The inhibition effects of dimethylol-5-methyl hydantoin and its derivatives on carbon steel alloy

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Abstract

Dimethylol-5-methyl hydantoin MHD and its derivatives were used as corrosion inhibitors to protect carbon steel alloy against deterioration from corrosion. Effectiveness of heterocyclic molecules as corrosion inhibitor is based on their chelating, temperature and pH range. Generally, the action and the formation of an insoluble physical diffusion barrier on the electrode surface prevent the metal reaction and dissolution. Dimethylol-5-methyl hydantoin and its derivatives containing hetero atom, such as N, with free electron pairs which are readily available for sharing, are found to be effective corrosion inhibitors for many metals and alloys. It has been commonly recognized that feed back coordinate covalent bonds formed between organic inhibitors and metal surface during chemical adsorption process. MHD as heterocyclic compound containing N-atoms was used to synthesis four compounds by its reaction with the prior starting materials to produce the compounds (A, B, C, and D). The study exhibited that MHD has higher efficiency(97.81%) than other inhibitors (A-D)inhibitors due the steric effect in case of (A-D) inhibitors, but the efficiency of MHD inhibitor was decreased as temperature increased due to destroying of the protective film of this inhibitor at 40ºC , also the efficiency decreased for all inhibitors MHD and (A-D) in acidic media due to due to protonation of some hetero atoms that presence in meaning inhibitor that lower the basicity for other non protonated hetero atoms then reduce the efficiency. This true in basic media because in basic media caustic corrosion is an important factor that reduced the efficiency due to solubility of some of protective film. Different behaviors for inhibitors as temperature change, some of them has physical adsorption mode C and D inhibitors and other has chemical adsorption mode MHD,A and B due to their variation behaviors with temperature.

Key words: Hydantoin, corrosion, amino compounds, Tafel plot

1. Introduction

Corrosion problems have been received considerable attention due to their attack on material [1,2]. Addition of inhibitors remains one of the necessary procedures used to protect metals and alloys against attack in many industrial environments, therefore the development of corrosion inhibitors based on organic compounds containing nitrogen, sulfur and oxygen atoms are growing interest in the field of corrosion and industrial chemistries as corrosion poses a serious problem to the service life time of alloys used in industry [3,4].

Carbon steel is widely used as constructional material in many industries due to its excellent mechanical properties and low cost [5-7]. The highly corrosive nature of aqueous mineral acids on most metals requires degree of restraint to achieve economic maximum safety condition. Organic compounds containing nitrogen atom are commonly used to reduce the corrosion attack on steel in acidic media. These compounds can adsorb on the metal surface, block active sites on the surfaces and thereby reduce the corrosion attack. The efficiency of these compounds as corrosion inhibitors can be attributed to the number of mobile electron pair present [5,8,9]. The effectiveness of organic compounds containing heteroatom as corrosion inhibitors for steels in sulfuric acid well developed the nature of hetero atoms and constituents play the major role in adsorption phenomenon. Also the existing data show that most organic inhibitors adsorb on the metal surface by displacing water molecules on the surface and forming a compact barrier film [6,10-12].

The important prerequisites for a compound to be an efficient inhibitor are: (i) it should form a defect free compact barrier film, (ii) it should chemisorbs on the metal surface, (iii) it should be polymeric or polymerize in situ on the metal and (iv) the barrier thus formed should increase the inner layer thickness [13]. The adsorption of natural molecules has been studied on different metals and alloys however, it is well known that adsorption from solution onto the surface of an electrode is a replacement reaction between the adsorbent and an appropriate number of water molecules [14] .

Perhaps, presence of CO_2 gas in cooling water systems make them acidic or leakage of acidic materials that used in industrial toward cooling waters an important aim of measuring at pH=2, for example leaching of H_2SO_4 and NH_3 toward cooling water system in South Fertilizes Company in Basrah (Iraq), due to old establish and no presence of spare parts , make the medium either acidic in presence of sulfuric acid or basic in presence of ammonia, therefore, the research include all pH ranges to cover the effect of inhibitor against basic and acidic corrosive media.

2. Experimental

The new anti-corrosion compounds which illustrated in Table (1) were prepared according to the references [15].

Corrosion study for CS alloy by electrochemical method (Tafel plots):

2.1. Composition of alloys:

The alloy that has been used in this study is carbon steel, which has the composition illustrated in Table (2):

Table 1. The chemical structures for the new amino resins

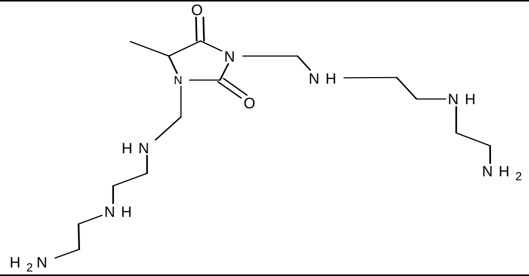
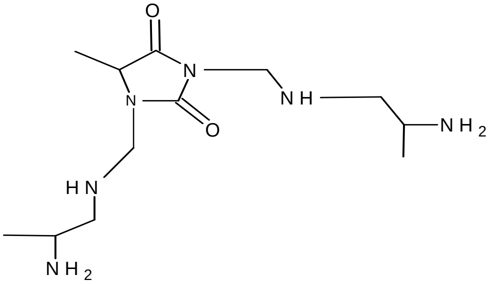
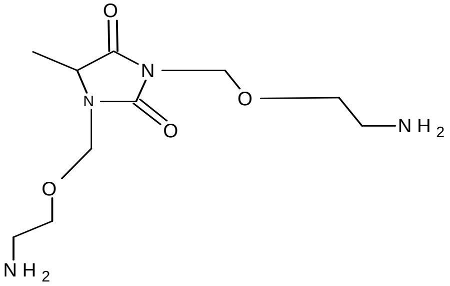
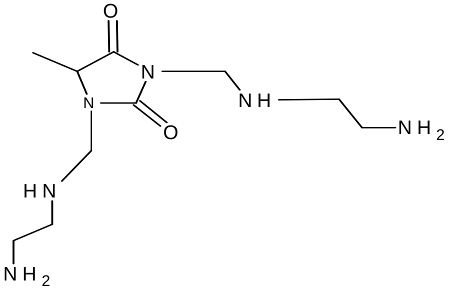
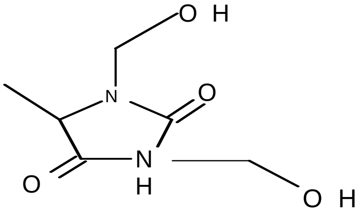
comp	*Structure*
A	
B	
C	
D	
MHD	

Table 2 Chemical composition of carbon steel alloy

Alloy	Composition
Carbon steel	0.3%C, 1.2%Mn , 0.05%P , 0.06%S , Fe for balance (%by weight)

The specimens obtained as discs have been taken from the south oil company in Basrah.

