Number 11 Volume 19 November 2013 Journal of Engineering

Effect of Velocity on Dissolved Oxygen Cathodic Polarization using a Rotating Cylinder Electrode

Prof. Dr. Qasim Jasim Muhammed Slaiman
Hala Muhammed Hussain
Al – Nahrain University
d6mj8q@yahoo.com
Hala_muhammed@ymail.com

ABSTRACT

The aim of the present work to study the effect of changing velocity (Reynold's number) on oxygen cathodic polarization using brass rotating cylinder electrode in 0.1, 0.3 and 0.5N NaCl solutions (PH = 7) at temperatures 40, 50 and 60^0C. Cathodic polarization experiments were conducted as a function of electrode rotational speed and concentration.

KEY WORDS*:* Brass, oxygen, polarization, rotating cylinder electrode

أ.د. قاسم جاسم محمد سليمان
م.م. هالة محمد حسين

تأثير السرعة على الأستقطاب الكاثودي للأوكسجين بأستخدام القطب الدوار

المقدمه

تهدف الدراسه الحاليه الى متابعة تأثير تغير سرعة الدوران على ألأستقطاب الكاثودي للأوكسجين بأستخدام أسطوانه براص دواره في محاليل NaCl بتراكيز 0.1 و0.3 و0.5 مولاري (عندما يكون الأس الحامضي = 7) عند درجات الحراره 40و 50و 60 درجه مئويه . أجريت التجارب بدلالة سرعة القطب الدوار و تركيز الملح NaCl .

مفتاح الكلمات: براص، أوكسجين ، الأستقطاب، القطب الدوار

1. INTRODUCTION

A brass alloy, 39%- Zn-Cu, has been employed to investigate the cathodic polarization of dissolved oxygen [3].

Polarization methods involve changing the potential of the working electrode and monitoring the current which is produced as a function of time or potential. For anodic polarization, the potential is changed in the anodic (or more positive) direction, causing the working electrode to become the anode and causing electrons to be withdrawn from it. For cathodic polarization, the working electrode becomes more negative and electrons are added to the surface, in some cases causing electrodeposition.[6]

The limiting current is defined as the maximum current that can be generated by a given electrochemical reaction, at a given reactant concentration, under well-established hydrodynamic conditions, in the steady state. This definition implies that the limiting rate is determined by the composition and transport properties of electrolytic solution and by the hydrodynamic conditions at the electrode surface[4].

In general, for a rotating cylinder, when Reynolds number is greater than 200 the flow is turbulent [2].

The aim of the present work is to study the effect of changing the velocity (Reynolds number) on oxygen cathodic polarization curve using on surface of brass rotating cylinder electrode at different concentrations of NaCl: 0.1, 0.3 and 0.5N at 40, 50 and 60^{0}C.

2. EXPERIMENTAL DETAILS

The chemical composition (in wt %) of the brass alloy used analyzed in Ebn Siena labortary was (Cu = 60.24, Zn = 39.22, Sn = 0.52). The dimensions of the cylindrically- shaped metal specimen was 3 cm long and 3 cm in diameter. The specimen was connected to a rotating shaft driven by a motor. The brass specimen was ground sequentially with Sic papers to 600, 400, 300, 250, 200, 150 and 100 grit and immersed in alcohol 1 min. and acetone 1 min and dried by paper tissues and placed in desiccator over night before the electrochemical tests. The polarization runs were conducted in 0.1, 0.3 and 0.5N NaCl solutions (PH = 7). A saturated Calomel electrode (SCE) was used as the reference electrode and graphite was used as the counter electrode. The rotation speed was varied from 0 to 2000 rpm.

3. RESULTS AND DISCUSSION

Figures 2 to 10 show experimental results conducted to demonstrate the effect of rotational speed on O_2 cathodic polarization curves. On increasing the velocity, the limiting current will be increased at constant temperature and concentration this appear in table (1 to 9). These results are in agreement with Stern and Uhlig [5,7]. Velocity primarily affects electrochemical reaction rate through its influence on diffusion phenomena. It has no effect on activation-controlled processes. The manner in which velocity affects the limiting diffusion current is a marked function of the physical geometry of the system. In addition the diffusion process is affected differently by velocity when the flow conditions are laminar as compared to a situation where turbulence exists. For most conditions the limiting diffusion current can be expressed by the equation:

$$i_\ell = K \times U^n \qquad (1)$$

Where (K) is a constant, (U) is the velocity of the environment relative to the surface and (n) is a constant for a particular system. The value of n varies from 0.2 to 1 [5,7].

