ELECTROCHEMICAL STUDIES OF ALUMINIUM 7075 ALLOY IN DIFFERENT CONCENTRATION OF ACID CHLORIDE MEDIUM

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ABSTRACT: *The corrosion behavior of Al 7075 was investigated in Hydrochloric acid over a range of acid concentration electrochemical techniques like Tafel extrapolation and electrochemical impedance spectroscopy were started and the studies have revealed that the corrosion rate of Al 7075 samples increase with increase in concentration of Hydrochloric acid in the medium.*

KEYWORDS: Al 7075, Acid solutions, EIS, Polarization

INTRODUCTION

Corrosion of structural elements is a major issue for any industry because of the chemical environment of chemical processing. Al 7075 are special class of ultra-high strength metals that differ from conventional Aluminium in that they are hardened by a metallurgical reaction. Recently, the needs of high reliable substances of high strength and high ductility are gradually increased with the development of aerospace industry.[1] The characteristics of this grey and white steel are high ductility, formability; high corrosion resistance, high temperature strength, ease of fabrication; weldability and maintenance of an invariable size even after heat treatment. the corrosion rate of Al 7075 in acid solutions such as sulphuric acid, hydrochloric acid, formic acid, and stearic acid are substantial. Heat treatment affects the corrosion rate. Critical and passive current densities increase as the structure is varied from fully annealed to fully aged. Several technical papers covering alloy design, material processing, thermo-mechanical treatments, welding, strengthening mechanisms, etc., have been published. These Aluminium have emerged as alternative materials to conventional quenched and tempered steels for advanced technologies such as aerospace, nuclear and gas turbine applications. They frequently come in contact with acids during cleaning, pickling, descaling, acidising, etc. Most of the reported studies were conducted on corrosion of various metals and alloys in HCl and H_2SO_4 medium. Phosphoric acid is also used in pickling delicate, costly components and precision items where rerusting after pickling has to be avoided. But no literature seems to be available which reveal corrosion behavior of Al 7075 in acid medium. So it is intended to study the corrosion behavior of Al 7075 in Hydrochloric acid medium.

EXPERIMENTAL PART

Composition of Al 7075(weight %)

7075 aluminum alloy's composition roughly includes 5.6–6.1% zinc, 2.1–2.5% magnesium, 1.2–1.6% copper, and less than a half percent of silicon, iron, manganese, titanium, chromium, and other metals.

Material

Rectangular shape of metals were cut from the plate and covered with Teflon tape in such a way that, the area exposed to the medium is 1 cm^2. These metals were polished as per standard metallographic practice, followed by polishing with emery papers, finally on polishing wheel using legated alumina to obtain mirror finish, degreased with acetone, washed with double distilled water and dried before immersing in the corrosion medium.

Medium

Standard solutions of Hydrochloric acid having concentration 0.1 N, 0.05 N, 0.025 N, were prepared by diluting analytical grade (Nice) Hydrochloric acid with double distilled water. Experiments were carried out at Laboratory temperature.

Electrochemical measurements

Tafel polarization studies

Electrochemical measurements were carried out by using an electrochemical work station, CH Instrument (USA). Tafel plot measurements were carried out using conventional three electrode Pyrex glass cell with platinum counter electrode and Ag/AgCl electrode as reference electrode. All the values of potential are therefore referred to the SRE. Finely polished Al 7075 specimens of 1 cm^2 surface area were exposed to corrosion medium of different concentrations of Hydrochloric acid (0.1N,0.05N,0.025N) at Laboratory temperature and allowed to establish a steady state open circuit potential. The potentiodynamic current- potential curves were recorded by polarizing the specimen to -250 mV catholically and +250 mV anodically with respect to open circuit potential (OCP) at scan rate of 5 mV s^{-1}.

Electrochemical impedance spectroscopy studies (EIS)

