

An Investigation to 304 Stainless Steel Corrosion in Acid Nitric Environment (HNO₃) and Sodium Chloride (NaCl)

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ABSTRACT

Electro Chemical Studies For testing effect of NaCl and HNO₃ concentration and also temperature has been conductor on corrosion action of 304 stainless steel. The results show that 304 corrosion of steel become active and passive. During active corrosion, Increasing HNO₃ concentration decreases corrosion intensity and have no high effect upon corrosion. Increasing NaCl concentration to solution cause to reduce OCP (open circuit potential) is expanded through increasing anode reaction and delaying cathode reactions, creating hole, active extinction, more extensive corrosion current. Also increasing NaCl, passive layer with putting 304 steel in HNO has been created and is vanished. Whereas NaCl including aggressive ion Cl⁻. It worsens passivity and increasing Anode current. The test polarization of temperature resulted in one fixed density, Nitric Acid of increasing temperature for being passive decreases electrode level of 304 steel as well. 304 steel in high temperature till 45°C according to test. It has no corrosion and used the steel kind of the range from temperment without worry. It is better to use the steel in environment containing Acid Nitric as well. Since 304 steel fall sin corrosion in environment involving sodium chloride.

KEYWORDS: 304 Stainless Steel, Acid Nitric, Sodium Chloride, Polarization, Open Circuit Potential.

1. INTRODUCTION

304 stainless steel have been dedicated vital part of production for the conserving mechanical qualities in high temperature degree and below zero and resistance against Oxidation as well as most corrosive environment among iron alloy family. These days, using 304 stainless steel, so as to creating various industries (chemical and petrochemical industries, aero plane making, transportation, food material production, health, drug as well as nuclear plant, ...) is inevitable. If we accept to prevent from destroying or corrosion of industrial and industrial settings can have part for producing and economics of one country finally, it can be discovered the major role of using 304 stainless steel for making various pieces [1]. 304 stainless steel or the same 304 stainless steel is one the most useful and perhaps the most useful type of stainless steel is located at stainless steel as teensy group. 304 stainless steel is named in 1,43.1 European standard.

Processing and studying Actinide salts in Nitric Acid (HNO₃) plays an important role for reducing extra materials of radioactive and long term saving of radioactive. Condenser materials to conduct test such as pipes or dishes for holding Nitric Acid normally from AISI water proof 304 steels or (304ss) built. Yet 304 steel resistances against corrosion are not certain while it is an exposure HNO₃ of holiday environments. As a usual, corrosion 304 steel action has been recorded in texts well. The present text included studies about general and regional 304ss corrosion that face against Nitric Acid solution or chloride sodium solution. Nevertheless, fewer studies have been published regarding the 304ss corrosion at exposure of solutions containing Nitric Acid and chloride sodium together. So far No test investigated of common action of 304ss corrosion in yields of molarity .01 molar till 10 molar in presence of Na Cl. Various researches investigated weight reduction in one or a few Acid or chloride exposures. Also, Dynamic polarization curve reduced in the environments as well. Polarization curves of static potential for 5Ti- 10Ni-17Cr steels prepared seemed to approve the NaCl concentration increase in passive dense increase. In which test at solution containing HNO₃ one molar happens. Curves unfortunately consist of little data. So, the result needs more thoughts and perspectives [2].

The 18Cr-10Ni-0.7Ti corrosion action has been tested and ended as a result that Na Cl viscosity increase caused to change non active behavior to active one. In addition to this case, corrosion action was drawn as a function of viscosity Na Cl and NO₃⁻ in PH0 , 0.5 and 1 used methods in drawing the function is not certain. The results show that materials can be active, passive/Active/passive or depends on PH or NO₃⁻ viscosity holes created in it [3].

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304ss corrosion behavior for function of viscosity of NaCl and HNO₃ has been considered and drawn. The results obtained from corrosion intensity points and crack, passive, being active, creating hole using scan, the obtained result from electronic Microscope following 120 hours of floating materials in solutions boiling and in different positions tested taken. Since hole in each special point created, the drawn way of different areas was unclear. Yet the results of the test show that no hole in solution of NaCl with molarities less than 0.5 and density between 0.1 molar till 2 molar has not been seen [4].

2. LITERATURE REVIEW

It has been the most complete test and the studies conducted by Mirolyubov et al. [5] so far even though small yield only tested one sample of concentration (between 1 through 5 molar). The researcher added the chloride concentration increases so as to activate 0.5 Ti – 9 Ni – 18 Cr steel with temperature increase, HNO₃ concentration and (Cr) chrome weight percent available in metal. And with increasing weight percent (%wt), is decreased (Ni), corrosive solution concentration.

The effect of increasing HNO₃ concentration through active corrosion: Mirolyubov et al. [5] found that during active corrosion, increasing HNO₃ concentration decreases corrosion speed. However in general, increasing HNO₃ density goes around a special point of concentration and causes to be passive. Therefore, the most corrosive speed is seen in HNO₃ average concentration.

