iJRASET
International Journal For Research in Applied Science and Engineering Technology



INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 5 **Issue:** XI **Month of publication:** November 2017

DOI:

www.ijraset.com

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor:6.887
Volume 5 Issue XI November 2017- Available at www.ijraset.com

Study of Corrosion Behavior of Some Nitrogen Containing Steel Alloys in Hydrochloric Acid Solutions

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Abstract: Addition of certain alloying elements in steels increase the amount of nitrogen which can be retained on solidification. Addition of nitrogen in austenitic stainless steels can improve their mechanical properties. The increase in nitrogen content along with manganese additions to austenitic steels can balance the decrease in molybdenum and nickel contents of the steels, thus making them cost efficient. Considering the utility and importance of steel alloys, it is very much important to understand the corrosion behavior before using them in industries in the presence of aggressive environments. The study of the systematic investigation and to understand the effect of adding nitrogen and other elements on the dissolution and passivation of stainless steel without molybdenum in hydrochloric acid solutions have been carried out using weight loss and electrochemical techniques. Alloy-2 containing 1087 ppm nitrogen is found to be more resistant to corrosion in HCl solutions than Alloy-1 (853 PPM nitrogen) and Alloy-3 (1447 ppm nitrogen).

I. INTRODUCTION

Austenitic stainless steels are of very common use in a wide variety of industries especially in chemical and power plant industries. These steels are used for their heat and creep resistance, high ductility and good resistance to general and localized corrosion. Austenitic steels usually contain alloying elements like chromium, nickel and molybdenum, whereas chromium is an unpronounceable alloying element, use of higher nickel content is recommended to improve the resistance to chloride attack and molybdenum is added to get better resistance to pitting corrosion. f certain alloying elements[1] in steels increases the amount of nitrogen which can be retained on solidification. Chromium and manganese have been found to affect the properties of conventional austenitic stainless steel to an appreciable extent. The austenitic stabilization properties of manganese [2] have been utilized in stainless steel. Chromium is an internal part of the austenitic steels whereas manganese additions can be made to vary the nitrogen contents of the steels. They differ from the conventional austenitic stainless steels in a way that manganese has been substituted for part of nickel, thus allowing greater amount of nitrogen to be dissolved in the matrix of the alloy. Incidental levels of nitrogen are normally higher in stainless steels than in low chromium steels because of the effect of chromium on solubility. Deliberate additions can be made to control structure, to increase strength or to delay in the precipitation of carbides and inter metallic phases [3], in the austenitic and martenistic groups. The requirements of increasing the corrosion resistance of stainless steels to acids, chloride media and increasing the levels of toughness and strength can be met by adding chromium, molybdenum and nitrogen in stainless steels. Magdowski et al.[4] found that a high nitrogen high chromium austenitic cold worked steel is resistant to stress corrosion cracking in environments where a high carbon low chromium austenitic of similar yield strength is highly susceptible to stress corrosion cracking. Conventional austenitic stainless steels (ALSI 304L, 316L) are very prone to stress corrosion cracking in hot chloride environments and the use of higher nickel and molybdenum containing stainless steels or ferritic steels are recommended to avoid it. Alloying with higher contents of nickel and molybdenum makes the steels more expensive and prone to welding problems. It has been reported that alloying with manganese and nitrogen can balance to some extent the addition of nickel and molybdenum. It has been indicated by several authors that the addition of nitrogen to conventional austenitic stainless steels can lead to improvements in general and localized corrosion resistance[5-9]. The nitrogen contents are 0.03% and 0.19% for normal and modified steels respectively. Clayton and Martin[10] found that passive films formed on alloyed steels contain higher concentration of chromium and molybdenum than comparable steels containing less amount of nitrogen. It was found that the low nitrogen steels had high nickel content to ensure austenitic structure and this reduces corrosion rate. The low manganese, high nitrogen steels had only slightly inferior behavior despite the lower nickel content. Steels with higher manganese but similar nitrogen content gave substantially inferior results. Many more data are needed for a conclusive picture.

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Understand the influence of elements on the corrosion characteristics, three steel alloys were studied by weight loss and polarization techniques in different concentrations of hydrochloric acid solutions.

II. EXPERIMENTAL

The experimental work was planned to study the corrosion behavior of three commercially important alloys in different concentrations of hydrochloric acid solutions.

