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PROTECTION LOW CARBON STEEL FROM CORROSION USING COATING PROCESS

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Abstract: In this research work, samples of low carbon steel AISI 1017 subjected to shot peening process for 15 minutes. These samples were cleaned and coated with epoxy. The coating process were carried out with epoxy, epoxy mixed with alumina powder, epoxy mixed with silicon carbide powder and the last case, the steel coated with epoxy mixed with alumina and silicon carbide powders. Results showed that the corrosion resistance of steel coated with epoxy and alumina were better as compared with other samples .

Keywords: *carbon steel, corrosion resistance, coating.*

1. Introduction

Most metals interaction with surroundings. This interaction makes an effect on the material appearance and causes damage in the material and change the mechanical and physical properties. In metals, there is loss in material due to oxidation or corrosion [1, 2]. Corrosion is the result of the deterioration of metals due to reversers' interaction with surrounding environment (corrosion media) [3, 4]. The free energy of oxidation is the driving force for material to oxidize [5, 6]. Pitting corrosion is one of the types which corrode the steel and regarded a localized type of corrosion, where holes or cavities are generated in the surface of material as illustrated in figure (1). The damage caused via pitting is beheld more severe than that cause via uniform kind of corrosion because it is harder to predict and design system against it. The pits are often covered with the products of corrosion, these pits usually narrow and small on the surface and if there is overall loss in metal, this perhaps can lead to the failure of the system. Mouth open pits can be generated via pitting corrosion and it may be covered or uncovered with products of corrosion (semipermeable). Pits shape can be either cup shaped or hemispherical but in some cases it may be regular walled or have unequal shape.

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This type of corrosion happens when separated areas of a metal are subjected to rapid attack while the other near areas remains unaffected. Pitting corrosion probably has the same mechanism of crevice corrosion, where oxidation process happens inside the pit itself with totally reduction at the metal surface. Pits perhaps initiated via a defect at the surface like a small change in composition or scratch [7, 8].

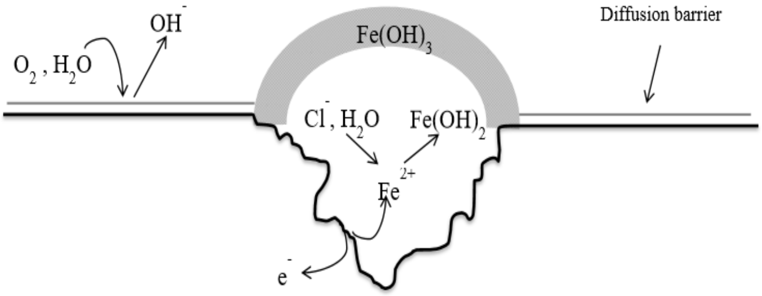

Figure 1. Growth of pit on the surface on iron [9]

Steel is an engineering material; it has a wide range of applications. It is used in automobile and in machines components [10, 11]. Steel with carbon content of 0.15 % to 0.35 % is called low carbon steel. This type of steel has many applications and it has lower tensile strength and is malleable due to lower content of carbon [12, 13]. Coating is one of methods which were used to protect the steel from corrosion problem [14], coating prevents corrosion via one of the three main mechanisms or via two of them, and these are:

1. Cathodic protection, where the coating on the metal acts as a sacrificial anode.
2. Barrier influence, where any contact between metal and corrosive medium is prevented.
3. Passivation/Inhibition, where it is act as an anodic protection [15].

Selected coating material shall be suitable for the purpose that it was used to and it should be provide the following aspect:

1. Protection against corrosion.
2. Requirements to safety, environment and health.
3. Economics and availability of coating materials [16].

Paint with epoxy is one of coating types, and it consists of two main constituent, these were:

1. The binder, it is usually oil or resins but it may be inorganic compounds.
2. The solvent, it is used either as a dispersant to facilitate application of the paint or used to dissolved the binder or the solvents are usually water or organic.
3. The pigments, are finally ground and it perhaps organic or inorganic powders which provide a film cohesion, color and as a corrosion inhibition.

Film formation occurs when the solvent evaporates and leaving the pigments and binder on the surface as a dry film [17].

2. Electrochemical impedance spectroscopy (EIS) test

Electrochemical impedance spectroscopy (EIS) is utilizes a small amplitude and rotating current (AC) sign to test the impedance qualities of a cell. The AC sign is looked over a wide scope of frequencies to create an impedance range for the electrochemical cell under test. EIS varies from direct current (DC) strategies in that it permits the investigation of capacitive, inductive, and dispersion procedures occurring in the electrochemical cell. EIS has extensive applications including coatings, batteries, power devices, photovoltaic, sensors, and organic chemistry [18].

