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Corrosion Mitigation of Milk Can by Aloe Vera.

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Research Article

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ABSTRACT

Not only does the corrosion of metals by milk become an economic problem from the point of view of equipment replacement, but it is important also from the marketability and physiological factors involved. Milk is very an essential food for human beings. It is highly rich protein containing substance. Generally People keep milk in stainless steel can. Stainless steel uses pasteurizing, storage and transportation of milk. Milk develop corrosion cell on the surface of metal thus stainless steel starts corroding. Improper equipment may lead to contamination of the milk by the products of corrosion to such an extent that not only is the flavor affected, but also the food value. The flavor may be affected by simple metal contamination, giving the characteristic metallic taste or by the indirect action of the dissolved metals on the microorganisms in the milk, resulting in the “mealy” flavor. Due to electrochemical reaction harmful metal goes into milk hence it is contaminated. The contaminated milk produces several types of diseases. To check such types of corrosion aleovera uses as inhibitors. It produces anticorrosive affect with milk. Its inhibition affects study at different concentrations and temperatures on different interval of times. Aloevera takes as concentrations of 2ml, 4ml and 6ml and temperatures maintain those concentrations 20^{0}C, 25^{0}C, 30^{0}C and 35^{0}C.The corrosion rate of stainless steel determined absence and presence of inhibitor at different concentrations and temperatures with help of gravimetric methods. The corrosion current with and without inhibitors calculated by potentiostic polarization technique. The use inhibitor decreases the concentration of H+ and produce thin film on metal surface. The surface film adsorption phenomena study with help of Langmuir, Temkin and Arrhenius equation and other parameters are activation energy, free energy, heat adsorption, enthalpy and entropy. The thermodynamical results show that aloevera is bonded with metal by physical adsorption. The inhibition efficiency and surface coverage area increase as concentrations and temperatures of inhibitor increases.

INTRODUCTION

Milk contains both organic and inorganic radicals. Ordinary milk is slightly acidic [1,2] and its pH at room temperature is 6.5-6.7 when sweet, to 4.6 when sour. Milk contacts with metals not only acquire a metallic test but also corrode these metals readily. A considerable amount of information has been obtained on the effect of metals [3,4] in foods upon animals and human beings. Many recent studies indicate that corrosion products enter into solution of milk and deteriorate quality [5,6] of milk. When a metal goes into solution one can say that it is an electrochemical phenomenon. As the metal goes into solution and passes from a zero charge as the metallic state is designated to positively charged ions an equivalent amount of electricity must pass from the solution to the metal so as neutralize the charge. In the case of acid corrosion this may be expressed as follows:

$$M \quad + \quad HCl \quad = \quad MCl \quad + H_2$$

Stainless steel [7,8,9] corrodes because all common structural metals form surface oxide films when exposed to pure air but oxide formed on stainless steel is readily broke down and in the presence of moisture it is not repaired. The other factors which affect the rate of corrosion are temperature, P^H and flow rate. The relative acidity of the solutions is the most important factor to be considered at low P^H, the evolution of hydrogen trends to eliminate the possibility of protective film formation so that steel continues to corrode but in alkaline solutions, the formation of protective film greatly reduces corrosion rate [10].

