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Study the Effect of Different Parameters on the Corrosion and Inhibition Rate for Copper in Saline Solutions

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Abstract:

The corrosion of copper in highly concentrations of NaCl in present and absence of sodium soccinate (SS), has been reported using weight loss, and potentiodynamic polarization measurements. NaCl solutions were studied at stagnant condition and different temperatures (35-55^{o}C), constant temperature and different rotational velocity (400 – 1200 rpm). The maximum inhibition efficiency at 35^{o}C and decrease with increasing temperature and rotational velocity. The inhibition efficiency of 0.006 M SS obtained by weight loss measurements is about 14%, increasing to about 65% in 5 M NaCl solution and about 6. 76 %, increasing about 64.13 % in 1 M NaCl solution. The potentiodynamic polarization measurements showed that SS is a mixed type inhibitor. The inhibition mechanism involves adsorption of SS on the copper surface.

Keywords: copper, NaCl solutions, sodium soccinate, inhibition efficiency

Introduction

Copper is a very common substance that occurs naturally in the environment and spreads through the environment through natural phenomena. Copper is widely used in different industries and in agriculture. The production of copper has lifted over the last decades. Due to this, copper quantities in the environment have increased [1]. Copper has been one of the preferred materials in industry due to its high electrical and thermal conductivities, mechanical workability, and its relatively noble properties. It is widely used in many applications in electronic industries and communications as a conductor in electrical power lines, and pipelines for domestic and industrial water utilities, including sea water, heat conductors, heat exchangers, etc.Thus, corrosion of copper and its inhibition in a wide variety of media, particularly when they contain chloride ions, have attracted the attention of a number of investigators[2].

Copper is metal that has a wide range of applications due to its good properties. It is used in electronics, for production of wires, sheets, tubes, and also to form alloys[3].

Copper dissolves anodically in most aqueous environments forming the divalent ion Cu^{++}, as the equation below:-

$$Cu^{++} + 2e^{-} \rightarrow Cu \quad \ldots\ldots\ldots \quad (1)$$

On the other hand, if complexes are formed, as, for example, between Cu$^+$ and Cl$^-$ in a chloride solution, the continuous depletion of Cu$^+$ by convection to $CuCl_2^-$ favors the univalent ion as the major dissolution product[4].

According to Bacarella and Griss[5], the anodic dissolution of copper is under mixed control by the electro dissolution of copper and the diffusion of soluble $CuCl^-_2$ from the Helmholtz plane into the bulk solution. On the other hand, at concentrations higher than 1 M, higher cuprous complexes such as $CuCl_3^{-2}$ and

$CuCl_4^{-3}$ are formed in addition to ones with fewer chlorides such as CuCl and $CuCl_2^-$ [6]. Copper is resistant to seawater, the corrosion rate in climate temperate being about 0.5-1.0 gmd (0.001-0.002 ipy) in quite water and somewhat higher in moving water. In sea water and in fresh waters, corrosion resistance depends on the presence of a surface oxide film through which oxygen must diffuse in order for corrosion to continue[4]. Due to its high thermal conductivity, anticorrosion and antifouling properties, copper is frequently used in heat exchangers, heat conductors and marine engineering [7,8]. Many accidents of copper corrosion have happened in the cooling system of electric machine recently. And the pitting corrosions of copper pipes are also serious problems [9].

Many parameters that influence corrosion can vary with temperature: dissolved oxygen (DO) solubility, solution properties (e.g. viscosity and ion mobility), ferrous copper oxidation rate, thermodynamic properties of copper scale (leading to formation of different phases or compounds), and biological activity[10].In general, corrosion rates increase with increasing temperature. In seawater, this increase is much less than the doubling of reaction rates with each 18°F rise in temperature that would be expected if the reactions were under diffusion control as are many other chemical reactions, For many materials, such as steels, copper where the oxygen content of the water directly affects the corrosion rate, the effect of temperature is minimal as in situations where the corrosion rate would be increased by increased temperature, the solubility of oxygen is decreased with increasing temperatures and the two effects counteract each other. Steels and copper alloys are particularly insensitive to temperature effects in normal marine immersion [11].

Velocity primarily affects corrosion 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[12,13].

Copper is resistant toward the influence of atmosphere and many chemicals, however, it is known that in aggressive media it is susceptible to corrosion. The use of copper corrosion inhibitors in such conditions is necessary since no protective passive layer can be expected. The possibility of the copper corrosion prevention has attracted many researchers so until now numerous possible inhibitors have been investigated. Amongst them there are inorganic inhibitors [3], but in much greater numbers there are organic compounds and their derivatives such as azoles [14], amines [15], amino acids [16,17] and many others.

In general, the adsorption of an inhibitor on a metal surface depends on the nature and the surface charge of the metal, the adsorption mode, its chemical structure, and the type of the electrolyte solution[18]. There are several industry-based comparative studies in the area of copper corrosion inhibitors, such as Musiani et al.[19], Lewis [20], Horner et al. [21,22], and others. Many publications cover corrosion protection in water flow systems such as boilers, radiators, chemical containers and seawater systems. Industrial inhibitors are all subject to much harsher conditions than those to which an archaeological artifact would be exposed. Such industrial environments have little direct relevance to conditions a treated archaeological artifact would generally experience in a storage area or a showcase.

The aim of the present work is to investigate the influence of sodium succinate (SS) on the corrosion rate of copper in highly concentrated of (NaCl) media under the influence of various experimental conditions. For this purpose, gravimetric (weight loss) and electrochemical polarization measurements have been used.

Experimental work

Operating conditions

All experiments were done under the same conditions as follows:-

i. Different temperatures (35, 45, and 55^{o}C) at stagnant condition.
ii. Different rotating velocity (400, 800 and 1200 rpm) taken at 45 and 55^{o}C respectively.

Electrolyte solution

NaCl and distilled water used for preparing test solution of 1 M and 5 M NaCl for all experiments.

Specimen

The cylindrical copper sample of out diameter 2.5cm and 3 cm hight was used in the present work, Before each experiment the specimen was polished successively with 150, 400, 1200 of emery papers respectively, rinsed with distilled water and then immersed in ethanol for 3 min and dried, then etched in a 0.5 M HCl solution for 30 sec. The HCl etching method provided a fresh and active (oxide- free) copper surface. The samples were dried and kept in desiccators. Such pretreatment of the samples was repeated after each experiment. For weight loss experiments after all the above for preparing the sample followed by oven drying at 110^{o}C for 15 min before and after each experiment[23, 24,25] .

1. Inhibitor

Sodium soccinate (SS), $C_4H_4O_4Na_2$ (> 99 %), most time use as medical purpose.

Weight loss experiments

Figure 1 shows the experimental apparatus that was used for performing the experimental work.

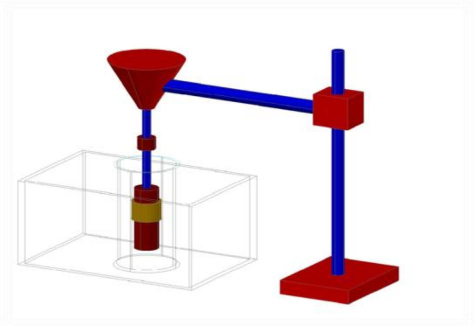

Fig. 1 a sketch showing the weight loss apparatus.

