

Original Research Article

NEW ORGANIC POLYMERS AS GREEN CORROSION INHIBITORS OF BRASS IN COOLING WATER SYSTEM

ABSTRACT

Using the microwaves energy new organic polymers were synthesized by radicalic polymerization. These new organic compounds have anticorrosive and antiscaling properties and for this reason, were used for cooling water systems protection. We presume that, these new organic polymers inhibit corrosion of brass by a protective mechanism, forming insoluble copper complexes and repairing the porous oxide layers. The methods employed were potentiodynamic polarization, electrochemical impedance spectroscopy and metallurgical microscopy techniques. The inhibition efficiency was high in all the studied cases. The corrosion parameters obtained from polarization curves and from EIS spectra are in good concordance and point out the inhibitory action of these new organic polymers. The adsorptions of the organic compounds on the carbon steels surface obeyed Langmuir's isotherm. Using FT-IR it was proved the adsorption of organic inhibitors and the formation of corrosion products on the brass surface. The inhibition process was attributed to the formation of the adsorbed film on the brass surface that protects the material against corrosive agents. The EIS measurements have confirmed this protection and pointed out the formation of adsorption layers on the electrode surface.

Keywords: organic inhibitor, brass, cooling water, potentiodynamic polarization, electrochemical impedance spectroscopy and FT-IR

INTRODUCTION

Copper and its alloys (brass), because of their excellent resistance to corrosion in neutral aggressive media and their ease of processing, they are widely used in many industrial environments. Brass is an alloy (Cu-Zn) that has wide range of applications due to its outstanding properties. That alloy has a long history of service, in marine environments and saline water systems, heat exchangers, water distribution systems, water treatment units, multi-stage flash in the desalination plants. These applications can be ascribed to the attractive combination of properties these alloys possess, good machinability, high thermal and electrical conductivity and resistance to corrosion. Copper and brass are resistant toward the influence of

atmosphere and many chemicals; however, it is known that these materials are susceptible to corrosion in aggressive media. Among the several methods of corrosion control and prevention, the use of organic corrosion inhibitors is very well known. This method remains one of the necessary procedures used to protect metals and alloys against attack in many industrial environments. [1-9]

Brass materials are relatively noble for which brass possesses attractive properties, namely, good corrosion resistance, high thermal and electrical conductivity and better resistance to biofouling. It has been widely used in water distribution systems, water treatment units, condensers, desalination, power plant condensers and petrochemical heat exchangers, shipboard condensers, and many other applications [1-8]. Brass with 65% Cu and 35% Zn is prone to corrosion attack when exposed to a corrosive media because of the brass α -phase. Increasing the zinc content in the alloy changes the α -phase to β -phase and accelerates corrosion damage [1]. Dezincification of brass is one of the well-known and common processes by means of which brass loses its valuable physical and mechanical properties leading to failure of structure [1, 9-13]. Therefore, the corrosion mechanism and corrosion prevention of brass in different corrosive media has been attracted many investigators [10-15]. Several researchers have investigated brass in view of resistance to corrosion. Many techniques are used to improve the corrosion resistance of the brass used as mechanical parts in industry.

Corrosion is a major problem in cooling water industrial systems, in oil and gas production systems. Metal corrosion in water-conveying systems such as cooling water circuits is of major concern in industrial applications. It is well known that, in all the cases of cooling water systems at the metal/water interface contact appear frequent corrosion processes which determine deposition of corrosion products, like scales. Due to the scales formation the heat exchange becomes more difficult, that disturbs the normal function of industrial installation. In this regard, aspects like cost of treatment versus cost of corrosion damages as well as process safety and the impact of corrosion and corrosion treatment on the environment have to be taken into account. It is well known that, excessive corrosion does not only lead to serious damage of installations, it also causes considerable environmental pollution. Most previous research into their usage has concentrated on relationships between chemical structure and inhibition performance [1-7]. Recent investigations have additionally emphasized the importance of the nature of the metal surface in inhibition performance [1]. The ability of an inhibitor to provide corrosion protection therefore depends to a large extent upon the interaction between the inhibitor and the metal surface under corrosion conditions. Generally, it is assumed that strong adsorption of the inhibitors is a prerequisite. The adsorption of inhibitors leads to the formation

of a physical barrier that reduces the metal reactivity in the electrochemical reaction of corrosion [2]. Early studies considered the adsorption of inhibitors on metal surfaces to be primarily physical adsorption and/or chemisorptions [3-6, 9-11]. New investigations have shown that adsorption could also occur through hydrogen bonding [1, 7-8]. Most of these studies made use of sensitive surface analysis tools such as X-ray photoelectron spectroscopy (XPS) to resolve the nature of inhibitor adsorption [13-17]. Some earlier works has however been carried out under conditions that are not representative of on actual application. In this paper, the inhibition of brass corrosion in cooling waters by organic compounds was investigated by potentiodynamic polarizations, EIS measurements and metallography analysis [17-22]. Electrochemical measurements are used to assess the relevant physical properties of new corrosion inhibitors. This paper presents some attempts of analyzing of corrosive phenomena, which occur in cooling water systems, and relates to the protection of metallic surfaces from corrosion using these new polymers obtained in microwaves field.

