CORPUS PUBLISHERS

Current Trends in Engineering Science (CTES)

Volume 1 Issue 1, 2020

Article Information

Received date: May 31, 2020

Published date: July 07, 2020

*Corresponding author

Pruthviraj RD, Associate Professor, R&D Centre, Department of Chemistry, Rajarajeswari College of Engineering, Bengaluru, Karnataka, India

Keywords Corrosion; Aluminium 7075; MMCs; Phosphoric acid; Tafel polarization; EIS

Research Article

Corrosion Characterization of Aluminum 7075 Reinforced with Silicon Carbide Metal Matrix Composites (MMCs) in different Concentration of Phosphoric Acid Medium

Pruthviraj RD[1]* and Rashmi M[2]

[1]*Associate Professor, R&D Centre, Department of Chemistry, Rajarajeswari College of Engineering, India*

[2]*Research Scholar, R&D Centre, Department of Chemistry, Rajarajeswari College of Engineering, India*

Abstract

The corrosion behavior of Aluminium 7075 reinforced with SiC metal matrix composites was investigated in various concentrations of phosphoric acid solution at 25^{0}C. The study was done by electrochemical method using polarization techniques (Tafel) and electrochemical impedance spectroscopy (EIS) technique. The surface morphology was studied using scanning electron microscope (SEM). The results exhibited that the Aluminium 7075 matrix experience intense corrosion in phosphoric acid medium. The corrosion rate of SiC reinforced Aluminium 7075 composites increases with an increase in the strength of an acid. The outcome obtained by Tafel polarization and electrochemical impedance spectroscopy (EIS) technique were in good agreement with each other.

Introduction

Composites have extended the horizon of engineering materials beyond the realm of natural combinations to man-made combinations. The conventional divisor of materials into metals, ceramics and polymers have been bridged by human ingenuity, developing metal/ceramic, ceramic/polymer and metal/polymer composites possessing a combination of properties, which cannot be obtained in one of the constitutes alone [1]. Modern composites establish an important class of weight efficient and design structural materials that are invasive every sphere of engineering application. Superior directional properties, stiffness properties, high specific strength and design tailoring, ease of manufacturing complex shapes as well as scores of other attributes make these materials ideally, "Designers choice". Metal lattice composites (MMCs) have essentially attractive properties including high explicit quality; damping limit, explicit modulus and great wear opposition contrasted with base compounds. A metal framework composite (MMC) is composite material within any event two constituent parts, one being a metal. The other material might be an alternate metal, for example, an artistic or natural compound. When at any rate three materials are available, it is known as a half breed composite.

MMCs are made by scattering a strengthening material into a network metal. The framework is the solid material into which the fortification is coordinated and is totally nonstop. This implies there is a way through the lattice to any point in the material, not at all like two materials sandwiched together [2]. The framework is normally a lighter metal, for example, aluminum, titanium, or magnesium and offers a similar help for the fortification. The fortification is inserted into the grid. It is utilized to change physical properties, for example, rubbing coefficient, wear opposition or warm conductivity. Consumption is the crumbling or decimation of materials by synthetic or electrochemical association with their condition. Consumption, which is a serious issue looked by most of the enterprises can be considered as one of the more awful specialized cataclysms within recent memory [3]. The outcome of consumption is numerous and the impacts of these on the protected, productive, and dependable activity of structures are frequently more genuine than the straightforward loss of a metal and furthermore adds to the exhaustion of our regular assets. Presently a-days erosion control has been improved, because of expanding utilization of metals in all field of innovation.