1- Stand, 2- Ball bearing, 3- Container (3L), 4- Rotating motor , 5- Teflon shaft, 6- Water Bath with temperature controller 7- sample.

The loss in weight of copper specimen in 1and 5 M of NaCl solutions respectively at the previous operating conditions without and with 0.006M SS inhibitor were determined after 3 h of immersion period. The inhibition efficiency, %IE, was determined by :-

$$IE(\%)= \frac{CR_{(Blank)} - CR_{(inhibitor.)}}{CR_{(Blank)}} \times 100 \ldots..(2)$$

where CR_{blank} and $CR_{(inh)}$ are the corrosion rates of copper in the absence and presence of the inhibitor, respectively.

Electrochemical polarization experiments

Figure 2 shows the experimental apparatus that was used for this technique.

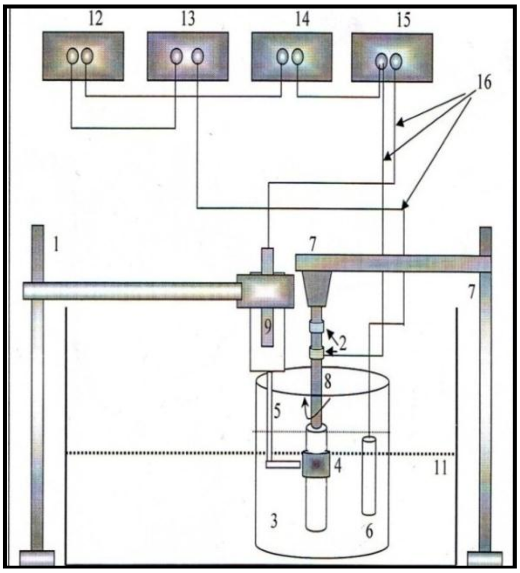

Fig. 2 A sketch showing the details of the laboratory polarization system

1- Stand, 2- Ball bearing, 3- Container (3L), 4- Cathode , 5- Salt Bridge, 6- Anode 7- Rotating motor, 8- Teflon shaft, 9- Saturated Calomel Electrode(SCE), 10- Water Bath with temperature controller, 11- stand, 12- D.C Power supply, 13- Multirange Ammeter, 14- Resistance Box., 15- Multirange Voltmeter, 16- Connecting Wires.

The polarization study of copper specimens were carried out in 1M NaCl solution separately in absence and presence of 0.006 M SS were determined after 3 h of immersion period at the same operating conditions in weight loss method. The potential of the metal electrode was measured against Saturated Calomel Electrode (SCE) by using indigenously assembled galvanostat having the range of 10- 100 mA. A constant distance approximately1-2 mm between the tip of Luggin capillary and working electrode surface and this distance was kept constant for all experiments. Graphite electrode was used as a counter electrode. Tafel constants were calculated from the linear region of the polarization curves. The corrosion current density (Icorr.) was determined from the intersection point between the linear parts of theanodic and cathodic curves with the stationary corrosion potential ($E_{corr.}$). Percentage inhibition efficiency was calculated using corrosion rate or $I_{corr.}$ values as the following equation:-

$$IE(\%)=\frac{I_{corr(Blank).}-I_{Corr.(inhibitor)}}{I_{corr.(Blank)}}\times 100\ldots..(3)$$

Where $I_{corr.(blank)}$, $I_{corr.(inhibitor)}$ are corrosion current density of absence and presence of 0.006 M (SS) respectively.

Corrosion rate Determination

Weight loss method [26,27]

The simplest, and longest-established, method of estimating corrosion losses in plant and equipment is weight loss analysis. A weighed sample of the metal or alloy under consideration is introduced into the process, and later removed after a reasonable time interval. The sample is then cleaned of all corrosion product and is reweighed. So that the corrosion rate can be determined using:

$$\text{corrosion rate (CR)}=\frac{\Delta w}{A\ t}\qquad \ldots\ldots(4)$$

This expression takes into account the influence of area and time. Second expression used is the corrosion current calculated from weight loss by Faradays law:

$$i_{corr.=}\ zFNo_2\qquad \ldots\ldots(5)$$

Where NO2 = is the molar flux of oxygen which is defined as the moles of O2 reacted per unit area per unit time ($gmole/m^2.s$). Also, according to reactions in Eq. (1) ;
$NO_2 = 0.5\ N_{Cu}$ [31] where N_{Cu} is the molar flux of Cu.

Polarization method

Polarization technique within 10 mV more noble or more active than the corrosion potential, it is observed that the applied current density is linear function of the electrode potential,Tafel

Extrapolation Method technique uses data obtained from cathodic and anodic polarization measurements. Cathodic data are preferred, since these are easier to measure experimentally, Figure (3) shows the anodic and cathodic polarization curves and the way used to measure the corrosion current (icorr) and Tafel slopes βa, βc

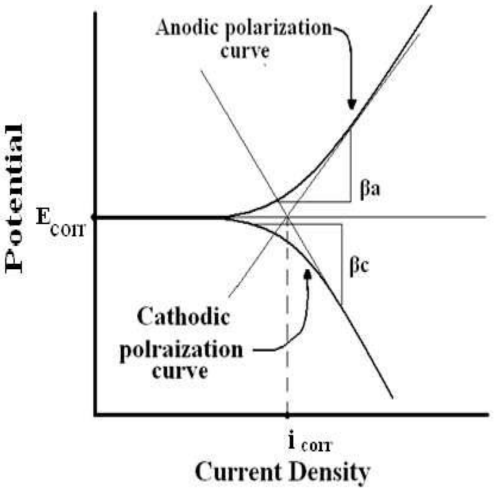

Fig. (3) Anodic and cathodic polarization curves with Tafel slopes [31].

At the corrosion potential, the rate of hydrogen evolution is equal to the rate of metal dissolution, and this point corresponds to the corrosion rate of the system expressed in terms of current density. Tafel constants must be calculated from both the anodic and cathodic portions of the Tafel Plot. The units of the Tafel constants is V/decade. A decade of current is one order of magnitude[28,29,30].

Results and Discussion

Weight loss measurements

Using the obtained weight loss values and equation (1), the corrosion rate profiles were calculated. The current density of the corrosion process with constant temperatures were studied in 1.0 M, 5M NaCl with 3 hr immersion both in the absence and in the presence of 0.006 M SS . Table (3- 4) and Figures(3-11), represent the result of weight loss experiments.