The Passive action and effective elements upon passive time automatically: Mirolyubov et al. [5] also understood special time so as to be passive stainless steel is necessary exposure to solution containing special HNO₃ and NaCl. The action is called passive automatically. Since material automatically is passive lacking foreign poles. Passive time automatically decreases with raising concentration HNO₃ temperature, Cr weight percent, Mo weight percent Ti weight percent, Fe weight percent and NO₂ concentration and increasing NaCl concentration and solution proportion of surface (volume property of passive automatically is related to Autocatalirization HNO₃ is suggested by others. However no evident is available for corrosion comprising from Autocatalized (such as increasing corrosion speed).

The effect of increasing chloride to Acid Nitric solution: Tomashov [6] suggested adding chloride to solution using stainless steel of austenitic causes reducing OCP (open circuit potential) through increasing Anode reaction and delaying cathode reaction. It seems preventing cathode reaction due to surface attraction Cl happens on surface so that it present, through decreasing HNO₃ to HNO₂.

The effect of chloride concentration and temperate upon corrosion speed: Matantsev [2] showed that increasing chloride concentration and temperate increases corrosion speed in 6.5% HNO₃. Ciriscili et al. [7] found through losing weight that corrosion speed along with temperate linearly increases in 5%HNO₃ + 20%MgCl₂, 5%HNO₃ + 30%MgCl₂, and 60%HNO₃ + 4%MgCl₂.

The growth of Hole development: Green and Fontana [8] ranced the results using 304 stainless steel that Nitrate ions prevent the growth of hole start more efficiently, while starting to create hole to solution HNO₃ added, Nitrate ions increase hole speed. Schwenk [9] found that Cl critical concentration for creating hole increase NaNO₃ in 18Cr – 10 Ni steel.

The effect of environmental parameters on corrosion among 304 and 321 stainless steel seed: Soltanpoor and Pakshir [10] showed that increasing salt concentration in solution makes increase corrosion background among 321 and 304 steel seed and increase in Anode current and recurrent. Expelling oxygen solute in salt solution, increasing corrosion sensitivity temperature increased of each steel. Lack of oxygen of Anode current and cathode decrease and lowering down is considered Anode current in 304 steel. In 304 steel increasing salt solution speeds, first in low speed of corrosion decreases and increasing motion speed, decreases sensitivity degree of corrosion. In 321 steel corrosion increasing lowering down corrosion sensitivity degree inter granular. Increasing Sulfuric acid concentration in salty solution and PH decreases, has been shown Anode current increases and recurrent and resistance of corrosion of inter granular in 321 steel decreased and increased First for 304 steel and then is decreased. Kazazi and Afshar [11] investigated in a research preventive effect of safe polyethylene upon hole corrosion of stainless steel of Austenitic in 3.5% NaCl solution and found the results of tests of electro chemical impedance color showed that preventive yield of safe polyethylene becomes high and by increasing preventive concentration, increase polarization resistance of protective layer, however, the rate of changes in concentration of higher than 1000 ppm becomes slow heavily. In addition, they found the cycle polarization tests that preventive case used stop from hole corrosion of the steel well. Preventive absorption behavior upon stainless surface steel in 3.5% NaCl solution using nuclear power microscope investigated. Phase and topographical pictures showed the preventive surface absorption one layer of compressive two ply and inner ply.

3. MATERIALS AND METHODS

304 steel used in the paper. The steel prepared from steel store and steel in Babol. After providing the steel so as to access the related mix of the steel conducted under spectrometric test and received the same 304 steel mix exactly.

Acid Nitric (HNO₃) and sodium chloride (NaCl)

One sample of Nitric Acid related in steel company of Amol (FZA) with 0.1 concentration molar and 0.01 molar provided. Acid nitric solution an sodium chloride of each other in Razi research place with 10% concentration of Acid nitric, 10% Acid nitric plus 100 ppm sodium chloride and 10% Acid nitric plus 500 ppm sodium chloride.

Test for determining chemical combination through propagation emission spectrometric method.

The test conducted through spectrolab M9 machine made of Germany in Amol melt steel in Amol Industrial Township. The chemical combination test conducted through emission spectrometric method with standard referring to ASTM – E1086 with laboratory temperature 19 °C and 53% humidity. At first, sample with 10×10 mm concentration provided then for determining chemical combination the sample by using Analyzed spectrometric machine and After analyzing characterized that obtained combination has been the same steel combination of 304. Based on Table 1, high level of chrome caused resistance of corrosion of the steel.

Table 1. 304 steel chemical combination

C	Si	Mn	P	S	Cr	Mo
0.0663	0.4780	1.15	0.0414	0.0192	18.23	0.142
Ni	Al	Co	Cu	V	W	Fe
8.21	0.0062	0.0763	0.185	0.107	0.022	71.3

Polarization test (temperature)

The test with potentiostat / EG & G273A machine made of Canada with standard test ASTM G05 and in test qualification of Electrode type: 304, reference electrode: Ag/AgCl, supplementary electrode: Graphite, electrolyte: solution of one molar Acid nitric, potential limitation: -0.6 < OCP < +0.6, conducted speed potential: 10mv/s. In the test used 3 different temperature 45, 35, 25 degree centigrade. It has been showed that increasing temperature for passive electrode level decreased corrosion speed. Also, corrosion potential increased with temperate raise and decreases corrosion current contrary to polarization concentration test.