Consumption investigation of metal grid composites has gotten extensive consideration by specialists on account of their wide scope of mechanical applications and financial contemplations. (Christian Vargel, 2004; costing and Heins, 1931; Paul and Sigwalt Juniere, 1964). The requirement for lodging, vitality age and transportation in the creating nations is driving the improvement of metal framework composites into the created world. There is likewise increment in the metal framework composite research in some creating nations like China, India, Egypt, and Argentina. These endeavors perceive the way that the simplicity of creation, practical expenses and the quality and toughness of metal lattice composites make them the perfect crude material for minimal effort dependable items. Because of their wide scope of uses, they every now and again interact with acids during de-scaling, pickling, electrochemical drawing and broadly utilized in different concoction businesses. The vast majority of the exploration considers were led on erosion of different metals and amalgams in HCl and H_2SO_4 media (Paul and Sigwalt Juniere, 1964; Ating et al., 2010; Umoren et al., 2009; Obi-Egbedi et al., 2012; Nnanna et al., 2011) [4].

Phosphoric corrosive medium is widely utilized for corrosive cleaning and electro cleaning of aluminum (Christian Vargel, 2004). As indicated by the open writing, very little examination has been finished with respect to the erosion conduct of Aluminum 7075 fortified composites in H_3PO_4 medium. As a piece of our investigations with erosion conduct of Aluminum 7075 framework and SiC strengthened with Aluminium 7075 composite in phosphoric corrosive medium was considered and we report thus the aftereffects of consumption conduct of Aluminum grid and fortified with SiC particulates in phosphoric corrosive mode of various fixations at 25^{0}C.

Table 1: Composition (wt%) of Aluminium 7075 alloy.

Element	Ti	Cr	Mn	Fe	Si	Cu	Mg	Zn	Al
Percentage	0.15	0.2	0.4	0.5	0.5	1.8	1.9	3.25	Bal

Materials

The experiment were performed with Al 7075 matrix and Al 7075 containing 2, 4, 6 percentage of SiC particulates of size 60-80 µm specimens .The raw materials used for this present work is Al 7075 alloy, cut into small pieces add in to the bottom pour furnace by liquid melt metallurgy technique and which is connected to the thermocouple by the additions of SiC in the percentage of 2%,4%,6%the stirrer is introduced to equal distribution of the reinforcement The composition of Aluminum 7075 is given in Table 1. Cylindrical test specimens were sealed with Teflon resin material in such a way that the area exposed to the medium was 1.0 cm^2. It was polished thoroughly with 280, 600, 1000 and 2000 grade emery papers. Further polishing done with disc polisher using levigated alumina to get mirror surface and to remove grit [5]. It was then dried and stored in desiccators to avoid moisture before using it for corrosion studies.

Medium

A stock solution of phosphoric acid medium was prepared using analytical grade phosphoric acid medium (85%) using double distilled water. Phosphoric acid medium concentrations 0.5M, 0.75M and 1.0M was prepared by appropriate dilutions as and when required. Experiments were carried out at 25^0C.

Electrochemical measurements

Electrochemical measurements were carried out by using an electrochemical workstation, CH608E-series, Instrument (USA) with electrochemical analyzer CH instrument beta software shown in (Figure 1). Tafel Polarization measurements were made using conventional three electrode assembly having platinum counter electrode and saturated calomel electrode (SCE) as reference electrode as shown in (Figure 1). The working electrode was made up of Al7075 matrix and composite specimens. All the potential values were measured with reference to the saturated calomel electrode. The polarization curves were recorded immediately after the EIS studies on the same electrode continuously one after the other [6].

Tafel polarization studies

Finely polished Al 7075 specimens of 1.0cm^2 surface area were exposed to corrosion medium of different concentrations of phosphoric acid (0.5N, 0.75N and 1.0N) at 25^0C. The potentiodynamic current- potential curves were recorded by polarizing the specimen to -250mV cathodically and +250mV anodically with respect to open circuit potential (OCP) at scan rate of 5mV/s.

