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Effect of the Heat Treatment on the Corrosion Behavior of the Duplex and 304 Stainless Steels

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Abstract
For some components in some nuclear reactors such as boiling water reactors (BWRs) made of austenitic stainless steel; For example recirculating tubes, primary internal parts and some reactor pressure vessel parts such as flow control device housings and control rod stub tubes, corrosion has been a significant deterioration mechanism with age. The effect of heat treatment on the corrosion behavior of the duplex and 304 stainless steels in 3 % NaCl solution was studied in this work. The duplex and 304 stainless steels samples were heated at 1100 ^{0}C astonished temperatures for 60 minutes and water quenching. After that , the samples were heated at 700 ^{0}C for 1,2 and 3 hour. These samples were then immersed in 3 % NaCl solution. The results show that the optimum condition at 1100 ^{0}C austenized temperature /1h quenching water and was heated at 700 ^{0}C /3h.
Keywords: *Environmental Engineering - Materials Engineering – Corrosion- Stainless steel*

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I. Introduction

There are many metallic alloys, non-metallic materials and other components in various nuclear reactors. Many cases of corrosion crack damage in BWRs have been reported in many countries in the world. One of the main reasons for such damage was the occurrence of corrosion that had not been considered in the original design of the BWRs.

Steel is one of the alloys that has great tensile strength, and this makes it resistant to breakage and becomes suitable in construction and Infrastructure [1]. Steel is also characterized by the strength of ductility, which gives an appropriate level of ability to control and change the shape of steel when exposed to pressure or external force, and as a result, steel becomes suitable for use when making different shapes or structures, as well as many other uses [2,3] . Good strength and toughness, making it resistant to pressure as well as external corrosion [4]. Steel is good for heat and electricity, and this property makes it very important and necessary for the manufacture of utensils and electrical wires[5]. Steel becomes resistant to rust, when certain elements are added to its manufacture that make it resistant to corrosion[6,7].

Stainless steel alloy contains at least 12% chromium. It has a high corrosion resistance as a negative film of chromium oxide is formed on the surface. However, a greater proportion of chromium is added to the alloy in order to resist corrosion in chemical media that attack the surface of the stainless steel, [8]. Other alloying elements such as nickel, molybdenum, titanium, manganese, nitrogen and other elements are also added to greatly increase resistance to various forms of corrosion. And also to strengthen the mechanical properties and weldability without decreasing corrosion resistance [9,10]. Stainless steel consists of 5 groups: ferritic, austenitic, martensitic and duplex stainless steels, and precipitation-hardening stainless steels, based on their microstructure [11]. Stainless steel 304 has a chromium hardness of 18% and a fine nickel luster of 8%, and is considered best in most applications such as the production of kitchen sinks, worktops, food processing equipment and other equipment that is regularly exposed to corrosive environments. In general, 304 steel is the first consideration for purchasing sanitary stainless steel products. Duplex stainless steel (DSS) has a microstructure consisting of ferrite and austenite in approximately equal proportions and exhibits better corrosion resistance and mechanical properties compared to single-phase steels [12] In this research paper, some heat treatments are done on stainless steel in order to improve the mechanical properties and corrosion resistance for both stainless steel alloy 304 and duplex.

The purpose of this research is to improve the performance of steel alloy used in nuclear reactors by studying the effect of corrosion in some types of stainless steel after some heat treatments.

II. EXPERIMENTAL WORK

2.1 Material and Methods

Tables 1and 2 illustrate Chemical Composition of both 304 and duplex stainless steel alloy

Table (1) illustrate Chemical Composition of 304 stainless steel alloy

SS 304	Cr %	Ni %	Mn %	Si %	% C	N %	Ti %	Others %	Fe
	18	8	2	1	0.05	0.0007	0.01	0.03	Balance

Table (2) illustrate Chemical Composition of duplex stainless steel alloy

SS dup	Cr %	Ni %	Mo %	Cu %	% C	N %	W %	Others %	Fe
	25	7	3.5	1.5	0.05	0.0003	1.5	0.05	Balance

2.2. Heat Treatment

The duplex and 304 stainless steels samples were heated at 1100 ^{0}C astonished temperatures for 60 minutes and water quenching. After that , the samples were heated at 700 ^{0}C for 1,2 and 3 hour.