Test for determining curve polarization and corrosion rate (concentration)

The test conducted with the help of machine in environmental conditions of laboratory with 25 °C, 30% humidity and standard reference of test ASTM G1-11 & G3-13. Test qualification was that reference electrode: calomel electrode saturated KCL-sat, working electrode 304 steel, counter electrode: platine, scan rate: 0.5 mvs⁻¹, solution: Acid nitric solution and chloride sodium with different concentration is 10% Acid nitric solution, 100 ppm NaCl solution in 10% Acid nitric and 500 ppm NaCl solution in 10% Acid nitric prepared and observed that increasing NaCl concentration in Acid nitric of corrosion rate has increased. Also corrosion current increases with adding NaCl concentration in Acid nitric, but corrosion potential is decreased.

4. RESULTS AND DISCUSSION

The results of test determining chemical combination spectrometric method

Using spectrometric test reached the results that chemical combination comprising spectrometric test has been indicated the same combination of 304 steel sample according to 2. Table of chemical combination of the following test. As the appeared on the above table, iron with 71.3%, chrome with 18.23%, nickel whit 8.21% and manganese with 1.15% are basic elements of the steel.

Table 2. 304 steel chemical combination

C	Si	Mn	P	S	Cr	Mo
0.0663	0.4780	1.15	0.0414	0.0192	18.23	0.142
Ni	Al	Co	Cu	V	W	Fe
8.21	0.0062	0.0763	0.185	0.107	0.022	71.3

The results of Metallographic test

After 304 steel sample has been kept in 0.1 Acid nitric molar with 30 seconds then it has been given in H solution under light microscope observed structure Austenite background with Mechanical twin has been shown in 1, 2 and 3 respectively with 100, 200 and 400 magnification.

The reason for creating structure of austenite background mechanical twin is that austenite 304 steel and experimental sample was sheet form and it production is conducted by rolling. Therefore it has dislocation. So the reason for the structure observed is austenite background mechanical twin. After the sample in .01 Acid nitric put in molar so as to be studied the effect of 0.1 Acid nitric, molar upon 304 steel structure. Again the sample in Acid nitric is thinner with 0.01 concentration of molar and is observed that 0.01 Acid nitric, molar has had no effect on 304 steel. Therefore it is found that .01 Acid nitric molar causes to change in steel structure and mechanical twin, however 0.01 Acid nitric, has no effect on 304 steel structure.



Figure 1. Metallographic sample with a magnification of 100



Figure 2. Metallographic sample with a magnification of 200



Figure 3. Metallographic sample with a magnification of 400

Result of polarization Test (concentration)

The sample of 304 steel as an electrode working in Acid nitric and chloride sodium with three concentration 1) Acid nitric 10% 2) 100 ppm NaCl solution in 10% Acid nitric and 3) 500 ppm NaCl solution in 10% Acid nitric given and based on 4 figure has been shown from the test.

