Research Article

CORROSION CHARACTERISTICS OF AUSTENITIC STAINLESS STEEL SUBJECTED TO CHLORIDE ION IN NEUTRAL SALT SOLUTION

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ABSTRACT

In the present study the metallurgical evaluation and corrosion behavior of the SS316 material is reported. The increasing application of the SS316 in various fields of applications created the need of knowledge about the sample. The samples of SS316 are metallographically prepared for microstructural features in as received condition. The material is tested for hardness and fracture toughness during micro Vickers hardness test. As it is required to evaluate the lifetime and efficiency of performance in various marine applications, the corrosion behavior of the material is evaluated in 3.5% NaCl aqueous solution for prolonged immersion. Corrosion behavior is evaluated through potentiodynamic polarization studies. Corrosion rate decreased with the immersion time. The protective inhibition layer formed by the corrosion products is the phenomenon behind this trend of corrosion behavior.

INTRODUCTION

In present scenario, the usage of stainless steel is increased in different fields such as chemical and allied industries, household utensils, and marine structures. Stainless steel is also an alloy of iron and differs from iron with presence of other alloying elements such as chromium and nickel [1]. The alloying elements majorly chromium will help in high resistance of corrosion and ductility of stainless steel [1]. Depending upon the composition of alloying elements, stainless steels were classified as austenitic, ferritic, martensitic stainless steels [1,2]. Austenite stainless steels have relatively higher general pitting resistance than the ferritic and martensitic stainless steels [3]. Austenitic stainless steels such as SS316 are useful in fabrication of ship hulls, joints because of its less tendency of atmospheric corrosion [3]. Although resistant to corrosion, when exposed to some severe environments leads to the corrosion of austenite stainless steels [4].

The concentration of chlorides in sea water will vary from sea shore to middle of the sea. The maximum concentration of chlorides from literature in sea water is 35g/l. When a metal alloy is in contact with the corrosive electrolyte, there may be the formation of passive oxide layer which behaves as protective layer to resist corrosion and metal becomes passive [5,6].

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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].

In present study, experimental investigations are to find the corrosion characteristics of austenitic stainless steel of type 316 in higher chloride concentration environment.

MATERIALS AND METHODS

The composition of the SS316 is given in the following Table 1.

Table 1 Chemical composition of stainless steel SS316

Element	Cr	Ni	Mo	Mn	Si	C	P	S	Fe
Compositi on (% by mass)	14.38	7.98	1.22	1.02	0.57	0.12	0.015	0.018	Bal

Stainless steel samples of type 316 were procured from the commercial metal vendor in the form of large bars. It was cutted in the form of small coupons of size 2.5 X 2.5X 1cm. The samples were metallographically polished using silicon carbide papers of 1000 to 3000 numbers in decrementalsize of roughness and then followed by wet polishing on a rotating disc polishing machine 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. The polished sample is subjected to a load of 2Kg and for a dwell time of 15 seconds were the

experimental parameters used for each micro hardness test. An average of six microhardness test readings were reported.

Fig 1 The polished SS316sample in as received condition

To find the corrosion rate of a metal in a short time than the conventional weight loss studies, potentiodynamicpolarization studies were carried out using electrochemical work station. A laboratory scale electrochemical work station attached with computer for data acquisition and a horizontal three electrode electrochemical cell was used for the experimental studies. The sample was place in working electrode port with an exposure of 1cm diameter (0.785 cm^2 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 each immersion time, the electrochemical work station was switched on and the open circuit potential with respect to reference electrode (SCE) was measured. By assuming the basis as open circuit potential, polarization test was run starting from the cathodic side to anodic side with the potential range of -250 mV< OCP < +250 mV. The potential is scanned at a rate of 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 (β_a) and cathodic slope (β_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 SS316 in 35g/l NaCl solution for various immersion times are tabulated in Table 3.

