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Corrosion Behaviour of 304 and 316 Austenitic Stainless Steel in Strong Sulphuric Acid

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Abstract: *The sample of 304 and 316 austenitic stainless is characterized by Potentiate to determine the degradation rate and polarization resistance in the higher concentration of strong sulphuric acid. Results and analysis indicate an increase in corrosion rate (mm/year) with respect to the concentration of acid media for both samples. It has been observed from the overall result, 316 stainless steel is more favorable as compared to 304 due to better polarization resistance. It has found around 316 spotless, the cathodic polarization expanding with expanding in the grouping of H2SO4 corrosive. In by and large consequence of this study in light of an investigation, potentiating shows the 316 hardened steel is more ideal than 304 in a higher grouping of sulphuric corrosive because of good polarization opposition. The magnificent polarization obstruction of 316 tempered steel in the solid corrosive media might be expected high rate (Cr and Ni) alloying component which help to shape an oxide layer on the metal surface. It helps in the arrangement of concentrated corrosives.*

Keywords: Stainless Steel, Polarization, Corrosion, Degradation, Potentiate, Sulphuric Acid

I. INTRODUCTION

Austenitic stainless steels are widely used in industrial applications due to their strength, corrosion resistance, mechanical workability, and excellent electrical and thermal conductivities. Among them, AISI 316 stainless steel is of great practical interest because it is employed in pharmaceutical, petrochemical, offshore drilling marine shipping, water desalination, etc. AISI types 304 and 316 stainless sheets of steel are used to handle very diluted acid at low temperatures [1]. The high corrosion resistance of this material arises from the formation of a passive layer on its surface. Additionally, chromium content in the steel enhances its corrosion resistance. The passive film is constituted by an iron and chromium oxy-hydroxide layer and water containing-compounds which is formed at the metal/solution interface, and an underlying film formed by chromium oxide [2]. However, under certain circumstances, the passive state may be lost, and most stainless steel-based equipment failures are caused by pitting corrosion due to chloride ions [3-5]. Hydrochloric acid (next to seawater) remains the main source of aggressive chloride ions. Pitting corrosion is one of the most dangerous forms of localized corrosion, especially for steels in chloride media [6]. On the other hand, sulphuric acid is very corrosive for stainless steels too , and constitutes one of the basic raw materials encountered in the chemical industry. Despite the number of publications about stainless steel corrosion and passivation, the kinetics of the various complex processes involved has been investigated less extensively in concentrated solutions of these acids. Therefore, it is interesting both from the fundamental and practical standpoint to study the influence of acidity, chloride, and sulfate ions on those processes. The presence of such ions imposes the use of inhibitors to avoid the destruction of either the material surface or the passive layer in contact with the aggressive solution. Corrosion is the destruction of a material resulting from exposure and interaction with the environment [7]. Corrosion remains one of the most severe limitations for the use of various steels in the chemical and petrochemical industries. Millions of dollars are lost each year because of corrosion. Much of this loss is due to the corrosion of iron and steel [8]. Despite the introduction of polymers and composites in recent years, metals remain important in structures because of their strength, stiffness, toughness, and tolerance to high temperatures. The noble metals, such as gold and platinum are an exception to this, but they are rather too rare for common use [9]. Although one of the main reasons why stainless steels are used is corrosion resistance, they do in fact suffer from certain types of corrosion in some environments and care must be taken to select a grade that will be suitable for the application [8]. Corrosion can cause a variety of problems, depending on the applications and the environment. Corrosion occurs in many forms in structures made of these steels during service in various media. Some of these forms are intergranular [10].

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II. EXPERIMENTAL TECHNIQUE

2.1 Potentiostat

In the potentio-static Model (Nova-1.8), Potentiate & Galvanostatic (PGSTAT) will accurately the potential of the counter electrode (CE) against the working electrode we so that the potential difference between the working electrode we and the reference electrode (RE) is well defined and correspond to the value specified by the user. In galvanostatic mode, the current flow between these and the counter electrode is controlled. The potential difference between the RE and WE and the current flowing through the counter electrode is continuously monitored. counter electrode

1. By using a PGSTAT, the value specified by the user (i.e applied potential or current) is accurately controlled, at any time during the measurement by using a negative feedback mechanism.
2. Counter electrode: The counter electrode (also known as the auxiliary electrode) is an electrode that is used to close the current circuit in the electrochemical cell. It is usually made of an inert material (e.g., Pt, Au, graphite, glassy carbon) and usually, it does not participate in the electrochemical reaction.