Electrochemical impedance spectroscopy (EIS), which gives early 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 was also obtained from EIS technique using electrochemical work station, CH Instrument (USA). In EIS technique a small amplitude ac signal of 10 mV and frequency spectrum from 100 kHz to 0.01Hz was impressed at the OCP and impedance data were analyzed using Nyquist plots. The charge transfer resistance, R_t was extracted 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. The scanning electron microscope images were recorded to establish the interaction of acid medium with the metal surface using JEOL JSM-6380LA analytical scanning electron microscope (CPRI).
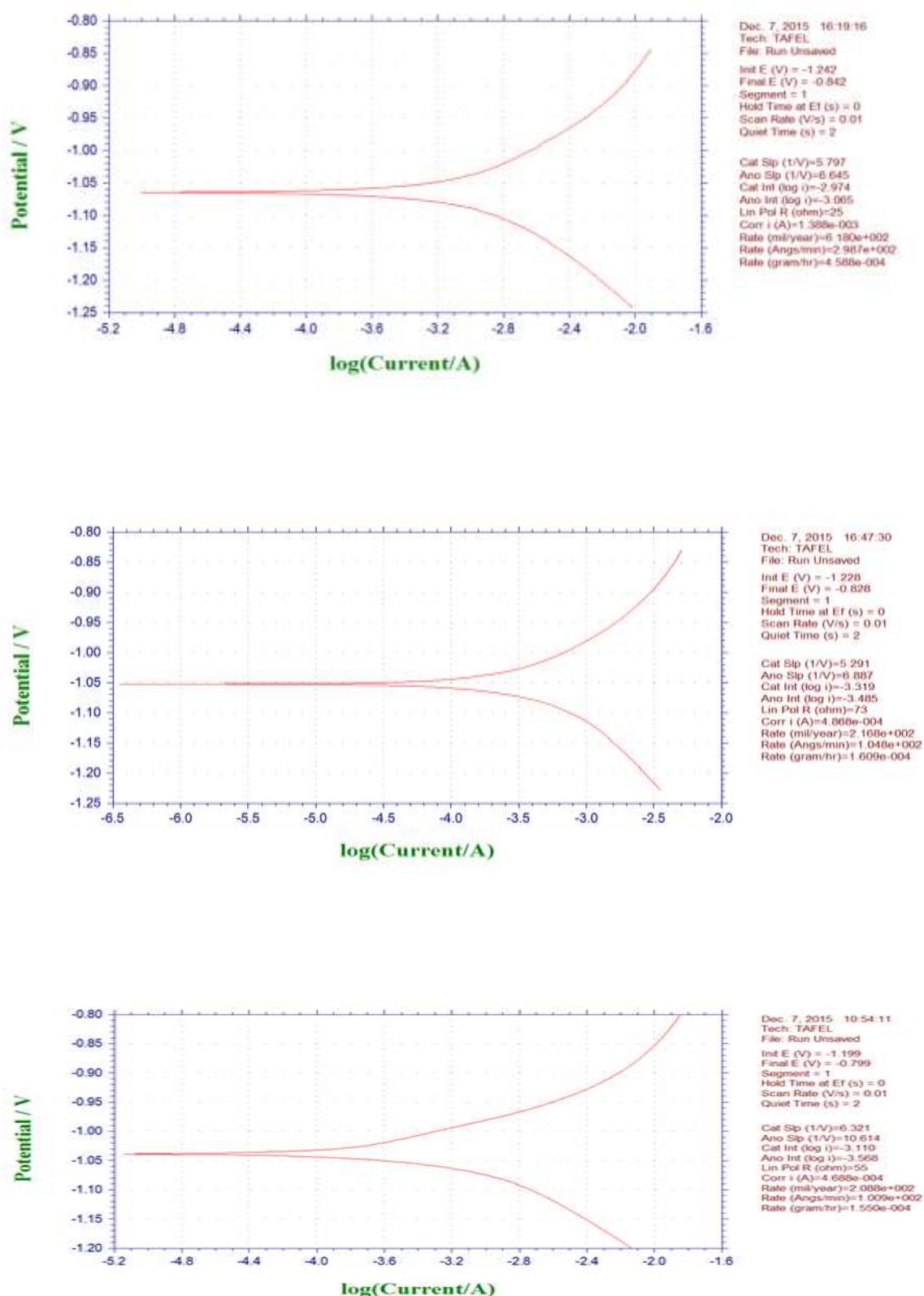
Figure 1 Potentiodynamic polarization curves of Al 7075 in different concentrations of HCl Solution at laboratory temperature.

The potentiodynamic polarization parameters like corrosion potential (E_{corr}), corrosion current (i_{corr}), polarization resistance (R_p), anodic and cathodic slopes (b_a and b_c), and corrosion rate are calculated from Tafel plots.

These results indicate that with increase of both concentration of HCl and solution the R_p value decreases, polarization curves are shifted to high current density region indicating increase in corrosion rate. The nature of polarization curves predicts active corrosion behavior at each temperature and concentration of HCl. It is observed from these results that the corrosion potential is shifted to noble values as the concentration of HCl is increased. This is in accordance with Murralidharan etal who proposed dependence of E_{corr} and I_{corr} on solution parameters. The positive shift in the corrosion potential, E_{corr}, indicates that the anodic process is much more affected than the cathodic. With increase of solution temperature b_a and b_c are almost unchanged indicating no change in the mechanism of corrosion with temperature. The increasing corrosion rate with increasing temperature is in agreement with the observation reported by Jones that, in open system, the corrosion rate of iron increases with temperature up to 80 ^{o}C. This can also be explained by the characteristics of the cathodic process of hydrogen evolution in acidic solutions. The hydrogen evolution overpotential decreases with increase in temperature that leads to increase in cathodic reaction rate.