RESULTS AND DISCUSSION

Fig. 2 shows the microstructure of the SS316 sample in as received condition. The grains were oriented in all directions.
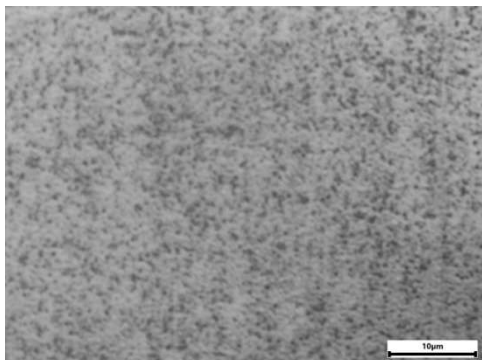

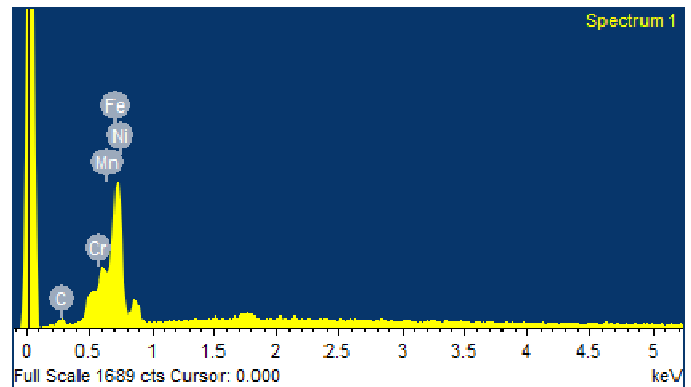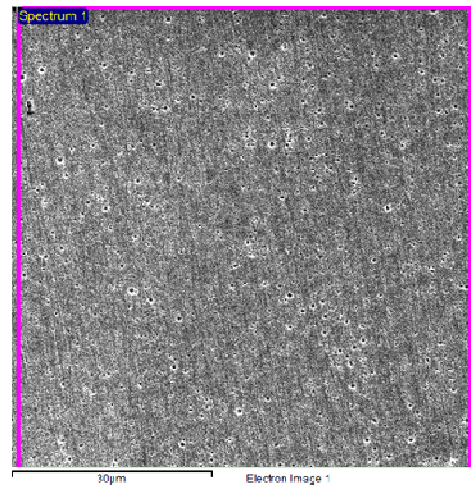**Fig 2** Optical microscope image of SS316

Fig 3 Energy dispersive spectroscopy (EDAX) of SS316 sample

Table 2 EDAX results of SS316 sample

Element	Weight%	Atomic%
C K	1.21	9.76
Cr K	18.02	17.40
Mn K	1.97	1.80
Fe K	69.09	63.76
Ni K	8.51	7.28
Totals	100.00	

The energy dispersive spectroscopy (EDAX) results were shown in fig. 2. This result is to ensure the constituent elements present in the SS316 sample. The respective amounts of constituent elements were given in table 2. The micro Vickers hardness of the SS316 sample was measured to have 189.2+5 Hvand 584.8Mpa fracture toughness which is obtained during hardness test. The optical microscope image of the indentation is shown in fig. 3. From the optical microscope image of micro hardness indentation of the SS316shows that during hardness measurements the material deformed along the diagonal of the indentation rhombus spring backed once the load was removed.
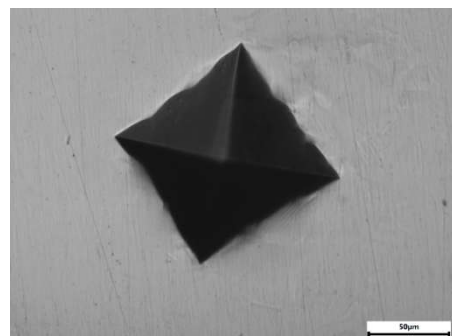
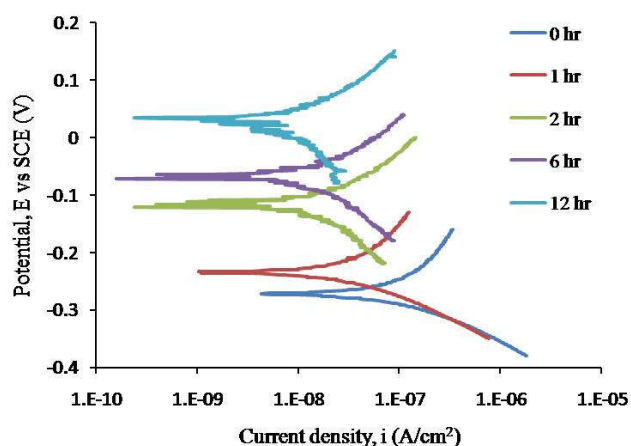**Fig 3** Optical microscope of the indention caused by micro Vickers hardness test