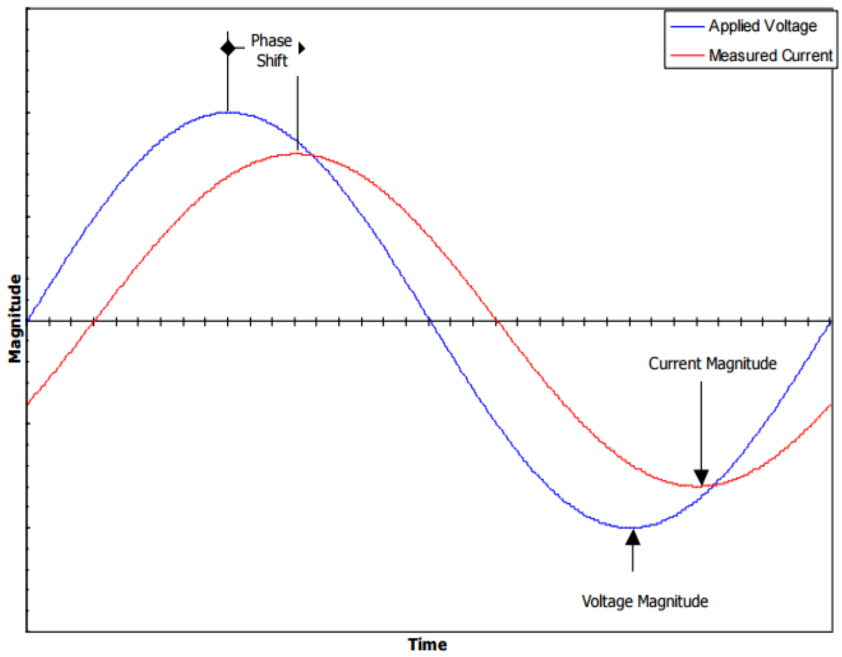

Figure 2. Excitation and Response in EIS

3. Characteristics of EIS

The characteristics of EIS consist from the following points:

1. An (AC) current of an explicit frequency in Hertz. ($\frac{\text{cycles}}{\text{seconds}}$).

Impedance: $Z\omega = \frac{E\omega}{I\omega}$ (1)

$I\omega$ = Frequency-dependent potential

$E\omega$= Frequency-dependent current

Ohm's law $R = \frac{E}{I}$ (2)

Where, R= impedance at the limit of zero frequency

2. Data substance of EIS is a lot higher than DC strategies or single recurrence estimations.
3. EIS might almost certainly recognize at least two electrochemical responses occurring.
4. EIS can distinguish dissemination restricted responses.

5. EIS gives data on the capacitive conduct of the framework.
6. EIS can test parts inside a collected gadget utilizing the gadget's very own anodes [19].

4. Experimental Procedure that used in this Research

Low carbon steel AISI 1017 was an alloy, first the samples subjected to stress relive by heating it in furnace for three hour at 200ºC, then the samples subjected to shot peening operation to give the surface some roughness before painting with epoxy. The sample was very small to make the shot peening operation on it because it may be stuffed inside the room of shot peening, so they held on a piece of wood to give it volume inside the room of shot peening as indicated in figure (3) and then placed in the devise as indicated in figure (4), where it was subjected to shot with a steel balls have a size of 1mm for 15 minutes.

Figure 3. Hold the steel samples on the wood before shot peening

Shot peening give many improvement in many properties of the steel, such as improve fatigue resistance, wear resistance in addition to improve surface hardness of the steel. This improvement is due to the effect of compressive residual stresses which generate from hitting the samples with the steel balls.

Figure 4. Shot peening device

After shot peening operation, the samples were cleaned with acetone and then prepared to paint with epoxy. Coating the samples with epoxy were done by using four cases as indicated in figure (5), these were:

1. Coating with epoxy.
2. Coating with epoxy mixed with alumina powder.
3. Coating with epoxy mixed with silicon carbide powder.
4. Coating with epoxy mixed with silicon carbide and alumina powder.

