An experiment study on corrosion rate variation of low welded carbon steel in a different solution

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Abstract. The corrosion reaction of low carbon steel alloy welded with different shape(V &X) method is investigated after relives stress by tempering at (600℃,) for (30)minute then specimens divided in three groups, first normalizing, the second group annealing, third group Quenching, all groups heated to(750℃,)then cooling with still air, in the furnace &water according to its heat treatment sort then immersed in three kind solution, acidic solution (0.5M HCl) basic(NaCl) & distal water for one month each (7days) take the weight to compute rate of corrosion in welded zone as weight loss.

Keywords: pitting corrosion, Heat treatment, Steel alloys Freshwater, Hydrochloric acid, and Metals.

1. Introduction

Corrosion is the interaction of metal or alloy with its corrosive environments. Welding affects the corrosion resistance of the metal even if a good metal filler usage; these places will be corroded in a different way. So which one of them will be corroded faster and easier is not clear depending on the difference in its chemical composition, structure, and retained stress. So that in order to have high corrosion- resistance, metal or alloy should have a structure consist of one phase type only if possible [1] Work environment contains a lot of corrosive media that lead to economic problems in the material its self or in equipment also it has a social problem because of toxic and inflammable chemical extract have an effect on the health. That caused to raise the costs.

The ore forms of metal in nature are oxide, sulfide, or metal compound except for gold that presents in metallic form. The process that aid metal to returned to this state is corrosion [2] Chloride ions effect the atmospheric corrosion rate of carbon steel specimen was studied. By taking specimen and cutting into dimensions (100× 45× 5 mm) Then exposed to (a different sea depth positions and industrial) environment. Using IR spectroscopy, SEM–EDAX analyses, linear polarization resistance and electrochemical impedance spectroscopy (EIS) to evaluate CL ions influence on the protective manner of the rust layers, the overcome showed that CL ion had an impacting factor on corrosion rate, also on the morphology and composition of the rust layer.[3]Temperature & acid concentration also have effect at corrosion rate for low carbon steel in a different concentration of HCL by using two ways mathematical and experimental methods using nonlinear regression method as a function of temperature and concentration obtain similarity in both methods.[4]
other research had been studied the behavior of heated welded low Carbone steel in different corrosive media (acidic, basic & distilled water solution) at room temperature the specimens were cut and weld by electric arc welding then subject to stress relieving and dividing to four groups to exposr each one to different sort of heat treat (annealing, normalizing & quenching) then immersed in corrosive media for twenty one day with checking their weight every 3 days. Regarding corrosion resistance in distilled water and low concentration basic solution, the annealed sample is the best while with a high concentration basic solution the quenched sample is the best, lastly, the normalized sample gives the best corrosion resistant in all different concentration of the acidic solution. [5] Or another one methods can be used to compute corrosion rate such as electrochemical techniques (acetic acid effect on the cathodic reaction). They recognize that acetic acid accelerates the cathodic reaction more than directly affecting the corrosion rate. When acetic acid dissociates on surface metal and give hydrogen ions that affect the cathodic reaction and it’s called buffering effect so with increasing hydrogen ion (lowering the PH ) then the charge transfer current increased and vice versa. [6] The method that’s used to join the metals also affects at its mechanical properties one of them is welding method that studied by Vuki Lazi et al they considered the hardness alteration affect at weld metal and heat-affected zone on mechanical properties of welded joints while quenching and tempering base material steel C45 (DIN EN 10083). Test results showed that the samples with hardness HV10 > 400 and tensile strength UTS > 600 MPa is useful only when the stress concentration is low (s>2) and when there are no residual stresses due to welding. [7] lastly, corrosion process has both harmful and useful effect on many fields. Harmful economically by raising the cost of the industrial products directly and indirectly while it’s useful in making the ultra-flat surface of silicon wafers in computer chips production and in the medical field when degrading special types of biopolymers [8]

The aim of this research is to study the influence of different solution media on the corrosion rate of low carbon steel samples after welding and heat treatment in a different method. And to learn about the importance of using right material in right application with understanding to the reasons that lead to product failure.

2. Methodology

Corrosion rate for all samples was computed by using the equation below

\[ C_R = \frac{k \Delta w}{A \times T \times \rho} \] ..(1)

\( C_R \) = Penetration (corrosion) rate (\( mm/\text{hour} \)), \( \Delta w \) = Weight change in gram, \( A \) = surface area of sample = circumference of square cross section - area of each sample \( \times \) length, \( \rho \) = Density of mild steel (\( g/cm^3 \)) = 7.86 \( g/cm^3 \), \( T \) = Time of exposure in hours, \( k \) = Constant for unit conversion = 8.76 \( \times 10^4 \).

The flow chart shows the procedures step by step that’s used to calculate the corrosion rate
The shape of the low carbon steel bar is square cross-section area, therefore, the surface area = 

\[ 4L \times L_1 + 2 \times L^2 \]

Firstly began the work by cutting the samples to have a dimension (10×10×100)mm in the workshop as shown in ‘figure 1’

![Figure 1. Cutting device.](image)

Then give the sample shape X with an angle (45°) and shape V with an angle (30°) as shown in ‘figure 2’.