Electrochemical impedance spectroscopy (EIS) studies

Electrochemical impedance spectroscopy, which gives prior information about the electrochemical processes, at the metal solution interface, has been used in many reports on the corrosion studies. The corrosion behavior of the Al 7075 matrix and composites were also obtained from EIS technique using electrochemical workstation, CH608E-Instrument (USA). The Impedance measurement were carried out in a small amplitude ac signal of 10 mV and frequency spectrum ranges from 100kHz to 0.01Hz at the OCP and data were analyzed using Nyquist plots. The charge transfer resistance, Rt was determined from the diameter of the semicircle in Nyquist plot. In all the above measurements, at least three similar results were considered, and their average values are reported [7].

Scanning electron microscopy (SEM)

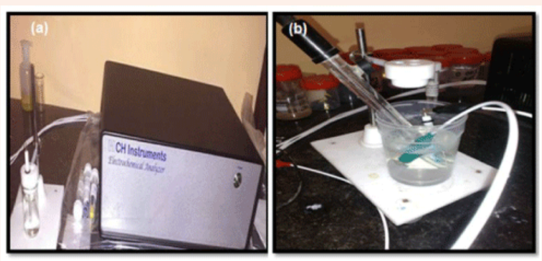

Figure 1: (a) The Electrochemical workstation and (b) Experimental setup.

The SEM images were recorded to establish the interaction of acid medium with the metal surface. The surface morphology shows the features of Aluminum 7075 matrix and composites after immersed in phosphoric acid medium [8]. The scanning electron microscope images indicated that composites having reduced pits while the base alloy Al7075 covered with corrosion products and appeared like full of cavities and pits. Hence the presence of reinforcement SiC protects Al7075 in H_3PO_4 solution.

Results and Discussion

Tafel polarization measurements

Tafel polarization technique used to investigate the effect of phosphoric acid medium on the corrosion rate of Al7075 matrix and composites containing 2, 4 and 6 percentage of SiC sample. (Figures 2-4) represents the potentiodynamic polarization curves of Al 7075 matrix and composites containing 2%, 4% and 6% of SiC in different concentration of phosphoric acid at 25^0C. Corrosion parameters such as corrosion current density (I_{corr}) corrosion potential (E_{corr}), cathodic slope (bc) and anodic slope (ba) are obtained from the polarization curves. Results are tabulated in (Table 2). The obtained result shows that the corrosion rate (υ_{corr}) of Al7075 increases with increase in strength of phosphoric acid and Corrosion rate decreases with increase in percentage of SiC particulate. The positive shift in the corrosion potential (E_{corr}) with the increases in the strength of phosphoric acid medium indicates that the anodic process is much more affected than the cathodic process (EI-Syed, 1997). This observation is in accordance with Muralidharan (Muralidharan and Rajag opalan, 1979), who proposed dependence of I_{corr} and E_{corr} on solution parameters [9].

Table 2: Tafel polarization and Impedance parameters for the Al7075 matrix and composite in different concentrations of H_3PO_4.

Tafel Polarization							EIS
Conc. Of H_3PO_4(N)	% of SiC	I_{corr} (Acm^{-2})	CR(υ_{corr}) (mmy^{-1})	ba (V dec^{-1})	bc (V dec^{-1})	E_{corr} (V vs SCE)	Rct ($ohmcm^2$)
0.5	0	7.078	2.903	5.464	7.457	-0.93	29.3
	2	6.219	2.561	5.014	7.159	-0.81	33.3
	4	5.959	2.454	5.063	7.482	-0.74	38.2
	6	3.118	1.284	5.063	7.913	-0.77	63.5
0.75	0	7.932	3.267	4.752	6.187	-0.75	33.1
	2	7.952	3.275	4.604	5.958	-0.74	36.9
	4	7.807	3.215	4.325	6.118	-0.91	65.2
	6	7.722	3.18	4.604	5.81	-0.74	67.4
1	0	9.386	3.865	4.466	5.862	-0.72	31.9
	2	9.408	3.874	4.39	5.699	-0.7	36.4
	4	8.262	3.403	4.335	5.946	-0.79	67.2
	6	8.102	3.337	4.622	5.944	-0.74	70.2