Chemists use various types of inhibitors for corrosion protection metal. Several works have been done with help of organic and inorganic materials for the corrosion protection of metal [11,12]. Oixdes of metals and phosphate of metals used as inhibitors. Sulpha drugs [13,14] gave good results for corrosion control of stainless steel in sugar industry. Aromatic amine, fused aromatic amine and hetero cyclic aromatic amine worked as inhibitors in phosphate inhibitors. Cyclic amine used for corrosion inhibition of metal in pulp and paper industry. Nanocoatings of organic and inorganic on surface of metal could produced good inhibition properties and improve life of material. Several types of nanocoating can be done on the surface of materials like nanocomposite thin film coating, thermal barrier coating, Top layer coating, nanostructural change and conversion coating. Thiourea and its derivates worked as inhibitors in petroleum industry in various operational units like production, storage and transportation. Recently natural products applied for corrosion protection of metal in acidic medium and these inhibitors were ecofriendly for environment. Metallic and nonmetallic coating mitigated affect of corrosion in corrosive environment. Organic compounds having nitrogen, oxygen and sulphur behave like anticorrosive inhibitors. Electron rich organic compounds have good inhibition capability against acid. The corrosion is controlled by the application of aliphatic and aromatic amines. It is also observed that primary, secondary, tertiary and quaternary amine is produced good inhibitive effect against acidic medium. Several workers used heterocyclic compounds as inhibitors which possessed nitrogen, oxygen and sulphur. Rubber, polymer and silicon are used as coating material for protection of metal. For this work aloevera is used as inhibitors for corrosion of protection of stainless in milk.

MATERIALS AND METHODS

The sheets of stainless steel metal of 0.1 cm thickness was mechanically cut into coupons of sizes of 5cm length by 3cm width, perforated with hole of same diameter centrally to allow the passage of thread. These coupons were surface prepared using emery paper, ethanol and water. The tested coupons were dipped into 40ml solution of milk in 100ml beakers. The coupons, exposure periods were 24hrs, 48hrs, 72hrs and 96hrs. Tests were performed at different concentrations 2ml, 4ml and 6ml aloevera and at different temperatures 20^{o}C, 25^{o}C, 30^{o}C and 35^{o}C and temperature were maintained constant by keeping the solutions in a thermostat. The average corrosion rates of the in various concentrations and temperatures were determined by using weight loss method. The corrosion current measured with Potentiostatic polarization by using an EG & G Princeton Applied Research Model 173 Potentiostate. A platinum electrode used as an auxiliary electrode and a calomel electrode used as reference electrode with stainless steel coupons.

RESULTS AND DISCUSSION

The Corrosion rate of metal was determined with and without inhibitor at different concentrations and temperatures with help of equation1.

$$K\ (mmpy) = 13.56\ W / D\ A\ t \qquad (1)$$

Where W = weight loss of test coupon expressed in kg, A = Area of test coupon in square meter, D = Density of the material in kg. M^{-3}.

The inhibition efficiency and surface coverage area were calculated by using equation 2 and 3.

$$IE = (1- K / K_o)\ 100 \qquad (2)$$

where K is the corrosion rate with inhibitor and K_o is the corrosion rate without inhibitor.

The surface coverage area may be written as:

$$\theta = (1 - K / K_o) \qquad (3)$$

where θ = Surface area, K = Corrosion rate with inhibitor, K_o = corrosion rate without inhibitor.

The Inhibition of Aloevera activity studied at 2ml, 4ml and 6ml concentrations and at different temperatures 20^{o}C, 25^{o}C, 30^{o}C and 35^{o}C. The rate of corrosion of inhibitors at different concentrations and temperatures were recorded in Table1, Table2 and Table3. Investigation of results of Table 1, Table2 and Table3 it observed that without inhibitor corrosion rate is high and addition of inhibitor corrosion rate is reduced. The results of Table1, Table2 and Table3 show that at lower concentration of inhibitor, the inhibition efficiency and surface coverage area values are smaller and higher concentration the inhibition efficiency and surface coverage area values are bigger. This trends mention in Figure 1. The recorded values of the rate of corrosion at different temperatures without inhibitor in Table1, Table2 and Table3 indicate that corrosion rate increase and addition of inhibitor corrosion rate decrease. This results show that use inhibitor active at high temperature and produces good inhibition efficiency. It is clearly observed in Figure 2.

Table1: Inhibitor Aloevera activities with milk at different temperatures and 2ml concentration.