Table (3). Corrosion rate variation and inhibition efficiency of 1 M NaCl at different operating conditions

Operating condition	Blank			0.006 M SS			IE (%)
	Δw (g)	CR. (mpy)	$I_{CORR.}$	Δw (g)	CR. (mpy)	$I_{CORR.}$	
T = 35°C	0.002	10.915	0.2387	0.0014	7.6406	0.1671	30.00
T = 45°C	0.0027	14.735	0.3222	0.0024	13.098	0.2864	11.11
T = 55°C	0.0034	18.556	0.4057	0.0029	15.827	0.3461	14.69
T = 45°C , u = 400 rpm	0.0031	16.737	0.3660	0.0011	6.003	0.1313	64.13
T = 45°C , u = 800 rpm	0.0107	58.396	1.2768	0.0044	24.013	0.5250	58.88
T = 45°C , u = 1200rpm	0.0034	18.737	0.4017	0.0022	12.007	0.2625	34.65
T = 55°C , u = 400 rpm	0.0243	132.619	2.8997	0.0195	106.423	2.3269	19.75
T = 55°C , u = 800 rpm	0.021	114.609	2.5059	0.0176	96.053	2.1002	16.19
T = 55°C , u = 1200 rpm	0.0207	112.972	2.4701	0.0193	105.331	2.3031	6.76

Table (4). Corrosion rate variation and inhibition efficiency of 5 M NaCl at different operating conditions

Operating condition	Blank			0.006 M SS			IE (%)
	Δw (g)	CR. (mpy)	$I_{Corr.}$	Δw (g)	CR. (mpy)	$I_{Corr.}$	
T = 35°C	0.0044	24.013	0.5250	0.0015	8.186	0.1790	65.91
T = 45°C	0.0056	30.562	0.6682	0.0044	24.013	0.5250	21.43
T = 55°C	0.0078	42.569	0.9308	0.0071	38.748	0.8472	8.98
T = 45°C , u = 400 rpm	0.0234	127.708	2.7923	0.0123	67.128	1.4677	47.44
T = 45°C , u = 800 rpm	0.0210	114.609	2.5059	0.0120	65.491	1.4320	42.86
T = 45°C, u = 1200 rpm	0.0180	98.237	2.1479	0.0106	57.949	1.2671	41.01
T = 55°C , u = 400 rpm	0.0305	166.456	3.6395	0.0132	72.040	1.5751	56.72
T = 55°C , u = 800 rpm	0.0169	92.233	2.0167	0.0121	66.037	1.4439	28.40
T = 55°C u = 1200 rpm	0.0129	70.403	1.5394	0.0111	60.579	1.3246	13.95

Effect of temperature

Temperature has a great effect on the rate of metal dissolution. Fig (4-6) show the effect of temperature for different electrolyte concentrations of NaCl , The current density starts to increase with increasing the concentration of NaCl due to formation of the passive layer on copper surface. The corrosion resistance in saline solutions depends on the presence of a surface oxide film through which oxygen must diffuse in order for corrosion to continue. Upon exposure to distilled water at room temperature the oxide film on copper is found to a mixture of Cu_2O and CuO [3].

At elevated temperatures the solubility oxygen required for repairing protective oxide films found on many passive materials is reduced and the reactions that cause the films to break down are enhanced by the increased temperatures. Temperature affects the corrosion rate of metals in electrolytes primari through its effect on factors which control the diffusion rate of oxygen. As temperature increases the diffusion coefficient of oxygen also increases which tends to increase the corrosion rate. However as temperature is increased oxygen solubility in aqueous solutions decreases until at the boiling point all oxygen is removed; this factor tends to decrease the corrosion rate[11].

The effect of temperature on the inhibition of copper is highly complex, because many changes occur on the metal surface, such as rapid etching and desorption of the inhibitor and the inhibitor itself, in some cases, may undergo decomposition and/or rearrangement. Figure 5,6 and table 3,4 shows the effect of temperature (35-55°C) on the current density at the immersion time in 1 and 5 M NaCl and 0.006 M SS solutions. It follows from the figure that the current density (and hence the rate of corrosion) increased, and therefore the corrosion inhibition decreased, with increase in temperature. This shows that the inhibitor has experienced a significant decrease in its protective properties of the inhibitor with increase in temperature .One possible mechanism of inhibition action of inhibitors as reported by Umoren and Ebenso [32] is the adsorption of the inhibitor onto the metal surface, which blocks the metal surface and does not permit the corrosion process to take place, but after immersion time in solutions the Increasing temperature leads to change two variables that act in a conflicting way. Firstly, increasing temperature accelerates the reaction rate as dictated by Arrhenius equation. Moreover, diffusion rate of dissolved oxygen by increasing the molecular diffusion coefficient. Secondly, as the temperature increases the oxygen solubility decreases [31, 33 and 34].

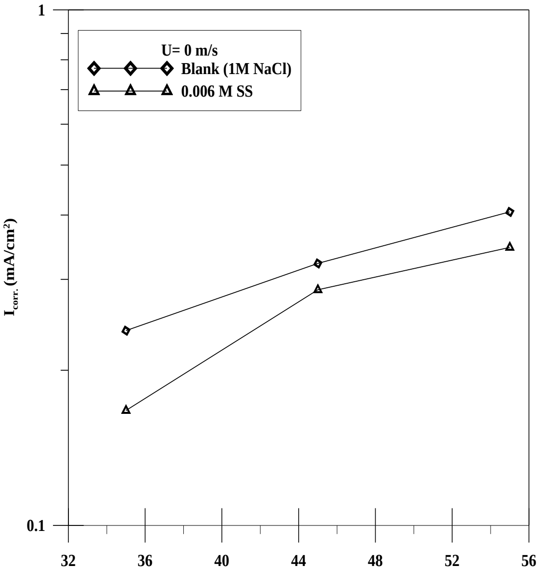

Fig.5 Relationship between $I_{corr.}$ and Temperature for 1M NaCl at U = 0 m/s condition

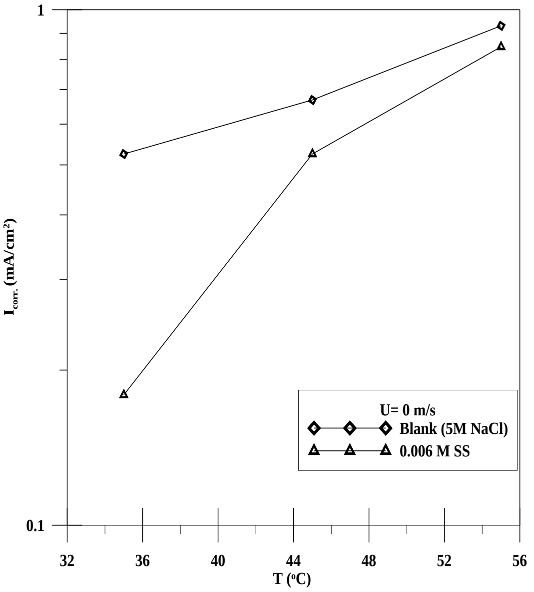

Fig.6 Relationship between $I_{corr.}$ and Temperature for 5M NaCl at U = 0 m/s condition

Effect of rotating velocity

Table (3- 4) and Figures (7-8) represent the influence of velocity 400 -1200 rpm at constant temperatures. these figures show an increase of current density with increasing the rotating velocity which is due to the fact that more oxygen is transported towards the copper surface as the rotating speed increases. It is clear that corrosion rate increase with increasing the concentration of NaCl for the whole range of rotational velocity.