Figure 1

3. Reference electrode: The reference electrode is an electrode that has a stable and well-known electrode potential and it is used as a point of reference in the electrochemical cell for potential control and measurement.

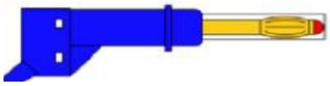


Figure -2

2.2 Electrodes Uses in the Cell

A. Working Electrode

The working electrode is the electrode in an electrochemical system on which the reaction of interest is occurring. common working electrodes can be made of inert materials such as Au, Ag, Pt, glassy carbon (GC), and Hg drop and film electrodes, etc. for corrosion application the material of the working electrode is the material under investigation which is actually corroding.

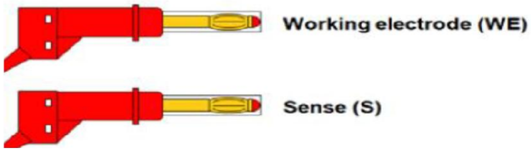


Figure 3

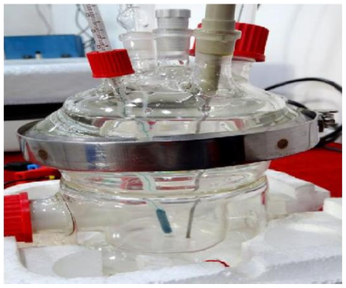


Figure 4: Corrosion Test Equipment (Nova1.8Potentiostat /Galvano stats)

III. EXPERIMENT PROCEDURE

3.1 Sample Preparation

Austenitic stainless steel AISI 316 and AISI 304 have been used. Table 1 provides its nominal chemical composition. The nominal composition of Type 304 and 316L stainless steels (in wt.%)

Table 1: Chemical composition of the AISI 316 austenitic stainless steel.

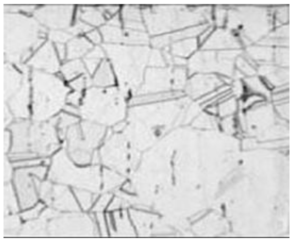
Element	C	Mn	Cr	Ni	MO	P	S	N	Fe
Wt%	0.08	2	0,75	10	0.45	0.045	0.03	0.1	balance

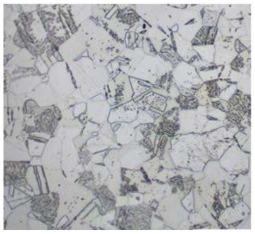
Table 2: Chemical composition of the AISI 304 austenitic stainless steel

Element	C	Mn	Cr	Ni	MO	Si	S	Ni	Fe
Wt%	0.06	1.40	18,75	8.03	0.45	0.045	0.005	8.03	balance

3.2 Preparation of Samples for Potentiate

Plates of stainless steel were cut to dimensions 1 cm X 2 cm X 0.1 cm. The surface was ground employing a gradual sequence of emery papers of different grit sizes, namely 400, 600, 800, 1000, 1200, and 1500 grades. The ground specimen was rinsed, cleaned in an ultrasonic bath successively in twice-distilled water and absolute ethanol, for 10 min each, and finally dried in air. The chemicals used in this work with H2SO4 as an electrolyte. Selected concentrations of sulphuric acid were prepared by dilution of the corresponding concentrated solutions using twice-distilled water. Electrochemical studies were carried out in a conventional three-electrode single-compartment, 50 ml volume. The Steel plates were used as the working electrodes by putting only one side of the specimen in contact with the electrolyte. The potential of the working electrode was measured against a saturated calomel electrode (SCE). The SCE was connected through a KCl-containing agar-agar salt bridge, the tip of which was placed as close as possible to the surface of the working electrode in tonimize the solution resistance between the test and reference electrodes.


