Study of corrosion of Al- bronze in Sodium Chloride Solution in the Presence of benzotriazole

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Abstract

The corrosion behoviour of Aluminum bronze in sodium chloride solution has been studied potentiostatically at five temperatures in the range 293-313K.The corrosion potential shifted to more negative values with increasing temperature. The corrosion current density increased with increasing temperature. Values of Tafel slopes and the transfer coefficients indicated hydrogen evolution reaction to occur at the cathode and mainly the dissolution at the anode.Benzotriazole (BTA) had an inhibiting effect on the corrosion of the Al-bronze in deaerated NaCl solution at a concentration ($1x10^{-3}$- $1x10^{-1}$) mol dm^{-3} over the temperature range 293-313K. Values of the protection efficiency and kinetics parameters were obtained from the corrosion current densities. The results indicated that corrosion reaction on Al-bronze occurred on surface sites having different energies of activation.

Introduction

Aluminum and the aluminum alloys lend themselves too many engineering applications because of their combination of lightness with strength [(1)]. Aluminum –bronzes are used in sea water application [(2)], for manufacture of gears for pumps, and valves .They have a good strength [(2-5)] and superior resistance to cavitations –erosion and impingement attack [(6)]. Aluminum-bronzes usually contain 5-10 %. Al, the structure being duplex when more than about 8 % Al is present .Alloying elements are added to improve their corrosion resistance and mechanical properties [(7)]. The present paper involves a potentiostatic corrosion investigation of an important Aluminum-bronzes in sodium chloride solution in the absence and the presence of benzotriazole(BTA). BTA is known to be a good inhibitor for Copper. Although, the mechanism of its inhibitive action is the subject of continuous debate [(8-12)]. Therefore, BTA has been selected to inhibit the corrosion behavior of the alloy in NaCl solution .The purpose of this paper is to evaluate the efficiency of BTA as a corrosion inhibitor for Al-bronze in 0.5MNaCl, particularly with respect to polarization and kinetic of the corrosion .

Experimental

The Aluminum bronze alloy specimen had the following

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composition as revealed by emission spectroscopic analysis:

Element:	Al	Fe	Ni	Si	Mg	Cu
Wt%	7	0.04	0.01	0.04	0.006	bal

Sodium chloride was analar sample obtained from B.D.H. The cell assembly consisted of working, the platinum auxiliary and a saturated calomel electrode which has been immersed in 750 ml of the test solution .The temperature of the solution was controlled to within 0.01C. The working electrode which was made from aluminum bronze specimen was cylindrical, the exposed area to the corrosion medium was circular in shape with a diameter of 2.3 cm and 1.5 cm length were polished successively with 220,500 and 800 grade silicon carbide papers. Usually the specimens were finally polished on a soft cloth with diamond paste as a polishing material using few drops of a lubricating oil .After that, the specimens were degreased with benzene, dried with acetone. The reference calomel electrode was connected to the working electrode via a Luggin capillary bridge which was filled with the test solution. The polarization curve was obtained using a potentiostat type PRT 10-0.5L which was obtained from Tacussel , France [13].Both the cathodic and anodic current-potential curves were obtained by decreasing and increasing polarization The potential of the working electrode started at-1.0V with scan rate of 150 mv /min until the potential become +1.0v versus the saturated calomel electrode. A potentiodynamic was used recording the current continuously with the change of potential. Corrosion current densities (ic) and corrosion potential (Ec) were calculated from the polarization curves as explained in other publications [14].Experiments were carried out under nitrogen atmosphere .In a series of experiments the NaCl solution , prior to the immersion of the working electrode, was purged for a minimum of 2 hours with pure nitrogen gas (.99.9% purity)at a rate of 150cm^3 min^{-1}.

Result and Discussion

1-polarization behaviour:-

A general increase in the corrosion current density with increasing temperature has been observed, it appears from the previous data that the overall anodic behaviour of Aluminum -bronze in deaerated solution in the presence of the chloride ions is strongly influenced by the dissolution kinetics of copper in alloy [15] .Copper interface in alloy via Cu(I) and Cu(II) spices do occur.Table (1) lists values of corrosion current density and potentials together with Tafel slopes and Transfer Coefficients (&) which have been derived from the slopes of the respective Tafel lines [16-18]. Similar behaviour was noticed in the presence of BTA in deaerated chloride solution as shown in fig (1) .The presence of BTA has a much stronger inhibiting effect on the anodic than on the cathodic reaction .BTA at (5x10^{-2} M) Iowers the corrosion current density by about two orders of magnitude and potential tend to positive direction .This indicates that BTA acts as a predominantly anodic inhibitor, in agreement with previous result[8,19].Table(2) lists values of ic and Ec for the corrosion of the alloy in NaCl solution in the presence of (1x10^{-3}-1x10^{-1}) of (BTA) in deaerated solution