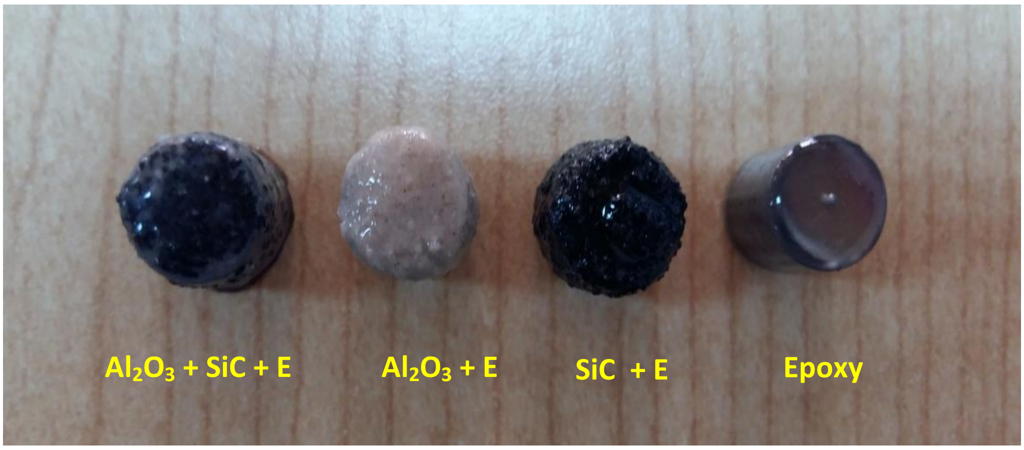

Figure 5. Coated samples

4.1. Corrosive medium

Sample of water from Tharthar regulator (Iraq) was used as corrosive medium after coating operation for steel AISI 1017 because the gate of regulator are made from this alloy and to protect it against corrosion it was coated with epoxy. In this research the epoxy was mixed with different powder to show if this adding materials will improve the corrosion resistance and thus prolong the life of the regulator gate, this water contain medium amount of salt and the chemical composition of this water before and after corrosion test were explained in table (1) and it was evident that the first seven parameter was the reason in corroding operation.

Table 1. Chemical analysis for water sample

Type of Analysis	Before corrosion	After corrosion
pH	7.86	7.7
EC (μs/Cm)	146	180
T.D.S (mg/l)	1040	1117
Ca^{+2} (mg/l)	196	213
Cl^{-} (mg/l)	85.2	96
HCO_3^{-} (mg/l)	73.2	90
SO_4^{2-} (mg/l)	528	597
NO_3^{-} (mg/l)	2	2
CO_3^{2-} (mg/l)	0	0

4.2. *Electrochemical Impedance Spectroscopy tests results*

Electrochemical Impedance Spectroscopy is a dominant technique to estimate for short times the behavior of corroding material electrically. EIS method can give increasingly quantitative data contrasted with the established maturing tests. This technique needs control of the working conditions. Besides the translation of the outcomes needs a proper decision of the electrical comparable circuits to clarify the framework under examination. Figure (6) shows the Nyquist of the EIS scan to sample of low carbon steel in water sample from Tharthar regulator with and without coating the steel at room temperature it shows that the resistance range of the coated steel in the salt water medium was more than the low carbon steel without adding coating which means that the resistance which depends on the temperature, type of ions, ionic concentration and the geometry of the sample area will blocking electrons from passing and thus reducing amount of current and hence the current flow decreased which means that the corrosion rate decreased too. The resistance of the steel coated with epoxy mixed with alumina has the better results in addition to the improvement with other type of powder that it was added to the epoxy.