2.2. Preparing the specimen:

The specimen of carbon steel discs was produced by cutting rods into 1.4-1.7cm^2 disc, 2-3 mm thickness, the rod specimens were divided into discs 14mm diameter. The opposing faces of each specimen were then grind and polished by emery cloth paper to 400 micron. Thereafter, the specimens were degreased with acetone, washed with distilled water and ethanol and dried with hot air. The specimens were stored in desiccators during the interval between polishing and polarization measurements. The specimen was placed on the holder metal base and inserted through electrode mounting rod, which was screwed onto the rod by Teflon cover to isolate the disc and to avoid leakage from the working environment.

2.3. Solution choice and preparation:

The aim of this study was to determine the inhibition effects of some new aliphatic diamines as corrosion inhibitors for carbon steel. The solution chosen for the corrosion study were supplied by using water cooling system of desalination station of water in Shatt Al-Arab at Garmatt Ali (Basrah/Iraq). The solutions were found to be having naturally present dissolved solids (820-1680) mg/l with pH (7.20-8.66), the compositional analysis of crud cooling water is present in Table(3). The working solution contains the naturally present chemical species including calcium, magnesium, sodium salts, chloride and also dissolved gasses such as oxygen and carbon dioxide, therefore the corrosive medium was an aqueous solution of crude cooling water with out and with different concentration of additives. The additives investigated were compared to Nalco™ as commercial additive as indicated in the following manner:

Table 3 Analysis for raw water

(D)ate/2007	pH	E.C µS/cm	Tur mg/l	Cl^- mg/l	T-H mg/l	Ca-H mg/l	T-Alk mg/l	SO_4^{2-} mg/l	SiO_2 mg/l	COD mg/l
16-4	8.00	4650	6.98	1156	1260	560	120	1776	0.88	3.80
23-4	8.30	5910	10.80	1551	1560	670	82	3370	4.07	3.60
14-5	8.38	4030	10.40	1051	1070	540	99	1547	3.10	3.00
28-5	7.83	3330	7.00	846	870	384	83	1323	2.60	3.10
4-6	8.30	4730	17.38	1184	1260	590	100	1792	3.60	5.50
18-6	8.14	5830	13.20	1551	1570	740	60	3197	5.60	4.80
25-6	8.50	5580	18.18	1438	1500	700	95	2547	5.60	7.80
9-7	8.66	6170	12.00	1636	1660	790	83	2701	11.50	6.00
16-7	8.55	5530	10.10	1466	1480	730	189	2159	5.60	5.70
23-7	8.10	6280	8.40	1646	1680	820	142	2638	7.30	6.40
6-8	8.30	3180	6.20	740	820	410	129	1195	7.30	6.60
13-8	8.35	4680	13.60	1184	1600	640	136	1727	11.70	6.00
20-8	8.20	3120	9.60	705	850	450	76	1114	8.50	5.80
10-9	8.10	4970	11.20	1255	1410	700	144	2192	9.60	5.70
17-9	7.90	3750	14.40	846	1020	500	118	1445	4.50	5.70
24-9	7.46	4120	7.20	1015	1120	550	104	1765	6.60	6.20
19-11	8.12	3720	6.60	931	1000	500	142	924	3.74	6.70
26-11	7.20	3620	11.50	874	920	450	112	1825	3.46	3.20
3-12	8.10	3980	5.20	1001	1020	480	128	1465	1.69	3.30
10-12	8.10	3730	6.25	931	970	460	142	1300	1.80	2.70

2.3. The electrochemical cell:

The arrangement of the test cell which illustrated in ref [16], the main cell was 500ml round flask fitted with five necked as following:

1- The working electrode (polished specimen).
2- The Lugging capillary probe which was connected by salt bridge containing the test solution to a saturated calomel reference electrode, which lies in front of working electrode nearly.
3- Two graphite electrodes fitted by round adapters, these electrodes behave as auxiliary electrodes.
4- The event to allow enters the oxygen and exits it.

The disc specimen is fitted within a specimen holder. The Teflon holder is designed to accept specimen 15.00mm and up to 3.00mm thickness. The sealing washer is made of Teflon and exposes $1cm^2$ of the specimen to the test solution. The flat specimen holder attaches to the electrode mounting rod and electrode holder so that it can be used with the corrosion cell.

2.4. Experimental procedure:

A microprocessor-based corrosion measurement system (EG & G PARC model 350A) performs potentiodynamic polarization scan, Tafel plots, linear polarization scan, and other specialized measurements. This can be illustrated in ref [16].

3. Results and discussions

The results can be explained by studying the four below effects.

3.1. Effect of concentration:

The increasing in concentration in resin (MHD) leads to increasing in its efficiency to (97.81%) at (50mg/l) as optimum concentration, due to increasing of the viscosity of inhibitor with increasing concentration then more adsorption ability for the inhibitor, these are true for compound (A) and for compound (D). But for compounds (B) and (C) the reverse was happened i.e., increasing the concentration leads to decrease the efficiency where their efficiencies are (70.83%) and (64.09%) respectively. This can be explain by the little dissociation pressure for oxygen in protective film as compared with the atmospheric pressure [17]. All electrochemical data for those compounds illustrated in Table (4):

3.2. Effect of structure:

The studying of the effect of structure on efficiency are taking the optimum efficiency at optimum concentration into account, and that can be explain by starting with compound (MHD) where its efficiency is (97.81%) at (50mg/l) which is higher efficiency than the commercial inhibitor Nalco™ (94.48%) at (40mg/l).

The etherification of two hydroxyl groups in (MHD) by two molecules of Ethanolamine (Etham) to form compound (C) was reduced the efficiency to (64.09%) as optimum efficiency for compound (C) at (10mg/l), this is due to the steric effect that presence by the two etherified molecules of (Etham), although these two molecules has donating inductive effect which should be increasing the electron density on CS surface to decrease the corrosion rate.

The steric factor overcome to the inductive effect, when each two oxygen atoms in compound (C) substituted by N-atom to form compound (D), this could be achieved by amination process for (MHD) group by two molecules of ethylenediamine (Ethdam). The efficiency then reduced to (62.28%) compared with compound (C), this meant although the O-atom has more electronegativity than N-atom but the adsorption of O-atom on Fe atom in CS alloy is higher than N-atom [18].

The substitution of the two proton in each of the two ethylene groups in compound (E) to form compound (B) could be archived by amination process on compound (MHD) with two molecules of 1,2-diamino propane (1,2-diamp). This process increased the efficiency to (70.83%) at (10mg/l) compared with compound (E) due to the donating inductive effect for two methyl groups, the later process increased the electron density on Fe atoms in CS alloy then increasing the inhibition efficiency.

