve $CaCO_3$, also tend to be corrosive media.

The duration test for all the specimens was 33 days. After removing the welded and non-welded specimens from the water that was used in experiments, it was seen that from the visual observations, all the exposed areas of the specimens have gained new color (dark orange color) and the water has gained orange color, which is attributed to the color of the corrosion products. This is due to the chemical reaction that was done between the water and the surface of the specimens. Figure 6 shows the unpainted non welded specimens before the immersion and figure 7 after the immersion.

Figure 6. Shows the specimen before the immersion

Figure 7. Shows corrosion products on the specimen

According to the observations of the undiluted paint surfaces after the immersion as seen in the above figures (3-3, 3-4, and 3-5), it was found that there were a lot of bubbles appear on the paint surfaces, these bubbles were expected to be filled by water.

All the specimens were dried before weight.

(a)

(b)

Figure 3-3,a and b. Shows corrosion products on the welded areas of the welded specimens

Figure 3-4. Shows corrosion products on the heat affected zone of the welded specimens

Figure 3-5. Shows corrosion products on the base metal areas of the welded specimens

Table 2. Results of average corrosion rate for all the specimens

No.	Specimens	Average corrosion rate cm/year
1	Non welded specimens	**0.00565**
2	welded area of the welded specimens	**0.0252**
3	Heat affected zone of the welded specimens	**0.0147**
4	the base metal areas of the welded specimens	**0.0127**

From table 2, it is seen that the non-welded specimens, which not painted, have less average corrosion rate than the other welded specimens that were painted in different positions. Whereas, the corrosion rate of the painted specimens in different positions have different average corrosion rates. As can be seen from the average corrosion rates of the welded specimens that painted in different positions, it was found that the average corrosion rate of the heat affected zones (HAZ) have higher average corrosion rate than that of the base metal and less than that of the welded areas of the welded specimens (fusion regions), (i.e. the highest average corrosion rate is for the welded areas (fusion regions)). The weldment metal always appears to be anodic with respect to HAZ and base metal [10]. Also, the filler metals with composition different from the base material may produce electrochemical potential difference that makes some regions of the weldment more active [11]. This what was expected from the results obtained from the experiments in this work that show the average corrosion rate for the welded areas (fusion regions) more than the other areas. Moreover, there are some porosity and incomplete weld penetration or fusion were observed on the welded areas, which may effect on the corrosion of fusion area (or the filler metal) and this let these areas have more corrosion rate than the HAZ and base metal areas respectively. Also, may be the choice of the filler metal and the surface finish are not perfect and also some amount of impurities, these may effect on the corrosion of welded areas (fusion regions).

Conclusions

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1. Langelier saturation index (LSI) indicates that Sebha water is a corrosive media.
2. The colure of all the exposed areas of the specimens immersed in Sabha water was changed to the dark red orang colure.
3. The average corrosion rate of the heat affected zones (HAZ) have higher average corrosion rate than that of the base metal and less than that of welded areas of the welded specimens (fusion regions), (i.e. the highest average corrosion rate is for the welded areas "fusion regions").
4. The average corrosion rate of non-welded specimens is less than all the tested specimens in this work, this is because of the biggest areas belongs to the non-welded specimens compared with the other specimens.
5. The drying time for Al waha paint should be more than 24 hours when used without dilution.
6. The impurities, surface finish and the type of filler metal are effected on the corrosion process of the welded areas, this is the result of why these areas have higher corrosion rate than the others.

References

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[1]. Amstead, B., H, Ostwald P, F, Begeman M, L, (ed) (1987). "Manufacturing Process." John Wiley Publication Singapore.

[2]. Handbook, A. "from the Mauritius Standard Bureau- Moka) ".

[3]. Joseph F. Bosich, corrosion prevention for practicing engineers, Copyright©1970 by barnes and noble, Inc ISBN 389 01264 5**.**

[4]. W. E. Berry. NACE Basic corrosion course. corrosion by water and steam. Chapter 7. Copyrighted 1970. USA.

[5]. Corrosion Doctors, corrosion by water. (As viewed on 26/4/2016). http://www.corrosion-doctor.org/corrosion-by-water.htm.

[6]. Technology., W. s. a. (2007. ISBN 81-224-2073-7). "Md. Ibrahim Khan."

[7]. Norman E. Hamner. NACE Basic corrosion course. Coatings for corrosion protection. Chapter 7. Copyrighted 1970. USA.

[8]. Herbert H. Uhlig. Corrosion and corrosion control. second edition. Copyright © 1963, 1971, by John Wiley & Sons Inc.,USA. ISBN 0-471-89563-6.

[9]. Corrosion Doctors, corrosion by water. (As viewed on 26/12/2018). http://www.corrosion-doctor.org/corrosion-by-water.htm.

[10]. Lei Huang, Bruce Brown, Srdjan Nesic. Investigation of environmental effects on Intrinsic and galvanic corrosion on mild steel weldment in CO2 Environment. Corrosion 2014. Paper No. 4374. Texas. USA.

[11]. ASM International. corrosion of weldments. Chapter 1, Basic understanding of weld corrosion. www.asminternational.org (as seen on 21/1/2018).