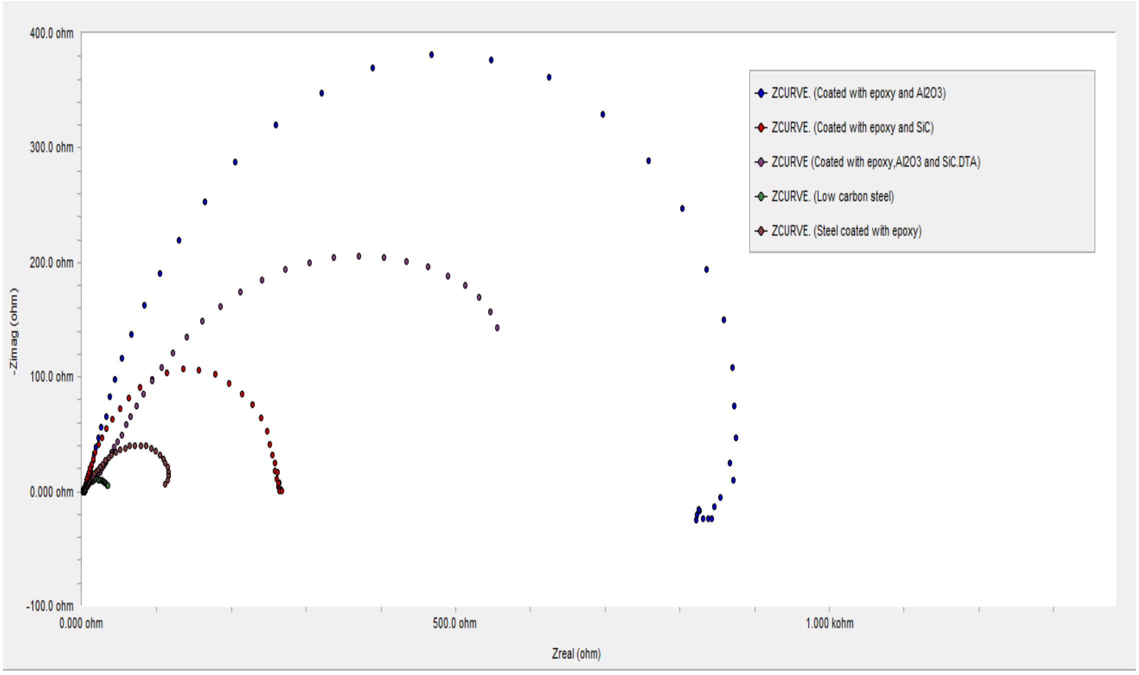

Figure 6. Nyquist plot of EIS scan for uncoated and coated samples in water sample from tharthar regulator

Bode plot which clarifying the impedance and the phase angle was explained in figure (7), Impedance is a measure of the ability of a circuit to resist the flow of electrical current it's unlike resistance, the impedance for coated samples were more than the impedance of the uncoated sample which means coated samples having a high resistance to salt water compared with the resistance of steel without coating.

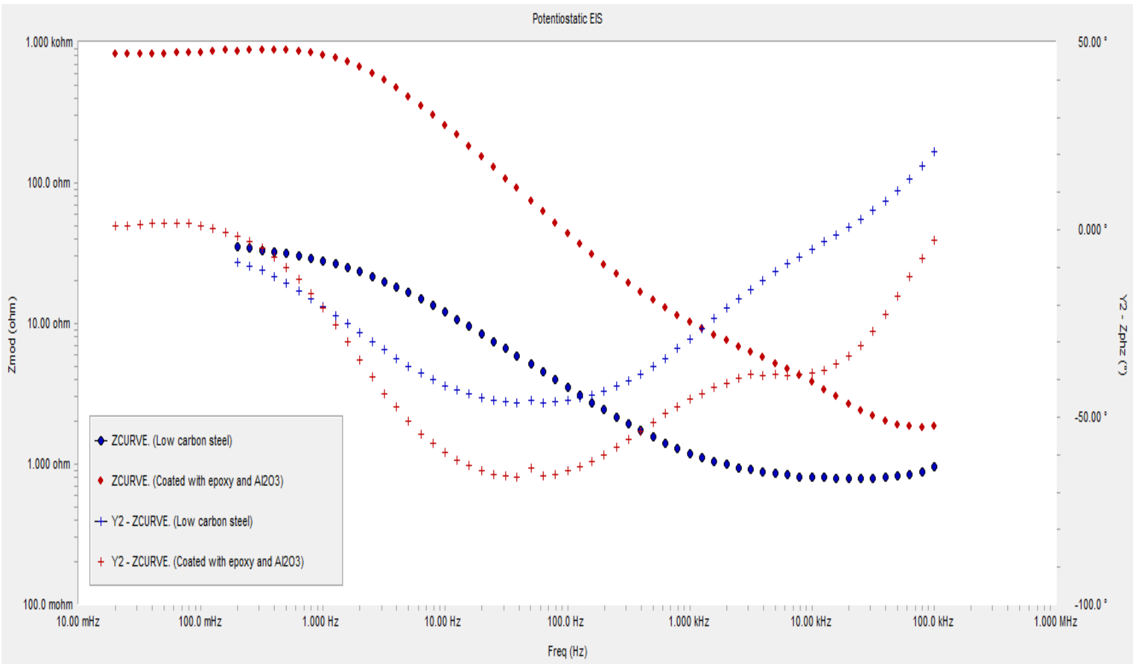

Figure 7. Bode plot of EIS scan for uncoated and coated samples with epoxy and alumina which have the better resistance in water sample from tharthar regulator

5. Conclusions

Present epoxy on the surface of low steel carbon steel prolong its life and to improve that further, mixing alumina powder, silicon carbide powder, alumina and silicon carbide powder with epoxy will improve corrosion resistance largely. EIS test was done to improve corrosion resistance of the steel in sample of water from Tharthar regulator and the results exhibited that all adding material prolong the life of the steel but better results was for the sample coated with epoxy and alumina which has the better corrosion resistance compared with the other samples.

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