Application Electrochemical Impedance Spectroscopy Methods to Evaluation Corrosion Behavior of Stainless steels 304 in Nanofluids Media

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Abstract. Corrosion is a common problem in many engineering metals and alloys. Electrochemical methods are commonly instrument to use as tool to study the corrosion behavior of the metals and alloy. This method was examined interaction between a surface of the metals and alloys in corrosive media. The present paper, the effects of nano particle ZrO2 as an additive to aqua de mineralized on the corrosion behavior of stainless steel were investigated. Electrochemical impedance spectroscopy (EIS) testing was performed in both de mineralized water and demineralized water contain nano particle 0,01% ZrO2 as Nano fluid. Surface morphology examination of the specimens showed that microstructure of stainless steel 304 alloys relatively unchanged after corrosion and EIS testing. According to the corrosion potential examination of the stainless steel 304 in nanofluid media, it showed that stainless steel 304 actively corroded in nanofluid media. The value of anodic Tafel slope stainless steel 304 in nanofluid higher compare with in demineralized water. Tafel polarization examination show that corrosion rate of stainless steel 304 in nanofluid higher compare with corrosion rate in demineralized media.EIS technique show that impedance of stainless steel 304 in nanofluid lower compare with in demineralized media, resulting in an increase in the corrosion rates of these stainless steel 304 specimens in nano fluids

1. Introduction
Electrochemical impedance spectroscopy (EIS) is a technique commonly used for studying corrosion of metal and alloy in environment system. A majority of the experiments apply small amplitude perturbation to measure the impedance as a function of frequency and the analyses employ linearization of the equations [1,2]. EIS is non destructive testing to observe changes in the surface electrode as a function with time. Basically, EIS measures the electrochemical response to a minute AC voltage applied at different number frequencies. This electrochemical reaction occured on the surface of anode and cathode electrode is interpreted in terms of an equivalent circuit [3,4]. For example, a capacitor has the same frequency response as a reaction step when electrons or ions build up on a surface, and a resistor represent the transport of charge surface of materials or interface between solution and surface of metal. Results are commonly reported as a plot of imaginary vs. real components of impedance as a Nyquist plots or impedance vs. frequency and phase angle vs. frequency as a Bode plots [5,6,7].

The present work is to investigate the electrochemical impedance spectroscopy (EIS) behavior of stainless steel 304 in Nano fluid solution contain 0,1 gpl nanoparticle ZrO2. A series of experiments have been conducted, including potential measurement to assess the influence of nanoparticles against
on open circuit potential (OCP) and Tafel polarization measurements to study the corrosion of the stainless steel 304 and EIS.

2. Experimental Methods

2.1. Materials and nanofluids
The stainless steel 304 used in this experiments were discs stainless having 1.6 Cm in diameter and 2 mm in thickness. The chemical composition (in wt%) 18.21% Cr, 8.40% Ni, 0.39% Si, 1.56% Mn, 0.45%Mn, 0.025% C balanced Fe. The specimen was wet abraded with 500, 800 and 1200 emery paper, degreased with detergent finally cleaned with ultrasonic cleaner in alcohol solution [8]. Nanofluid preparation were described in [9].

2.2. EIS study
Electrochemical experiments were conducted in three electrode cell, a stainless steels 304 disk as the working electrode, a saturated calomel electrode (SCE) as reference electrode and platinum wire were used as an auxiliary electrodes. The experiments were conducted by an instrument PCI4, G300 Potentiostat/Galvanostat series and connected to a personal computer provide with DC 105 software from Gamry [10]. Electrochemical impedance spectroscopy curve were obtained by the polarization of working electrode from 100 KHz to 10 Hz with ac current 0.1mA. Nyquist and Bode plot were acquired by EIS300 software from Gamry.

2.3. Characterization
Corroded and un corroded samples were analyzed by optical microscopy.

3. Result and Discussions
Figure 1 shows the variation of open circuit potential (OCP) with immersion time 600S of stainless steel 304 alloys in demineralized water and demineralized water + 0,01gpl ZrO2 Nano fluid at the room temperature. At the primary stage, OCP of stainless steel 304 alloys in demineralized water and demineralized water + 0,01gpl ZrO2 Nano fluid at the value almost of -38 mv then decreases rapidly. After 20S the value of OCP SS 304 in demineralized water and demineralized water + 0,01gpl ZrO2 Nano fluid nearly -88 mV and -119 mV respectively. After that the variation of OCP with time are increases slowly with SS 304 in demineralized water lower compared with demineralized water + 0,01gpl ZrO2 Nano fluid all the time. Finally, after 600S the value of SS 304 in demineralized water and demineralized water + 0,01gpl ZrO2 Nano fluid were -65mV and -126 mV respectively.

![Figure 1. The OCP of stainless steel 304 immersed in demineralized water and Nano fluid as a function of time](image-url)
3.1. This indicates that the OCP of stainless steel 304 in Nano fluids more positive compared with demineralized water due to corrosion of stainless steels 304 before stable protective film took place. The OCP of demineralized water + 0,01gpl ZrO2 Nano fluid higher compared with demineralized water indicates nano fluid more corrosive compared with demineralized water.