A. Materials

Commercial steel alloys used for the study were procured from M/S JINDAL STRIPS LTD. in the form of sheets. The chemical composition of the steel alloys was as follows:

SAMPLE	COMPOSITION (wt %)									
	Cr	Ni	N	C	Si	Mn	P	S	Cu	Fe
Alloy-1	14.60	1.95	853ppm	0.068	0.50	9.03	0.058	0.006	1.81	Balance
Alloy-2	15.20	2.06	1087ppm	0.062	0.72	9.05	0.077	0.007	1.76	Balance
Alloy-3	14.52	1.82	1447ppm	0.090	0.55	8.29	0.074	0.013	1.60	Balance

Alloys sheet samples were used in as received conditions. Double distilled water was used to prepare all the solutions. All the chemicals used were of AR grade. The experimental work was carried out with the help of following techniques.

B. Weight Loss Method

For weight loss study, steel alloys specimens of size 5.0 cm X 1.0 cm were used. After polishing, the surface of the specimens were washed and dried. The specimens were dipped in 200 ml solution of 1.0M and 0.1M hydrochloric acid solutions for 3 hours. The temperature inside the air thermostat was maintained at 40^0C with an accuracy of ± 0.2^0C.

C. Potentiostatic Polarization Technique

Polarization experiments were carried out potentiostatically using a potentiostat/ galvanostat PGS20 IT(Radiometer Analytical, SA, France). For potentiostatic polarization studies rectangular working electrodes of 5.0 cm X 1.0 cm were prepared. Only 1.0 cm^2 area of the specimen was used as working area for electrochemical experiments. The experiments were carried out in 1.0M and 0.1M hydrochloric acid solutions at 40^0C.

III. RESULTS AND DISCUSSION

In the present work, corrosion behavior of three nitrogen containing steel alloys have been investigated in 1.0M and 0.1M hydrochloric acid solutions at 40^0C using weight loss and electrochemical polarization techniques. An attempt has been made to understand the influence of nitrogen on the corrosion behavior of steel alloys in hydrochloric acid solutions. Corrosion rates for three nitrogen bearing steel alloys have been experimentally measured by weight loss method and polarization technique in 1.0M and 0.1M solutions of hydrochloric acid at 40^0C and are recorded in Table 1 and Table 2 respectively. The results obtained by weight loss and polarization technique are in good agreement within the limit of experimental error. It is clear from the results obtained that corrosion rate goes on decreasing from Alloy-1 to Alloy-2 but again increases as we move from Alloy-2 to Alloy-3. This suggested that increasing the nitrogen content from 853 ppmto 1087 ppm decreases the corrosion rate but further increase in nitrogen from 1087 ppm to 1447 ppm increases the corrosion rate appreciably. These results show that the addition of nitrogen to conventional stainless steel up to a limit of 1087 ppm improves the corrosion resistance considerably. However, when the nitrogen content is more than 1087 ppm, corrosion rate again increases. This is very amazing, important and interesting result and it is suggested that the amount of nitrogen in conventional stainless steel should be kept about 1087 ppm to get maximum corrosion resistance. Hence the addition of nitrogen beyond a limit of 1087 ppm in the chromium-nickel containing steels is detrimental from corrosion point of view. This detrimental effect of nitrogen is in good agreement with the results reported by other workers[11,12] on alloy containing 1500 ppm nitrogen content.

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TABLE 1

Corrosion rate of steel alloys by weight loss and polarization technique in 1.0 m hcl at 40^0c.

SAMPLE	CORROSION RATE (WEIGHT LOSS METHOD) (mpy)	CORROSION RATE (POLARIZATION TECHNIQUE) (mpy)
Alloy-1	10832.62	10479.78
Alloy-2	5190.28	5144.24
Alloy-3	11278.56	10972.26

TABLE-2

Corrosion rate of steel alloys by weight loss and polarization technique in 0.1 m hcl at 40^0c.