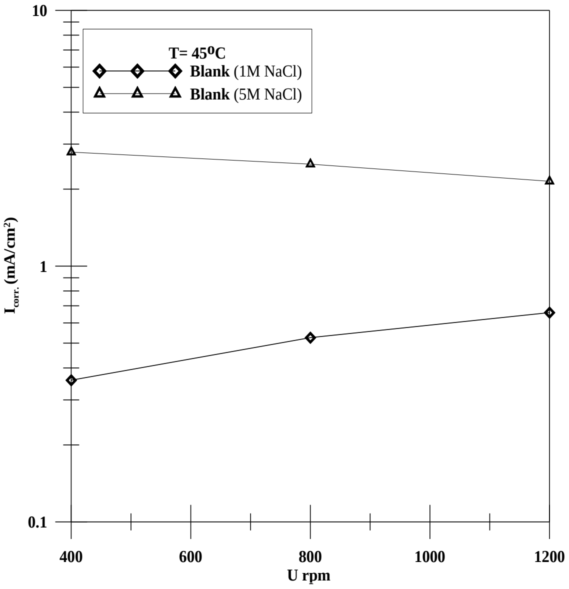

Fig.7 Variation of current density at T = 45°C and different rotating velocity

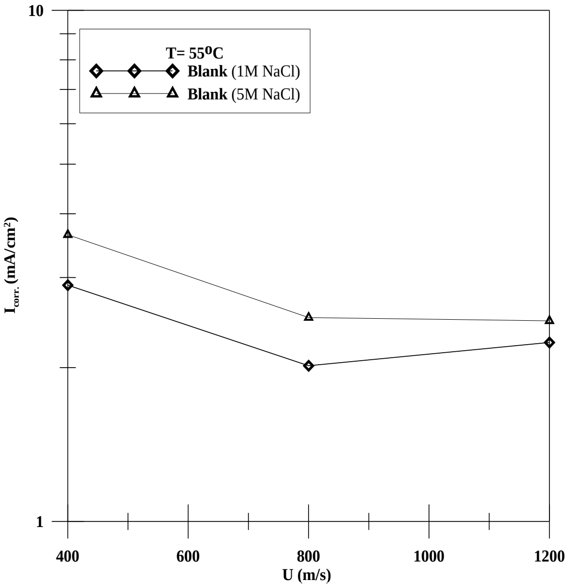

Fig.8 Variation of current density at T = 55°C and different rotating velocity

Effect of Inhibitor

The figures (9- 12) represent the influence of velocity 400 -1200 rpmat constant temperatures in presence and absence of 0.006 M SS. It is clear that The current density decrease in presence of inhibitor ,this behavior is the same for the various concentrations of NaCl as shown in figures below; However, in all cases, a preliminary stage of adsorption of the inhibitor can be envisaged and to the extent, the adsorption theory has fulfilled its purpose [35]. Another theory says that these inhibitors are adsorbed on the metal surface forming protective layer. The adsorption is considered either as physical adsorption or chemisorption [35]. Generally the presence of inhibitors lead to decrease the corrosion rate for the whole investigated range of rotational velocity as the concentrations of inhibitor increased the corrosion rate decreased at any particular value of rotational velocity.

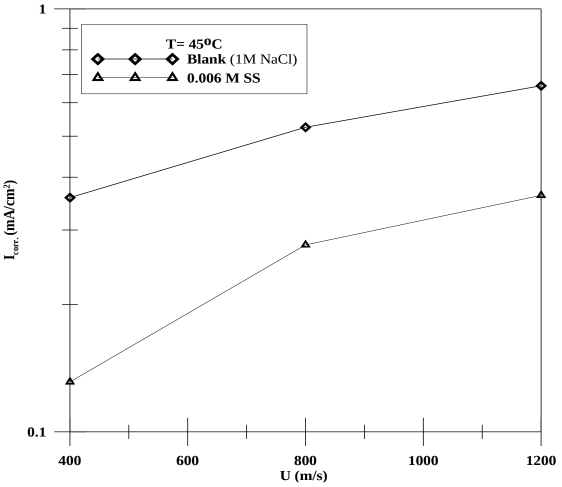

Fig.9 Relationship Between $I_{corr.}$ and different rotational velosity for 1M NaCl at T = 45ºC

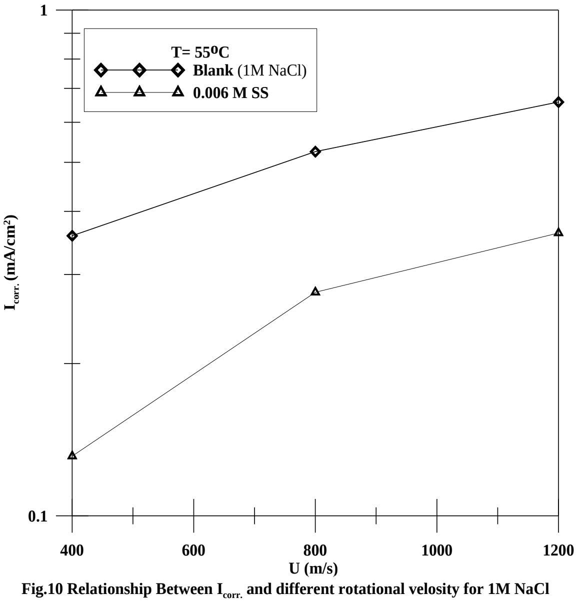

Fig.10 Relationship Between $I_{corr.}$ and different rotational velosity for 1M NaCl at T = 55ºC

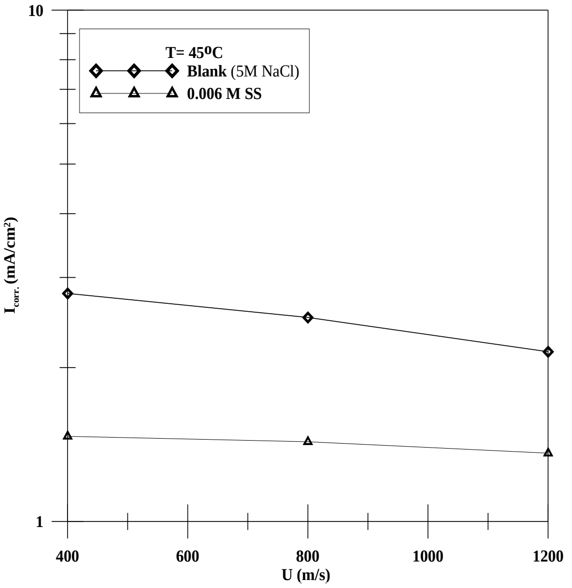

Fig.11 Relationship Between $I_{corr.}$ and different rotational velosity for 5M NaCl at T = 45ºC

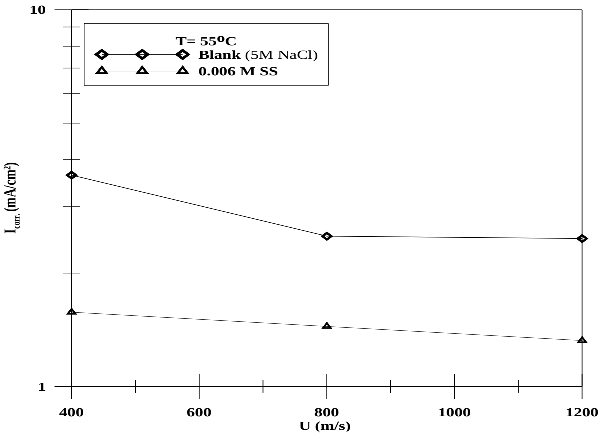

Fig.12 Relationship Between $I_{corr.}$ and different rotational velosity for 5M NaCl at T = 55ºC

The polarization studies of copper specimens were carried out in 1M NaCl and 1M NaCl + 0.006 M SS solutions separately in different operating conditions and the results are shown in figures (13-24). The polarization parameters such as corrosion potential (Ecorr) and corrosion current density (I_{corr}) obtained by intersection of the two Tafel lines (cathodic and anodic) are listed in Table (5) and (6).