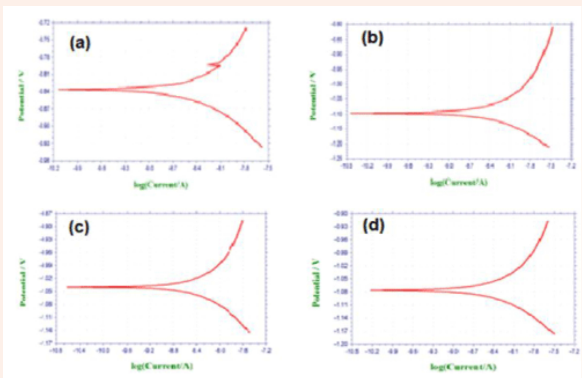

Figure 2: Tafel polarization curve for Al7075 in 0.5N H_3PO_4 containing (a) 0% SiC, (b) 2% SiC, (c) 4% SiC, (d) 6% SiC particulates at 25^0C.

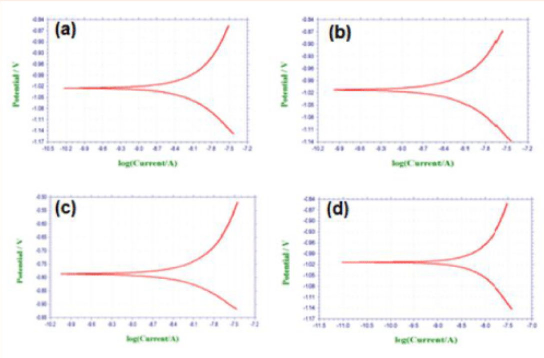

Figure 3: Tafel polarization curve for Al7075 in 0.75N H_3PO_4 containing (a) 0% SiC, (b) 2% SiC, (c) 4% SiC, (d) 6% SiC particulates at 25°C.

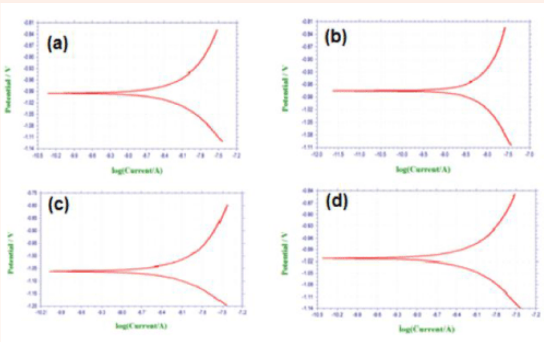

Figure 4: Tafel polarization curve for Al7075 in 1.0N H_3PO_4 containing (a) 0% SiC, (b) 2% SiC, (c) 4% SiC, (d) 6% SiC particulates at 25°C.

Electrochemical impedance spectroscopy (EIS) measurements

The corrosion behavior of Al 7075 matrix and composites were also studied with the help of EIS techniques in different concentrations of phosphoric acid medium [10]. The impedance spectra data were recorded and displayed as Nyquist plots as a function of acid strength. Nyquist plots for different concentration of phosphoric acid medium at 25°C are shown in (Figures 5-7). The EIS data is reported in (Table 2). Nyquist plots for Aluminum 7075 reinforced with different percentage of SiC in different concentrations of phosphoric acid are shown in (Figures 5-7), the Nyquist plots show semicircles, indicating that the corrosion process is mainly charge transfer controlled (Wit and Lenderink, 1996; Lenderink et al., 1993).

The depressed semicircles of the Impedance spectra suggest the distribution of capacitance due to inhomogeneous surface associated with the metal surface (Morad, 1999). It was evident from these plots that the impedance response of Aluminium

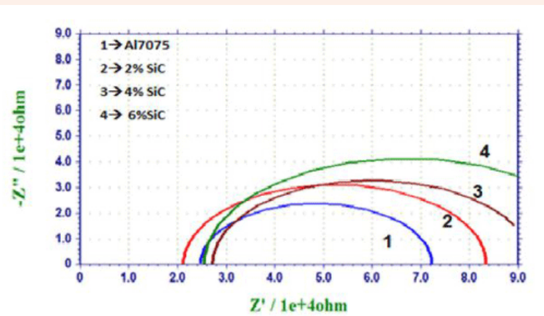

Figure 5: Nyquist plots for Al7075 in 0.5N H_3PO_4 containing different percentage of SiC at 25°C.