The substitution of the proton in each of the two free amino groups by two molecules of (Ethdam) to form compound (A) [dimerization of (Ethdam) in compound (E)] it was achieved by amination process of compound (MHD) by two molecules of diethylentriamin (dieth). This procedure increase the efficiency to (72.78%) for compound (A) compared with compound (E) due to the increasing of the N-atoms in compound (A) leads to increased the active center that ready to adsorbed on Fe atoms in CS alloy then increase the inhibition efficiency. But in general, compound (MHD) has efficiencies higher than compounds (A-D) due to steric effect on those compounds as compared with compound (MHD).

4.3. Effect of temperature:

The effect of temperature can be explained depending on two principles, the first include that the increasing of the inhibitor efficiency with decreasing in temperature is related to a physical adsorption mode was happened on the surface of metal, and the second include that the increasing of the inhibitor efficiency as temperature increased is due to the chemical adsorption mode which that happened on the metal surface [10]. The electrochemical data which that obtained from this study explained in Table (5), and Tafel lines as shown in Figures (1-4).

Table 4: An electrochemical data for new compounds at pH=7 and 30ºC

comp	*Conc. (mg/l)*	*Temp. ºC*	*Effe.%*	E_{corr} *(volt)*	$I_{corr}\times E4$ *(nA/cm^2)*	*Ba (volt)*	*Bc (volt)*	*Rp×E4 Ω*	*CR (mpy)*
water	0	30	0	-0.883	3.265	0.191	0.278	0.150	15.080
Nalco™	10	30	39.82	-0.630	0.889	0.173	0.279	0.532	4.108
	20	30	85.65	-0.648	0.211	0.107	0.300	1.620	0.979
	30	30	87.54	-0.583	0.184	0.212	0.114	1.747	0.850
	40	30	94.48	-0.303	0.082	0.414	……	6.612	0.377
	50	30	93.92	-0.265	0.089	0.414	0.202	6.557	0.417
MHD	10	30	63.35	-0.646	1.304	0.141	0.400	0.347	6.025
	20	30	73.86	-0.676	0.930	0.163	0.360	0.374	4.297
	30	30	……	-0.586	4.259	0.220	0.312	0.131	19.670
	40	30	61.77	-0.586	1.361	0.114	0.360	0.277	6.285
	50	30	97.81	-0.230	0.077	0.303	……	5.118	0.360
A	10	30	61.82	-0.677	1.359	0.079	0.285	0.198	6.276
	20	30	30.71	-0.619	2.466	0.178	0.335	0.204	11.390
	30	30	37.22	-0.649	2.233	0.144	0.293	0.187	10.320
	40	30	32.23	-0.648	2.411	0.167	0.301	0.193	11.140
	50	30	72.78	-0.711	0.968	0.081	0.203	0.258	4.474
B	10	30	70.83	-0.710	1.038	0.086	0.270	0.273	4.794
	20	30	66.02	-0.668	1.136	……	0.389	0.149	5.585
	30	30	24.45	-0.672	2.588	…….	0.382	0.147	12.420
	40	30	24.45	-0.677	2.588	…….	0.355	0.145	12.420
	50	30	40.93	-0.682	2.102	0.109	0.338	0.170	9.711
C	10	30	64.09	-0.690	1.278	0.079	0.225	0.204	5.903
	20	30	35.09	-0.646	2.310	0.110	0.367	0.158	10.670
	30	30	…….	-0.648	3.922	0.204	0.365	0.144	18.120
	40	30	…….	-0.638	3.368	0.169	0.380	0.151	15.560
	50	30	…….	-0.658	2.296	0.173	0.329	0.214	10.600
D	10	30	21.53	-0.689	2.688	……	0.333	0.124	12.900
	20	30	52.06	-0.718	1.642	…….	0.289	0.182	7.880
	30	30	62.28	-0.710	1.342	0.073	0.281	0.186	6.201
	40	30	39.90	-0.725	2.058	…….	0.293	0.175	9.880
	50	30	52.06	-0.694	1.642	…….	0.311	0.189	7.880

As shown in Table (5) the corrosion rates (CR) of CS in the absence of all inhibitors were increased as temperature increased due to the increasing in corrosion current density (I_{corr}).

For Nalco™ the efficiency increased with increasing temperature, that combined with decreasing in E_{corr} value toward positive direction, while resistance polarization (R_p) increased, the max efficiency for Nalco™ at 40ºC is (96.39%), both βa and βc decreased as temperature increased therefore, the inhibition effect for Nalco™ can be interpreted by simple blocking reactions [19-21] as inhibitor adsorbed on CS surface by chemical adsorbed.

In the same way both MHD and (D) inhibitors, their adsorption on CS alloy obey to chemical adsorption mode, but for MHD increasing in βa value refers to anodic control for the anodic reaction this meant it has anodic behavior inhibitor, while for βc value is difficult to extrapolate because few of the curve appeared to show a distinct cathodic Tafel region [22] as shown in table (5). But for (D) inhibitor βa and βc decreased as temperature increased this leads to think that the inhibition achieved by simple blocking reaction sites, while for both (B) and (C) inhibitors the adsorption effect obey to physical adsorption mode, but (B) inhibitor shows increases in βa with increasing temperature then it affect on the anodic reaction which then can be considered as anodic inhibitor. While inhibitor (C) both βa and βc decreased as temperature increased therefore its inhibition effect can be interoperated by simple blocking reaction.

