Effect of Velocity Aqueous Media on Corrosion Behavior of Copper Alloy C 38500

Laith yousuf Yaqoob
Technical Middle University/Institute of Technology-Baghdad

Abstract— this work aims to study the corrosion behavior of copper alloy C38500 in aqueous media at different velocity. Many specimens were prepared for corrosion test in the dimensions of (15*15*3) mm according to ASTM (G71-31), optical microscopy used to observe the microstructure and phases of metal (α,β).Corrosion tests were investigated by using potential static polarization measurements in seawater 3.5% NaCl and tap water at different velocities (1, 2, and 3) m/min at room temperature, where the test specimen represents the positive electrode (anode) pole while tungsten pole represents the cathode, the voltage was determined by open circuit and compared with the positional of metal in the electrochemical series then voltage was increased ±100 mv , at each 10mv increasing in the current and calculate the corrosion current depending on Tafle role. From the obtained results it was found that velocities contributed in decreasing corrosion rate and tap water give the highest value than sea water.

Index Terms—Copper alloy, corrosion behavior, Sea water, tap water.

I. INTRODUCTION

Architectural bronze alloys enhance the inside and outside appearances of buildings and last for a long time. They are available in many forms and are generally completed by waxing. UNS C38500 architectural bronze alloys have a yellow-gold colour. Copper alloy with zinc as the principal alloying element, with or without small quantities of some other elements [1]. Alloys at the higher zinc levels of 35 to 40% Zn contain the bcc beta phase, especially at elevated temperatures, making them hot extrude able and forgeable .The beta alloys are also capable of being hot worked while containing additions of 1 to 4% Pb, or more recently bismuth, elements added to provide the dispersion of coarse particles that promote excellent machinability. characteristics available with various commercial Cu-Zn-Pb alloys (C31200 to C38500 .Copper and copper alloys are widely used in many environments and applications because of their excellent corrosion resistance, which is coupled with combinations of other desirable properties, such as superior electrical and thermal conductivity, ease of fabricating and joining, wide range of attainable mechanical properties, and resistance to befouling. [2] Copper corrodes at negligible rates in unpolluted air, water, and DE aerated no oxidizing acids. Copper alloy artefacts have been found in nearly pristine condition after having been buried in the earth for thousands of years, and copper roofing in rural atmospheres has been found to corrode at rates of less than 0.4 mm in 200 years. [2] Copper alloys resist many saline solutions, alkaline solutions, and organic chemicals. However, copper is susceptible to more rapid attack in oxidizing acids, oxidizing heavy-metal salts, sulfur, ammonia (NH_3), and some sulfur and NH_3 compounds. [2] The effects of free chlorine on the corrosion of copper in drinking water have been studied more thoroughly, because chlorine is a much more common disinfectant used in drinking water distribution systems. [3] Copper corrosion can be increased or decreased by chlorine depending on pH. At low pH, copper leaching caused by chlorine was found to be the highest. At pH 9.3, the chlorine residual decreased. [3] Sea water is a complex natural electrolyte. The corrosion is severe due to the presence of chloride ions and dissolved oxygen. Sea water has been used as cooling fluid in various industries. So, it is imperative to study the corrosion aspect and find out suitable corrosion inhibitors to be used in sea water. Phosphoric acids are extensively used sea conditions – Wind, waves, subsurface surge, and tidal or oceanic currents can create movements in a aquaculture enclosures. In addition to normal conditions, the aquaculture enclosure must occasionally tolerate storm conditions without failure. The form of the copper alloy material used for the enclosure must be selected to avoid premature failure caused by Motion under all conditions. Submerged structures will experience significantly less motion than structures floating on the surface. [4] Many studies have investigated the corrosion resistance of copper alloy in seawater Xiaoning Liao [5] studied the corrosion behavior of copper under chloride-containing thin electrolyte layers (TEL) finding that the copper corrosion rate increases as TEL thickness decreases during the initial stages and The corrosion behavior is uniform under TEL, and pitting is the primary corrosion type in the bulk solution. Gamal A. EL-Mahdy [6] studied the polarization resistance of copper subjected to NaCl and an ammonium sulfate solution under wet/dry cycling conditions was monitored using an EIS impedance technique. The copper samples were exposed to 1 h of immersion using different solutions, temperature and surface orientation and 7 h of drying. The copper plates corroded more substantially on the skyward side than those for a ground ward side. The degree of protection copper oxide provides decrease in an acidic medium (pH 4) more than in a neutral medium (pH 7). The corrosion rate of copper increases rapidly during the initial stages of exposure then decreases slowly and eventually attains the steady state during the last stages of exposure. L. Nunez a, [7] studied copper corrosion behavior which has been carried out under permanent immersion, water line, splash zone and at the