SAMPLE	CORROSION RATE (WEIGHT LOSS METHOD) (mpy)	CORROSION RATE (POLARIZATION TECHNIQUE) (mpy)
Alloy-1	49.25	43.66
Alloy-2	16.12	13.64
Alloy-3	63.87	54.98

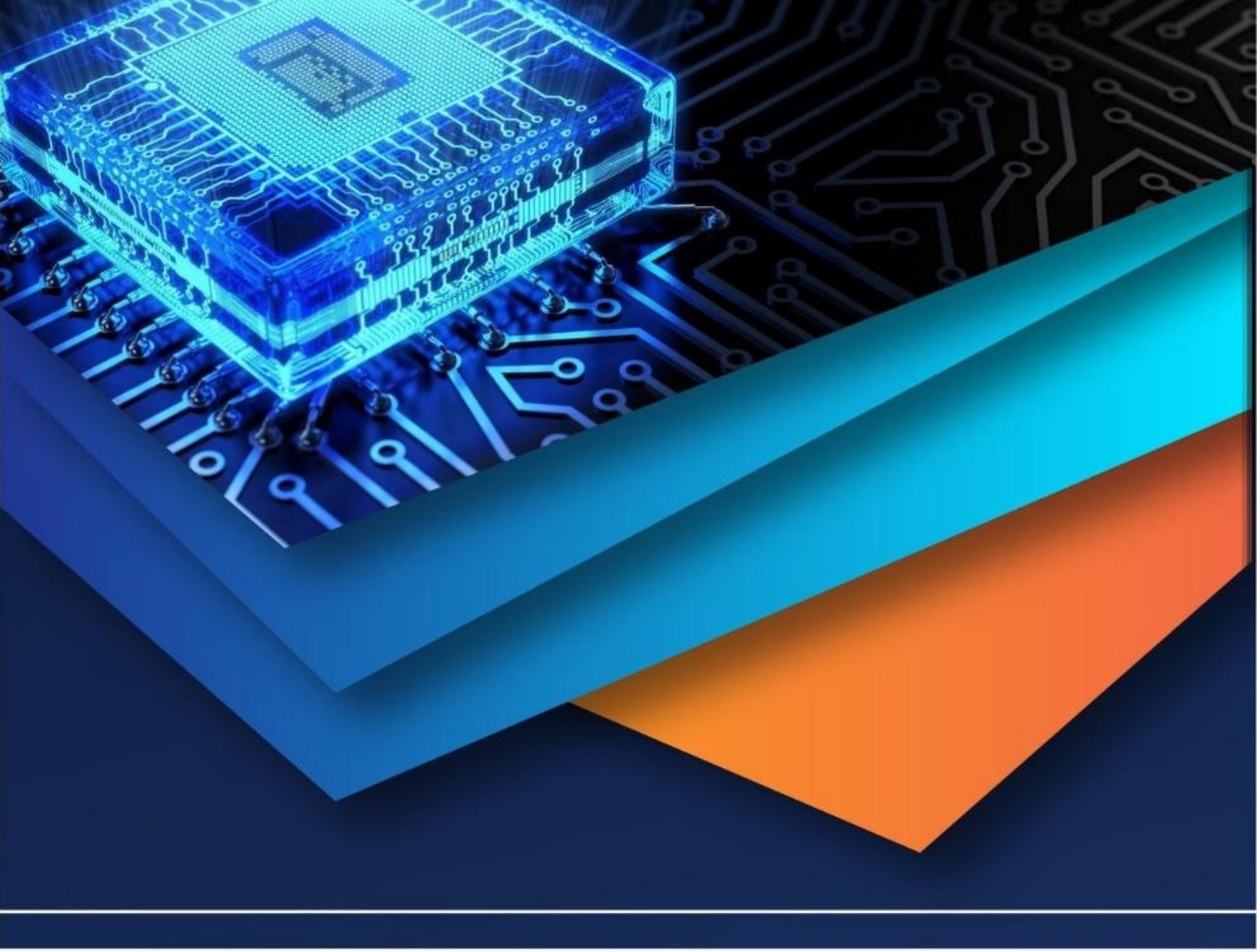
IV. CONCLUSIONS

In the light of corrosion rate results obtained for steel alloys containing different concentrations of nitrogen (853 ppm, 1087 ppm and 1447 ppm) in hydrochloric acid solutions at 40^0C, it is concluded that rate of corrosion decreases with the decrease in concentration of hydrochloric acid from 1.0M to 0.1M. Out of the three alloys studied, alloy-2 containing nitrogen content of 1087 ppm is found to be most resistant to corrosion and alloy-3 having nitrogen content of 1447 ppm is least resistant to corrosion. Hence the addition of nitrogen beyond a limit of 1087 ppm in the chromium-nickel containing steels is detrimental from corrosion point of view. Therefore, the nitrogen content in the steel should be kept about 1100 ppm to get the maximum corrosion resistance behavior.

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