At the interface of Al and acid electrolyte, the dissolution of Al can be written as follows:

$$Al + H_2O \Leftrightarrow Al(OH)_{ads} + H^+ + e^- \tag{1}$$

$$Al(OH)_{ads} \rightarrow Al(OH)^+ + e^- \tag{2}$$

$$Al(OH \Leftrightarrow Al^{3+} + OH^- \tag{3}$$

At medium and high concentrations of Hydrochloric acid, precipitation of Aluminium chloride occurs at the interface as follows:

$$HCl + Al \rightarrow Al(HCl) + H_2 \tag{4}$$

$$Al (HCl) \rightarrow Al_3(Cl)_2 + HCl \tag{5}$$

Electrochemical impedance spectroscopy

The corrosion behavior of Aluminium 7075 specimens was also investigated by EIS in various concentrations of Hydrochloric acid at Laboratory temperature. The impedance spectra recorded are displayed as Nyquists plots for Al 7075 specimen as a function of concentration of acid as shown in Fig 2.
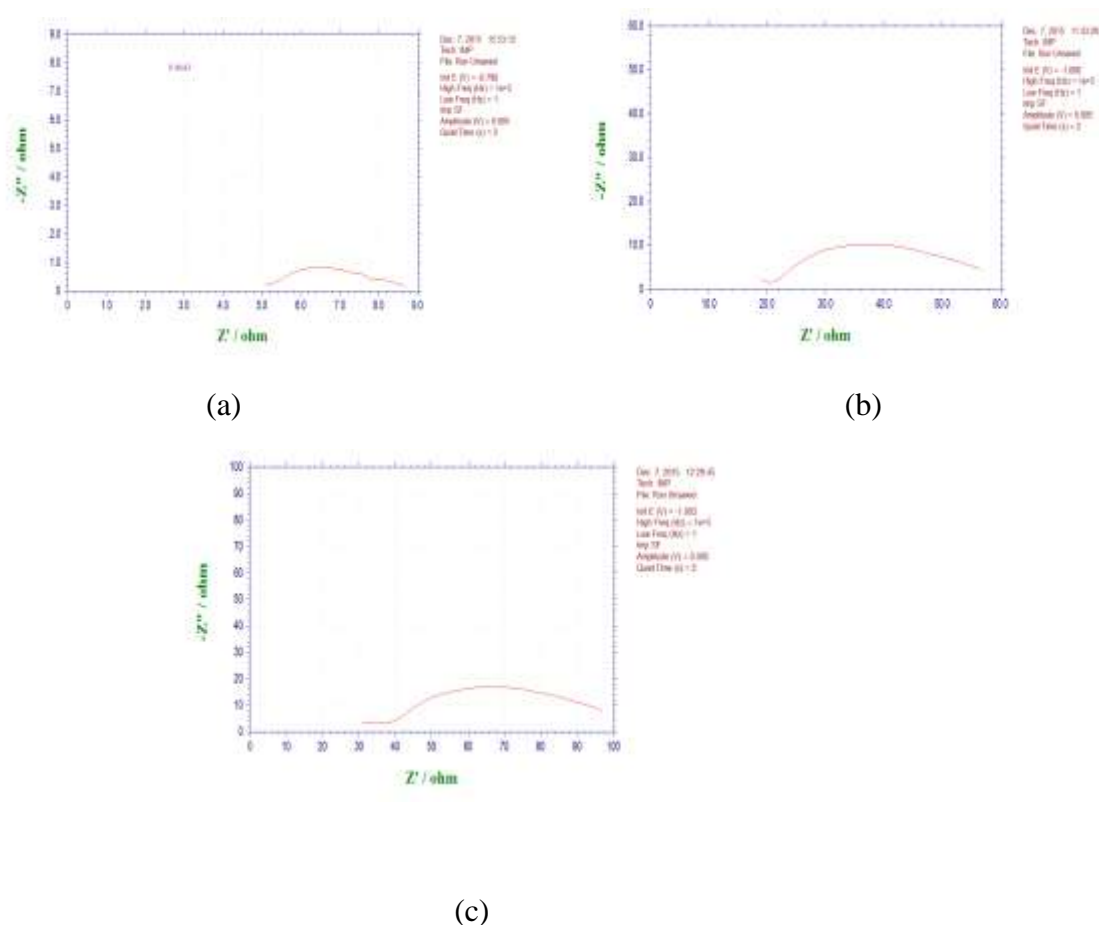
(a)

(b)

(c)