Inhibitor	Temp	20^0C	25^0C	30^0C	35^0C	C (ml)	logC
IH(0)	K_0	0.578	1.156	1.734	2.312	0.00	0.00
	$\log K_0$	-0.238	0.062	0.239	0.363		
IH(1)	K	0.411	0.781	0.901	0.1.127	2	-2.69
	logK	-0.386	-0.107	-0.045	-0.051		
	θ	0.29	0.32	0.48	0.51		
	$(1-\theta)$	0.71	0.68	0.52	0.49		
	$\log(\theta/1-\theta)$	-0.388	-0.327	-0.034	0.017		
	(C/θ)	-9.27	-8.40	-5.60	-5.27		
	$\log(C/\theta)$	-0.019	-0.201	-0.221	-0.568		
	IE (%)	30	26	21	23		

Table 2: Inhibitor Aloevera activities with milk at different temperatures and 4ml concentration.

Inhibitor	Temp	20^0C	25^0C	30^0C	35^0C	C (ml)	logC
IH(0)	K_0	0.578	1.156	1.734	2.312	0.00	0.00
	$\log K_0$	-0.238	0.062	0.239	0.363		
IH(1)	K	0.308	0.578	0.756	0.979	4	-2.39
	logK	-0.511	-0.238	-0.121	-0.009		
	θ	0.47	0.52	0.56	0.58		
	$(1-\theta)$	0.53	0.48	0.44	0.42		
	$\log(\theta/1-\theta)$	-0.052	-0.034	-0.104	0.140		
	(C/θ)	-5.08	-4.59	-4.26	-4.12		
	$\log(C/\theta)$	-1.09	-0.229	-0.585	-0.920		
	IE (%)	47	50	56	58		

Table 3. Inhibitor Aloevera activities with milk at different temperatures and 6ml concentration.

Inhibitor	Temp	20^0C	25^0C	30^0C	35^0C	C (ml)	logC
IH(0)	K_0	0.578	1.156	1.734	2.312	0.00	0.00
	$\log K_0$	-0.238	0.062	0.239	0.363		
IH(1)	K	0.219	0.375	0.457	0.608	6	-2.23
	logK	-0.659	-0.425	-0.340	-0.216		
	θ	0.62	0.67	0.73	0.74		
	$(1-\theta)$	0.38	0.33	0.27	0.26		
	$\log(\theta/1-\theta)$	0.212	0.307	0.431	0.454		
	(C/θ)	-3.59	-3.32	-3.05	3.01		
	$\log(C/\theta)$	-0.229	-0.494	-1.30	-2.01		
	IE (%)	62	67	73	74		