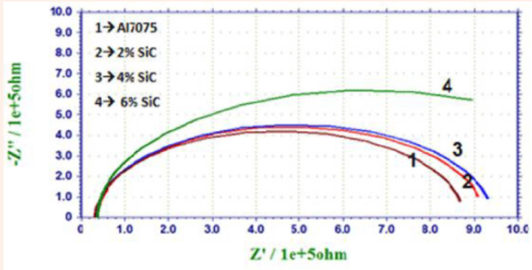

Figure 6: Nyquist plots for Al7075 in 0.75N H_3PO_4 containing different percentage of SiC at 25°C.

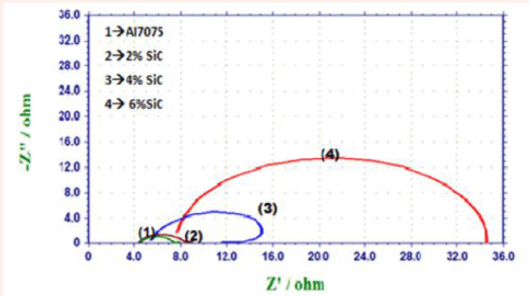

Figure 7: Nyquist plots for Al7075 in 1.0 N H_3PO_4 containing different percentage of SiC at 25°C.

7075 matrix in different concentration of phosphoric acid has significantly altered due to the presence of SiC particulates [11]. The plots were similar in all the composites. Semicircles are obtained which cut the real axis at higher and lower frequencies. At lower frequency end the intercept corresponds to R_s+R_t and higher frequency end, the intercept corresponds to R_s. The difference between these two values gives charge transfer resistance R_t. The results show that R_t values increases with increase of percentage of SiC particulates. The electrochemical impedance parameters obtained from the Nyquist plots are shown in (Table 2). The results derived from EIS method can be interpreted in terms of the equivalent circuit of the electrical double layer shown in (Figure 8) which has been used previously to model the Aluminum / acid and base interface [12]. The Nyquist plots were similar for the Aluminum/SiC composites. The semicircle in all cases corresponds to a capacitive loop. The semicircle radii depend on the percentage of SiC particulates.

The diameter of the semicircle increased with increase of SiC percentage, the increase is significant in 6% SiC particulates. Nyquist plots obtained in the real system represent a general behavior where the double layer on the interface of metal/solution does not behave as a real capacitor [13]. On the solution side ions control the charge distribution whereas metal side it is controlled by electrons. As ions are much larger in size than the electrons, the equivalent ions to the charge on the alloy will occupy considerably a large volume on the solution side of the double layer. From the (Table 2) it was clear that charge transfer resistance values were increased with increase in the percentage of SiC.

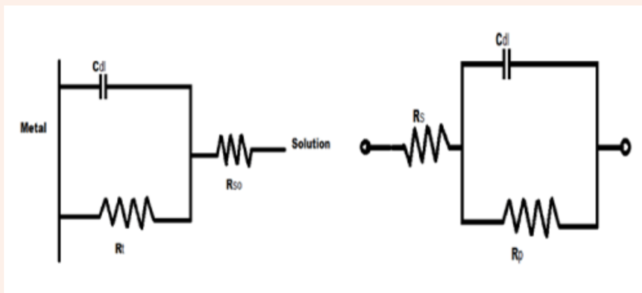

Figure 8: Equivalent circuit for the impedance measurements.