2.3 Electrochemical Corrosion testing

Samples were processed on SiC milling sheets left over from 220 to 1000 degrees, followed by polishing the coated cloth with 1 µm of suspended diamond. Then, grease and oils were removed with ethanol before being placed in the corrosion test solution in order to study the electrochemical corrosion behavior of the samples. The dynamic active polarization technique was applied using a potentiostat connected to a computer. Using the IMX8 the system computer is a critical component of the system. It controls the IMX8 by sending it simple commands through a USB connection.The most important function of these commands is to select which cell is active (connected to the system potentiostat). You can think of an IMX8 as a complex switch. One of the eight-cell cables on the IMX8 is switched so that it connects to the potentiostat's cell cable. All of the wires (including sense leads and shields) in the cell cable are switched. Other commands select the IMXB's control mode for the cells that are inactive (not presently connected to the potentiostat).

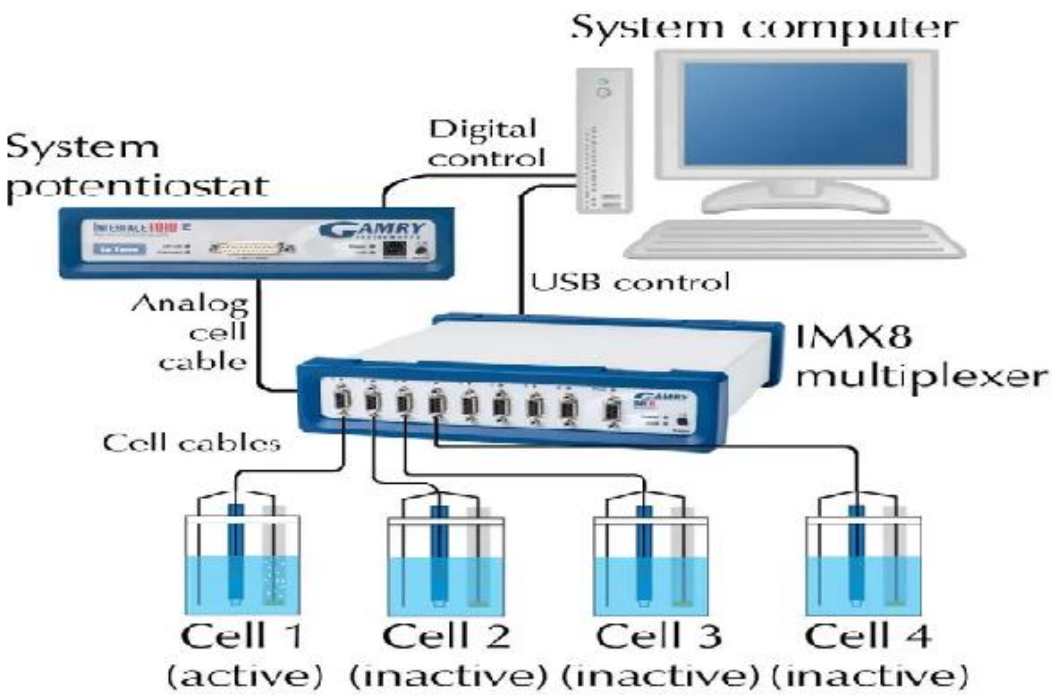

Figure 2 A Typical Electrochemical Test System **(R)**

III. Results and Discussion

Fig.1 show the microstructure features of (x200) (a) duplex stainless steels (b) stainless steels 304 samples were heated at 1100 ^{0}C astonished temperatures for 60 minutes and water quenching. After that , the samples were heated at 700 ^{0}C for 2 hour, then a corrosion test was performed on the samples**.**