(a) 304 SS


(b) 316 SS

3.3. Microstructure of the Sample

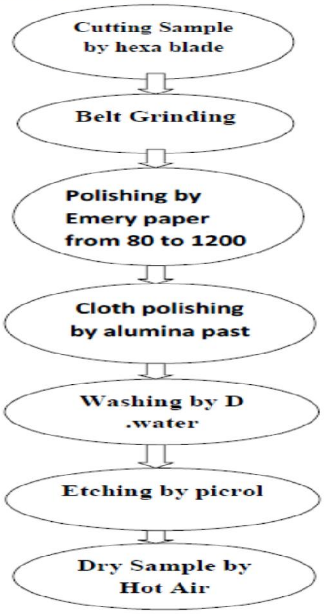


Figure 7: Steps in sample preparation

IV. RESULT AND DISCUSSION

The potentiometric result and data obtained of 304 and 316 ss (as observed) is as follows
304 SS graph and data at different concentrations:
0.5M H2SO4

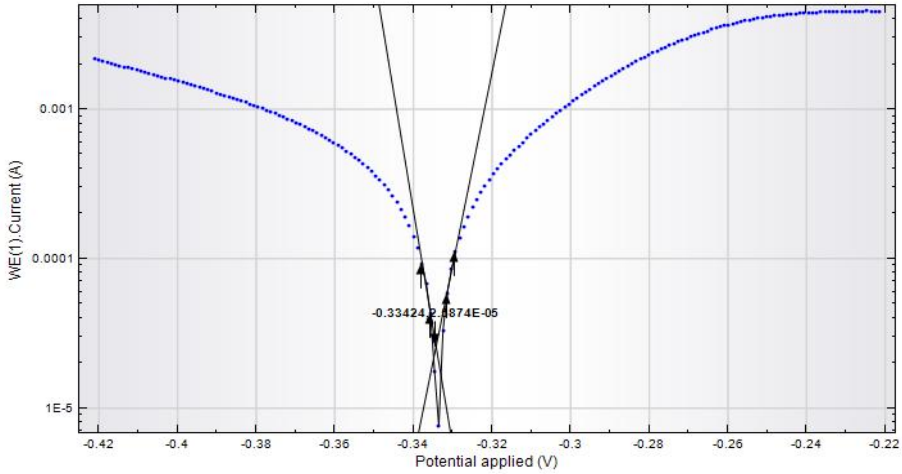


Figure: Graph for 304 ss sample in 0.5M H2SO4

Table 3: Corrosion rate of 304ss sample in 0.5M H2SO4

ba (V/dec) (V/dec)	Bc (V/dec) (V/dec)	Error, Calc (V) (V)	Ecorr, Obs (V) (V)	jcorr (A/cm²) (A/cm²)	icorr (A) (A)	Corrosion rate (mm/year) (mm/year)	Polarization resistance (Ω) (Ω)	E Begin (V) (V)	E End (V) (V)
0.054923	0.054923	-0.33424	-0.33388	0.000264	0.000264	3.0663	42.249	-0.33783	-0.32928