atmosphere (near and far from the sea) at the tropical Cuban archipelago and he saw that . No significant differences have been determined for corrosion of copper under complete immersion for test sites representative of Cuban archipelago. The result which obtained observed that, the maximum corrosion rate was observed on the line of water, related to the partial removing of the corrosion products layer due to water movement (waves) and a higher availability of oxygen. Xiaohui Zhang [3] studied the corrosion of pure copper for a period of 2–30 days in simulated tap water containing mono chloramine (normally at 4.0 mg/l) in the pH range of 7.6–8.4, using electrochemical impedance spectroscopy, potentiodynamic scan. The results showed that at pH of 8.0, the polarization resistances (Rp) Increased with time mainly during the first 6 days and then slowly from 8 to 30 days. the copper surface was covered heavily by cupric and cuprous oxides after 8 days of immersion.. And insist that the values of Rp increased with higher pH (from 7.6 to 8.4) from the beginning of the immersion to the 8th day and the process was faster at higher pH. Increases of ionic strength, DIC and temperature promoted corrosion, resulting in thicker oxide films and subsequently increasing Rp values. The aim of this work is to study the effect of media (sea water, tap water) velocities on corrosion resistance of copper alloy C38500. [8]

II. EXPERIMENTAL WORK

The experimental procedure was as follows

A. Metal Selection

Copper alloy C38500 was selected in this paper, its chemical analysis is indicated in Table (1) which was conducted by ARL Spectrometer in the specialized institution of engineering industries of Industry ministry.

Table (1) chemical composition of Brass alloy C 38500

Element	Copper	Lead	Iron	Zinc
Nominal [9]	57	3	-	40
Minimum	55	2.5	-	Rem
Maximum	59	3.5	0.35	Rem
Actual	Rem	2.9	0.26	40.5

B. Preparation of specimens

Many test specimens for corrosion test were prepared by the dimension (1.5*1.5*3) cm according to the ASTM G 71-31.and categorized into two groups , symbol (A) give for the specimens which tested in tap water and symbol (B) for the specimens tested in sea water.

C. Microstructure examination

For microstructure test the specimens were prepared as shown below:-

1- The specimens are treated with emery papers grad (220, 320, 500, 800, 1000, and 1200).

2- Polishing by gloss cloth with auxiliary glossing of Al2O3.

3- Etching for the structure by using of Ferric chloride attack

4- Photographing the microstructure by programmed

microscope type advanced polarizing Dark Field metallurgical microscope MTJ Corporation, the photographs of the microstructure of specimen's shows in Fig (1).
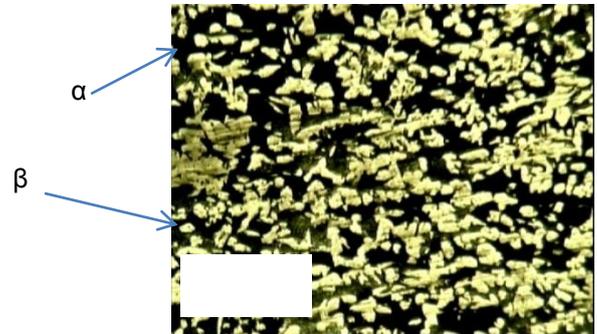

Fig.(1) microstructure of the alloy

D. Corrosion test

Corrosion test carried out as follows:

a- Preparation the Corrosion Solution which includes sea water and tap water. Sea water was prepared by dissolving 35 gm of sodium chloride (NaCl) with one litter of distil water. The pH is measured by pH meter and its found 6.9, and the second solution (tap water) pH was 7.6