Figures 11 and 12 show experiments conducted to find the effect of concentration on O_2 cathodic polarization curves. When the concentration of NaCl is increased the limiting current will be increase at constant Reynolds number (rotational velocity) and temperature show in table (10) which is in agreement with Fontana and Greene [1]. The effect of oxidizer additions or the presence of oxygen on electrochemical rate depends on both the medium and the metals involved. The rate of (limiting current) may be increased by the addition of oxidizers, oxidizers may have no effect on the corrosion rate, or a very complex behavior may be observed. By knowing the basic characteristics of a metal or alloy and the environment to which it is exposed, it is possible to predict in many instances the effect of oxidizer additions [1].

For diffusion-controlled process, an increase in concentration of the diffusing species in the bulk of the environment increases the concentration gradient at the metal interface. The concentration gradient provides the driving force for the diffusion process. Thus the maximum rate at which oxygen can diffuse to the surface (the limiting diffusion current) would be essentially directly proportional to the concentration in solution. Figs.11 and 12 are examples of the cathodic polarization diagrams which are operative for this system [5].

4. CONCLUSIONS

On brass alloy when increasing rotational speed limiting current will be increased. For diffusion controlled process, an increase in concentration of the diffusing species in the bulk of the environment increases the concentration gradient at the metal/solution interface. The concentration gradient provides the driving force for the diffusion process. Thus the maximum rate at which oxygen can diffuse to the interface surface (the limiting diffusion current) would be essentially directly proportional to the concentration in solution and temperature in presence of increasing NaCl concentration.

5. REFERENCE

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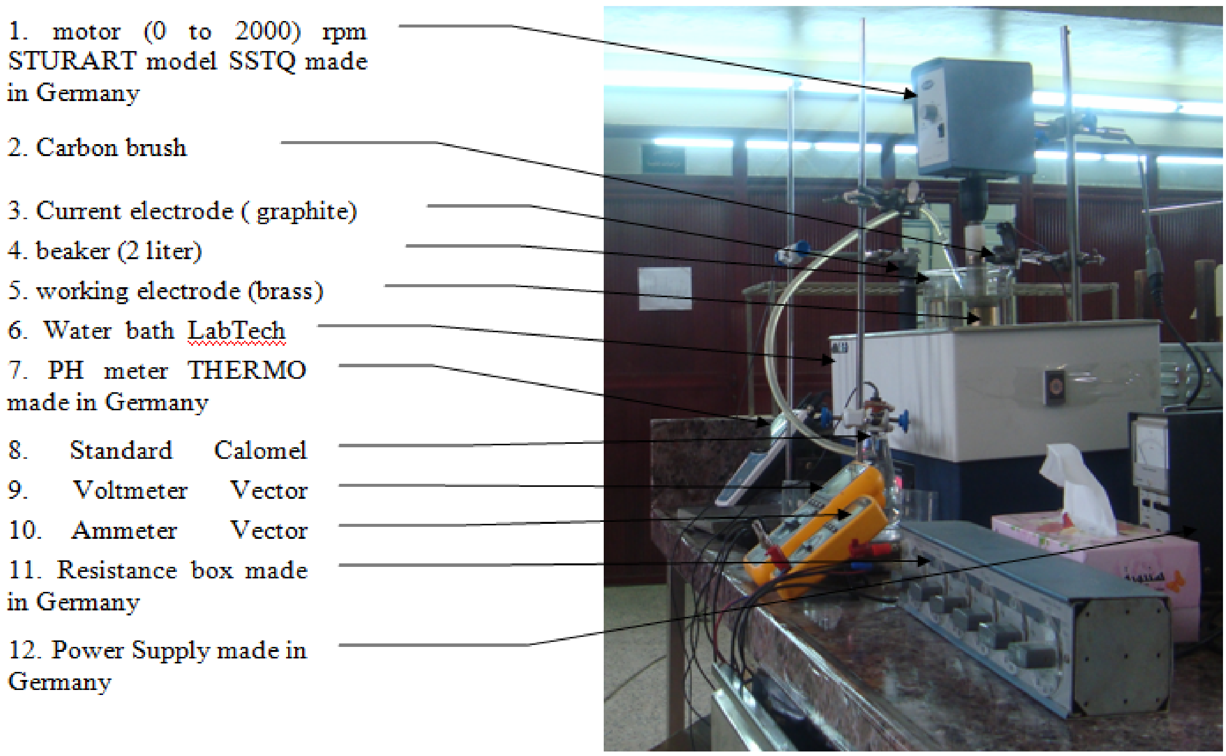