Table (5) Experimental data obtained from polarization measurements for 1M NaCl

condition		Blank (1 M NaCl)			
		$I_{corr.}$ mA/cm^2	$E_{corr.}$ (V)	β_a Vdec^{-1}	β_c Vdec^{-1}
U = 0 rpm	**T = 35°C**	0.07	-0.65	0.4323	-1.118
	T = 45°C	0.085	-0.45	0.4076	-0.871
	T = 55°C	0.125	-0.35	0.3774	-0.72
T = 45° C	**U= 400 rpm**	0.24	-0.55	1.3462	-1.25
	U = 800 rpm	0.21	-0.35	1.1657	-1.489
	U = 1200 rpm	0.19	-0.3	1.0132	-1.069
T = 55° C	**U= 400 rpm**	0.31	-0.7	1.0365	-0.812
	U = 800 rpm	0.195	-0.15	1.6312	-1.223
	U = 1200 rpm	0.24	-0.35	0.2083	-0.968

Table (6) Experimental data obtained from polarization measurements for 0.006 M SS

condition		0.006 M SS			
		$I_{corr.}$ mA/cm^2	$E_{corr.}$ (V)	β_a Vdec^{-1}	β_c Vdec^{-1}
U = 0 rpm	**T = 35°C**	0.05	-0.8	0.4302	-1.2
	T = 45°C	0.055	-0.75	0.4520	-1.179
	T = 55°C	0.085	-0.65	0.3859	-1.118
T = 45° C	**U= 400 rpm**	0.16	-0.62	1.1321	-1.168
	U = 800 rpm	0.15	-0.45	1.0675	-1.158
	U = 1200 rpm	0.11	-0.4	0.9435	-1.213
T = 55° C	**U= 400 rpm**	0.17	-0.9	1.6667	-1.327
	U = 800 rpm	0.18	-0.25	0.9453	-1.239
	U = 1200 rpm	0.23	-0.4	0.1575	-1.143

Effect of temperature

Figure (13) represent the influence of temperature 35-55^{o}Cat stagnant condition. This figure show the increase of current density with increasing temperature of the environment, the rate of oxygen diffusion to the metal surface also increases; the viscosity of solution decreases and the electrical conductivity of the solution increases. All these factors can enhance the corrosion rate. This behavior can be interpreted as follows: the temperature increment accelerates both the cathodic reaction rate and diffusion rate of oxygen by increasing the molecular movement of the ions [36]. Also Fig.(12) shows that the corrosion potential shifts to more positive with increasing temperature. The rise in temperature may decrease the equilibrium potential of Cu and H_2 but increase the equilibrium potential of O_2 [37], the increase the diffusion rate of oxygen species by increasing the molecular diffusion coefficient and decreases the oxygen solubility.

Effect of rotational velocity

The corrosion of copper in neutral solution is activation controlled because the corrosion resistance of copper is due to its being relatively noble metal. Its satisfactory service in water depends on formation of relatively thin adherent films of corrosion products (e.g., cuprous oxide and basic copper carbonate).It has only a weak tendency to passivation, and hence the effect of differential aeration is very slight. However, the influence of copper ion concentration on the potential of copper solution is very marked.

The reduction of copper ions takes place through two steps [38]:

$Cu^{+2} + e^- \xrightarrow{Slow} Cu^+$ Step (1)

$Cu^+ + e^- \xrightarrow{Fast} Cu$ Step (2)

It is assumed that the first step in this process occurred slowly and the rate is controlled by the equilibrium between Cu^{+2} and Cu^+. For this reason, when there are varying solution velocities over a copper surface (e.g., when the solution is stirred, the parts exposed to solution with the higher rate of movement becomes anode and not cathode as would be the case for iron [39,40]. This is seen in the analysis of figures (14,15), So these figures show only an active behavior in the anodic branch of the curve, with the current increasing with the applied potential without the presence of a passive layer. The anodic current density value remains more or less constant regardless of the rotating speed. Dislike this; the cathodic current density exhibited a limiting value, which increases as the rotating speed increases, which is due to the fact that more oxygen is transported towards the copper surface as the rotating speed increases.

The free corrosion potential value, *E*corr, becomes nobler as the rotating speed increases and the corrosion current density value, Icorr, increases with the rotating speed.

Effect of Inhibitor

The cathodic and anodic polarization curves of copper in 1M NaCl + 0.006 M SS solution at various operating conditions are shown in Figures (16-24), Tables(5) and (6) gives values of corrosion current (Icorr), corrosion potential (Ecorr), anodic &cathodic Tafel slope (β_a, βc) for SS. The addition of SS leads to a decrease in both the cathodic and anodic current densities. This result indicates that the tested SS acts as a mixed inhibitor. The cathodic portions rise to Tafel lines indicating that the hydrogen evolution reaction is activation controlled. Figures (16-18) represent the effects of 0.006 M SS on the anodic and cathodic polarization for copper electrode in 1 M NaCl at different temperatures were determined. These figures show the change of corrosion rate with the corrosion rates can obtain by extrapolation of the anodic and cathodic Tafel lines. The corrosion rate decreases with the SS; i.e. retards the corrosion of copper in 1 M NaCl. The corrosion potential (Ecorr) shifts towards more negative values and both anodic and cathodic current densities of corrosion were enhanced upon increasing temperature. The increase of the temperature from 35 to 55° C increases the corrosion rate due to desorption of inhibitor molecules from the surface. The high protective behavior of SS can explain it by formation a barrier thick SS film. The protective film formed by the initial adsorption processes of SS, similar behavior obtained by Morales-Gil [41]. The IE decreases with the increasing of the temperature.The change in both anodic and cathodic Tafel slopes indicate a mixed anodic and cathodic effect on the corrosion mechanism [42] i.e. mixed inhibitor. Figures (19-24) represent the effects of absence and presence of SS inhibitor along with different flow velocities by the varying the OCP of copper at constant temperature. The mixed nature of the inhibitor [34] induces a continuous shift in OCP (i.e E_{corr}) towards nobler potentials, indicating the spontaneous adsorption of inhibitor on metallic surface. It’s obvious from Tables (5), (6), and figures below the E_{corr}shifted to more negative direction while the i_{corr}reduced with flow velocity and the anodic current density value remains more or less constant regardless of the rotating speed. [43].