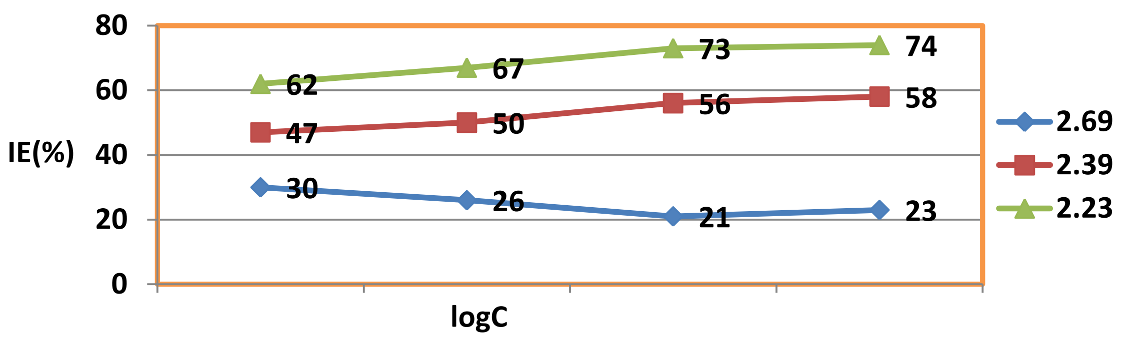

Fig.1 Plot of IE(%) Vs. C(ml) for Stainless steel at different concentrations

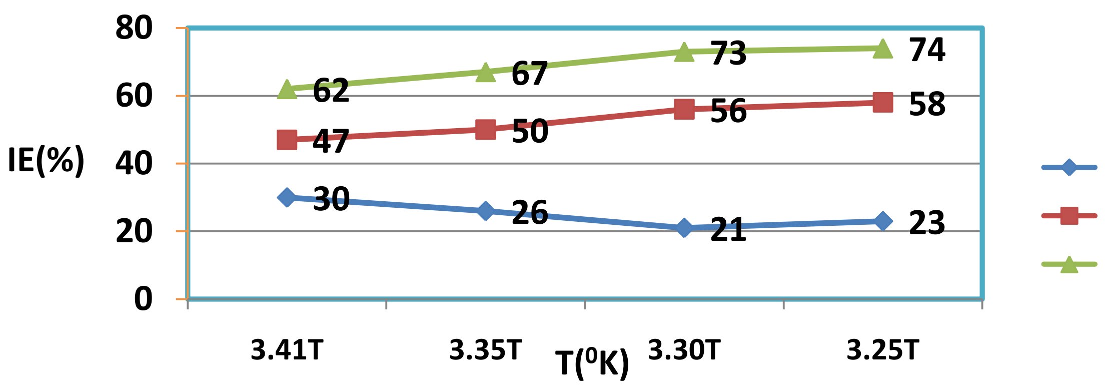

Fig. 2 Plot of IE(%) Vs. T(^{0}K) for Stainless steel at different temperatures

Activation energy was determined with help of Arrhenious equation 4

$$d/dt (\log K) = E_a / R T^2 \qquad (4)$$

where T is temperature in Kelvin and E_a is the activation energy of the reaction.

The values of activation energies were recorded in Table4, Table5 and Table6 absence and presence inhibitor. It absorbs that without inhibitor activation energies decrease and with inhibitor activation energies increase. The plot between log K Vs. 1/T in Figure 3 and log ($^\theta/1-{}^\theta$) vs. 1/T in Figure 4 are found to be straight line. It indicates that physical adsorption occurs on the surface metal.

Table 4: Thermodynamical parameters for Aloevera at different temperatures and 2ml Concentration

Thermodynamical Parameters	20^{0}C	25^{0}C	30^{0}C	35^{0}C
$E_{a(0)}$	26.87	7.11	4.04	11.75
E_a	25.18	6.85	2.84	3.17
Q_{ads}	-25.31	-20.95	-2.14	-1.05
ΔG	-28.00	-23.64	-4.83	-3.74
ΔH	-59.36	-40.37	-35.35	-27.97
ΔS	-34.81	-24.10	-21.42	-17.21

Table 5: Thermodynamical parameters for Aloevera at different temperatures and 4ml Concentration

Thermodynamical Parameters	20^{0}C	25^{0}C	30^{0}C	35^{0}C
$E_{a(0)}$	26.87	7.11	4.04	11.75
E_a	33.33	15.25	7.63	0.55
Q_{ads}	-3.39	-2.19	-6.56	-8.70
ΔG	-5.78	-4.58	-8.95	-11.09
ΔH	-67.84	-48.70	-39.77	-32.33
ΔS	-39.78	-29.07	-24.10	-19.89

Table 6: Thermodynamical parameters for Aloevera at different temperatures and 6ml Concentration

Thermodynamical Parameters	20^{0}C	25^{0}C	30^{0}C	35^{0}C
$E_{a(0)}$	26.87	7.11	4.04	11.75
E_a	42.98	27.23	21.46	13.42
Q_{ads}	-13.82	-19.67	-27.20	-28.22
ΔG	-16.05	-21.90	-29.43	-30.45
ΔH	-77.62	-60.88	-53.65	-44.76
ΔS	-45.52	-36.34	-32.51	-27.54