Fig.1. Rotating cylinder system.

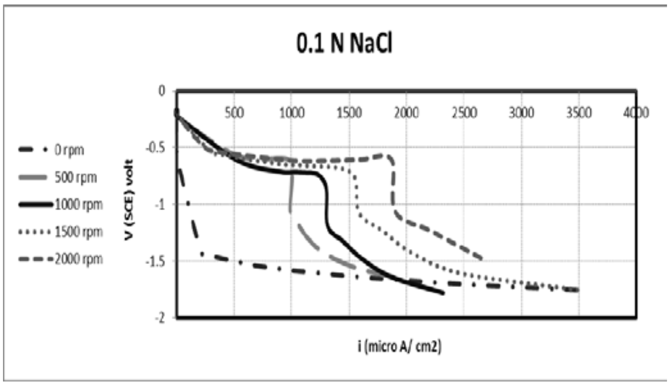

Fig. 2 Dissolved oxygen cathodic polarization curves on brass in 0.1N NaCl solution at 40^{0}C.

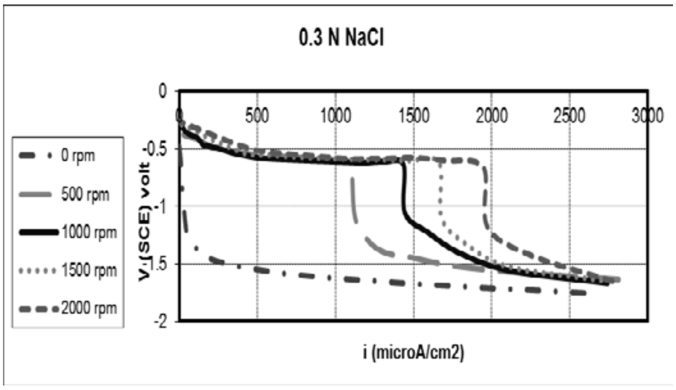

Fig. 3 Dissolved oxygen cathodic polarization curves on brass in 0.3N NaCl solution at 40^{0}C.

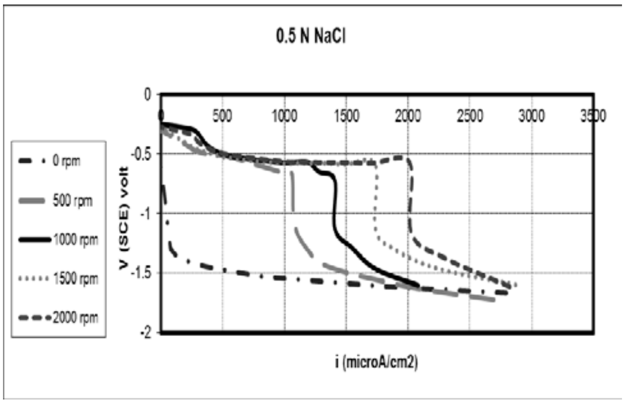

Fig. 4 Dissolved oxygen cathodic polarization curves on brass in 0.5N NaCl solution at 40^{0}C.