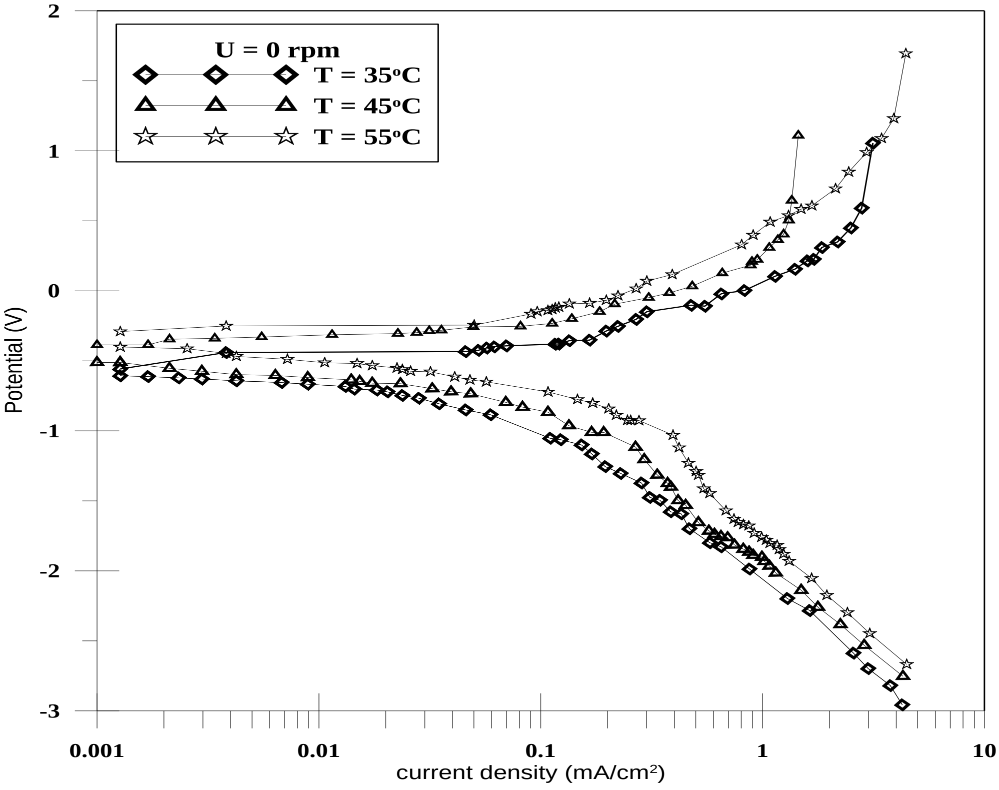

Fig. 13 Polarization curves at U = 0 rpm **for 1 M NaCl**

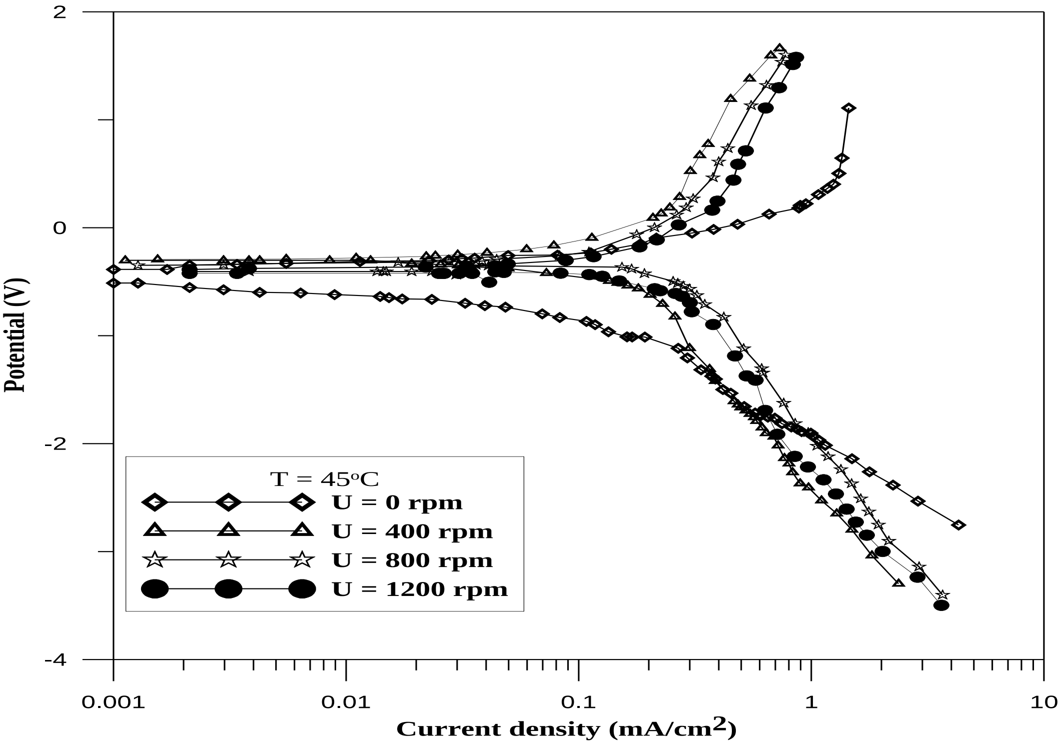

Fig. 14 Polarization curve at T = 45ºC and 1 M NaCl

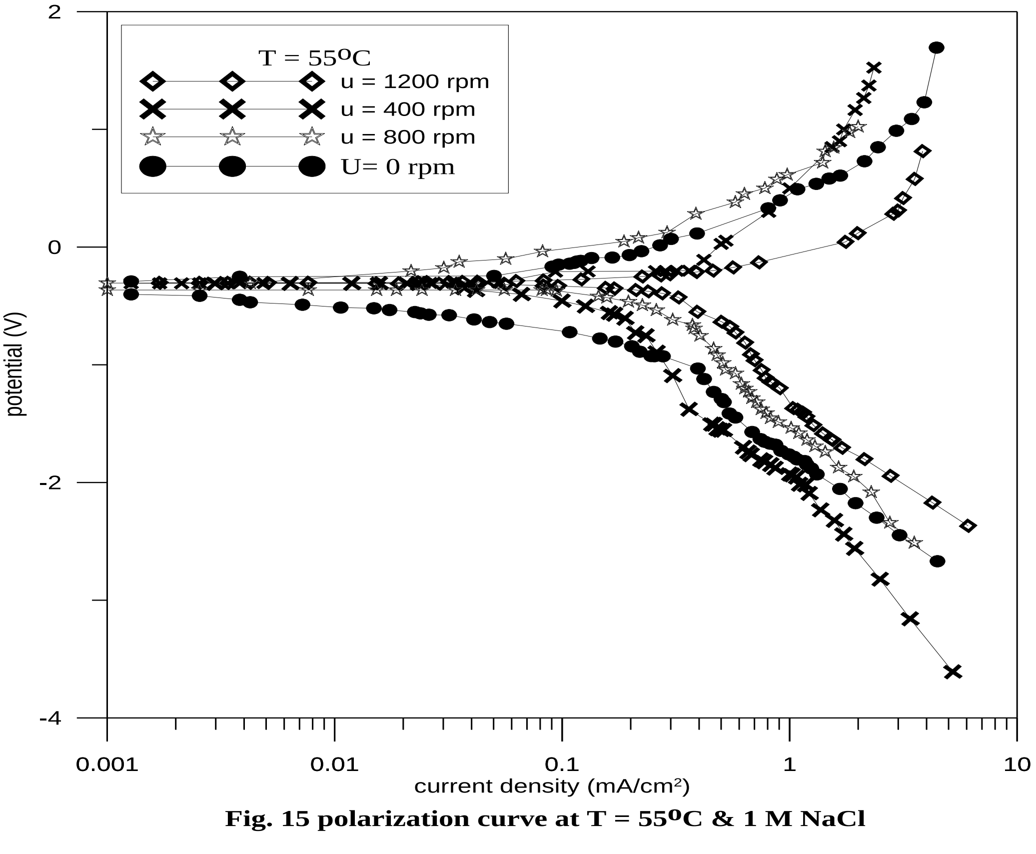

Fig. 15 polarization curve at T = 55ºC & 1 M NaCl

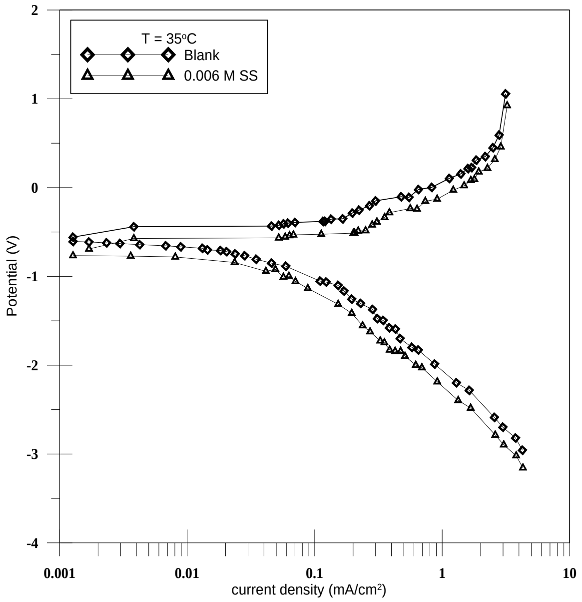

Fig. 16 Polarization curves at T = 35ºC and U = 0 m/s for 1 M NaCl

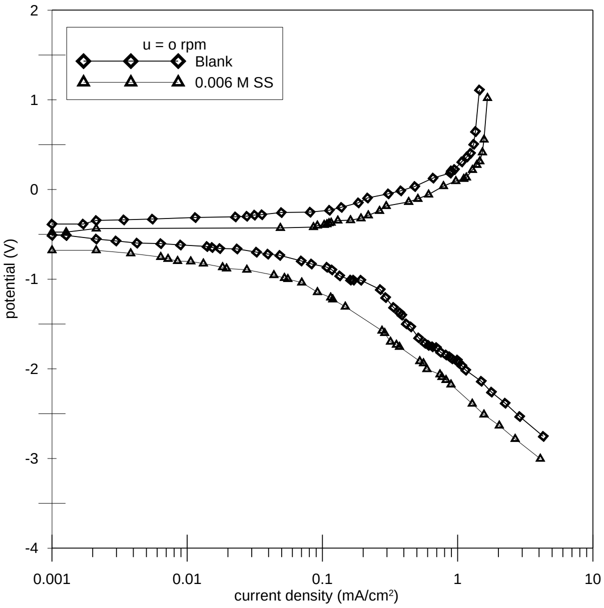

Fig. 17 polarization curves at T = 45ºC and u = o rpm

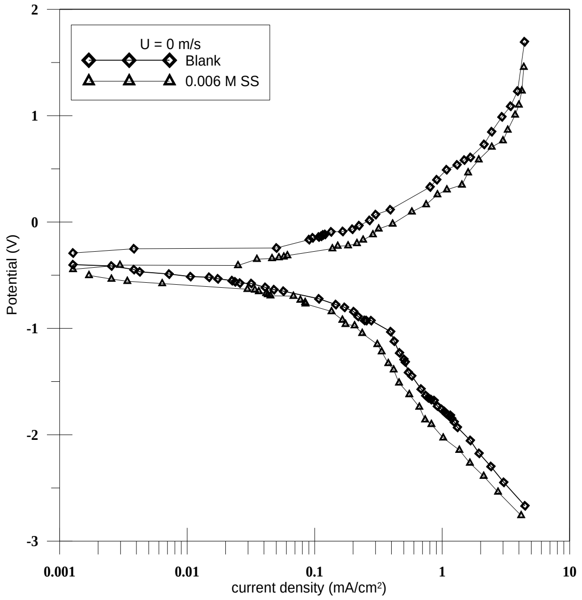

Fig. 18 Polarization curves at T = 55ºC and U = 0 m/s for 1 M NaCl

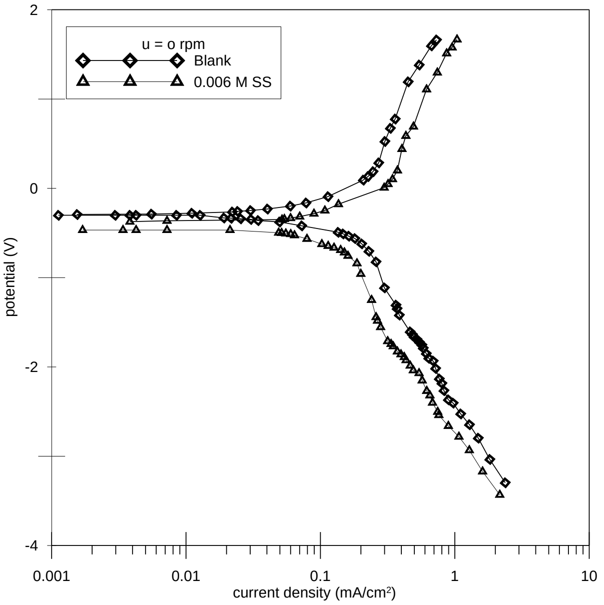

Fig. 19 polarization curves at T = 45ºC and u = 400 rpm

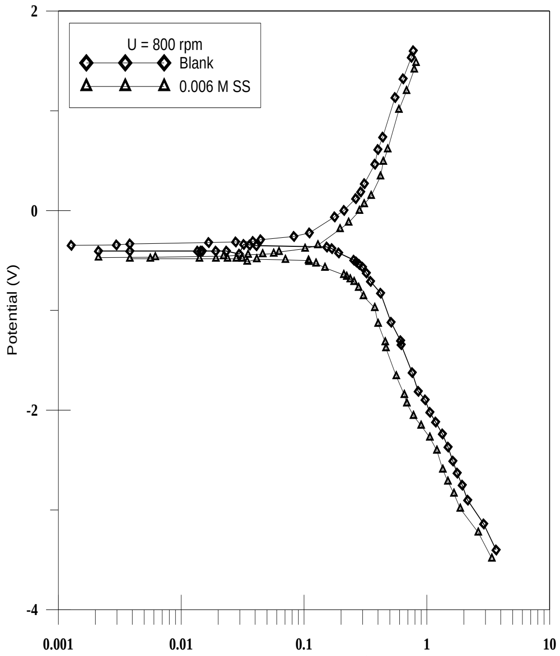

Fig. 20 Polarization curves at T = 45ºC and U = 800 rpm for 1 M NaCl

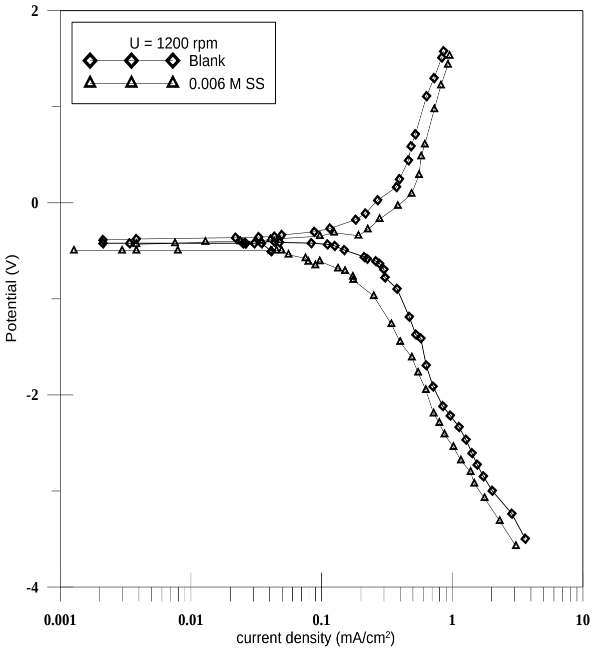

Fig. 21 Polarization curves at T = 45ºC and U = 1200 rpm for 1 M NaCl