Fig 4 Polarization curves of SS316 in 35 g/l NaCl solution for different immersion times

Fig. 4 shows the tafel extrapolation polarization curves of the SS304 sample immersed in chloride environment for different time periods. The extrapolation curves shifted to cathodic side with the increase in the immersion time which shows the inhibition effect by the corrosion product layer formed during early hours of immersion in 3.5%aqueous NaCl solution.

Table 3 Polarization parameters of SS316 in chloride environment for d ifferent immersion times

S. No.	Immersion time, hr	β_c, V	β_a, V	i_{corr}, µA/cm^2	Corrosion rate, mmpy
1	0	9.842	4.794	0.0729	0.0528
2	1	11.437	4.657	0.03414	0.01953
3	2	6.489	6.988	0.01711	0.009792
4	6	6.769	7.042	0.001707	0.009791
5	12	2.388	7.283	0.000827	0.002287

The variation of i_{corr} and corrosion rate in *mmpy* with the immersion time of working sample in electrolyte is shown in Fig. 5 and Fig. 6.
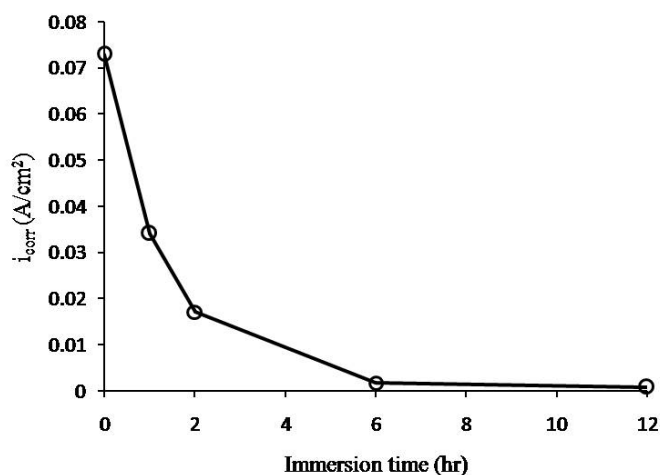

Fig 5 Variation of i_{corr} with immersion time for SS316 subjected to 35 g/l NaCl solution

It was observed that, the rate of corrosion decreased with the increase in immersion from 0hr to 6hr. 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 6hrs to 12hrs corrosion rate is slightly increased and corrosion rate is asymptotically constant but less compared to 0hr corrosion rate.
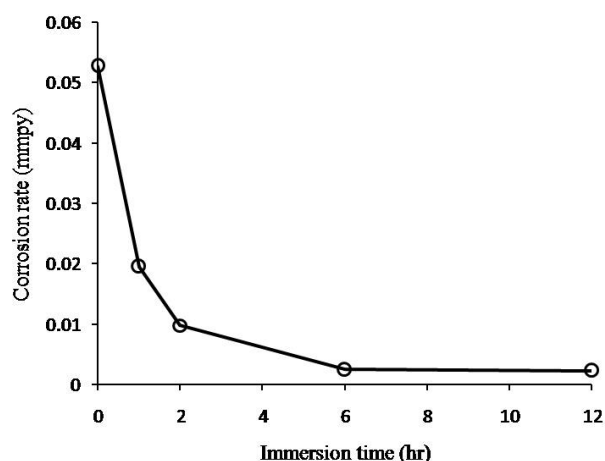

Fig 6 Effect of immersion time on corrosion rate for SS316 subjected to 35 g/l NaCl solution

Fattah *et. al* also reported that the current density values are decreasing as immersion time increases [10].

CONCLUSIONS

The change in experimental conditions by varying the immersion time subjected to neutral chloride environment provided an understanding about finding the variation in corrosion characteristics of a metal alloy subjected tocorrosive electrolyte. The range of potential from cathode side to anode side is close to the corrosion potential value to estimate 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 passive oxide film the rate of corrosion decreases under severe environmental conditions like chloride environments also.

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