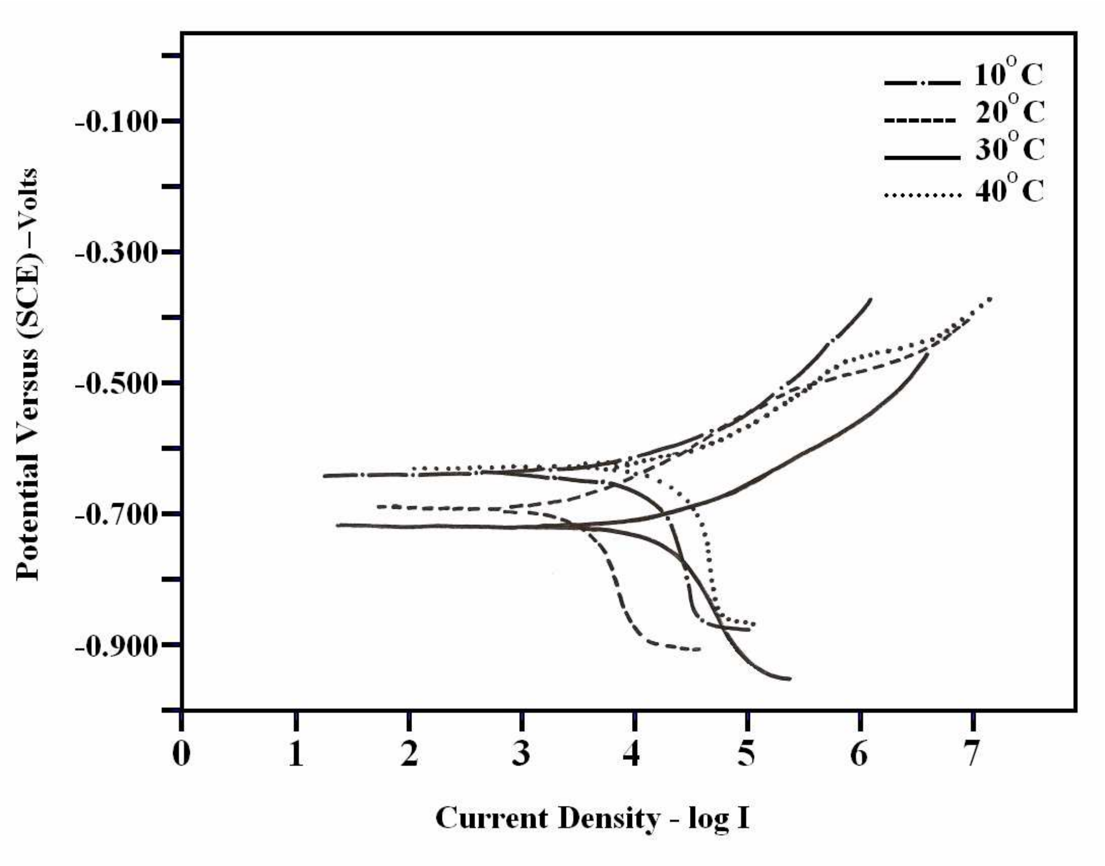


Figure 1. Tafel plots for CS in (A) solutions at different temperatures

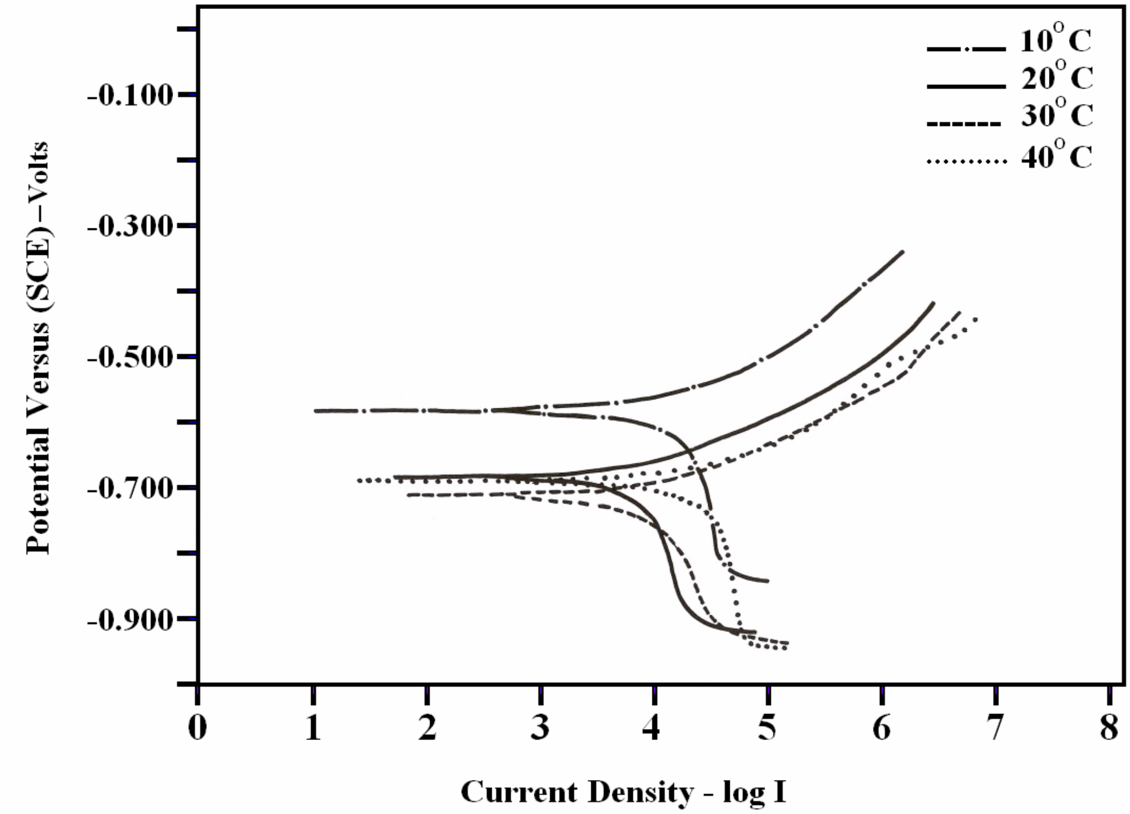


Figure 2. Tafel plots for CS in (B) solutions at different temperatures

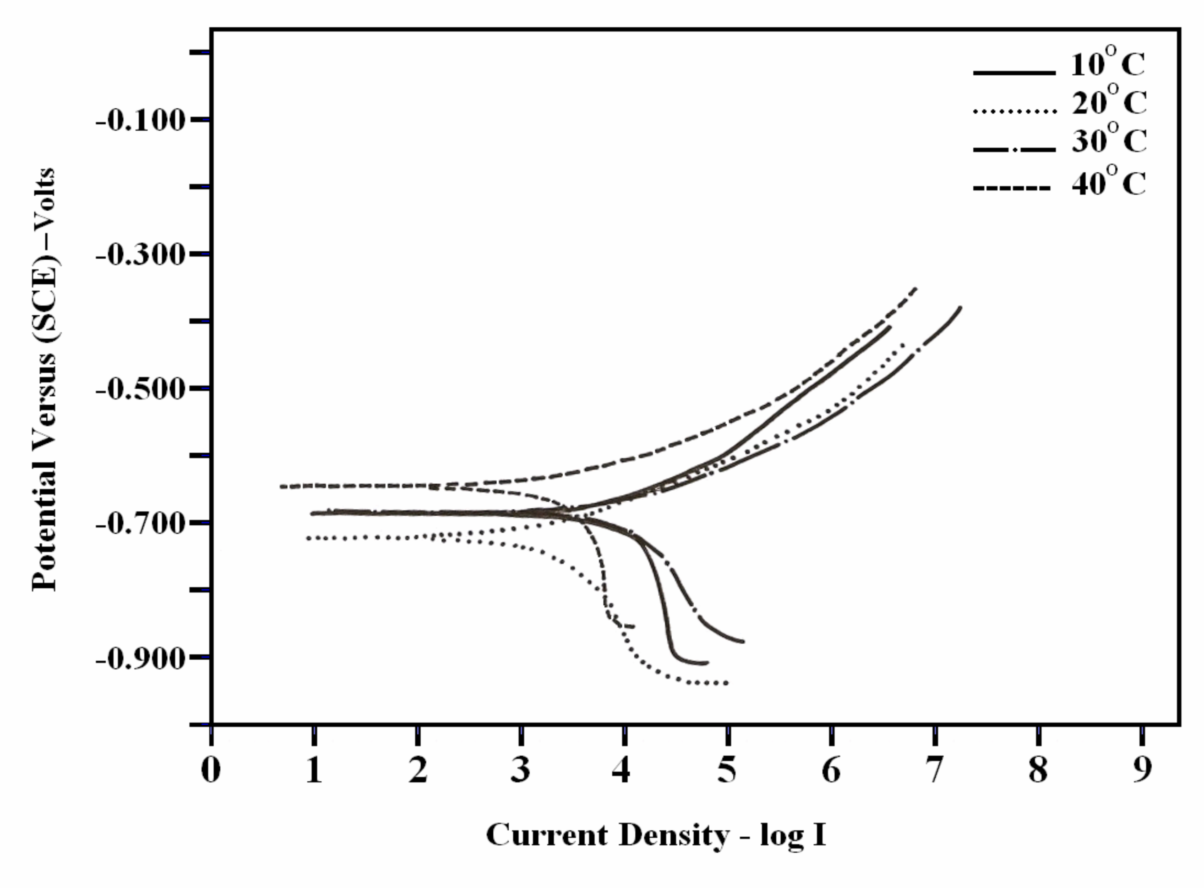


Figure 3. Tafel plots for CS in (C) solutions at different temperatures

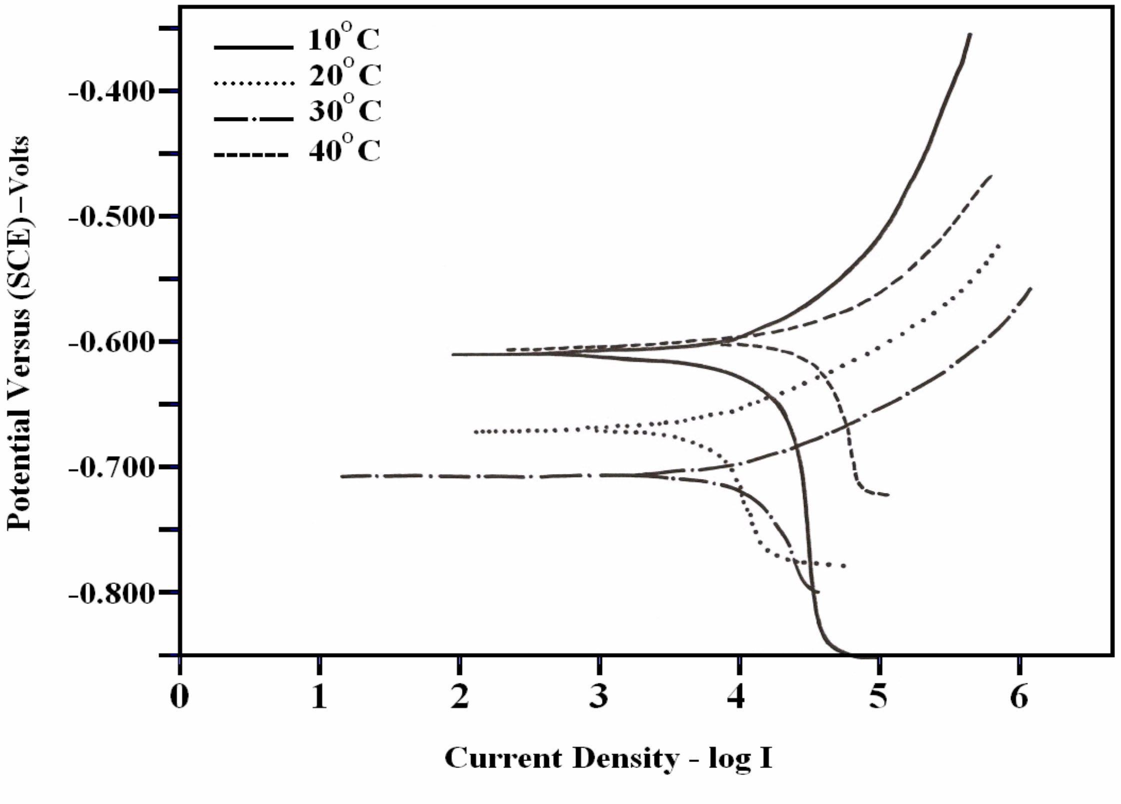


Figure 4. Tafel plots for CS in (D) solutions at different temperatures

Table 5. Electrochemical data for new compounds at pH=7 different temperatures

comp	*Conc. (mg/l)*	*Temp °C*	*Effe%*	*E_{corr} (volt)*	*I_{corr} (μA/cm^2)*	*βa*	*βc*	*Rp×E4 Ω*	*CR(mpy)*
water	0	10	0	-0.549	12.11	0.100	0.392	0.286	5.593
	0	20	0	-0.580	28.01	…	0.736	0.147	13.440
	0	30	0	-0.541	35.73	0.118	….	0.077	16.440
	0	40	0	-0.546	78.40	0.141	…..	0.061	36.046
Nalco™	40	10	52.29	-0.603	7.75	0.227	0.446	1.131	2.668
	40	20	64.18	-0.550	9.10	0.225	0.578	0.772	4.813
	40	30	94.48	-0.303	0.82	0.414	….	6.612	0.377
	40	40	96.39	-0.336	2.71	…..	0.311	1.530	1.300
MHD	50	10	36.88	-0.634	7.64	0.083	0.524	0.405	3.530
	50	20	56.14	-0.642	11.15	0.101	0.603	0.335	5.894
	50	30	97.81	-0.307	0.77	0.303	…	5.118	0.360