B-Electrochemical Tests

The prepared specimen is fixed with in the holder the reference electrode was fixed about (1 mm) apart from the surface of the specimen to be tested. The reference electrode used in this study was Saturated Calomel Electrode (SCE). The auxiliary electrode used in the electrochemical was platinum type. The specimen holder (working electrode) , together with the reference and auxiliary electrode were inserted in their respective position in the electrochemical cell used for this purpose than can fit all these electrodes as shown in Fig (3) Constant potentials (anodic or cathodic) can be imposed on the specimen, By using the potentiostat (Mlab200 of bank Eleck. Germany) . This potentiostat is able to induce a constant potentials ranging from (-1 + lv) the potentials of the standard reference electrode used in this study (SCE). The potential difference between the working and reference electrode (WE – RE) and any current passing in the circuit of working electrode were auxiliary electrode can be measured by using the SCI Computer Software. Any potential difference between the working and reference electrodes circuit can be automatically recorded. The result and plots were recorded. The scan rate can be selected also. Polarized resistance tests were used to obtain the micro cell corrosion rates. In the tests, cell current reading was taken during a short, slow sweep of the potential. The sweep was taken from (-100 to +100) mv relative to (OPC). Scan rate defines the speed of potential sweep in mv/sec. In this range the current density versus voltage curve is almost nearly linear. A linear data fitting of the standard model gives an estimate of the polarization resistance, which used to calculate the corrosion current density (lcor) and corrosion rate. The tests were performed by using a WENKING MLab

multi channels and SCI MLab corrosion measuring system from Bank Electronics – Intelligent controls GmbH, Germany 2007, as shown in Figure (2). The results of electrochemical corrosion are shown in Table (2) by using Tafel equation.

$$C.R = 0.13 * I\_cor * eq.Wt/\rho \qquad mpy \qquad (1)$$

Corrosion rate (C.R) = 0.13 *Icor*31.75 /8.6= 0.48 Icor

   Where:

   lcor   = corrosion current density

   ρ = density of corroding species (g/cm3)

   C.R= corrosion rate

Eq.wt.= equivalent weight

Fig (2) the electrochemical corrosion unit

Symbol	Icor,µA	Ecor mV	C,R mpy
A1	6.05	-291.5	29.04
A2	5.11	-302.1	24.57
A3	5.12	-305.9	24.52
B1	8.86	-106.8	42.2
B2	7.57	-116.5	36.4
B3	4.02	182.7	19.3

Table (2) the results of electrochemical test for copper alloys specimens

III. DISCUSSION

Fig. (1) Shows the microstructure of the alloy clear that brass Contains two phases (β and α) with a dendritic structure which obtained as a result of zinc addition element alloy which contribute in improving corrosion resistance. From fig.(3) and table (2) shows the corrosion behaviour polarization curve for Brass C38500 in sea water 3, 5 % NaCl and tap water at different water velocity (1,2,3) It is seen from cathode and anodic polarization curves that as increasing water velocity there is a decreasing in Icor value for all specimens. Velocity uniforms the cathode and anodic zones by removing possible local excess of H + and OH – ions in an open circuit moving water is a crated and oxygen uptake contributes movement of liquid prevents the formation of deposits under which corrosion can easing develop. [10] In fig.(3) for specimens (B) ,it can be seen an increasing in corrosion rate value in tap water comparing with sea water because tape water contain free chlorine which is used as disinfectant in drinking water. This chlorine ion has a major effect on copper corrosion, where corrosion rate can be increased or decreased by chlorine depending on pH. At low