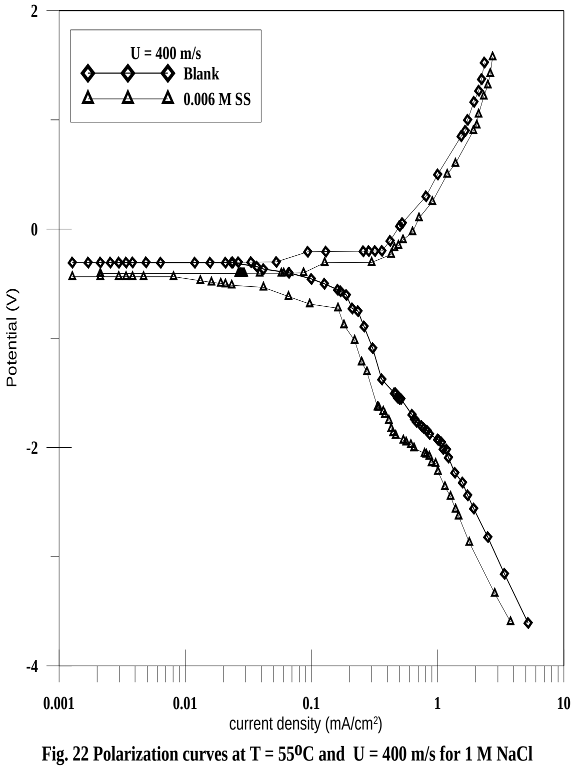

Fig. 22 Polarization curves at T = 55ºC and U = 400 m/s for 1 M NaCl

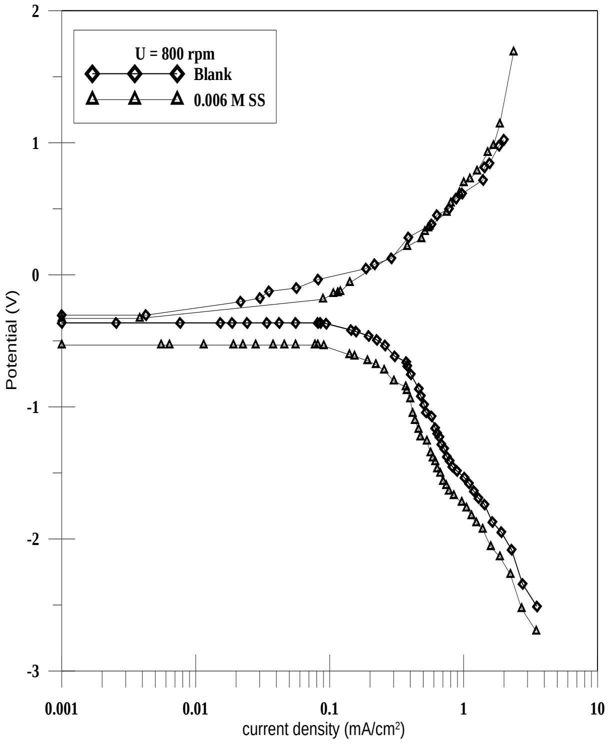

Fig. 23 Polarization curves at T = 55ºC and U = 800 rpm for 1 M NaCl

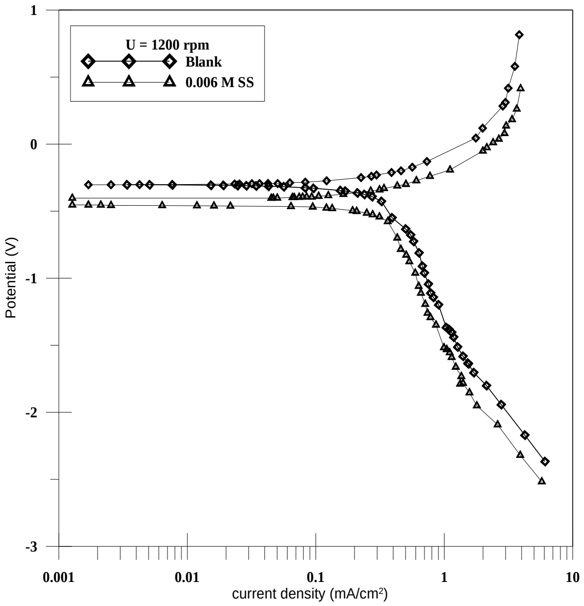

Fig. 24 Polarization curves at T = 55⁰C and U = 1200 rpm for 1 M NaCl

Conclusion

The inhibition of copper corrosion in Saline Solutions (1& 5M NaCl) with and without 0.006 M SS has been studied and the results can be summarized as follows:

1. The inhibition efficiency of SS inhibitor decreases with the increasing of temperature and rotational velocity.
2. SS is a good mixed-type inhibitor for copper corrosion by strongly adsorbing on the copper surface, decreasing the cathodic, anodic, and corrosion currents, as well as shifting the potential slightly to the more negative values, and the high protective behavior of SS can explain it by formation a barrier thick SS film.