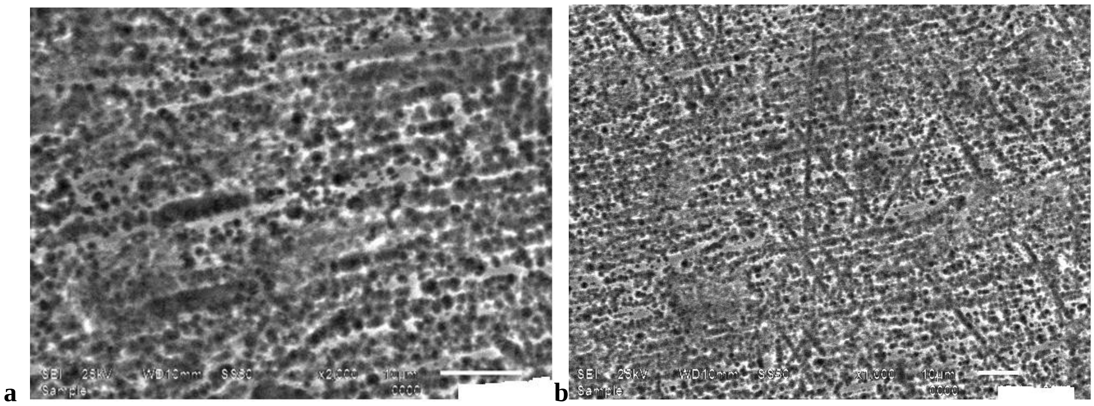

Fig.1 show the microstructure features after corrosion test of (x200) (a) duplex stainless steels (b) stainless steels 304

Fig (2) shows the anodic polarization curve for SS304 were heated at 1100 ^{0}C astonished temperatures for 60 minutes and water quenching. After that heat treated for 1 hr at 700 ºC , the corrosion potential is- 213 mv and current density 41.5 nA/cm2 , and the hardness is 257 Hv at 300 g load.

Fig (3) shows the anodic polarization curve for SS304 heat treated for 2 hr at 700 ºC , the corrosion potential is-246 mv and current density 184 nA/cm2 , and the hardness is 261 Hv at 300 g load.

Fig (4) shows the anodic polarization curve for SS304 heat treated for 3 hr at 700 ºC , the corrosion potential is-561 mv and current density 751 nA/cm2 , and the hardness is 268 Hv at 300 g load.

