

# International Journal of Innovative Research in Science, Engineering and Technology

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## Effect of Immersion Time on Corrosion Rate of Stainless Steel 304 Subjected to Chloride Environment

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**ABSTRACT:** In the present study the stainless steel 304 is tested for its corrosion rate in chloride conditions for prolonged immersion times. The samples are grounded to mirror surface finish for microstructure evaluation. The same polished samples are used for hardness measurement. The SS304 is tested for micro Vickers hardness and the same is reported. The SS304 sample is tested for its respective constituent elements under energy dispersive spectroscopy. The result is compared with the standard compositional details. The samples are immersed in chloride environment for different time periods and potentiodynamic polarization studies are conducted to evaluate the corrosion behavior.

**KEYWORDS:** Polarization, Immersion time, Corrosion rate, Potentiodynamic polarization

### I. INTRODUCTION

In recent past, the usage of stainless steel was prominently increased in various fields such as industrial applications, household appliances, defense infantry weapons, on shore and off shore structures. Stainless steel is also an alloy of iron with presence of other alloying elements such as chromium and nickel [1]. These alloying elements will help in high corrosion resistance and higher ductility of stainless steel [1]. Depending upon the composition of alloying elements stainless steels were classified as austenitic stainless steels, ferrite stainless steels, martensitic stainless steels [1,2]. Compared to the ferritic and martensitic, austenite stainless steels have higher general pitting resistance [3]. Austenitic stainless steels such as SS304 are useful in fabrication of ship hulls, joints because of its less tendency of atmospheric corrosion [3]. Although resistant to corrosion some severe environments leads to the corrosion of austenite stainless steels [4].

### II. RELATED WORK

The concentration of chlorides in sea water will vary from sea shore to middle of the sea. The higher concentration of chlorides from literature is 35g/l in sea water. When a metal alloy is in contact with the corrosive, there may be the formation of passive oxide layer which behaves as protective layer to resist corrosion [5,6]. Pipeline steel under acidic conditions for higher immersion times and higher temperatures shows increase in corrosion current density values [7]. There is little literature on long term corrosion behavior of other alloys but very less on austenitic stainless steel under higher concentration of chlorides [8].

Present experimental investigations are to study the corrosion characteristics of austenitic stainless steel of type 304 in chloride environment. The composition of the SS304 is given in the following Table 1.

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**Table 1:** Chemical composition of stainless steel SS304

Element	Cr	Ni	Mo	Mn	Si	C	P	S	Fe
Composition (% by mass)	18.42	8.16	0.04	1.59	0.61	0.02	0.018	0.011	Bal

### III. EXPERIMENTAL PROCEDURE

Samples of stainless steel 304 were procured from the metal vendor in the form of large bars. It was made in the form of small coupons of size 1" X 1" and 1cm thick. The samples were metallographically polished using silicon carbide papers of decremental size 1000 to 3000 and then followed by disc polishing with the addition of alumina powder as polishing agent. The polished sample is used for hardness measurement. The micro Vickers hardness tester (SCHIMADZU) was used to determine the Vickers hardness of the polished specimens. Load of 2Kg and the dwell time of 15 seconds were used for each micro hardness test. In the present study, an average of 6 readings for each sample is reported.



**Fig. 1.** The SS304 sheet in as received condition

To determine the corrosion rate of a metal in a short time than the conventional weight loss studies, polarization studies were carried out using electrochemical work station. A laboratory scale electrochemical work station attached with computer for data acquisition and a flat three electrode electrochemical cell was used for the experimental studies. The sample was placed in working electrode port with an exposure of 1cm diameter (0.785 cm<sup>2</sup> area). Saturated calomel electrode (SCE) was used as reference electrode and platinum (Pt) wire used as counter electrode. The sample was kept in contact with the electrolyte of 35g/l NaCl solution for different immersion times as 0hr, 1hr, 2hr, 6 hr and 24 hrs. At the end of immersion time, the electrochemical work station was switched on and the open circuit potential with respect to reference electrode was measured. By forming the basis as open circuit potential, polarization test was run starting from the cathodic side to anodic side with the limits of 250 mV on both sides from open circuit potential. The potential scan rate is 0.1667 mV/s as per ASTM standards. The obtained polarization data in the form of potential vs current was recorded in the form text file in the associated computer.

Tangents were drawn on linear parts of the cathodic and anodic polarization curves as per TAFEL extrapolation method using the software associated with the instrument [9]. The intersection point of anodic and cathodic slopes was extrapolated to the x and y axes to find the polarization characteristics, corrosion current density ( $i_{corr}$ ), anodic slope ( $\beta_a$ ) and cathodic slope ( $\beta_c$ ) values.  $i_{corr}$  is used to calculate the corrosion rate in *mmpy* by incorporating the physical properties of the alloy. The obtained polarization characteristics of SS304 in 35g/l NaCl solution for various immersion times are tabulated in Table 3.