	50	40	59.55	-0.623	31.57	0.097	0.533	0.113	14.580
A	50	10	…..	-0.644	30.76	0.174	0.595	0.190	14.210
	50	20	82.84	-0.688	4.99	0.085	0.325	0.588	2.305
	50	30	72.78	-0.711	9.68	0.081	0.203	0.258	4.474
	50	40	4.25	-0.629	50.83	0.112	0.504	0.078	23.480
B	10	10	…..	-0.589	26.92	0.162	0.649	0.208	12.430
	10	20	72.58	-0.686	7.97	0.081	0.384	0.362	3.684
	10	30	70.83	-0.710	10.38	0.086	0.270	0.273	4.794
	10	40	20.63	-0.591	61.94	0.142	0.778	0.084	28.610
C	10	10	….	-0.586	20.32	0.114	0.550	0.201	9.389
	10	20	89.01	-0.727	3.17	0.070	0.227	0.734	1.476
	10	30	64.09	-0.690	12.78	0.079	0.255	0.204	5.903
	10	40	1.09	-0.646	7.40	0.089	…	0.093	35.650
D	30	10	….	-0.611	50.49	0.220	0.754	0.146	23.320
	30	20	61.25	-0.675	11.27	0.115	0.409	0.346	5.207
	30	30	62.28	-0.710	13.42	0.073	0.281	0.186	6.201
	30	40	11.80	-0.606	68.82	0.171	0.674	0.085	31.790

3.4. Effect of pH:

The effect of pH on inhibition effect for MHD and its derivatives (A-D) on CS surface was studied in both acidic (pH=2-4) and basic (8-10) media relative to neutral condition (pH=7) at 30ºC. The electrochemical data that obtained at these conditions are shown in Table (6), and Tafel plots for these effects are presented in Figures (5-8).