0.75M H2SO4

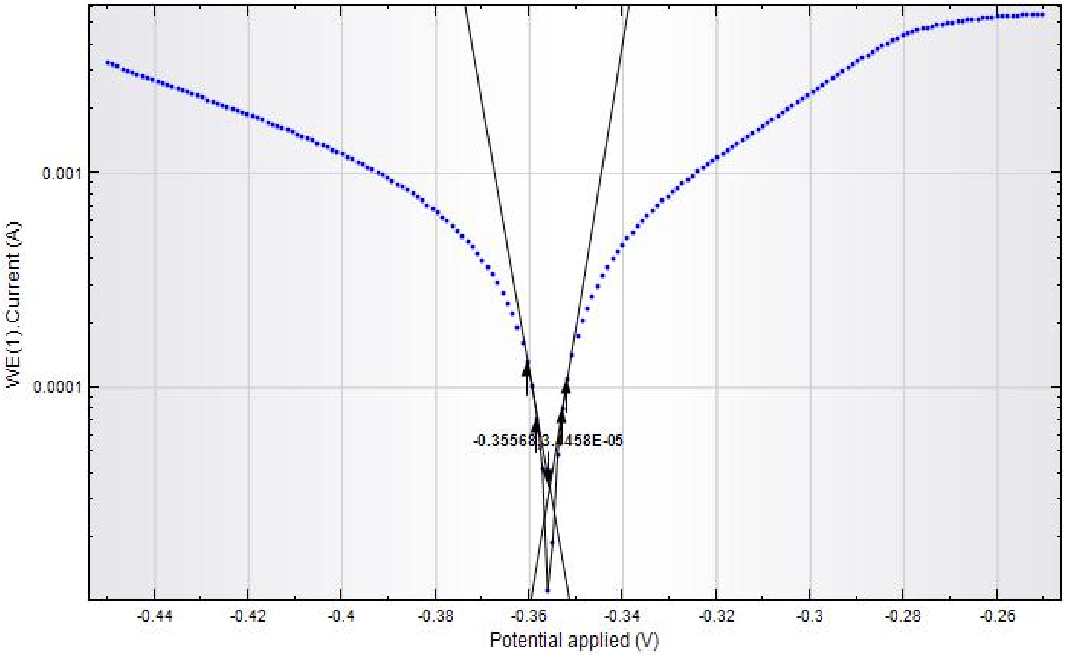


Figure: Graph for 304 ss sample in 0.75M H2SO4

ba (V/dec) (V/dec)	bc (V/dec) (V/dec)	Ecorr, Calc (V) (V)	Ecorr, Obs (V) (V)	jcorr (A/cm²) (A/cm²)	icorr (A) (A)	Corrosion rate (mm/year) (mm/year)	Polarization resistance (Ω) (Ω)	E Begin (V) (V)	E End (V) (V)
0.061523	0.054634	-0.35568	-0.35574	0.000354	0.000354	4.1165	35.474	-0.36041	-0.35187

Table 4: Corrosion rate of 304ss sample in 0.75M H2SO4

1M H2SO4:

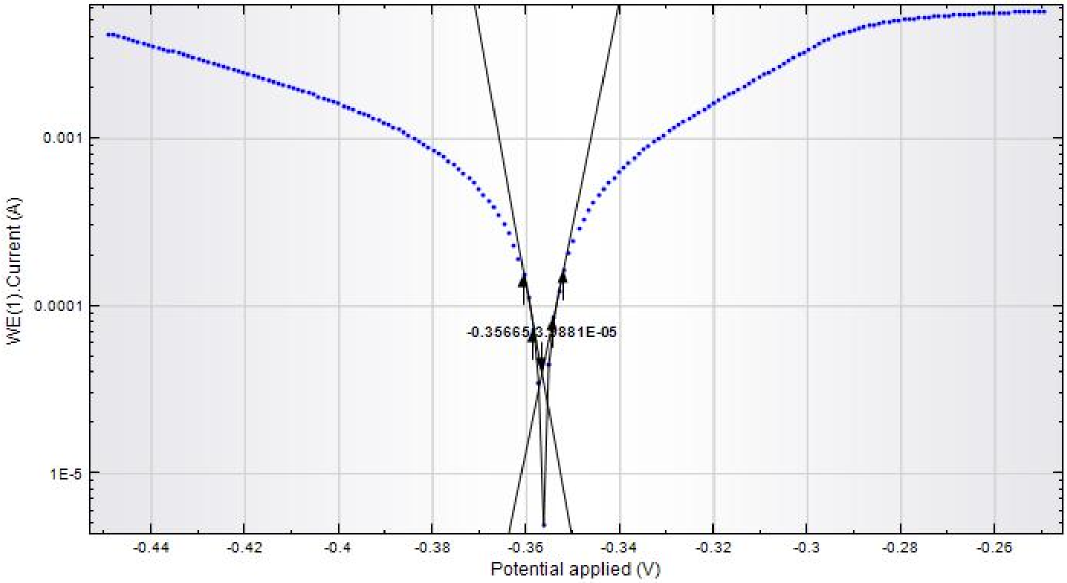


Figure: Graph for 304 SS sample in 1.0M H2SO4

ba (V/dec) (V/dec)	bc (V/dec) (V/dec)	Ecorr, Calc (V) (V)	Ecorr, Obs (V) (V)	jcorr (A/cm²) (A/cm²)	icorr (A) (A)	Corrosion rate (mm/year) (mm/year)	Polarization resistance (Ω) (Ω)	E Begin (V) (V)	E End (V) (V)
0.03973	0.038374	-0.35665	-0.35642	0.000313	0.000313	3.6343	27.105	-0.36057	-0.35202

Table 5: Corrosion rate of 304ss sample in 1.0M H2SO4

1.25M H2SO4:

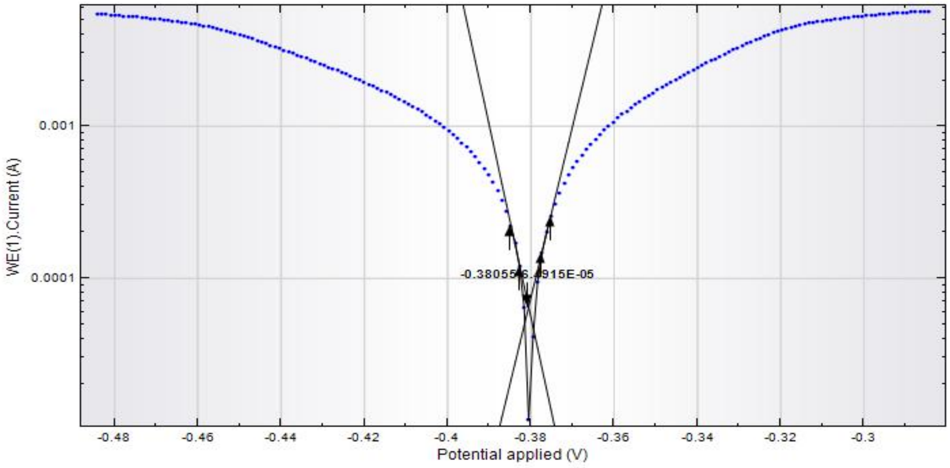


Figure: Graph for 304 ss sample in 1.25M H2SO4

Table 6: Corrosion rate of 304ss sample in 1.25M H2SO4

ba (V/dec) (V/dec)	bc (V/dec) (V/dec)	Ecorr, Calc (V) (V)	Ecorr, Obs (V) (V)	jcorr (A/cm²) (A/cm²)	icorr (A) (A)	Corrosion rate (mm/year) (mm/year)	Polarization resistance (Ω) (Ω)	E Begin (V) (V)	E End (V) (V)
0.062637	0.058065	-0.38055	-0.38032	0.000647	0.000647	7.5176	20.227	-0.38483	-0.37521

316 Stainless Steel

0.5M H2SO4

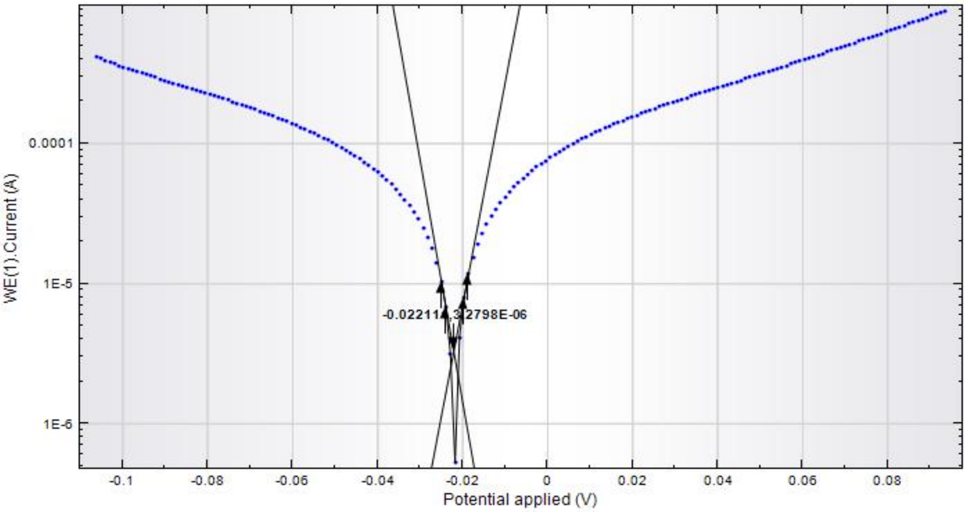


Figure: Graph for 316 ss sample in 0.5M H2SO4

ba (V/dec) (V/dec)	bc (V/dec) (V/dec)	Ecorr, Calc (V) (V)	Ecorr, Obs (V) (V)	jcorr (A/cm²) (A/cm²)	icorr (A) (A)	Corrosion rate (mm/year) (mm/year)	Polarization resistance (Ω) (Ω)	E Begin (V) (V)	E End (V) (V)
0.03115	0.028796	--0.0221	-0.02198	2.23E05	2.23E05	0.25892	291.64	-0.02502	-0.01862