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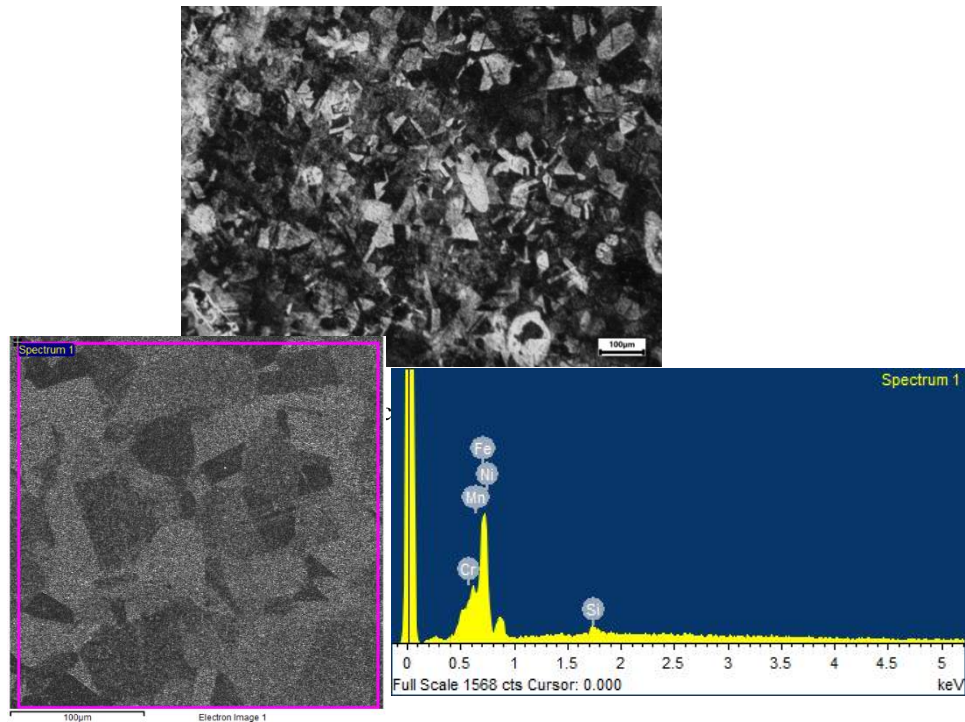
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## IV. RESULTS AND DISCUSSION

Fig. 2 shows the microstructure of the SS304 sample in as received condition. The grains were oriented in all directions.



**Fig.3.** Energy dispersive spectroscopy (EDAX) of SS304 sample

**Table. 2:** EDAX results of SS304 sample

Element	Weight%	Atomic%
Si K	0.66	1.29
Cr K	19.15	20.22
Mn K	1.92	1.92
Fe K	70.39	69.20
Ni K	7.88	7.37
Total	100	

The energy dispersive spectroscopy (EDAX) results were shown in fig. 3. This result is to ensure the constituent elements present in the SS304 sample. The respective amounts of constituent elements were given in table 2. The micro Vickers hardness of the SS304 sample was measured to have  $189.2 \pm 5$  Hv. The optical microscope image of the indentation is shown in fig. 4. From the OM image of indentation it is evident that due to the load during hardness measurements the material was deformed with striations parallel to the diagonal of the indentation rhombus.

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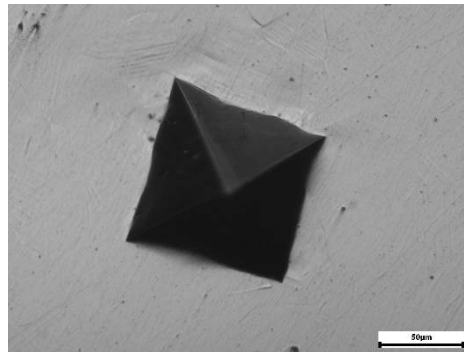


Fig. 4. Optical microscope of the indentation caused by micro Vickers hardness test

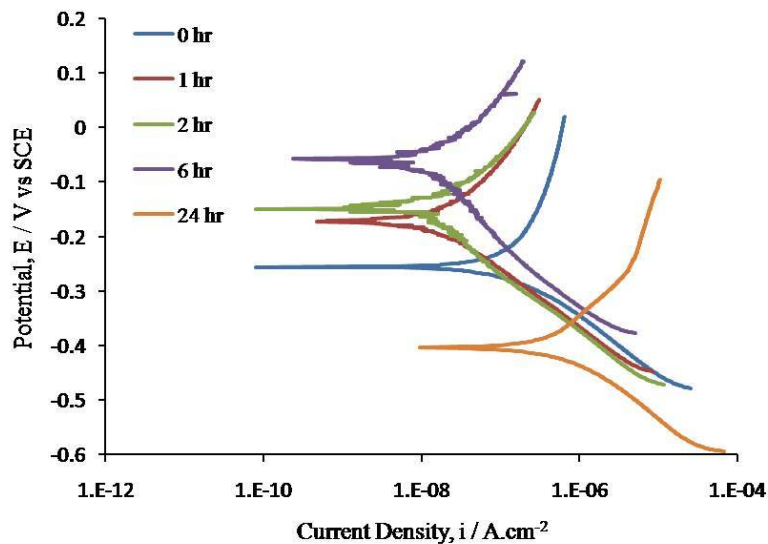


Fig. 5. Polarization curves of SS304 in 35 g/l NaCl solution for different immersion times

Fig. 5 shows the tafel extrapolation polarization curves of the SS304 sample immersed in chloride environment for different time periods. With prolonged immersion time in electrolyte the tafel extrapolation curves shifted to cathodic and anodic sides depending upon the rate of formation of oxide protection layer.