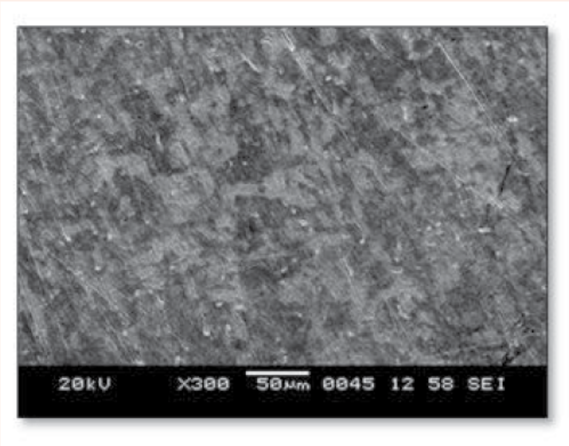

Figure 9: SEM image of polished surface of unreinforced Al 7075 before corrosion.

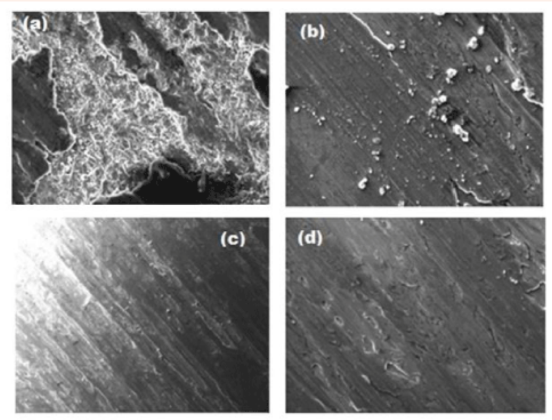

Figure 10: SEM images of Al 7075 after corrosion in 1M phosphoric acid containing (a) 0% SiC, (b) 2% SiC, (c) 4% SiC, (d) 6% SiC particulates.

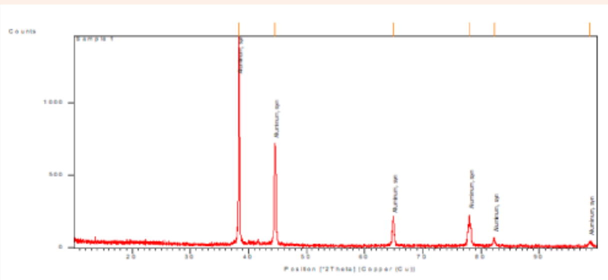

Figure 11: X-Ray diffraction analysis patterns of the unreinforced Al7075.

Scanning electron microscopic study

The SEM images of freshly polished surface of Al7075 are given in (Figure 9) which shows polished surface with few scratches due to polishing. The surface morphology of Al 7075 alloy sample was examined by SEM immediately after corrosion tests in 1.0M phosphoric acid medium. The SEM image of corroded sample given in (Figure 10) shows the degradation is more in unreinforced Al7075 than in MMCs containing 2, 4 and 6 % of Sic particulates [14].

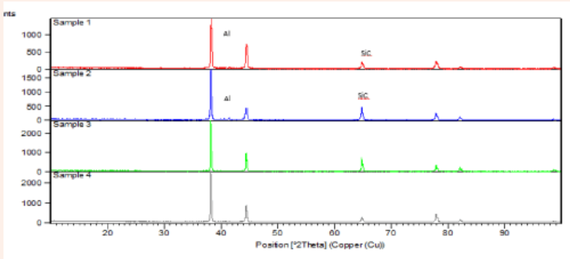

Figure 12: X-Ray diffraction analysis patterns of Al7075 containing 6% SiC particulates.

X-Ray diffraction analysis

The X-ray diffraction technique is an important method used to study phase analysis in MMCs to indicate the reaction between reinforcement and matrix and to determine composite composition. XRD pattern of unreinforced Al7075 and Al 7075/6 wt% SiC is given in (Figures 11&12). The XRD pattern shows the presence of Al7075 matrix and SiC particulates in the composite. From Fig. 11 it can be observed that a uniform structure is formed in Al 7075 matrix. From (Figure 12) it can be observed that, mainly there are peaks of Al matrix and SiC reinforcement. The XRD patterns confirmed the better distribution of SiC in Al7075 matrix, important technique in determining the resultant composite properties [15].