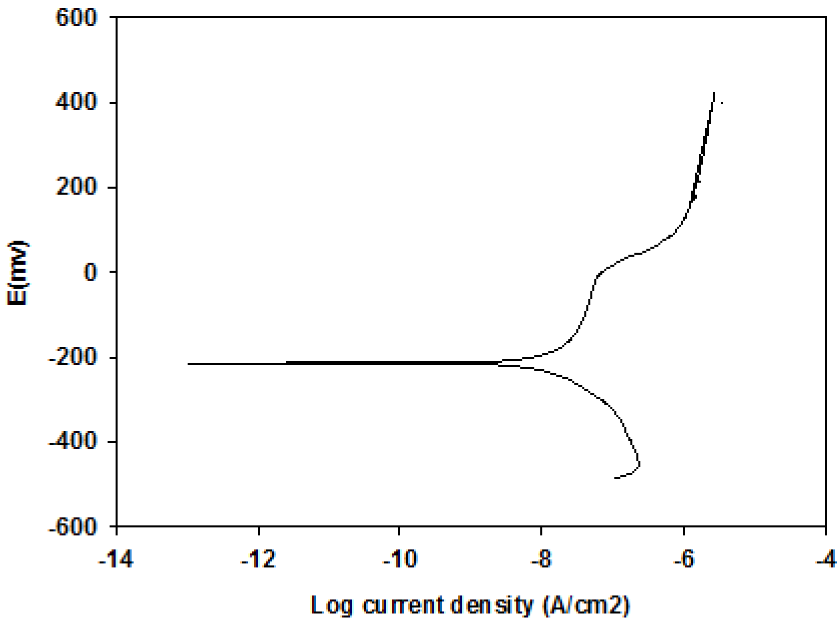

Fig.2 Anodic polarization curve of SS304 heat treated for 1 hr at 700 ºC

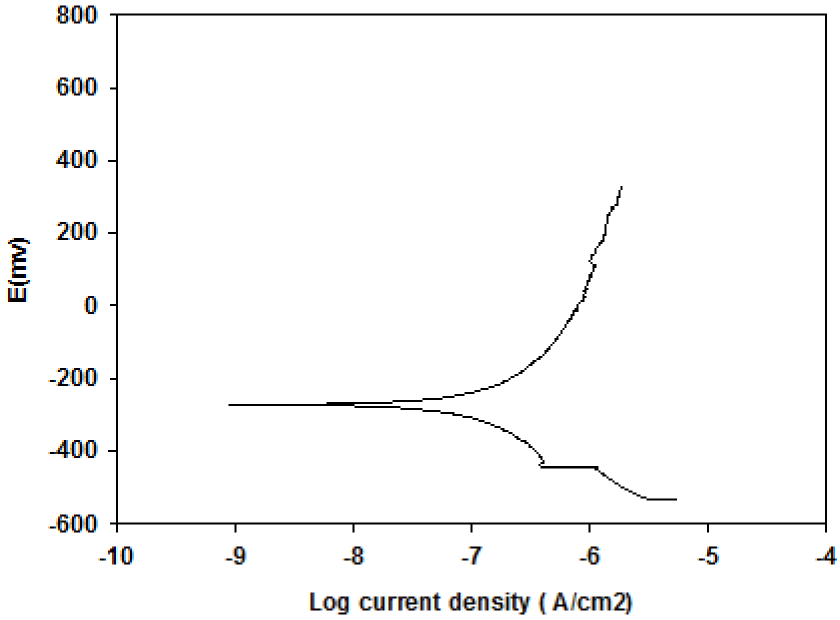

Fig.3 Anodic polarization curve of SS304 heat treated for 2 hr at 700 ºC

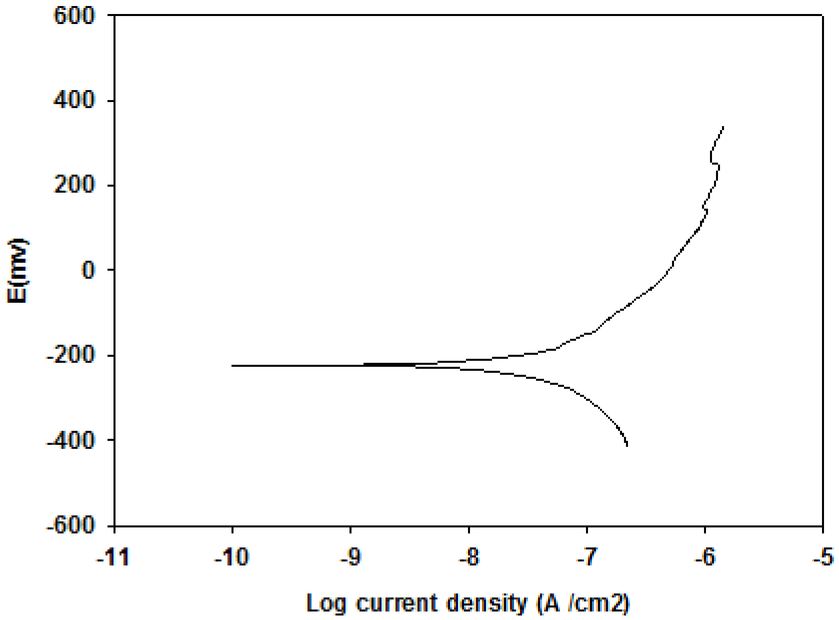

Fig.4 Anodic polarization curve of SS304 heat treated for 3 hr at 700 ºC

Fig (5) shows the anodic polarization curve for duplex stainless steel were heated at 1100 ^{0}C astonished temperatures for 60 minutes and water quenching. After that heat treated for 1 hr at 700 ºC , the corrosion potential is- 245 mv and current density 250 nA/cm2 , and the hardness is 224 Hv at 300 g load.