In this study different solutions have been used from both sulfuric acid and sodium hydroxide to study the effect of changing in pH value for the environments (in the absence and presence of these inhibitors) on CR of CS and then on inhibition efficiencies of these inhibitors.

In case of Nalco™ decreasing in pH value in acidic media as shown in Table (6) leads to increasing in the efficiency to 97.75% at pH=2 compared with the absence of this inhibitor at this pH value, this can be explained by decreasing both CR and I_{corr} and increasing in R_p value. The increasing in βc value of this inhibitor as changing in pH toward pH=2 refers to cathodic reaction control in contrast to βa that witness decreasing in its value at same conditions. Cathodic inhibitor behavior can be observed this insist by shifting in E_{corr} toward negative value. The increasing in efficiency as pH decreased in acidic media is due to columbic attraction forces that occur by protonated inhibitor in presence of acid solution with metal. This metal should have an electron density that ready to oxidize while the protonated inhibitor behave as surface active agent to prevent an electron to translate toward the cathode electrode **[23]**.

The increasing in efficiency at basic solutions as pH increased shows that Nalco™ has an efficiency of 98.11% at pH=10 as shown in Table (7) that due to the presence of sodium hydroxide which increase the electron density in the environment then a passive film can be formed on CS surface leads to inhibit the corrosion reaction [24]. In basic media as in Table (7) both βa and βc values increased as pH increased this mean both cathodic and anodic reactions can be controlled, therefore its behavior can be considered as cathodic inhibitor due to shifting in E_{corr} value toward negative direction.

Generally for MHD and its derivatives, reducing in efficiencies can be obtained in both acidic and basic media compared with neutral media. Where in acidic media reducing in efficiencies are due to the protonation for some of O-atoms in MHD and for some of N-atoms for each one its derivatives that lower the basicity of other lone pairs that not protonated [3], but in basic media reducing in efficiencies can be explained by forming the caustic corrosion that leads to soluble of some protective film that adsorbed on CS surface [25], also decreasing in efficiencies followed by increasing in CR and I_{corr}, as well as the lowest values in R_p and shifting in E_{corr} values toward negative values evidence to decreasing in efficiencies.