Table 7: Corrosion rate of 316ss sample in 0.5M H2SO4

0.75 M H2SO4

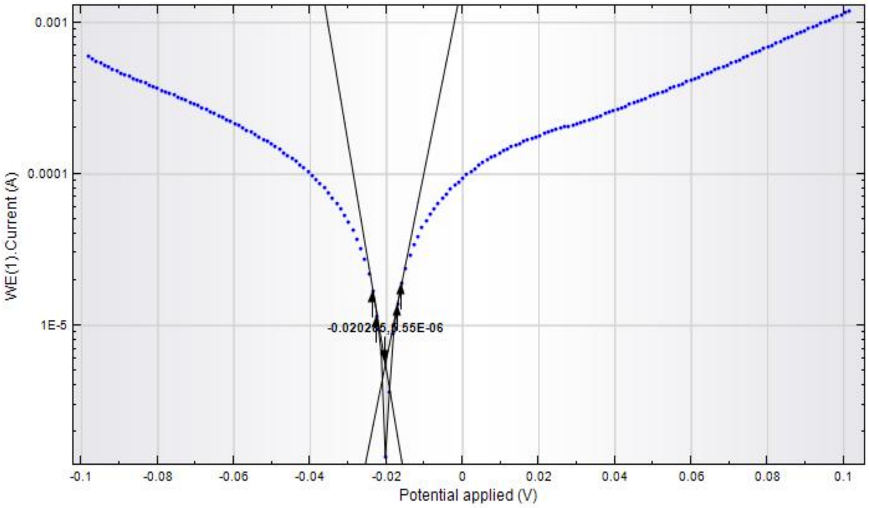


Figure: Graph for 316 ss sample in 0.75M H2SO4

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ba (V/dec) (V/dec)	bc (V/dec) (V/dec)	Ecorr, Calc (V) (V)	Ecorr, Obs (V) (V)	jcorr (A/cm²) (A/cm²)	icorr (A) (A)	Corrosion rate (mm/year) (mm/year)	Polarization resistance (Ω) (Ω)	E Begin (V) (V)	E End (V) (V)
0.059602	0.063357	-0.02029	-0.02001	6.35E-05	6.35E-05	0.73752	210.14	-0.0235	-0.01602

Table 8: Corrosion rate of 316ss sample in 0.75M H2SO4

1M H2SO4 :

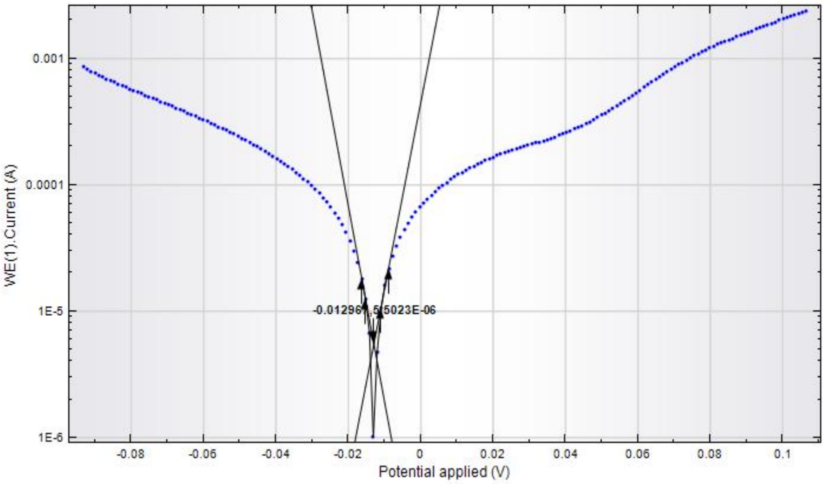

Figure: Graph for 316 ss sample in 1.0M H2SO4

ba (V/dec) (V/dec)	bc (V/dec) (V/dec)	Ecorr, Calc (V) (V)	Ecorr, Obs (V) (V)	jcorr (A/cm²) (A/cm²)	icorr (A) (A)	Corrosion rate (mm/year) (mm/year)	Polarization resistance (Ω) (Ω)	E Begin (V) (V)	E End (V) (V)
0.05873	0.060319	-0.01297	-0.01293	6.91E-05	6.91E- 05	0.80291	187.03	-0.01633	-0.00885