Table 3: Polarization parameters of SS304 in chloride environment for different immersion times

S. No.	Immersion time, hr	$\beta_c$ , V	$\beta_a$ , V	$i_{corr}$ , $\mu A/cm^2$	Corrosion rate, mmpy
1	0	9.855	3.794	0.11310	0.0017135
2	1	9.658	6.705	0.01499	0.0002171
3	2	7.736	7.605	0.01676	0.0002427
4	6	5.935	6.579	0.02048	0.0002964
5	24	3.209	6.909	0.02066	0.0002989

The variation of  $i_{corr}$  and corrosion rate in mmpy with the immersion time of working sample in electrolyte is shown in Fig. 6 and Fig. 7.

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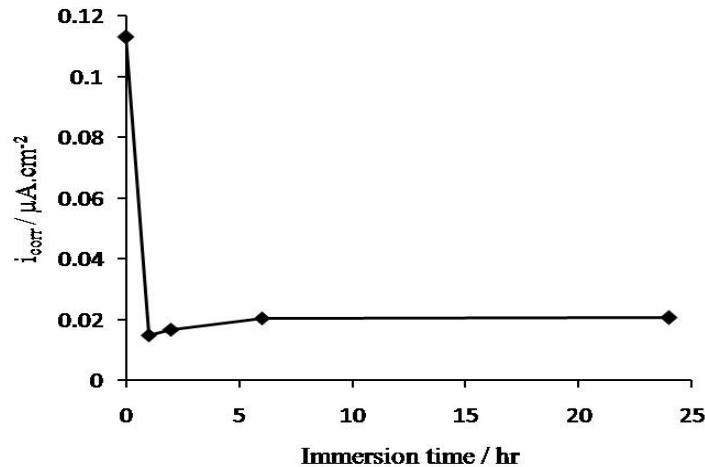


Fig. 6. Variation of  $i_{corr}$  with immersion time for SS304 subjected to 35 g/l NaCl solution

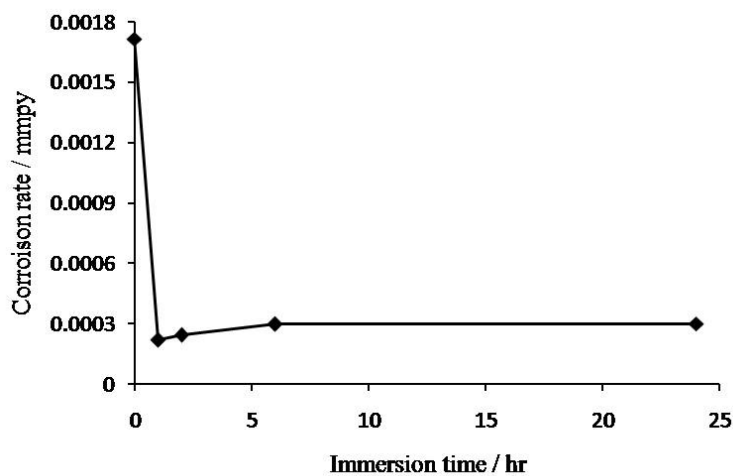


Fig. 7. Effect of immersion time on corrosion rate for SS304 subjected to 35 g/l NaCl solution

It was observed that, the rate of corrosion decreased with the increase in immersion from 0hr to 1hr. This is due to the formation of strong passive protective layer on the surface of the metal when exposed to electrolyte for more time. As the immersion time increases from 1hr to 6hrs corrosion rate is slightly increased and further increase in immersion time to 24 hrs the corrosion rate is asymptotically constant but less compared to 0hr corrosion rate. Fattah et. al also reported that the current density values are decreasing as immersion time increases [10].

## V. CONCLUSIONS

The change in experimental conditions by varying the immersion time subjected to chloride environment provided an understanding about prediction of variation in corrosion characteristics of a metal alloy in an electrolyte. The chemical composition was verified with EDAX studies. The range of potential from cathode side to anode side is close to the corrosion potential value to predict the tendency of dissolution. The decrease in corrosion rate at higher immersion times compared to no immersion time (0 hr) infers that whenever there is an ample time to form a protective oxide film the rate of dissolution decreases under severe environmental conditions also.

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