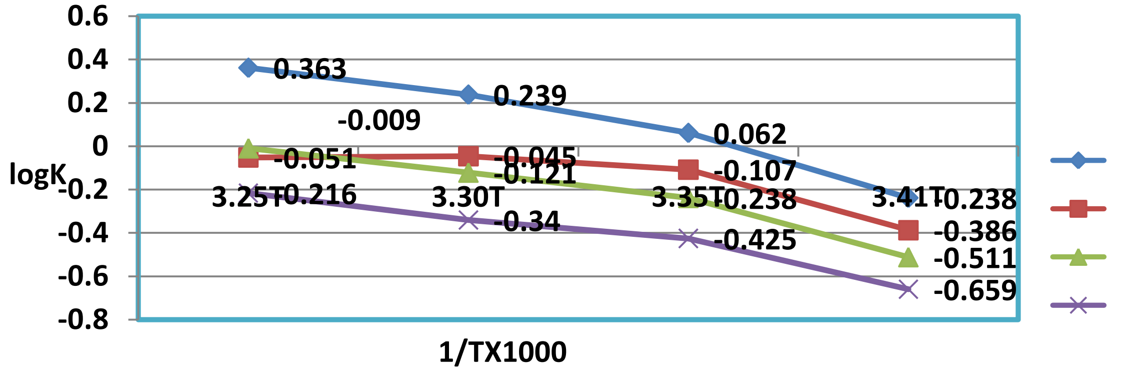

Fig. 3 Plot of logK Vs 1/T for Stainless steel at different temperatures

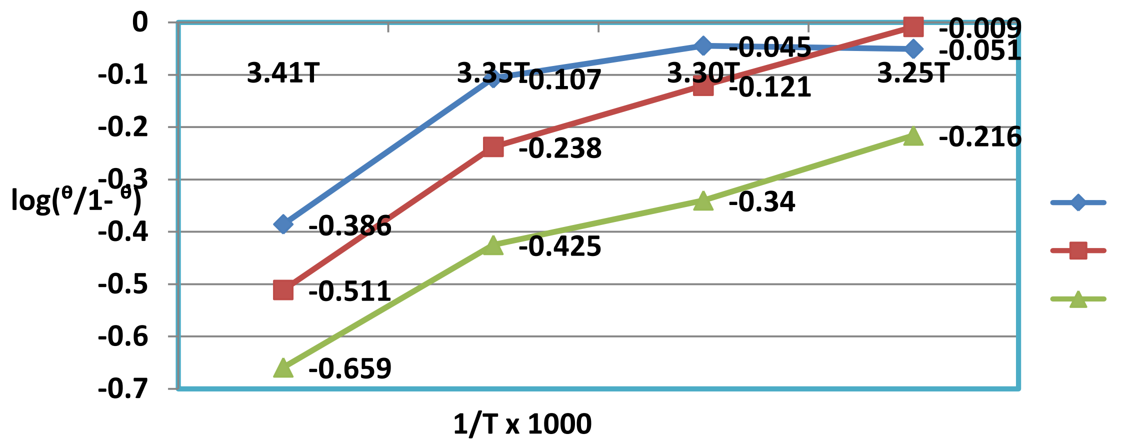

Fig.4 Plot of log(θ/1- θ) Vs. 1/T for Stainless steel at different temperatures

The heat of adsorption was calculated by Langmuir adsorption isotherm equation and it values recorded in Table 4, Table 5 and Table 6.

$$\log (\theta/ 1-\theta) = \log (A .C) - (Q_{ads}/ R T) \qquad 5$$

where T is temperature in Kelvin and Q_{ads} heat of adsorption

The heat of adsorption found to be negative so it indicated that adsorption occurred on the metal surface. The values of heat of adsorption were shown that inhibitors were bind with metal by physical adsorption. The plot between log (θ/1- θ) vs. log C found to be straight line in figure 5 which indicates Langmuir adsorption isotherm. It is a sign of adsorption.

Temkin equation of isotherm for adsorption expressed as:

$$\log (C/ \theta) = \log C - \log K \qquad 6$$

where C is concentration of inhibitor, θ is surface coverage area and K be constant.