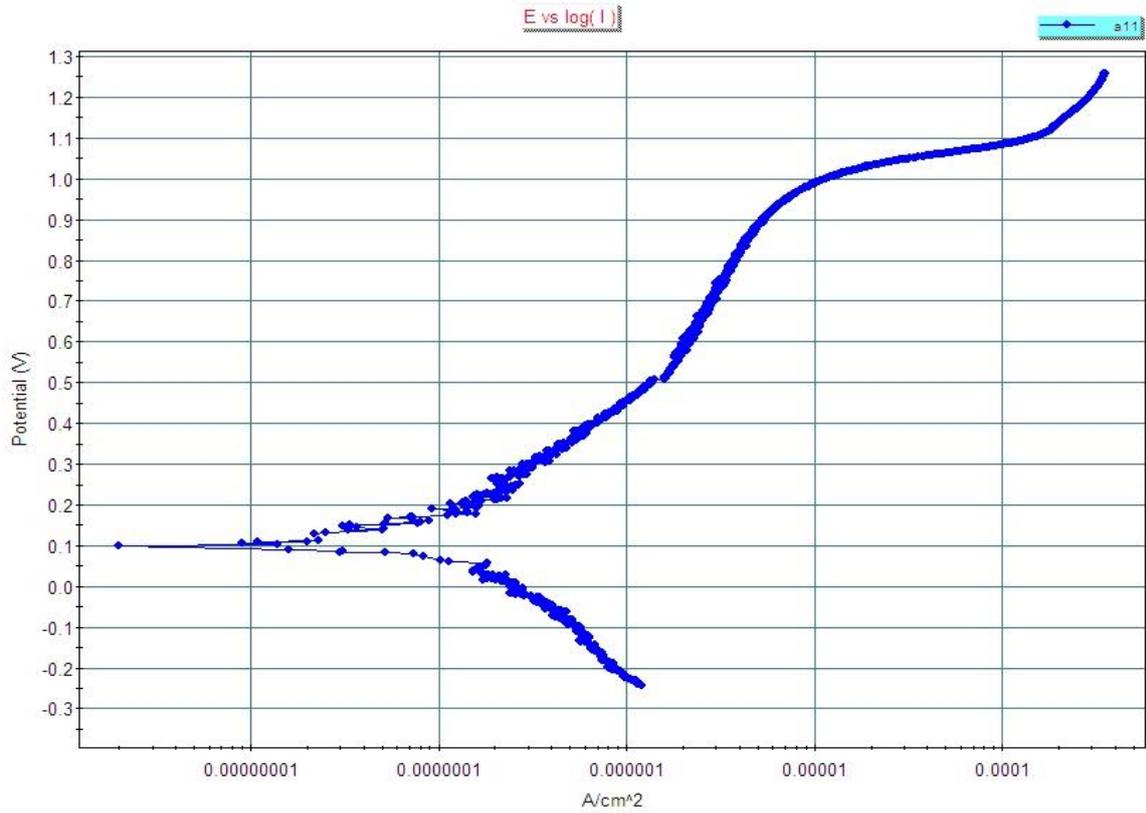


Figure 4. Graph polarization test concentration in 10% HNO₃

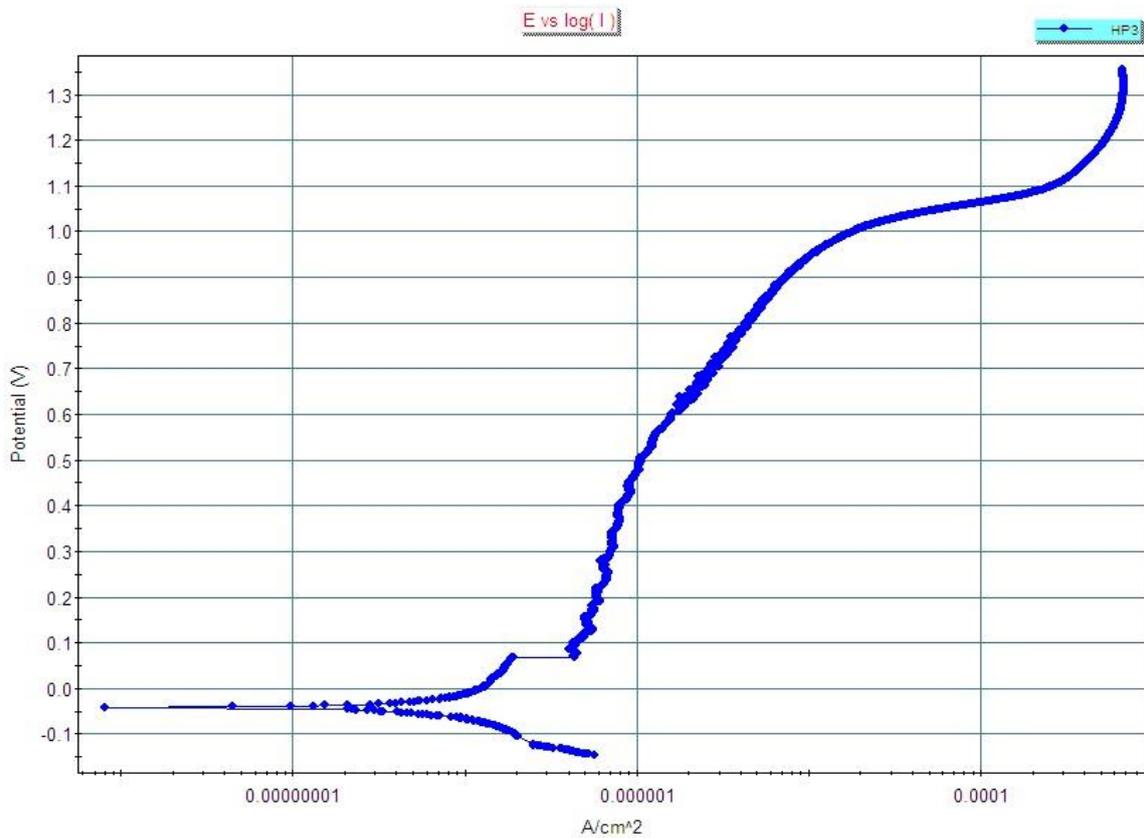


Figure 5. Graph polarization test concentration solution 10% HNO₃ in 100 ppm NaCl.

Acid nitric only caused to be passive corrosive rate in low level changes. Increasing 100 ppm NaCl concentration in Acid nitric 10% graph resulted from polarization test based on 5 figure changed and interpretation of the graph showing that corrosion rate and corrosion current increased and decreased corrosion

potentials. Increasing NaCl concentration to 500 ppm in Acid nitric 10% graph resulted from in creating NaCl concentration based on Figure 6 changed.