Fig (6) shows the anodic polarization curve for duplex stainless steel heat treated for 2 hr at 700 ºC , the corrosion potential is- 267 mv and current density 49 nA/cm2 , and the hardness is 240 Hv at 300 g load.

Fig (7) shows the anodic polarization curve for duplex stainless steel heat treated for 3 hr at 700 ºC , the corrosion potential is- 275 mv and current density 27 nA/cm2 , and the hardness is 247 Hv at 300 g load.

We find that duplex stainless steel has high mechanical properties, as well as corrosion properties, especially pitting corrosion, stress corrosion, and intergranular corrosion, which are of great importance in the properties of the alloy. The behavior of DSS in many corrosive environments is similar or superior to that of austenitic steels containing similar additions of chromium and molybdenum. Erosion pits are perhaps the most detrimental because wear pits often provide starting sites for fatigue cracks and stress corrosion cracks[13,14].

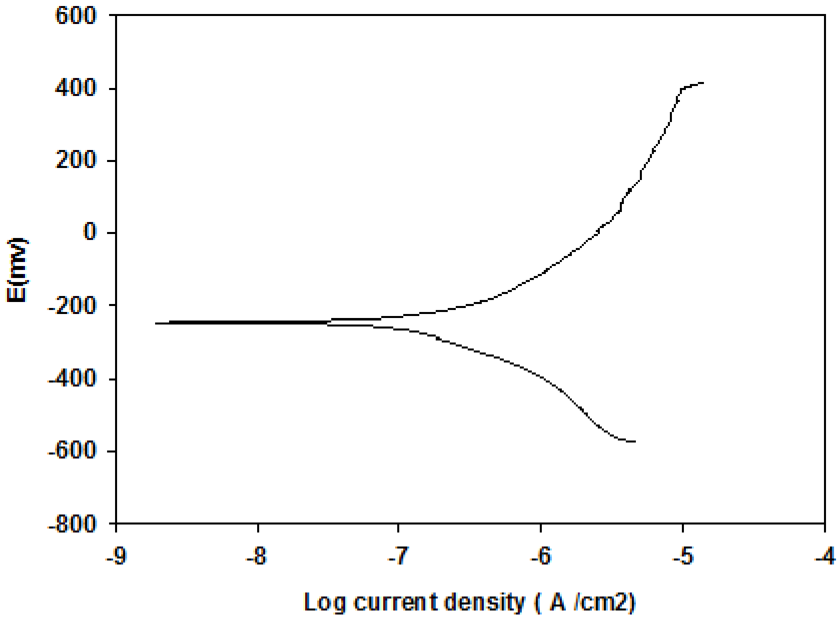

Fig.5 Anodic polarization curve of duplex SS heat treated for 1 hr at 700 ºC

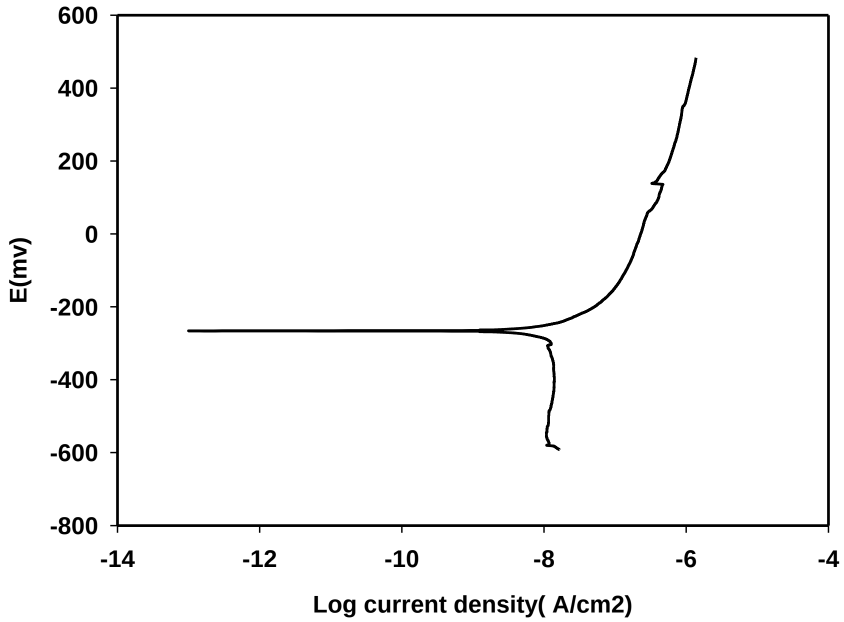

Fig.6 Anodic polarization curve of duplex SS heat treated for 2 hr at 700 ºC