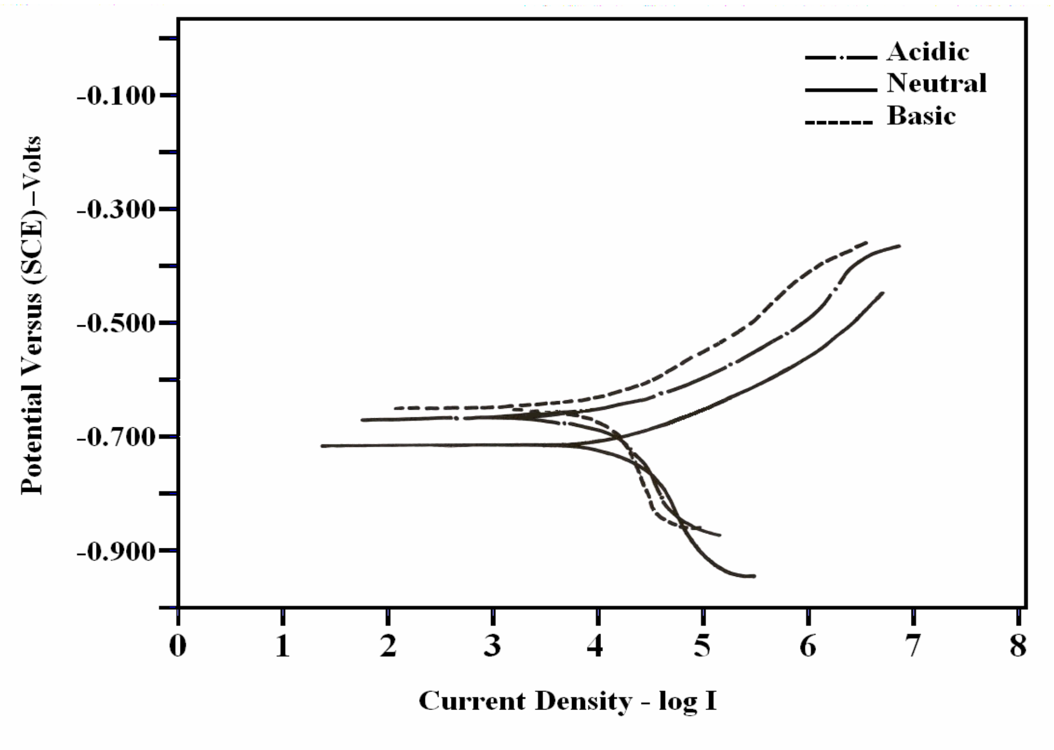


Figure 5. Tafel plots for CS in (A) solutions at different pH

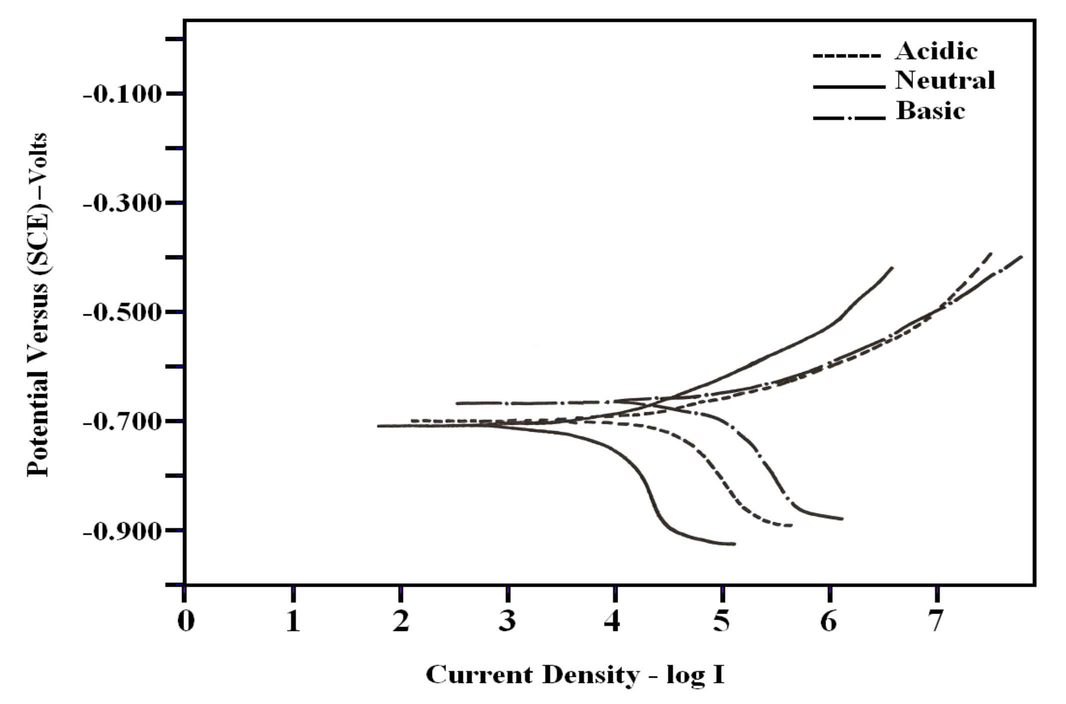


Figure 6. Tafel plots for CS in (B) solutions at different pH

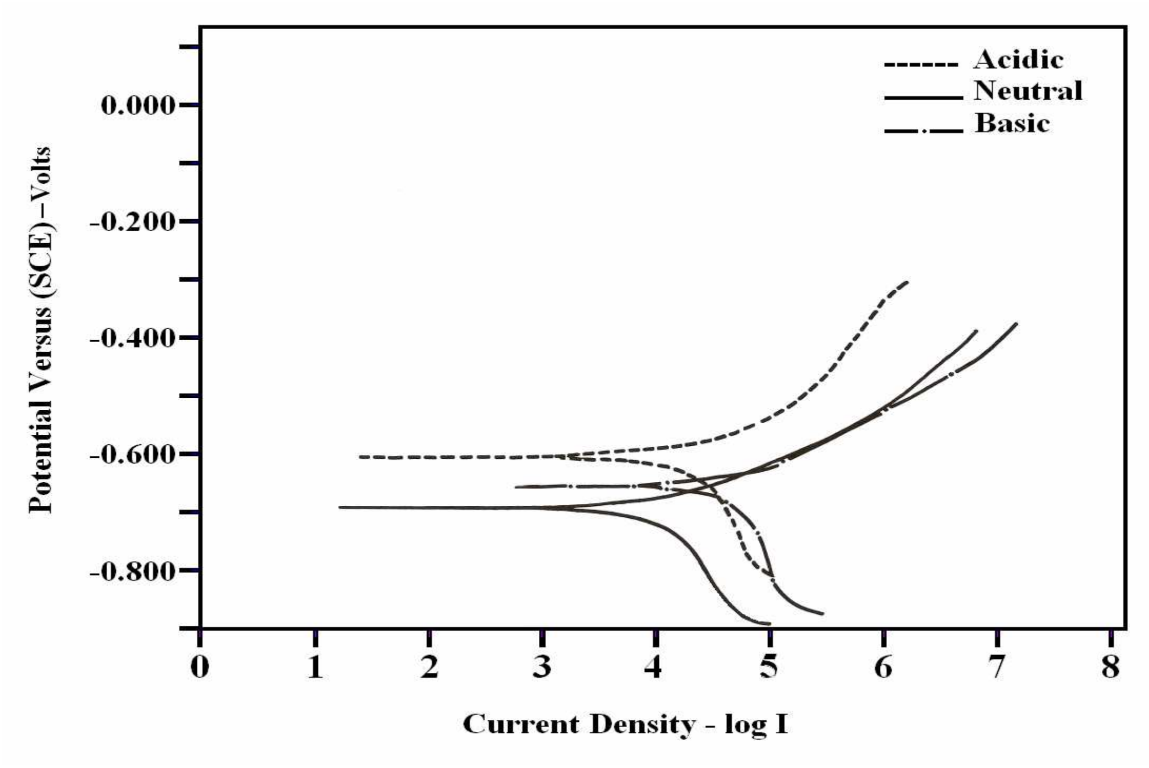


Figure 7. Tafel plots for CS in (C) solutions at different pH

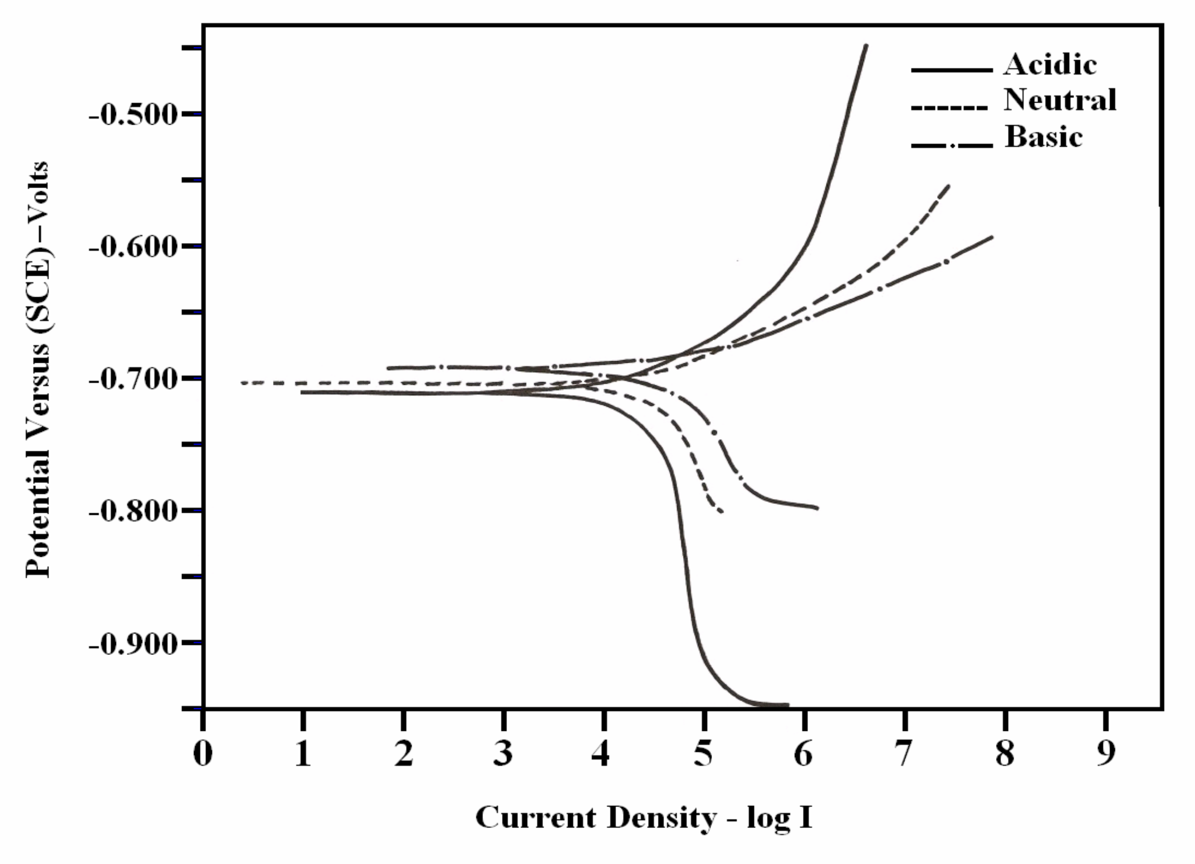


Figure 8. Tafel plots for CS in (D) solutions at different pH

Table 7. Electrochemical data for different pH values at 30ºC.

comp	*Conc. (mg/l)*	*Temp ºC*	*Effe%*	E_{corr} (volt)	I_{corr} ($\mu A/cm^2$)	*βa*	*βc*	*Rp×E4 Ω*	*CR(mpy)*	*pH*
H_2SO4	196	30	0	-0.866	46.26	0.058	0.272	0.114	21.37	2
	19.6	30	0	-0.876	13.06	0.058	0.272	0.158	6.031	3
	1.96	30	0	-0.890	11.6	0.072	0.248	0.208	5.360	4
Water	0	30	0	-0.541	35.73	0.118	…	0.077	15.08	7
NaOH	0.04	30	0	-0.880	11.65	0.061	0.247	0.182	5.384	8
	0.40	30	0	-0.839	25.58	0.144	0.277	0.161	11.82	9
	4.00	30	0	-0.819	37.48	0.163	0.335	0.126	17.31	10
Nalco™	40	30	97.75	-0.607	1.01	0.294	….	3.588	0.408	2
	40	30	49.06	-0.240	6.40	0.265	….	7.358	3.072	3
	40	30	48.17	-0.350	6.04	…	…..	7.438	2.778	4
	40	30	94.48	-0.303	0.82	0.414	…..	6.612	0.377	7
	40	30	94.53	-0.288	0.64	0.270	…..	8.536	0.294	8
	40	30	97.55	-0.290	0.60	….	…..	8.210	0.289	9
	40	30	98.11	-0.281	0.71	0.448	….	8.220	0.327	10
MHD	50	30	…..	-0.688	110.2	0.195	0.590	0.578	50.90	2
	50	30	51.60	-0.676	6.32	0.090	0.327	0.483	2.919	3
	50	30	….	-0.623	23.8	0.179	0.419	0.229	10.99	4
	50	30	97.81	-0.307	0.77	0.303	…	5.118	0.360	7
	50	30	36.32	-0.637	7.42	0.106	0.387	0.486	3.428	8
	50	30	32.72	-0.625	17.21	0.171	0.418	0.306	7.952	9
	50	30	62.31	-0.625	14.12	0.144	0.361	0.316	6.524	10
A	50	30	24.75	-0.703	34.82	0.163	0.371	0.141	16.08	2
	50	30	….	-0.655	20.95	0.113	0.328	0.173	9.678	3
	50	30	…..	-0.672	17.79	0.101	0.299	0.184	8.219	4
	50	30	72.78	-0.711	9.68	0.081	0.203	0.258	4.474	7
	50	30	….	-0.654	18.49	0.109	0.360	0.196	8.541	8
	50	30	……	-0.652	34.27	0.198	0.390	0.166	15.83	9
	50	30	47.37	-0.642	19.72	0.137	0.337	0.214	9.110	10
B	10	30	….	-0.689	46.01	…	0.351	0.059	22.08	2
	10	30	….	-0.660	22.78	0.110	0.354	0.159	10.52	3
