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Electro-chemical behaviour of different metals in Sodium Chloride solution

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ABSTRACT

As corrosion is defined as the degradation of metal whih is a chemical reaction occurs between metal surface and surrounding atmosphere. In the present work, an attempt has been made to find the corrosion rate of metals like Aluminium, Copper, Mild steel,which are analysed when it is exposed to 5% Sodium chloride (NaCl) solution where 1 cm^2 surface area exposed.The corrosion rate of metals under the influence of NaCl solution was generally analysed by Tafel Fit curve using EC Lab Software. Corrosion potential E_{corr} and Current density I_{corr} values are evaluated and compared for selected metals.

Key Words: Corrosion rate, Sodium chloride solution, E_{corr}, i_{corr}, Tafel plot, cathodic and anodic coefficients

1. INTRODUCTION

Materials are abundantly present and available in nature in the form of ores, which are extracted and undergoes different manufacturing process.By supply of energy they are fabricated and converted into different forms and fulfils the needs and comforts of mankind in daily life.By their natural tendency, these metals will try to react with surroundings and try to release their energy to surroundings which is an initiation of degradation of metals termed as Corrosion. This Corrosion is commonly known as “rust”,occurs due to chemical reaction between metal surfaces and surrounding atmosphere which is an electrochemical reaction. The American Society of Testing of Metals - ASTM: G – 59 – 97 (2014) standard describes about the method of conducting a photodynamic polarization measurement by using potentiostat equipment using two and three reference electrodes, electrochemical cells etc., In this test methods, a small potential is applied to find the corrosion rate potential (E_{corr}) and current density (i_{corr}) by experimentation. The corrosion rate of metal depends on several factors like time duration of exposure, depending upon surrounding atmospheric conditions, type of media,

Temperature of media, material density and surface area of exposure [1,2,3,5]. Several preventive measures are taken to control corrosion rate like coating the metals with paints, non-corrosive metal coatingsetc. There are different types of corrosions which are pitting corrosion, uniform and localized corrosion, crevice corrosion, galvanic corrosion, intergranular corrosion, selective corrosion, erosion corrosion etc., The corrosion rate or degradation of metal is defined as mass loss of material per unit surface per unit time and is measured by using electrochemical workstation in mmpy (millimetres per year) or mpy (mils per year). The relation between mpy and mmpy is given below.

$$1 \text{ mpy} = 0.0254 \text{ mmpy}$$

The corrosion of metals in aqueous solutions is an electrochemical processwhich is one type called wet corrosion. Dry corrosion is also termed as chemical reaction which occurs by the reaction of metal surface with oxygen present in surrounding atmosphere. To find the corrosion rate of metal, so many techniques are used. [4].One of them is potential technique done by the apparatus called electro chemical work station or potentiostat.Corrosion rate or material removal rate is expressed as Corrosion Penetration Rate (CPR) which is estimatedby the help of below formula

$$CPR = \frac{KW}{\rho At} \text{.......[1]}$$

Where, W is the weight loss of material after exposure of time, T is exposure time, A is the exposure area of specimen, K is the constant which depends on units of CPR and ρ is the density of material.

In-general, the corrosion penetration rate should be less than 20mpy (mils per year) or 0.50 mmpy (millimetres per year) is acceptable.

2. LITERATURE REVIEW

The surface of metals like iron, chromium,AISI type 446 stainless steel and other metals are analysed under the influence of H_2S / N_2 gas mixture flow at elevated temperatures, and infrared reflectance and Raman spectra was observed on iron,chromium and stainless steel at elevated temperatures, where high temperatures in surrounding media also influence s the corrosion rate of metals[1,2,3,5].

The method of fabrication of material specimen and its surface roughness also plays a role.When stainless steel metal is exposed to various liquids in most of the industrial applications, and to study the effect of corrosion rate and to determine the quantity of carbon depth profile,the Glow Discharge Optical Spectroscopy(GDOS)and Secondary -ion mass spectrometry (SIMS) technique are used [4].

In medical applications as bioimplants, some metals play a vital role like titanium and its alloys, 316 stainless steel and cobalt-based alloys etc., under the influence of body fluid conditions which are most preferable and advisableand bioimplants made by Laser engineered net shaping process shows less corrosion rate compared to conventional metals and its alloys[6,7,8, 9,16,19,30,33,34].

The process parameters considered to fabricate the component and surrounding media also widely influences the strength and surface finishing of materials while it is indirectly affects the corrosion rate of metals [15,23,24,25].

When the material used as implant in human body, the component undergoes different load conditions and its composition of material plays a role. The hardness of material is improved and wear rate of the material is decreased [10,11,12,13,14,17,18,20,21].