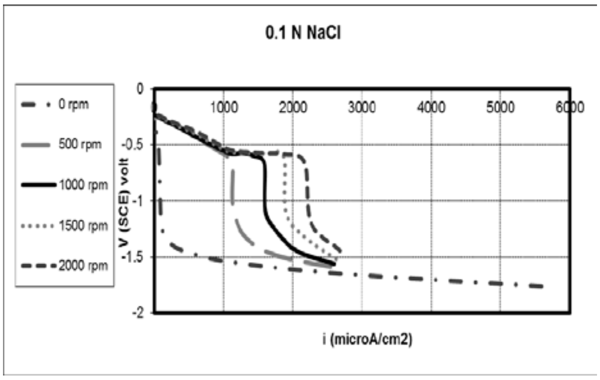

Fig. 5 Dissolved oxygen cathodic polarization curves on brass in 0.1N NaCl solution at 50^{0}C.

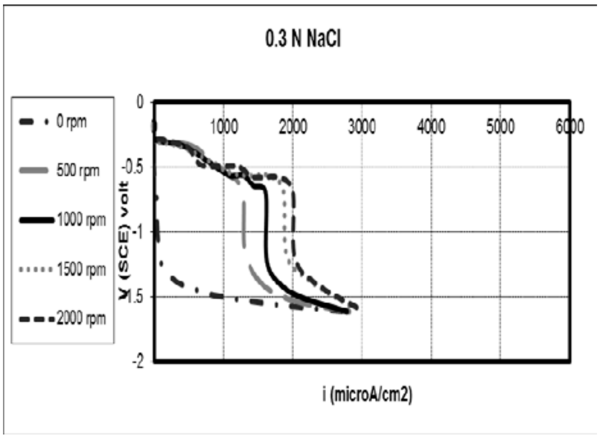

Fig. 6 Dissolved oxygen cathodic polarization curves on brass in 0.3N NaCl solution at 50^{0}C.

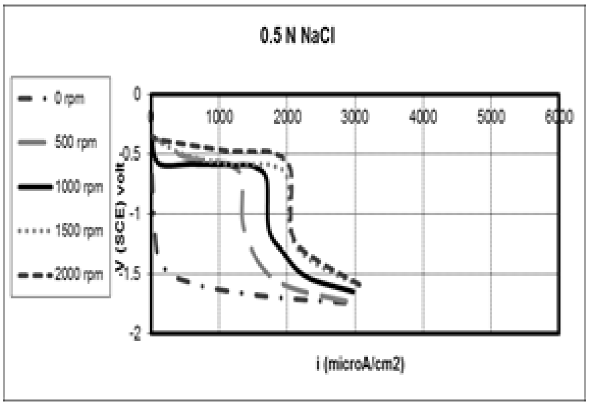

Fig. 7 Dissolved oxygen cathodic polarization curves on brass in 0.5N NaCl solution at 50^{0}C.

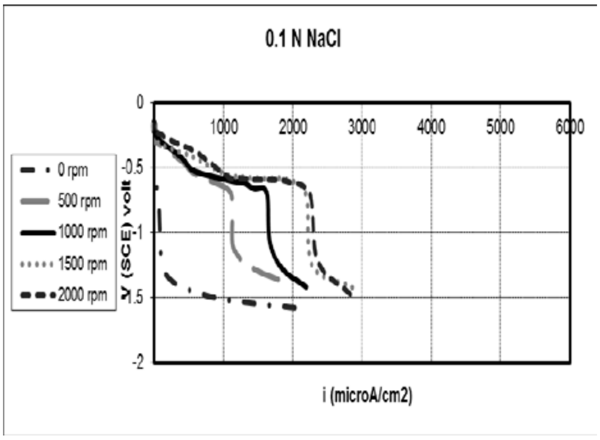

Fig. 8 Dissolved oxygen cathodic polarization curves on brass in 0.1N NaCl solution at 60^0C.