![Figure 2. a-V shape  b-X shape.](image)

After that, the samples were pretreated using polishing with a sandpaper to remove any obstacle, dust, color, and oil, washed with distill water before alcohol then dried with hot air and peace of clean cloth,
the samples welded by RC welding method and surface cleaned to remove any flying spot during the work. All the three groups put in the furnace at (600°C) for (30 minutes) for tempering to relieve any internal stresses, then each group were heated to (750°C for 30 minutes) then cooled by still air in normalizing, in furnace after switch off in annealing or in water in quenching. The samples were cleaned again and weight them using sensitive electric balance present in the metallurgy lab in Al-Mustansiriyah university. Finally immersed in three different solutions (acid, base and distill water) leave them for one month with weekly interval weighting.

Table 1. Show the name of the symbols with heat treatment applied.

| symbols | Type of heat treat |
|---------|-------------------|
| A       | Annealing         |
| K       | Quenching         |
| Z       | Normalising       |

3. Result and discussion

Welded structure need precision select of metal, dimension, a method of fabrication to get the best efficiency of function with under certain predicted service life. So to get high quality of welded joints by selection of the adequate welding procedure and welding parameter, as well as performing mechanical and technological tests in order to determine the magnitude of strength and deformation of the base material and welded joints.

Low Carbone steel is easier to form in to certain shapes this make it quite versatile and easy to weld due to their simple composition but are prone to corrosion so when using in attack with environment that destructive this equipment so must be careful in select material, samples that used in this research were chemically tested in (Ministry of Science and Technology) as shown in (table 2). Heating and cooling during the welding make the region suffering thermal cycle. This process generates residual stress distribution locally. The amount of these stresses can undergo a high control. There were many factors can be contributed in the quality of welding process even with a complete process control welding area yield to corrosion without expecting which area (base or weld metal) start to corrode.

Table 2. Show the chemical composition of low carbon steel used in research

| Elements | C% | Si%  | Mn% | P%  | S%  | Cr% | Mo% | Ni% | Al% | Cu% | Fe% |
|----------|----|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Ratio%   | 0.196 | 0.173 | 0.568 | 0.013 | 0.040 | 0.116 | 0.006 | 0.093 | 0.007 | 0.321 | Bal |

When the hardness be measured at HAZ (v-welded) method give the best than the (x-welded) and this can be seen in the (table 3&4) and this is one of the factors affecting the welding quality.

Table 3. Hardness to the sample v- welded method.

| Samples   | Hardness                      |
|-----------|-------------------------------|
| Without weld | 105.29R…304.3V….103.35R…274.1V…105.92R…309.4V |
| With weld  | 103.1R…302.8V…..107.62R…323V……107.3R…320.6V  |
K 103.01R…272.1V….110.15R364.3V……107.48R…321.8V
Z 96.84R…229.4V……96.45R…227.8V…99.56R…250.8V
A 102.91R…271.5V…95.34R…218.3V….103.33R…274.1V

| Samples | Hardness |
|---------|----------|
| With weld | 93.15R…208.6V…..106.21R...311.7V……107.43R….321.4V |
| K | 99.71R…251.5V……106.12R…310.9V…104.66R...290.6V |
| Z | 94.17R…213.9V……101.11R…260.8V…95.53R…219.1V |
| A | 97.57R…236.3V……101.84R…265.1V….100.68R...258.1V |

Table 4. Hardness to the sample X- welded method.

corrosions’ rate in acidic solution is greater and faster because of presence of (Cl⁻) ion that accelerates the corrosion reaction but ratio decreased with increase time as shown in ‘figure 3 and 6’ while in ‘figure 5 and 8’ basic solution corrosion rate take the same acidic behavior but with less ratio, finally in ‘figure 4 and 7’ distill water solution the metal reverse its behavior in which start without reaction but increased progressively.

Figure 3. Corrosion rate for V-welded in 0.5MHCL.

Figure 4. Corrosion rate for V-welded in distill water.
Figure 5. Corrosion rate for V-welded in base.

Figure 6. Corrosion rate for X-welded in 0.5MHCL.

Figure 7. Corrosion rate for X-welded in distill water.
Welding methods have an important role in corrosion rate in which X-welding method give more corrosion rate than V- method because many welding factors interfere with the quality of the product. And this can be seen clearly in ‘figure 10, 11&12’.

Figure 8. Corrosion rate for X-welded in base.

Figure 9. Show microstructure before immersing in sample a-without welded b- V-welded c-X-welded.

Figure 10. Microstructures after immersing in HCL solution with different heat treatment a-annealing b-quenching c-normalizing all samples V-welded method.
Figure 11: Microstructures after immersing in HCL solution with different heat treatment a: annealing b: quenching c: normalizing all samples X-welded method.

4. Conclusion
Hardness measurement gives the best result in V- than X-welded samples regarding to the method of welding while with heat treatment method hardness give good improvement with quenching then annealing and lastly normalizing but corrosion rate decreased in all three different solutions that’s used.

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