By heat treatment process, the life span of component can be enhanced. The wear rate can be decreased, hardness of the material is increased, and strength of material also improves [22,26,27,28,29,31,32]

3. EXPERIMENTATION

A Tafel plot is a graph defined as an electrochemical kineticsdrawn between two variables which are electrochemical reaction and potential ie., E and log(i) where E is taken on Y-axis in volts and log (i) is on X-axis in mA. The standard graph of Tafel plot and an interface to enter test parameters are shown in below Figure 1 and Figure 2.

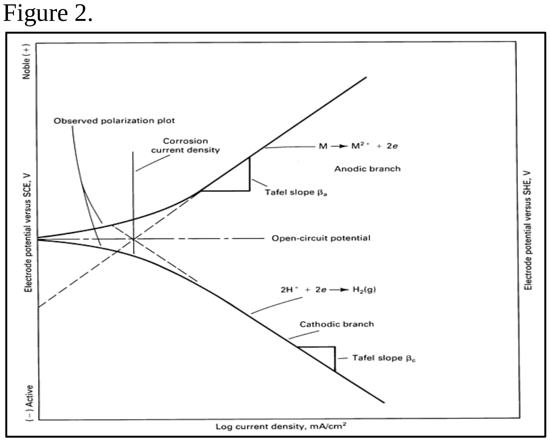

Figure 1: Standard Tafel plot curve

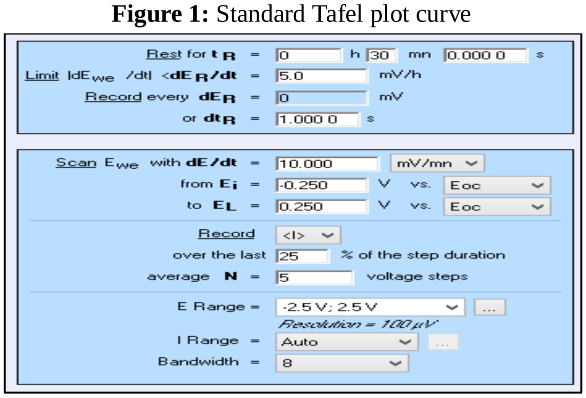

Figure 2: Interface of Test parameters of Tafel plot

3.1 Procedure: As the specimen is placed in apparatus where the specimen is in direct contact with NaCl solution and apparatus is connected to experimentation setup with electrodes.

Genarally, three electrodes Working Electrode, Counter electrode and Reference electrode) which has different potentials are placed in electrolyte. Here, the media is NaCl solution made as 5%.

A small current density is supplied to the apparatus in mV/s and experimentation is carried out. As the experimental setup is stabilized ie., variation in E_{co} value is very less in mV, the test is conducted and the required Tafel plot graph is drawn for the desired specimen.

4. NOMENCLATURE

i_{app} = applied current density of Electrochemical surface area

i_{corr}= corrosion current density in mA

E = applied voltage in volts

E_{corr}= Open circuit potential in volts

β_a= anodic Tafel coefficient

β_c = cathodic Tafel coefficient

$\frac{dE}{dt}$ **=** rate of change in applied potential

5.RESULTS AND DISCUSSIONS

The interface of Tafel plot analysis to enter the test parameters for selected metals is as shown in fig-2 Here in the present test, initial rest time t_R is taken as 2 min and dE/ dt which is current density is considered as 10 mV/s commonly for all materials. The result of Tafel curve for Aluminium and other metals (copper and SS) are shown in below fig-3, Fig-4 and Fig -5.

5.1 **Tafel Plot Curves:**

a) Aluminium: The graph between E (applied voltage) in volts and I (current density) in mA was obtained for Aluminum material which is shown in figure 3, from graph it is observed that the E_{corr} value was initiated above zero level ie., above X -axis.

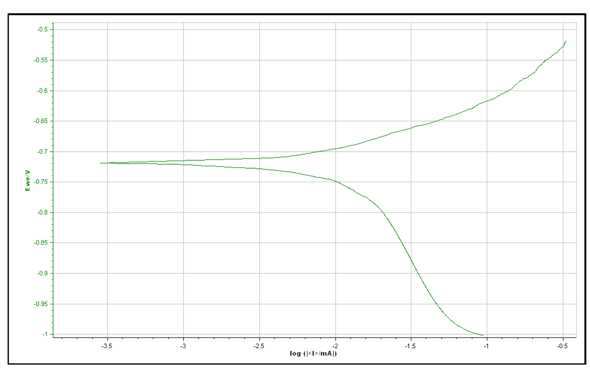

Figure 3: Tafel plot Curve of Aluminum

(a) Copper: parameters of initial rest in minutes (= 2 mn) was taken as common time for all materials and dE/dt is taken as 10 in mV/s and Tafel plot was drawn for copper and stainless-steel materials which are shown in below figure 4 and figure 5.