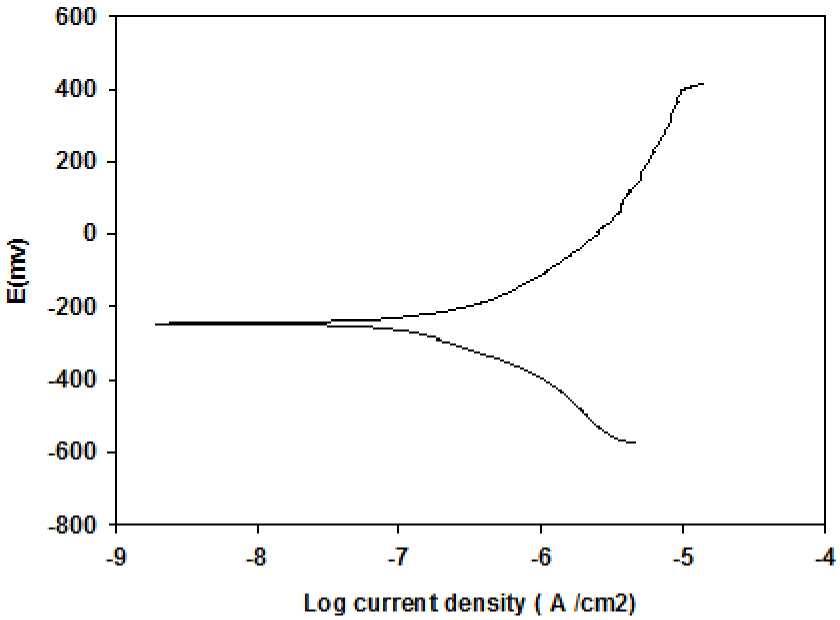

Fig.7 Anodic polarization curve of duplex SS heat treated for 3 hr at 700 ºC

IV. Conclusion

The duplex and 304 stainless sheets of steel samples ara heat-treated and immersed in corrosion solution, the results show that the optimum condition at 1100 ^{0}C customized temperature /1h quenching water and was heated at 700 ^{0}C /3h, the corrosion current density was Icorr= 751 n A/cm 2 and Ecorr=-561 mv in samples of SS304 while the corrosion current density was Icorr= 250 n A/cm 2 and Ecorr=-245 mv in samples of duplex stainless steel (DSS) at 1h/7000C, corrosion of both types of SS samples increased with an increase in time and this was due to the precipitation of chromium carbides at the grain boundaries of these metals.

Therefore, it was inevitable to combine efforts to cooperate in a fruitful manner with the specialty of (materials engineering) to reach an improved and good environmental design as a result of reaching, through practical experiments, an effective solution to the problem of rust, which may cause an unaccounted risk of radioactive leakage.

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