pH, copper leaching caused by chlorine was found to be the highest. At pH 9.3, the chlorine residual decreased copper corrosion [3]. The pH measured results shows that (tap water) pH was 7.6 for that this value caused an increasing in chlorine which causes an increasing in corrosion rate.
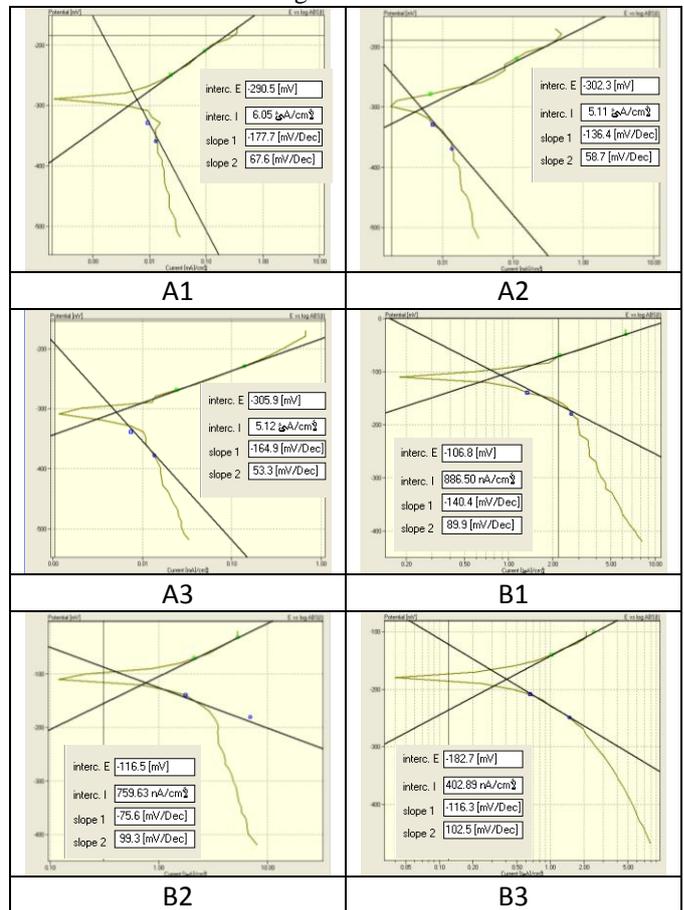

Fig. (3) Potential static polarization results for specimens (A) and (B)

IV. CONCLUSIONS

1- Tape water pH indicates the natural state of water ,but increasing the chlorine ion which is used as disinfectant a contributed in corrosion rate

2- Media velocity contributed in increasing corrosion rate for both Medias

3- Corrosion rat depends on dissolved oxygen ,for that corrosion rate increased in tap water than sea water.

V. FUTURE ENHANCEMENT

Since this alloy had many applications in architectural field, so I suggested measuring the corrosion rate in alkaline and acidic solution at different temperatures

REFERENCES

[1] An article "Architectural Bronze UNS C38500", www.AZom.com, November 27, 2012.

[2] "Corrosion of Copper and Copper Alloys", Key to metals data base, June 2001.

[3] Xiaohui Zhang, Simo O. Pehkonen," Copper corrosion in mildly alkaline water with the disinfectant monochloramine" Elsevier Corrosion Science, Vol.44 .pp.2507–2528, 2002.

[4] Carol Powell , Hal Stillman "Corrosion Behavior of Copper Alloys used in Marine Aquaculture", Article on net ,December 2009.

[5] Xiaoning Liao, Fahe Cao" Corrosion behavior of copper under chloride-containing thin electrolyte layer ", Elsevier Corrosion Science, Vol.53, pp. 3289–3298, 2011.

[6] Gamal A. EL-Mahdy''Atmospheric corrosion of copper under wet/dry cyclic conditions' 'Corrosion Science Vol .47 pp. 1370–1383, (2005).

[7] L. Nunez, E. Reguera, F. Corvo, E. Gonzalez"Corrosion of copper in seawater and its aerosols in a tropical island", Elsevier Corrosion Science Vol. 47 pp. 461–484, (2005).

[8] Xueyuan Zhang, Wenle He, "Determination of instantaneous corrosion rates and runoff rates of copper from naturally patented copper during continuous rain events" Department of Materials Science and Engineering, Division of Corrosion Science, Royal Institute of Technology (KTH), Dr. Kristinas Vol. 51, SE-100 44, Stockholm, Sweden.

[9] ASM Specialty Handbook: Copper and Copper Alloys (#06605G), 2001.

[10] M.B. Valcarce, M. Vazquez "Phosphate ions used as green inhibitor against copper corrosion in tap water" Elsevier Corrosion Science, Vol. 52, pp.1413–1420, (2010).

AUTHOR BIOGRAPHY

Laith yousuf Yaqoob: having M.Sc. from the University of Technology, Baghdad. Currently, lecturer at the institute of technology.