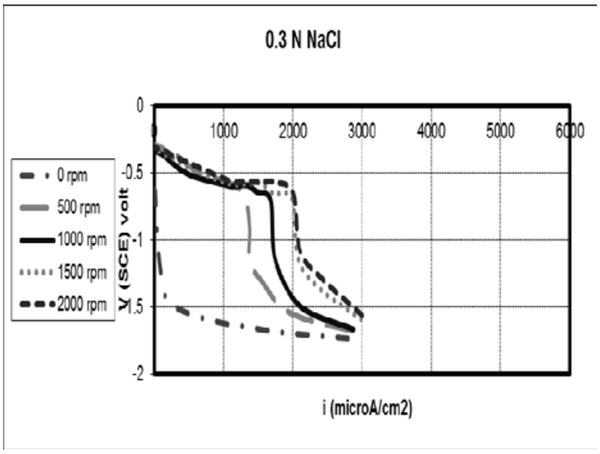

Fig. 9 Dissolved oxygen cathodic polarization curves on brass in 0.3N NaCl solution at 60^0C.

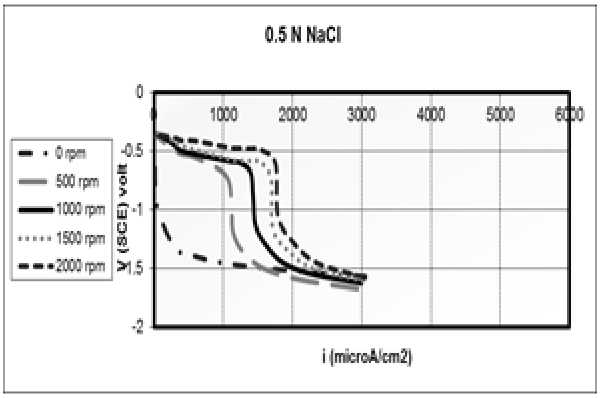

Fig. 10 Dissolved oxygen cathodic polarization curves on brass in 0.5N NaCl solution at 60^0C.

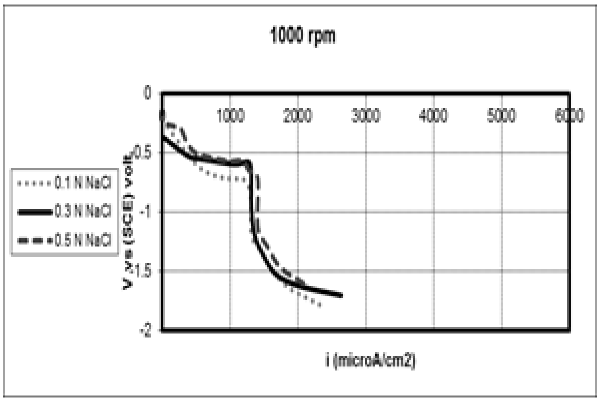

Fig. 11 effect concentration change on polarization curve on brass at 40^0C at constant rotational speed (ω = 1000 rpm)

Table.1. Experimental limiting current results of dissolved oxygen cathodic polarization on brass in 0.1 N NaCl solutions at T= 40 °C.

ω (rpm)	Re	i_ℓ (mA/cm^2)	i_ℓ (μA/cm^2)
0	static	0.011323425	11.323425
500	8823.155	1.0049540	1004.9540
1000	17646.31	1.3164510	1316.451
1500	26469.46	1.569.3560	1569.356
2000	35292.62	1.8683650	1868.365

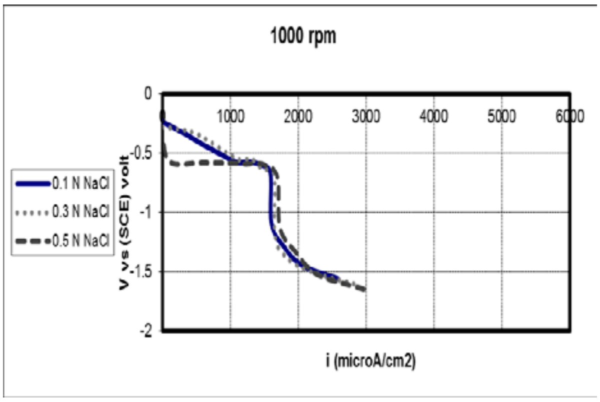

Fig. 12 effect concentration change on polarization curve on brass at 50^0C at constant rotational speed (ω = 1000 rpm)

Table.2. Experimental limiting current results of dissolved oxygen cathodic polarization on brass in 0.3 N NaCl solutions at T= 40 °C.