Protection efficiency

The protection efficiency (P) of BTA may be calculated from

$$\ldots\ldots\ldots P = 100\left[1 - \frac{(i_c)_2}{(i_c)_1}\right] \quad ..(1)$$

Where i_1 and i_2 is the corrosion current density in the absence and presence of the BTA under identical experimental conditions [20].Values of (p) that has been calculated for the three concentrations of BTA are given in table(3).The highest protection efficiency of the BTA at $5x10^{-2}$ M. The protection imparted to copper by the BTA was attributed to the retarding effect of the Cu(I) BTA film on the outward diffusion of copper ions which result from the dissolution of copper[7-9].This indicates that BTA interacts faster with the Cu_2O covered alloy surface. However, the Cu-BTA complex, which forms on the reduced alloy surface, has a slightly better inhibiting efficiency than that formed on the Cu_2O covered alloy surface.

Kinetics of corrosion

The rate(R) of the corrosion of Aluminum –bronze in sodium chloride solution increased with the rise of temperature from 293to 313K and the behaviour obeyed Arrhenius equation [21]

$$r = A \exp(-E/RT) \quad ....(2)$$

Where A and E are respectively the pre-exponential factor and the energy of activation. Since the corrosion current density is directly proportional [21] with the corrosion rate (r) ,then eqn.(2) may be put as :

$$i_c = A \exp(-E/RT) \quad .... (3)$$

A plot of log i_c against the reciprocal of the absolute temperature (1/T) was found to be linear as indicated in fig (2). Table (4) shows the resulting values of E and A for the corrosion of Aluminum –bronze in sodium chloride solution in the absence and the presence of BTA. The activation energies (E) of corrosion were generally higher in presence of BTA in sodium chloride solution The variation of log A values remained generally similar to those of E in absence and presence of BTA in sodium chloride solution .Equation (3) indicate that simultaneous increases or decrease in E and log A for a system tend to compensate from the standpoint of the reaction rate.

Table (1) Values of the corrosion current density (ic) and corrosion potentials (Ec) ,Tafel slope and Transfer coefficient for the corrosion of Al-bronze in deaerated solution of 0.5 mol dm^{-3} of NaCl solution at five temperature.

T/K	Ec/V	ic/Acm^{-2}	-bc/$Vdecade^{-1}$	ba/$Vdecade^{-1}$	αc	αa
293	0.060	$3.1x10^{-6}$	0.132	0.122	0.440	0.476
298	0.090	$4.2x10^{-6}$	0.129	0.123	0.458	0.481
303	0.108	$5.1x10^{-6}$	0.123	0.118	0.489	0.509
308	0.113	$6.4x10^{-6}$	0.119	0.116	0.513	0.526
313	0.120	$8.5x10^{-6}$	0.115	0.109	0.540	0.570

Table (2) :Effect of inhibitor concentration benzotrizole (BTA) for Al-bronze in deaerated of 0.5 $moldm^{-3}$ of NaCl solution at five temperatures.

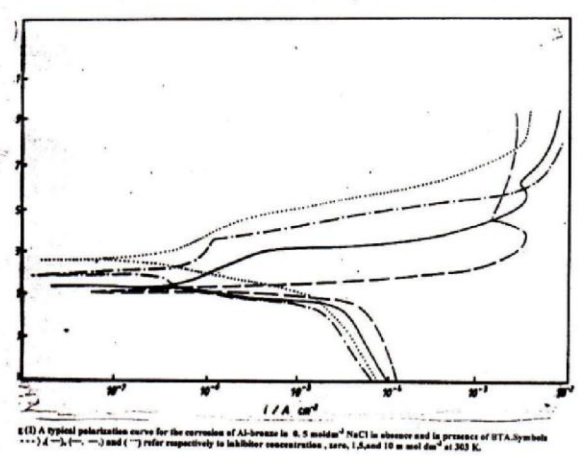
C/$moldm^{-3}$	293K		298K		303K		308K		313K	
	Ec/V	ic/Acm^{-2}	Ec/V	ic/Acm^{-2}	Ec/V	ic/Acm^{-2}	Ec/V	ic/Acm^{-2}	Ec/V	ic/Acm^{-2}
$1x10^{-3}$	0.180	$8x10^{-7}$	0.183	$8.3x10^{-7}$	0.190	$8.6x10^{-7}$	0.192	$9.0x10^{-7}$	0.201	$9.4x10^{-7}$
$5x10^{-2}$	0.191	$5x10^{-7}$	0.198	$6x10^{-7}$	0.210	$7.3x10^{-7}$	0.230	$8.1x10^{-7}$	0.250	$9.2x10^{-7}$
$1x10^{-2}$	0.293	$7.3x10^{-7}$	0.213	$7.4x10^{-7}$	0.228	$8.2x10^{-7}$	0.310	$9.1x10^{-7}$	0.390	$9.5x10^{-7}$

Table (3):Values of protection efficiency (%p) of BTA for the corrosion of Al-bronze in deaerated solution of 0.5 $moldm^{-3}$. of NaCl solution at five temperatures.