	10	30	…….	-0.694	15.24	0.078	0.265	0.170	7.040	4
	10	30	70.83	-0.710	10.38	0.086	0.270	0.273	4.794	7
	10	30	…..	-0.647	161.1	0.158	0.275	0.027	74.41	8
	10	30	5.92	-0.666	24.07	0.104	0.331	0.143	11.12	9
	10	30	49.50	-0.669	19.00	…..	0.309	0.162	8.74	10
C	10	30	…..	-0.667	150.3	0.171	0.522	0.037	69.43	2
	10	30	…..	-0.635	48.01	0.178	0.421	0.113	52.18	3
	10	30	…..	-0.601	41.71	0.204	0.341	0.133	19.27	4
	10	30	64.09	-0.690	12.78	0.079	0.255	0.204	5.903	7
	10	30	…….	-0.678	16.42	….	0.308	0.200	7.500	8
	10	30	…….	-0.661	26.89	0.142	0.311	1.677	12.37	9
	10	30	58.27	-0.660	15.64	0.093	0.297	0.196	7.223	10
D	30	30	48.66	-0.713	22.85	…	….	0.075	10.97	2
	30	30	…..	-0.677	25.88	….	0.330	0.151	12.42	3
	30	30	…….	-0.675	31.17	….	0.315	0.132	14.96	4
	30	30	62.28	-0.710	13.42	0.073	0.281	0.186	6.201	7
	30	30	…..	-0.691	34.01	….	0.361	0.132	16.32	8
	30	30	32.03	-0.685	1.73	0.070	0.347	0.147	8.033	9
	30	30	58.80	-0.686	15.81	0.089	0.298	0.187	7.304	10

5. Conclusion

1. MHD shows excellent inhibition on CS alloy in neutral environment, where reducing in its efficiency in both basic and acidic media, as well as in increasing temperature to 40ºC due to break down for some of protective film.
2. The steric effect is an important factor to reduce the efficiency for (A-D) compounds compared with MHD. Although, increasing in hetero atoms should increase the active center that ready to adsorb on CS surface then decreasing in corrosion reaction should be happened but the steric effect overcome on adsorption effect.
3. Different behaviors for inhibitors as temperature change, some of them has physical adsorption mode and other has chemical adsorption mode due to their variation behaviors with temperature.
4. The decreasing in efficiency in acid media due to protonation of some hetero atoms that presence in meaning inhibitor that lower the basicity for other non protonated hetero atoms then reduce the efficiency. In basic media caustic corrosion is an important factor that reduced the efficiency due to solubility of some of protective film.

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