The values of log (C/ θ) are mentioned in Table1, Table 2 and Table 3. The plot against log (C/ θ) vs. log C shows a straight line in figure 6 which indicates sign of adsorption.
Free energy was determined by equation 7 and it values recorded in Table 4, Table 5 and Table 6 at different concentrations.

$$\Delta G = -2.303RT [\log C - \log (\theta/1-\theta) + 1.72] \qquad 7$$

Free energy results show that use inhibitor produces an exothermic reaction so it indicates sign of adsorption.

The energy of enthalpy and entropy were determined by transition state equation 8 and it values mentioned in Table 2.

$$K = R\,T / N\,h \log (\Delta S^{\#} / R) \times \log (-\Delta H^{\#} / R\,T) \qquad 8$$

Where N is Avogadro's constant, h is Planck's constant, $\Delta S^{\#}$ is the change of entropy activation and $\Delta H^{\#}$ is the change of enthalpy activation.

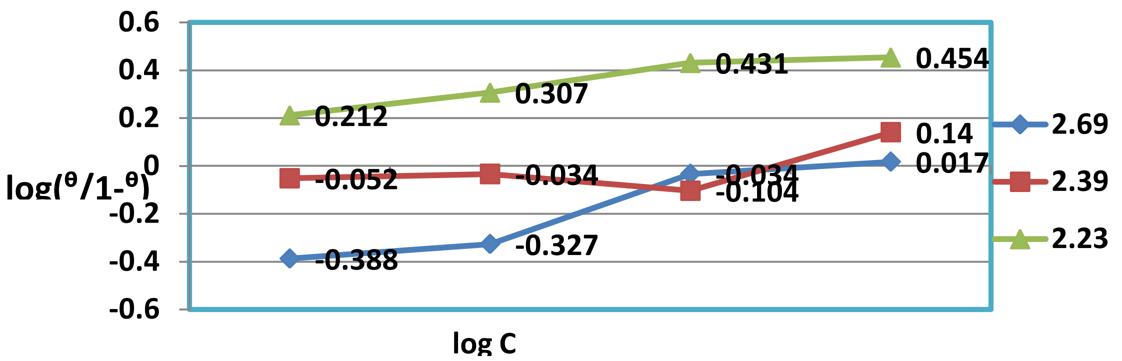

Fig.5 Plot of log(θ/1-θ) Vs. log C for Stainless steel at different concentrations

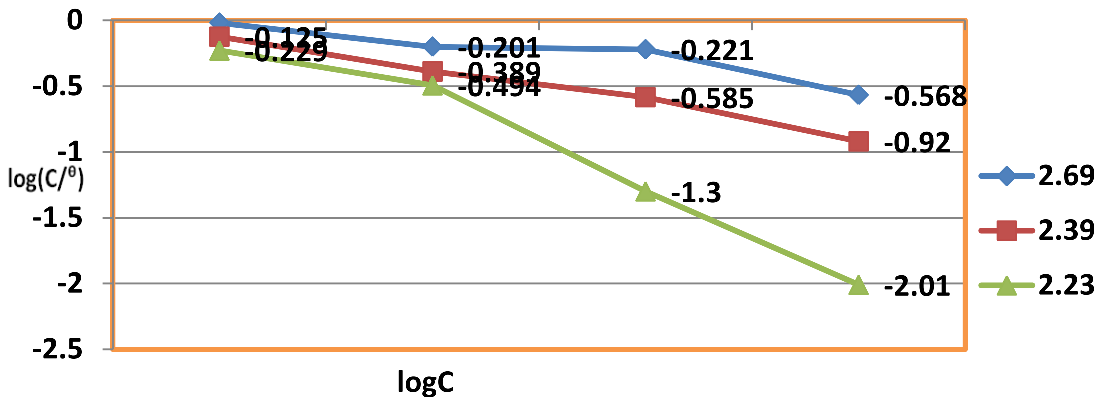

Fig. 6 log(C/θ) Vs logC for Stainless steel at different concentrations

Enthalpy and entropy values are mentioned in Table 4, Table 5 and Table 6 which are found to be negative, it exhibits an exothermic reaction. The negative values of entropy indicate that inhibitors stable on surface adsorption of metal.