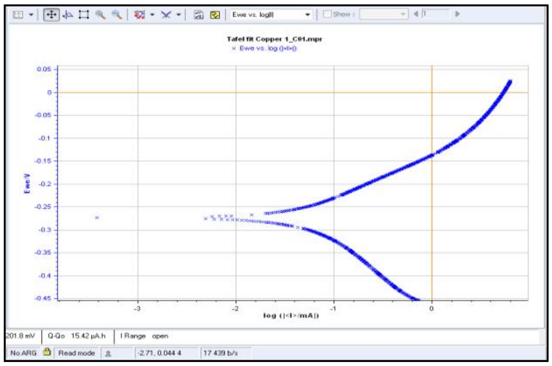

Figure 4: Tafel plot curve of copper

c) Stainless Steel:

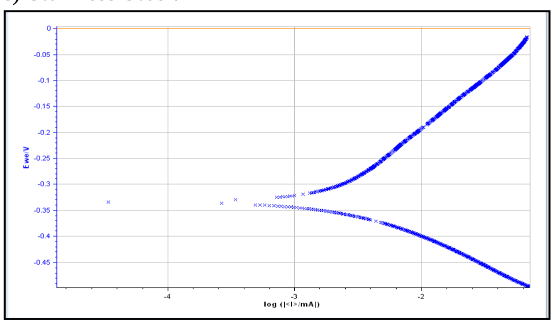

Figure 5: Tafel plot of Stainless Steel

The resulted values of E_{corr} & i_{corr} of specimens are shown in consolidated tabular form (Table 1).

Table 1 : Comparison of Ecorr and icorr values

Material	E_{corr}	i_{corr}	βc	βa
Units	mV	uA	mV	mV
Al	-822.679	12.265	313.6	174.7
Cu	-275.197	54.706	167.0	113.5
SS	-317.756	2.265	121.1	194.7

The graph was drawn between current density and potential for specimens which is shown below figure 6 and beta anodic cofficients and beta cathodic coefficients are compared by graph shown in figure 7 below.

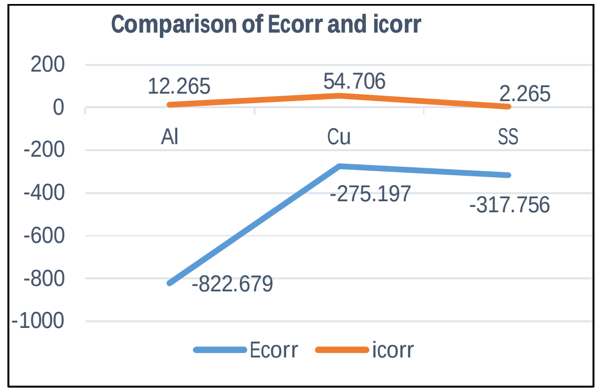

Figure 6: comparison of E_{corr} and i_{corr}

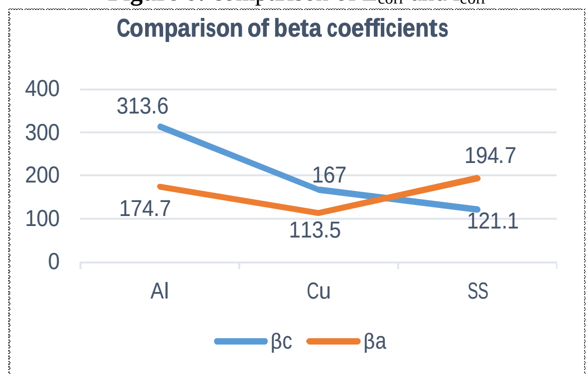

Figure 7: comparison of beta coefficients

After completion of experiment the corrosion rate occurred for different materials was tabulated in below table 2 expressed in mmpy (millimetres per year) and the graph of corrosion rate comparison is shown in Figure 8.

Table 2: Comparison table of corrosion rate values of specimens

Materials	Corrosion Rate in mmpy
Aluminum	**3.7713**
Copper	**6.9541**
Stainless Steel	**2.2208**

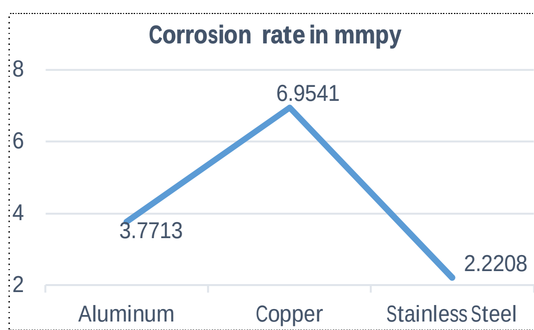

Fig-8 comparison of corrosion rate

6. CONCLUSIONS

The following conclusions are derived from the results obtained by experimentation to find the corrosion rate on selected materials are as follows. They are

- The corrosion rate of copper is more compared to other metals.
- The corrosion rate of stainless steel is less compared to other metals which are aluminium and copper.
- E_{corr} value is very less for Aluminium
- I_{corr} value is more for copper compared to other metals.
- Cathodic coefficient is more for aluminium than other
- Anodic coefficient shows less for copper than other metals

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