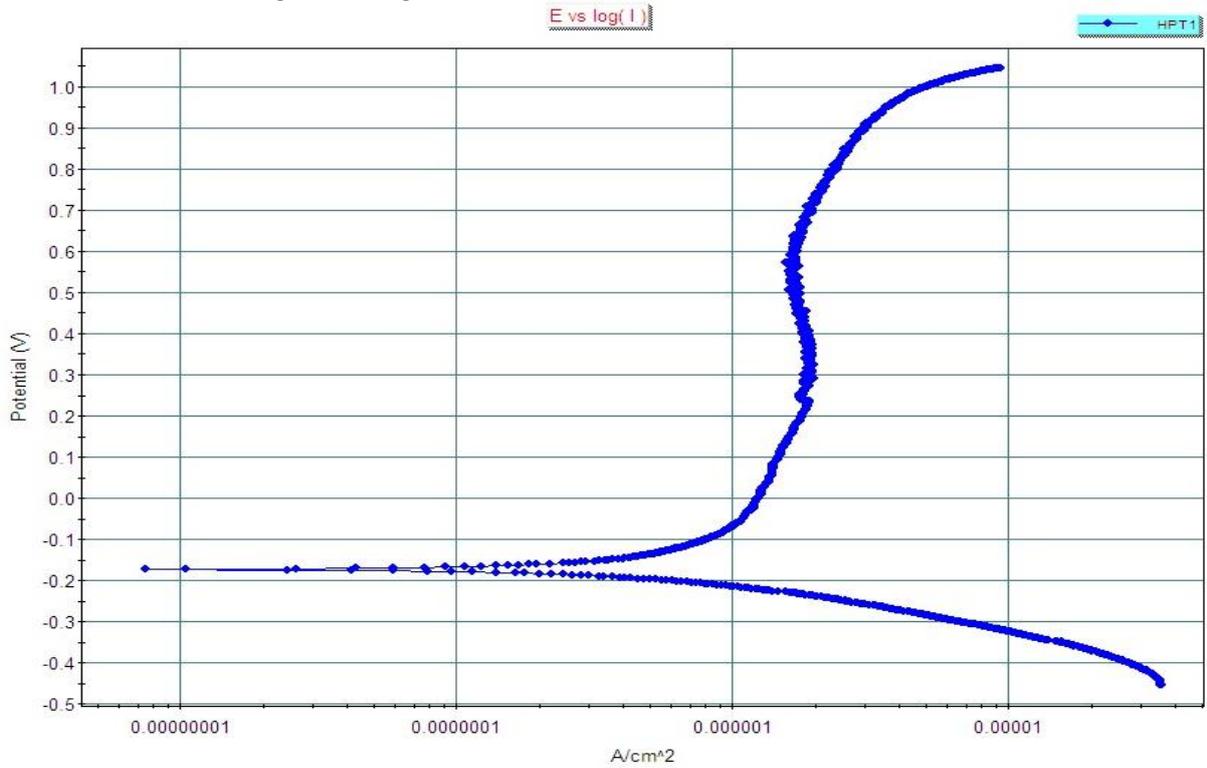


Figure 6. Graph of polarization test, concentration, solution 10% HNO₃ in 500 ppm NaCl.