The corrosion current density determined absence and presence of inhibitor with help of equation 9 and values recorded in Table 7.

$$\Delta E/\Delta I = \beta_a \beta_c / 2.303\, I_{corr} (\beta_a + \beta_c) \qquad 9$$

where $\Delta E/\Delta I$ is the slope which linear polarization resistance (R_p), β_a and β_c are anodic and cathodic Tafel slope respectively and I_{corr} is the corrosion current density in mA/cm^2.

Looks the results of Table 7, it is noticed that corrosion current increases without inhibitor and its values reduce after addition of inhibitor.

The metal penetration rate (mmpy) is determined by

$$C.\,R\,(mmpy) = 0.1288\, I_{corr}\,(mA/cm^2) \times Eq.Wt\,(g) / \rho\,(g/cm^3) \qquad 9$$

where I_{corr} is the corrosion current density ρ is specimen density and Eq.Wt is specimen equivalent weight.

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Figure 7 indicates that Tafel graph has plotted between electrode potential and current density and absence and presence of inhibitors. Anodic potential, current density and corrosion rate increased without inhibitors but addition of inhibitors these values decreased and inhibition efficiency increased.

Table 7: Potentiostatic Polarization values of Aloevera inhibitors with different concentration at 30⁰C.

Inhibitor	ΔE	ΔI	βa	βc	Icorr	K(mmpy)	IE(%)	C(ml)
IH(0)	-800	350	250	230	28.81	0.875	0.00	0
IH (1)	-575	260	145	170	1 5.26	0.352	59.01	2
	-550	250	140	165	14.95	0.454	48.11	4
	-525	225	135	160	13.65	0.415	52.25	6

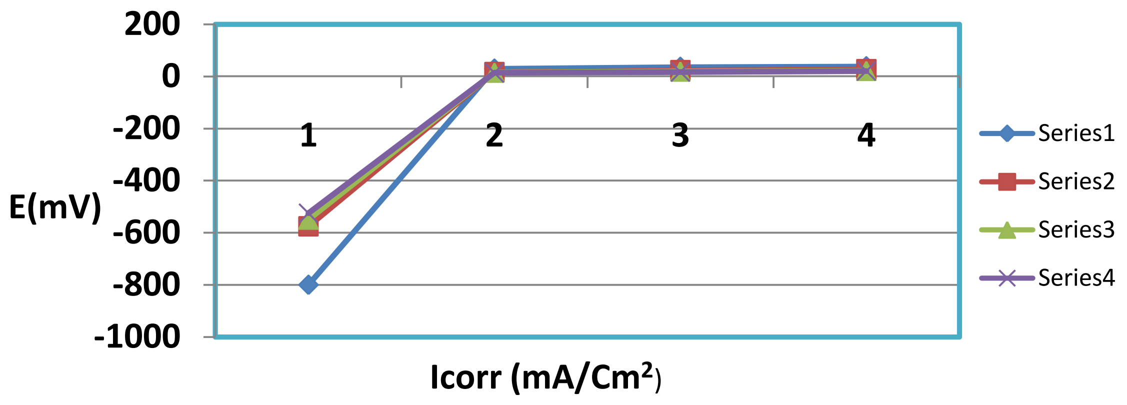

Fig.7 Plot of E (electode pot. Vs. I (corrcurrent) for Stainless steel

CONCLUSION

Aloevera is a medicinal natural plant. It is ecofriendly and it has no any side effect. Due to this character it is used as inhibitor in milk solution for protection of stainless steel. Its inhibition efficiency is low at lower concentration and its inhibition efficiency is high at higher concentration. The inhibition efficiency lies between 21 to 74% at different concentrations. It also produces good inhibitive effect at different temperatures. The results of activation energy, heat of adsorption, free energy, enthalpy and entropy show that aloevera bonded with metal surface physical adsorption. Potentiostatic polarization study results indicate that corrosion current decrease after addition of inhibitor.

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