C/mol dm^{-3}	% P				
	293K	298K	303K	308K	313K
$1x10^{-3}$	74.2	80.2	83	86	89
$5x10^{-2}$	83.8	85.7	85.6	87.3	89
$1x10^{-2}$	76.5	82.4	84	86	88.8

Table (4) Values of the activation energies (E/k $Jmol^{-1}$) and pre-exponential factors (A/molecules cm^2 s^{-1} for the corrosion of Al-bronze in absence and presence of (BTA) in deaerated of 0.5 $moldm^{-3}$ of NaCl solution at 298K.

Absence (BTA)		In-presence (BTA)					
		$1x10^{-3}$		$5x10^{-2}$		$1x10^{-2}$	
E	A	E	A	E	A	E	A
39.2	$1.94x10^{20}$	6.4	$6.8x10^{13}$	24.6	$7.7x10^{16}$	10.3	$2.64x10^{14}$



g(1) A typical polarization curve for the corrosion of Al-bronze in 0.5 $moldm^{-3}$ NaCl in absence and in presence of BTA.Symbols (···) ,(—), (—. —.) and (¨) refer respectively to inhibitor concentration , zero, 1,5,and 10 m mol dm^{-3} at 303 K.

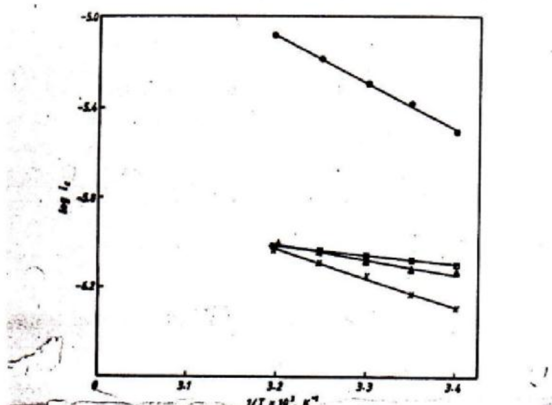


Fig (3) Arrhenius plots, relating log ic values to (1/T) for the corrosion of Al-bronze alloy in deaerated sodium chloride solution (0.5mol dm^{-3}) in the absence and the presence of BTA, symbols, O, □, X, and Δ refer respectively to inhibitor concentration zero, 1,5,and 10 m mol dm^{-3}

Conclusion

1- The corrosion potential shifted to the more negative value with rise temperature in deaerated sodium chloride solution .

2- BTA was found to have a much stronger inhibiting effect on the anodic dissolution of copper and corrosion potential shifted to less negative with increasing of concentration of BTA.

3- BTA interacts with the Cu_2O covered alloy surface, the Cu –BTA film which results in the latter case has a slightly better inhibiting efficiency than that in the former.

4- The kinetics of the corrosion were controlled by Arrhenius type rate equation, that suggesting the operation of a compensation effect in the kinetics of corrosion.

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دراسة تآكل برونز – المنيوم في كلوريد الصوديوم بوجود بنزوترايازول

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الخلاصة

تمت دراسة السلوك التآكلي برونز– المنيوم في محلول كلوريد الصوديوم في خمسة درجات حرارية في المدى 293 الى 313 كلفن باستخدام تقنية المجهاد السكوني. تم ملاحظة انحراف جهد التآكل نحو القيم الاكثر سالبية مع زيادة درجة الحرارة وتزداد قيم كثافة التيار مع زيادة درجة الحرارة . ويشير ميل تافل ومعامل الانتقال الى حدوث تحرر الهيدروجين على الكاثود والاذابة عند الانود . تم دراسة تاثير بنزو ترايازول (BTA) على برونز – المنيوم في محلول كلوريد الصوديوم الخالي من الاوكسجين وبتركيز تراوحت $1 X 10^{-3}$ الى 10^{-1} مول دسم $^{-٣}$ وعلى المدى من درجات الحرارة من 293 الى 313 كلفن ، وتم الحصول على قيم الحماية وقيم الحركية من قيم كثافة التيار . فالنتائج تشير الى تآكل بوزنز الالمنيوم على مواقع مختلفة طاقيا ً.