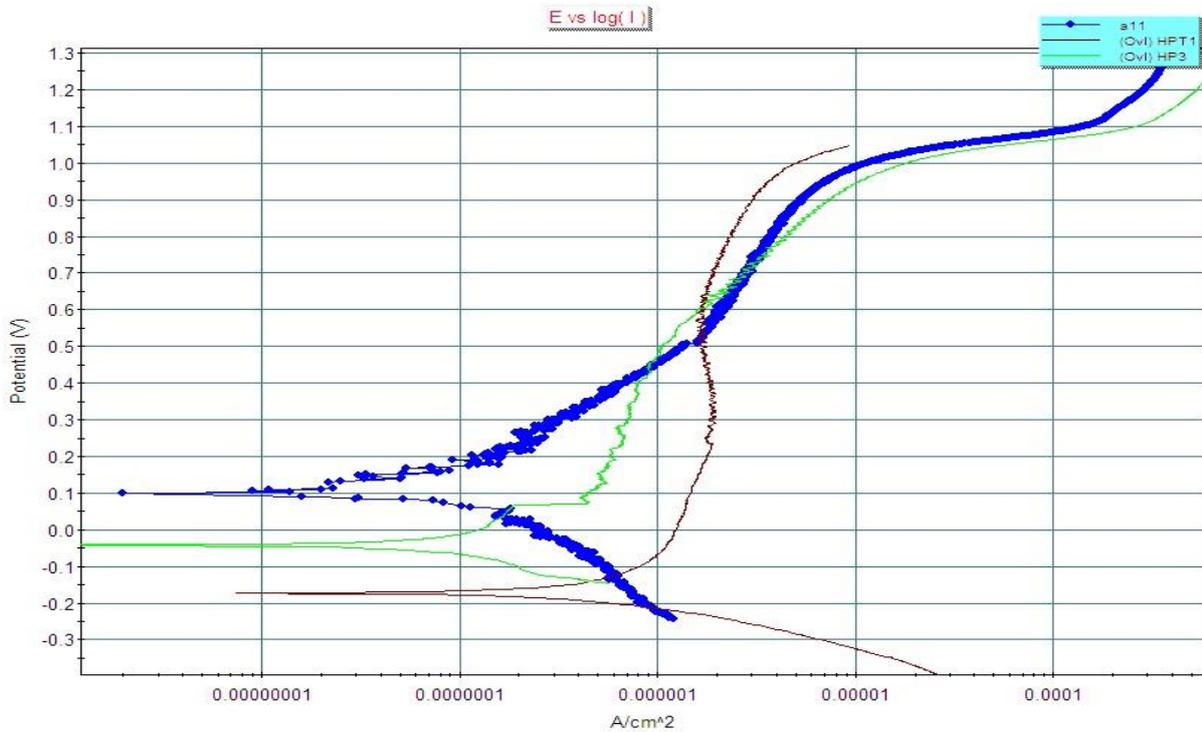


Figure 7. Graphs of polarization test, concentration, in 10% HNO₃, solution 10% HNO₃ in 100 ppm NaCl, solution 10% HNO₃ in 500 ppm NaCl

Table 3. Result of concentration polarization test in 10% Acid nitric

Anode beta β_a (mv/decade)	Cathodic Beta β_c (mv/decade)	Corrosion Potential E_{corr} (mv)	Corrosion Current I_{corr} (μA)	Corrosion Rate Mpy (mm/year)
87	97	11.6	3.2×10^{-2}	1.3×10^{-2} (3.3×10^{-4})

Table 4. Result of concentration polarization test, 100 ppm NaCl solution in 10% HNO₃

Anode beta β_a (mv/decade)	Cathodic Beta β_c (mv/decade)	Corrosion Potential E_{corr} (mv)	Corrosion Current I_{corr} (μA)	Corrosion Rate Mpy (mm/year)
81	81	-41	4.7×10^{-2}	1.9 (4.9×10^{-2})

Table 5. Result of concentration polarization test, 500 ppm NaCl solution in 10% HNO₃

Anode beta β_a (mv/decade)	Cathodic Beta β_c (mv/decade)	Corrosion Potential E_{corr} (mv)	Corrosion Current I_{corr} (μA)	Corrosion Rate Mpy (mm/year)
76	64	-171	2.0×10^{-4}	8.0 (2.0×10^{-4})

Tables 3, 4 and 5 resulted from concentration polarization test. Therefore, it is said that HNO₃ has no high effect on corrosion 304 steel. When NaCl increased to HNO₃, corrosion rate and corrosion current increased. Regarding obtained results from the test is shown that increasing NaCl concentration in 304 sample increasing condition of corrosion will have. Also, increasing NaCl concentration, passive layer created and whereas NaCl included Cl⁻ aggressive ion, it causes passive problem and causes to increase in Anode current. In 304 steel increasing motion speed of salty solution, first it decreases in low speed of corrosion potential and increasing motion speed, increases corrosion sensitivity degree.

Result of polarization test (temperature)

Figures 8,9,10 resulted from polarization found that by putting 304 steel sample in 1 molar solution of Acid nitric and increasing temperate from 25°c to 45°c is shown passive electrode level that decreased corrosion speed.