Table 9: Corrosion rate of 316ss sample in 1.0M H2SO4

1.25M H2SO4

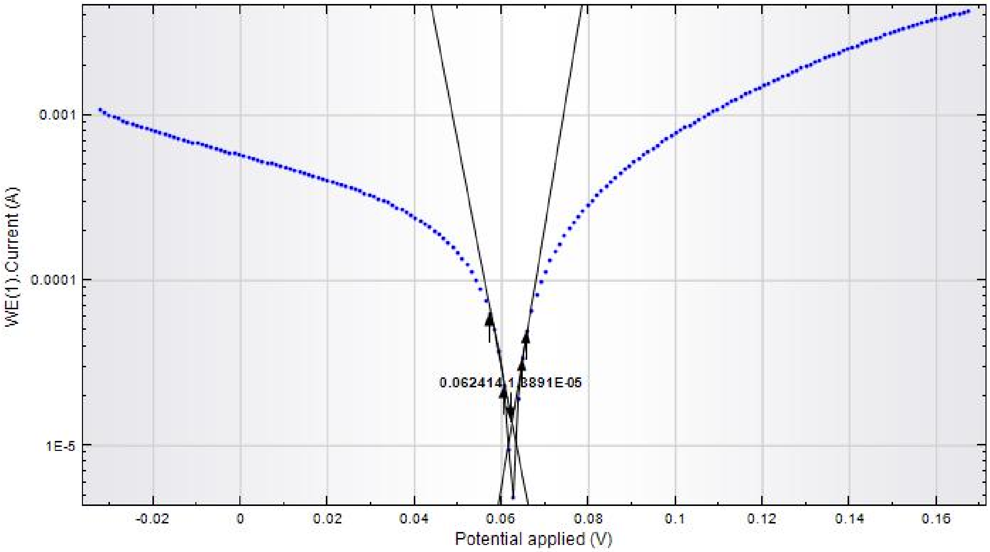

Figure: Graph for 316 ss sample in 1.25M H2SO4

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ba (V/dec) (V/dec)	bc (V/dec) (V/dec)	Ecorr, Calc (V) (V)	Ecorr, Obs (V) (V)	jcorr (A/cm²) (A/cm²)	icorr (A) (A)	Corrosion rate (mm/year) (mm/year)	Polarization resistance (Ω) (Ω)	E Begin (V) (V)	E End (V) (V)
0.047468	0.033523	0.062414	0.062351	0.000113	0.000113	1.3149	75.402	0.057373	0.065918

Table 10: Corrosion rate of 316ss sample in 1.25M H2SO

Cathodic and Anodic Polarization with respect to corrosion rate (mm/year) and polarization Resistance:

Table 11: Data of 304 stainless steel

Materials	ba	bc	CR	PR
0.5	0.04993	0.05493	3.0663	42.249
0.75	0.061543	0.054634	4.1165	35.474
1.0	0.03973	0.038374	3.6343	27.105
1.25	0.062637	0.058065	7.5176	20.227

Table 12: Data of 316 stainless steel

Materials	ba	bc	CR	PR
0.5	0.3115	0.028796	0.25892	291.64
0.75	0.059602	0.063357	0.7375	210.14
1.0	0.05873	0.060319	0.80291	187.03
1.25	0.047468	0.033523	1.3149	75.402

V. CONCLUSION

1. The studied stainless-steel type 304 and 316 corrodes in the H_2SO_4 with an activation polarization and the corrosion rate increases with the increase in acid concentration.
2. In the Case of 304 stainless steel, the cathodic polarization increases as compared to anodic polarization which means the rate of gas evolution becomes more than a dissolution of metal in the concentration of acid media.
3. It clears from the data of 304 stainless steel; there is no effect of higher concentration from 0.5M to 1.0 M Sulphuric Acid. This predicts the formation of oxide film on a metal surface, after that, we find that the corrosion rate sudden increases to double at the highest concentration which indicated the breakdown of an oxide film and also anodic reaction take place gradually which show little bit amount of degrading in term of charge from the interface.
4. It has been found about 316 stainless, the cathodic polarization increasing with an increase in the concentration of H_2SO_4 acid.
5. In overall result of this study based on analysis by potentiating shows that 316 stainless steel is more favorable than 304 in a higher concentration of sulphuric acid due to good polarization resistance.
6. The excellent polarization resistance of 316 stainless steel in the strong acid media may be due to a high percentage (Cr and Ni) alloying elements which help to form an oxide layer on the metal surface. It helps in the solution of concentrated acid.

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