ω (rpm)	Re	i_ℓ (mA/cm²)	i_ℓ (μA/cm²)
0	static	0.01433121	14.33121
500	14785.87	1.1004955	1100.4955
1000	29571.74	1.3694508	1369.4508
1500	44357.6	1.6719745	1671.9745
2000	59143.47	1.9125974	1912.5974

Table.3. Experimental limiting current results of dissolved oxygen cathodic polarization on brass in 0.5 N NaCl solutions at T= 40 °C.

ω (rpm)	Re	i_ℓ (mA/cm²)	i_ℓ (μA/cm²)
0	static	0.016100495	16.100495
500	14907.89	1.1150000	1115.0000
1000	29815.77	1.4081755	1408.1755
1500	44723.66	1.7055910	1705.5910
2000	59631.54	2.0099080	2009.9080

Table.4. Experimental limiting current results of dissolved oxygen cathodic polarization on brass in 0.1 N NaCl solutions at T= 50 °C.

ω (rpm)	Re	i_ℓ (mA/cm²)	i_ℓ (μA/cm²)
0	static	0.042285915	42.285915
500	10651.02	1.2652160	1265.2160
1000	21302.05	1.6047415	1604.7415
1500	31953.07	1.8825195	1882.5195
2000	42604.09	2.1939135	2193.9135

Table.5. Experimental limiting current results of dissolved oxygen cathodic polarization on brass in 0.3 N NaCl solutions at T= 50 °C.

ω (rpm)	Re	i_ℓ (mA/cm²)	i_ℓ (μA/cm²)
0	static	0.036447275	36.447275
500	17840.91	1.2853855	1285.3855
1000	35681.82	1.6277425	1627.7425
1500	53522.73	1.8966735	1896.6735
2000	71363.64	1.9975230	1997.5230

Table.6. Experimental limiting current results of dissolved oxygen cathodic polarization on brass in 0.5 N NaCl solutions at T= 50 °C.

ω (rpm)	Re	i_ℓ (mA/cm²)	i_ℓ (μA/cm²)
0	static	0.01167700	11.67700
500	17987.2	1.3145760	1314.576
1000	35974.41	1.6808210	1680.821
1500	53961.61	1.9709835	1970.9835
2000	71948.82	2.0169850	2016.985

Table.7. Experimental limiting current results of dissolved oxygen cathodic polarization on brass in 0.1 N NaCl solutions at T= 60 °C.

ω (rpm)	Re	i_ℓ (mA/cm²)	i_ℓ (μA/cm²)
0	static	0.057356705	57.356705
500	12602.43	1.1431325	1143.1325
1000	25204.86	1.6135880	1613.5880
1500	37807.3	2.1443735	2144.3735
2000	50409.73	2.2381455	2238.1455

Table.8. Experimental limiting current results of dissolved oxygen cathodic polarization on brass in 0.3 N NaCl solutions at T= 60 ^{o}C.

ω (rpm)	Re	i_ℓ (mA/cm^2)	i_ℓ (μA/cm^2)
0	static	0.03556263	35.56263
500	21117.77	1.3782730	1378.2730
1000	42235.55	1.6808210	1680.8210
1500	63353.32	1.9904460	1990.4460
2000	84471.09	1.9986765	1998.6765

Table.9. Experimental limiting current results of dissolved oxygen cathodic polarization on brass in 0.5 N NaCl solutions at T= 60 ^{o}C.

ω (rpm)	Re	i_ℓ (mA/cm^2)	i_ℓ (μA/cm^2)
0	static	0.01127728	11.27728
500	21290.47	1.0744870	1074.487
1000	42580.95	1.3959660	1395.966
1500	63871.42	1.6737440	1673.744
2000	85161.89	1.7374380	1737.438

Table.10. Oxygen solubilities at atmospheric pressure[8]

C(N) / T(^{0}C)	Oxygen solubility in (mg/l)		
	0.1	0.3	0.5
40	**6.389**	**6.1945**	**6**
50	**5.399**	**5.0495**	**4.7**
60	**4.490**	**3.795**	**3.1**