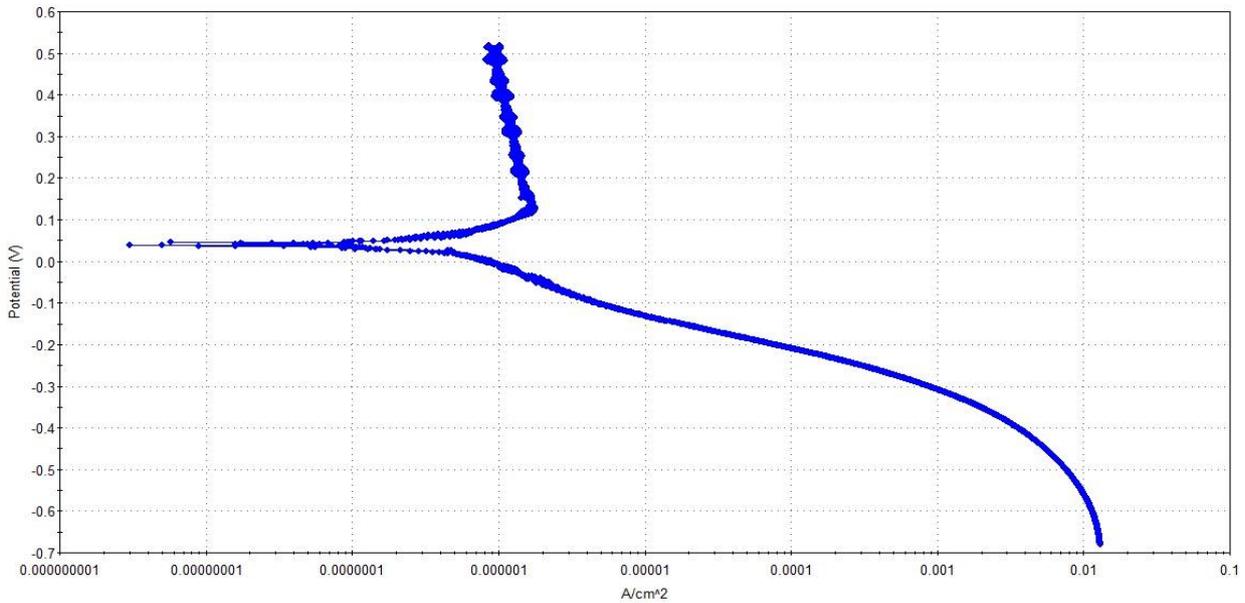


Figure 8. Graph of polarization Test, Temperature 25°c

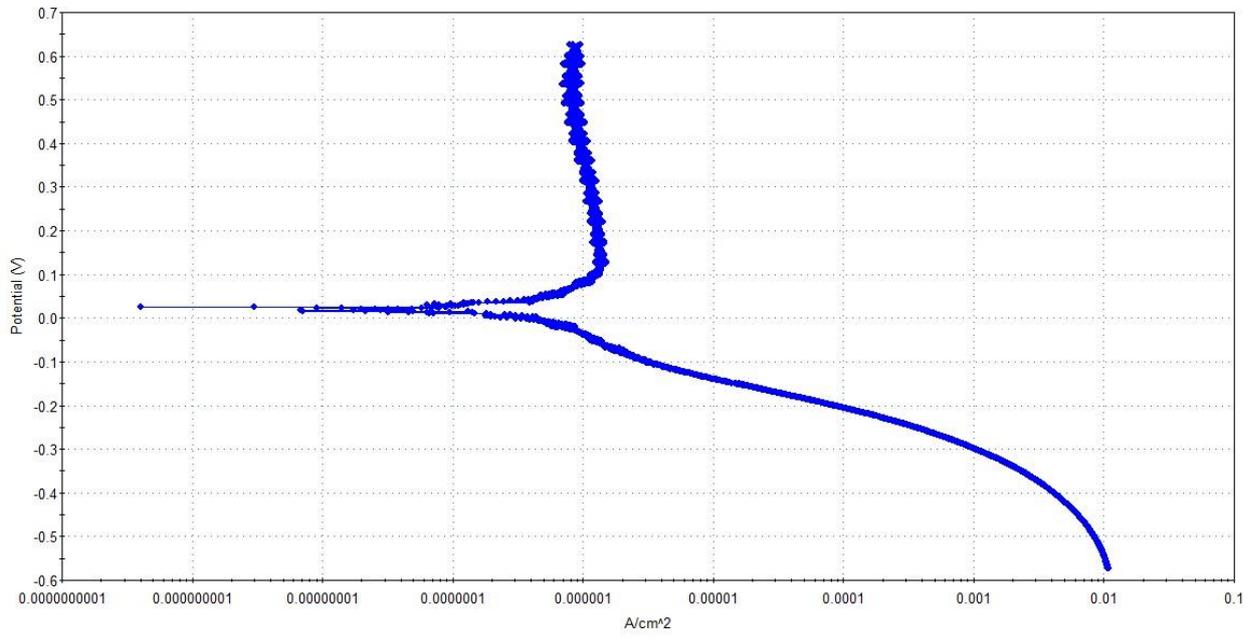


Figure 9. Graph of polarization Test, Temperature 35°C

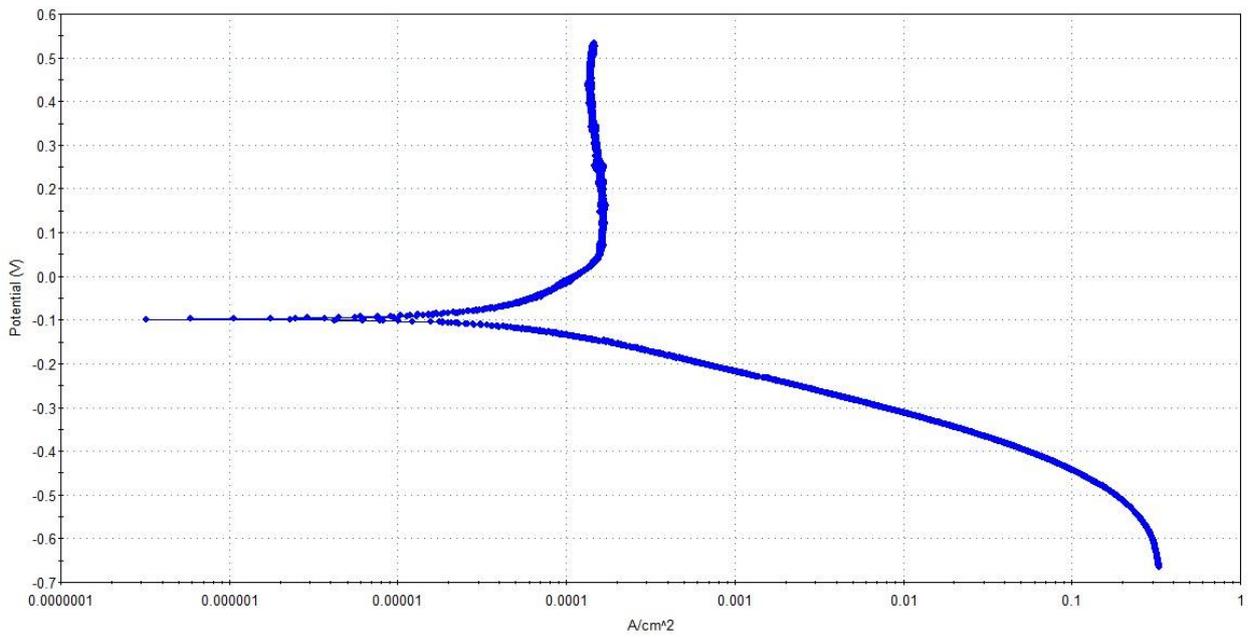


Figure 10. Graph of polarization Test, Temperature 45°C

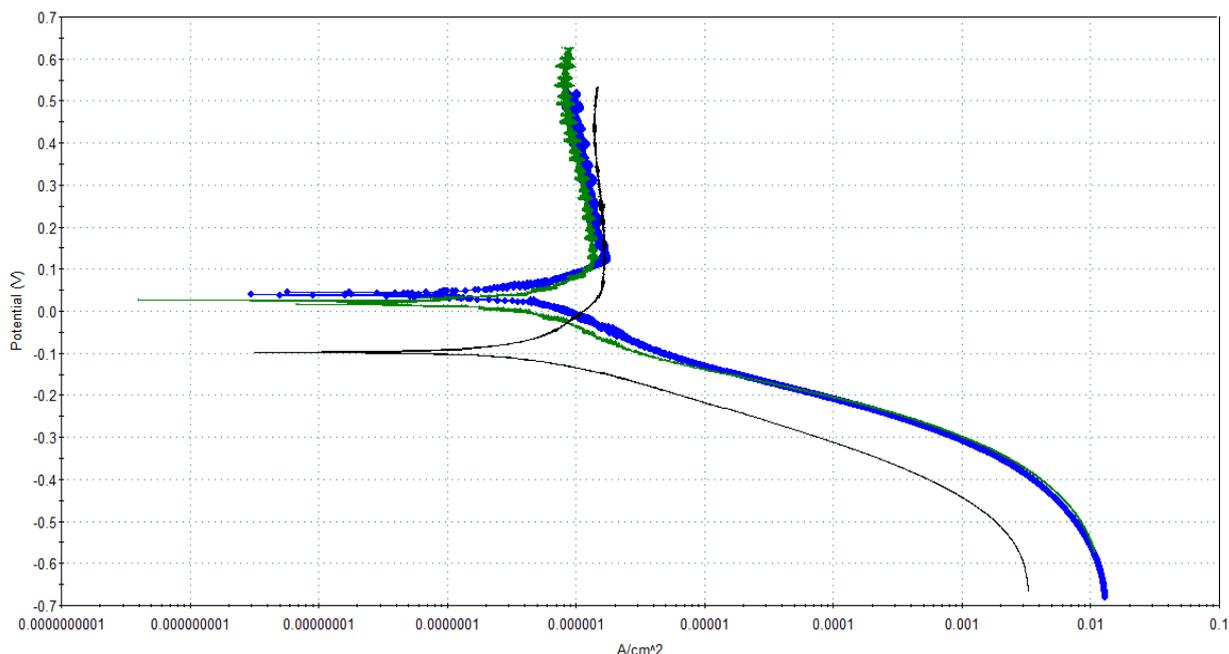


Figure 11. Figures of polarization test, in temperatures 25, 35 and 45 °C

i.e, putting 304 steel in Acid nitric 1 molar and temperature increase, corrosion rate doesn't increase but it caused to decrease corrosion rate. Another result obtained from the test that was by increasing temperature, corrosion potential increased and decreased corrosion current. More general results of the test have been given in Table 6.

Table 6. polarization test of temperature in 25°C, 35°C, 45°C.

Temperature T	Potential E (mv)	Corrosion current I_{corr} (μA)	Anode beta β_a (mv/decade)	Cathode beta β_c (mv/decade)	Corrosion Rate Mpy (mm/year)
25	-51	0.73	315.208	83.88	14.89
35	25	0.414	134.428	131.126	8.43
45	42	0.383	96.65	126.173	7.78

Regarding polarization test of temperature on HNO₃ has high effect in 304 corrosion steel. In fact 304 steel in Acid nitric is not corrosive. Whenever NaCl is added to solution is increased corrosion. In fact increasing chloride sodium caused 304 corrosion steel. The results show that one fixed concentration solution in Acid nitric increases temperature from 25°C to 45°C for being passive of 304 corrosion electrode decreases as well. Increasing salt concentration in solution causes corrosion potential increases inter granular of 321- 304 steel, increasing in Anode current and recurrent. Sending out oxygen solute in salt solution, sensitivity degree of corrosion inter granular of both steel decreased. Lack of oxygen of Anode current and cathode decreases together and decreasing Anode current in 304 steel is considerable [10].

CONCLUSION

304 steel in high temperature through 45°C based on test has no corrosion and can use it without any worry at the steel from the range. Also, it is better to use the steel more in environment containing Acid nitric since 304 steel become corrosive in exposure to chloride sodium.

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