Polarization curve of stainless steel 304 in demineralized water and demineralized water + 0,01gpl ZrO2 Nano fluid showed in figure 2. It should be noticed that OCP and the anodic and cathodic Tafel constants value of stainless steel 304 are depend on electrolyte solution. From figure 2 it can be presented that OCP stainless steel 304 in demineralized water + 0,01gpl ZrO2 nano fluid more positive (-83 mv) compared with demineralized water (-134mv). This result indicated that potential stainless steel 304 in demineralized water + 0,01gpl ZrO2 Nano fluid more anodic and nano fluid more corrosive compared with demineralized water. The anodic and cathodic Tafel constant of stainless steel 304 alloys in demineralized water and demineralized water + 0,01gpl ZrO2 Nano fluid displayed the kinetic anodic and cathodic reaction. The anodic and cathodic curve of stainless steel 304 alloys in demineralized water revealed smoothly compare with in demineralized water + 0,01gpl ZrO2 Nano fluid. The anodic and cathodic plateau of stainless steel 304 in demineralized water + 0,01gpl ZrO2 nano fluid is highest compared with demineralized water. This results presented that corrosion stainless steel 304 in demineralized water + 0,01gpl ZrO2 nanofluid more dynamic of charge transfer and resistance of nanofluid during equilibrium. From Figure 2, anodic and cathodic Tafel constant and corrosion rate of stainless steel 304 in demineralized water and demineralized water + 0,01gpl ZrO2 nano fluid can be calculated by using DC 105 corrosion software from Gamry.

![Figure 2. Tafel polarization curve stainless steel 304 immersed in de mineralized water and Nano fluid](image)

3.2. Cathodic and anodic Tafel constants value of stainless steel in demineralized water and Nano fluid are 0,188v/decade and 0,249v/decade and 0,227 v/decade and 0,315 v/decade, respectively. Moreover corrosion rate stainless steel 304 in demineralized water and demineralized water + 0,01gpl ZrO2 Nano fluid are 0,058 MPY and 0.069 MPY, respectively.

Electrochemical impedance spectroscopy (EIS) stainless steel 304 were performed in demineralized water and demineralized water + 0,01gpl ZrO2 Nano fluid in order to evaluate electrochemical behavior of stainless steel 304 in different electrolyte. EIS data was recorded for all two of the electrolytes demineralized water and demineralized water + 0,01gpl ZrO2 Nano fluid after immersion of stainless steel 304 up to 10 minute. The Nyquist plot of data real impedance as vertical axis and imaginary impedance as horizontal axis showed in Fig.3. Fig. 3 shows that impedance increases with time for stainless steel 304 in all two electrolyte demineralized water and demineralized water + 0,01gpl ZrO2 Nano fluid. The results show that the impedance decreases as demineralized water content nano particle ZrO2. Decreases impedance suggesting an activation of the corrosion process took place in stainless steel 304 in the presence of nano particle ZrO2 of
demineralized water. This results in good agreement with the Tafel polarization curves where an enhancement of the corrosion occurred if stainless steel 304 immerse in nanofluid contain nano particle ZrO2.

![Figure 3. Nyquist plot stainless steel in demineralized water and Nano fluid](image)

![Figure 4. Bode plot stainless steel in demineralized water and nano fluid](image)

Figure 4 depicted the Bode plot data impedance and frequency of stainless steel 304 in demineralized water and demineralized water + 0.01gpl ZrO2 Nano fluid. Basically, it can be observed that the conditions of linearity of impedance at different frequency are similar but impedance of stainless steel in demineralized water higher compare with in demineralized water + 0.01gpl ZrO2 Nano fluid. Non-linearity’s are observed particularly at high frequencies. The Bode plots are suitable to compare the behavior of the stainless steel 304 electrodes in demineralized water and demineralized water + 0.01gpl ZrO2 Nano fluid due to the electrochemical reaction. The large changes in impedance took place because the redox reaction on the stainless steel in demineralized water and demineralized water + 0.01gpl ZrO2 Nano fluid is different in the electron transfer. The effect of the charge transfer affect the corrosion rate stainless steel in demineralized water lower compare with in demineralized water + 0.01gpl ZrO2 Nano fluid.

Surface morphology of specimens stainless steel 304 before and after corrosion testing in demineralized water and Nano fluids showed in Figure 5 a and b, respectively. In Figure 5a and 5b showed that the surface morphology specimen still free of product corrosion scale. From the data surface morphology stainless steel, it can be concluded that Nano fluid solution is not corrosive electrolyte.
Figure 5. Surface morphology of stainless steel before (5a) and after (5b) corrosion test in the Nanofluids

4. Conclusion

The corrosion stainless steel in nanofluid contains adm+0.01 gpl ZrO$_2$ nanoparticles was performed by Tafel polarization and Electrochemical Impedance spectroscopy. Following results are obtained

1. The results show that according corrosion potential examination of the stainless steel 304 in nanofluid media 0.01gpl ZrO2 nanoparticle was actively corroded.
2. The value of anodic Tafel slope stainless steel 304 in nanofluid higher compare with in demineralized water.
3. The results of Tafel polarization technique show that corrosion rate of stainless steel 304 in nanofluid higher compare with in corrosin rate in demineralized media.
4. The results of EIS technique show that impedance of stainless steel 304 in nanofluid lower compare with in demineralized media.

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