Figure 2 . Nyquist plots for Al 7075 specimen in various concentrations of HCL, a) 0.1N HCl b) 0.05N HCl and c) 0.025N HCl

The depressed semicircles of the Nyquist plots suggest the distribution of capacitance due to inhomogeneities associated with the electrode surface. In order to analyse the impedance spectra containing one capacitive loop, the equivalent circuit given in Fig is used, which has been used previously to model Aluminium/acid interface. The capacitive loops are not perfect semicircles, because the Nyquist plots obtained in the real system represent a general behavior where the double layer at the metal solution interface does not behave as an ideal capacitor. The fact that impedance diagrams have a semicircular appearance shows that the corrosion of Al 7075 is control by charge transfer process. The intersection of capacitive loop with the real axis on the high frequency region represents the ohmic resistances of corrosion product films and the solution enclosed between the working electrode and the reference electrode, R_S. R_t represents the charge transfer resistance whose value is a measure of electron transfer across the surface and is inversely proportional to corrosion rate . In evaluation of Nyquists plot, the difference in real impedance at lower and higher frequencies is considered as charge transfer resistance R_t . The diameter of the semicircle decreases as acid concentration increases indicating increase in corrosion rate.
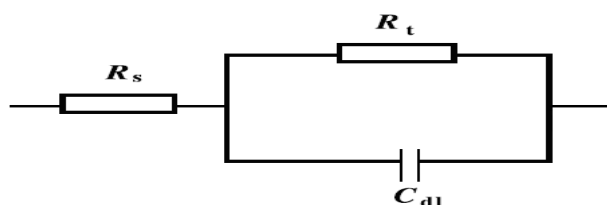
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Figure 3 Equivalent circuit for the metal/acid interface.(R_S solution resistance, R_t charge transfer resistance, C_{dl} double layer capacitance.)

Where R_t is charge transfer resistance obtained from Nyquists plots. A is area of cross section of material under observation b_a and b_c are Tafel constants.

The results obtained by EIS method at various concentrations of are similar to that of Tafel polarization results.
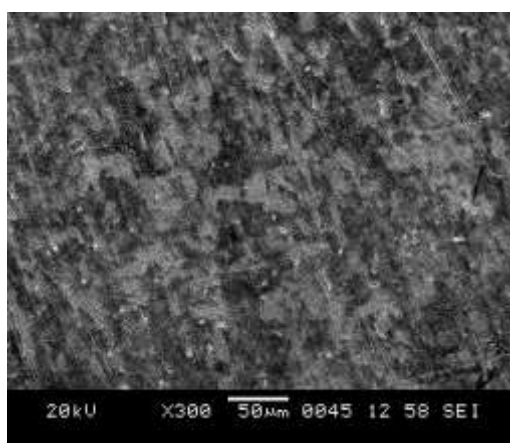
(a)
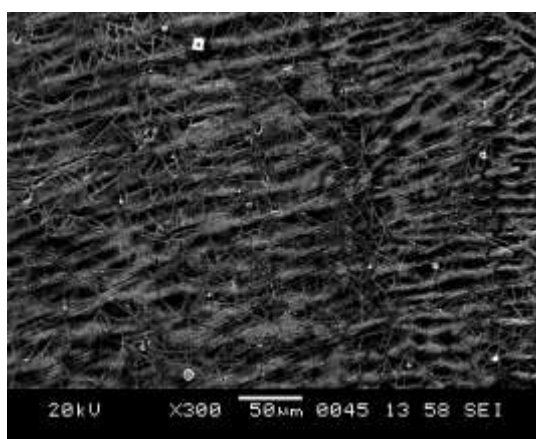
(b)

Figure 4. SEM images of Al 7075 specimen. (a). Freshly polished surface (b). Corroded surface after polarization experiment in HCL

Scanning electron microscope studies (SEM)

The SEM images of freshly polished surface of Al 7075 samples of are given in Figures and which show uncorroded surface with few scratches due to polishing. The surface morphology of the Al 7075 samples was examined by SEM immediately after corrosion tests in Hydrochloric acid medium. The SEM image of corroded Al 7075 sample in Fig 4 shows degradation of alloy, with more or less uniform attack. In the case of corroded samples this degradation is highly pronounced as shown above seems to be concentrated more on and around the grain boundaries. The intermetallic precipitation at grain boundary may be responsible for the higher rate of corrosion.

CONCLUSIONS

Based on results of investigation, the following conclusions may be drawn.

1.   The corrosion rate of Al 7075 specimen in Hydrochloric acid medium is substantial.

2.   The corrosion rates of the specimens are influenced by concentration of Hydrochloric acid medium. The corrosion rate of the specimens under investigation increases with increase in concentration of Hydrochloric acid.

Acknowledgments

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