3. The inhibition efficiencies obtained from weight loss, electrochemical polarization are in good agreement.

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دراسة تأثيرات مختلفة لمعدل التآكل ومانع التاكل للنحاس في محلول ملحي

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جامعة النهرين – كلية الهندسة – هندسة كيمياوية

الخلاصة:

كمانع للتآكل SSتم دراسة تآكل النحاس في محاليل ملح الطعام عالية التركيز بوجود وغياب
بأستخدام تجارب فرق الوزن, و تقنيات الكهروكيمياوية القطبية . تم دراسة محاليل الاملاح
بمختلف الظروف وهذه الظروف هي: السرعة الدورانية, درجة الحرارة. اعلى كفاءة للمانع
م وتقل هذه الكفاءة كلما ازدادت درجة الحرارة والسرعة الدورانية. oفي درجة حرارة 35
في تجارب فرق الوزن وجد ان كفاءة المانع عندما يكون تركيز ملح الطعام 5 مولاري
تتراوح بين (14-65%) وتتناقص هذه الكفاءة عندما يكون تركيز الملح 1 مولاري. اما في
تجارب الكهوكيمياوية القطبية وجد ان نوع مانع التآكل هو مختلط وان تقنية المانع تتمثل في
امتزاز سطح النحاس للمانع.