Conclusion

i. Corrosion behavior of Al7075 MMCs was studied by Tafel polarization and EIS measurements in phosphoric acid medium.

ii. EIS is a powerful technique to investigate the corrosion resistance of Al7075 MMCs.

iii. The corrosion rate of Al7075 MMCs increases with an increase in the concentration of phosphoric acid medium.

iv. The corrosion rate decreases with increase in percentage of SiC particulate in Al7075.

Acknowledgment

The authors gratefully acknowledge VGST, Govt. of Karnataka for financial support under the project CISEE/2014-15/GRD No. 325.Also express their gratitude to Management and Principal, Raja Rajeswari College of Engineering, Bangalore for providing infrastructural facilities.

References

1. Sastry KY, Narayanan R, Shamantha CR, Sunderason S, Seshadri SK, et al. (2003) Stress corrosion cracking of maraging steel weldments. Mat Sci and Techn 19: 375-381.
2. Prabhu Deepa, Rao Padmalatha (2017) Corrosion behaviour of 6063 aluminium alloy in acidic and in alkaline media. Arabian Journal of Chemistry 10 (S2234-S2244).
3. Lee DG, Jang KC, Kuk JM, Kim IS (2005) The influence of niobium and aging treatment in the 18% Ni maraging steel. J of Mat Proc Techn 162: 342-349.
4. Bellanger G, Rameau JJ (1996) Effect of slightly acid pH with or without chloride in radioactive water on the corrosion of maraging steel. J Nuclear Mat 228: 24-37.
5. R A Prabhu, T V Venkatesha, A V Shanbhag, G M Kulkarni, R G Kalkhambkar (2008) Inhibition effects of some Schiff's bases on the corrosion of mild steel in hydrochloric acid solution. Corrosion Science 50: 3356-3362.
6. Bellanger G (1994) Effect of carbonate in slightly alkaline medium on the corrosion of maraging steel. J Nuclear Mat 217:187-193.
7. Poornima T, Nayak J, Shetty AN (1964) Data bulletin on 18% Ni maraging steel. The International Nickel Company, INC.
8. Rezek J, Klein IE, Yhalom J (1997) Electrochemical properties of protective coatings on maraging steel. Corros Sci 39: 385-397.
9. Sinha PP (1999) IIM Metal News.
10. Speller FN (1951) Corrosion: Causes and Prevention. 3rd (Ed) McGraw Hill, USA.

11. Larabi L, Harek Y, Benali O, Ghalem S (2005) Hydrazide derivatives as corrosion inhibitors for mild steel in 1 M HCl. Prog Org Coat 54: 256-262.

12. P D Reena Kumari, JagannathNayak, A Nityananda Shetty (2011) 3-Ethyl-4-amino-5-mercapto-1,2,4-triazole as a Corrosion Inhibitor for 6061/Al –15 vol% SiC Composite in a Sodium Hydroxide Solution. Synthesis and Reactivity in Inorganic, Metal-Organic, and Nano-Metal Chemistry.

13. Gunasekaran G, Chauhan LR (2004) Eco friendly inhibito r for corrosion inhibition of mild steel in phosphoric acid medium. Electrochim Acta 49: 4387- 4395.

14. Almeida E, Pereira D, Figueiredo MO, Lobo VMM, Morcillo M (1997) The influence of the interfacial conditions on rust conversion by phosphoric acid. Corros Sci 39: 1561-1570.

15. El Neami KKH, Mohamed AK, Kenawy IM, Fouda AS (1995) Inhibition of the corrosion of iron by oxygen and nitrogen containing compounds. Monatsh Chem J 126: 369-376.