EXPERIMENTAL

The inhibitory action was studied through tracing the polarization curves obtained using the, potentiodynamic method calculation of the kinetic parameters of corrosion in case of solutions with inhibitors, especially the corrosion current densities, and their comparison with the kinetic parameters of the solution without inhibitors. The polarization curves were obtained by potentiostatic and potentiodynamic methods. In all experiments the electrochemical polarizations were started about 30 minutes after the working electrode was immersed in solution, to allow the stabilization of the stationary potential. The working electrode potential was always measured with reference to the saturated calomel electrode (SCE) and was plotted against current from external circuit, obtaining the anodic or cathodic curves according to the variation of the working electrode potential. In order to reduce the ohmic resistance, we used a single compartment cell in which the working electrode was situated in the cell center and surrounded by the auxiliary electrode made of bright platinum gauze. The studied material was the brass. The used organic inhibitor were three polymers namely PASAC1 (maleic anhydride and urea molar ratio 1.5:1 at $t=140^{\circ}\text{C}$), PASAC-11 (polyaspartic acid and H_3PO_4 molar ratio 1:0.025 in propylene carbonate with sodium tartrate at $t=200^{\circ}\text{C}$) and PASAC-13 (polyaspartic acid 0.07M and H_3PO_4 , in ethylene carbonate/propylene carbonate, gravimetric ratio 1/1 with trisodium citrate at $t=150^{\circ}\text{C}$) which were obtained by radicalic polymerization in presence of microwave field from.

Table 1. The chemical composition of the working electrode

Electrode	Fe%	Cu%	Zn%	Si%	Pb%
Brass	0.29	65.60	34	0.060	0.059

The working electrode was brass in the form cylindrical with an exposed area of 0.5 cm^2 . This shape is preferred, because it assures a greater surface and a reduce number of edges. Prior to each determination, the working electrode was mechanically ground and polished with emery paper of varied granulation up to mirror-luster, degreased in benzene at boiling temperature in order to remove all traced of fat and remained abrasive powder on the electrode surface after polishing. After that, the working electrode was washed with distilled water and inserted in the polarization cell, which was the usually three-electrode cell. All tests have been performed at 25°C under atmospheric oxygen without agitation. The electrochemical measurements were made using an automated model VoltaLab 40 potentiostat/galvanostat. Surface analysis on the carbon steel electrode of the formed adsorbed film was accomplished by both FT-IR (FT-IR spectrometer Bruker optik) and metallographic micrographies (Hund H660). The corrosion medium was industrial cooling water type S1 with the chemical composition given in table 2.

Table 2 The chemical composition of the cooling water type S₁

Indicators	UM	Water type S ₁ , values of parameters
PH		8.42
Conductivity	$\mu\text{s/cm}$	1061
Alcalinity p	mval/L	0.1
Alcalinity m	mval/L	3.3
Total Hardness	mval/L	8.3
Calciu Hardness	mval/L	3.0
Chloride, Cl^-	mg/L	117.01
Sulfate	mg/L	155
Solid substances	mg/L	2.75
Organic compounds	mg/L	11.37
Iron	mg/L	0.073
Aluminium,	mg/L	0.0175
Nitrite, NO_2^-	mg/L	<0.1
Nitrate, NO_3^-	mg/L	10
Phosphate, PO_4^{3-}	mg/L	0.046
Copper, Cu^{2+}	mg/L	<0.015
Zinc, Zn^{2+}	mg/L	<0.1

All tests have been performed at 25°C under atmospheric oxygen without agitation. The

electrochemical measurements were made using an automated model VoltaLab 40 potentiostat/galvanostat. The used organic inhibitor was PASAC1, PASAC11 and PASAC13.

RESULTS AND DISCUSSION

The polarization behaviour of brass mentioned above was studied through the plotting of the polarization curves obtained using the potentiodynamic method, finding the kinetic parameters of corrosion (especially the density of the corrosion current) from solutions without inhibitors and their comparison with the kinetic parameters from solutions with different concentrations of inhibitor. The corresponding Tafel parameters were obtained by Mansfeld's method, employing polarization data near the corrosion potential. In the present paper, when values of $E-E_{\text{cor}}$ are higher than about 70 mV, slight but significant changes in the anodic and cathodic Tafel slopes were found. The figures 1-3 show a series of potentiodynamic polarization curves of brass electrode in industrial cooling water type S₁ (it was not aerated) in absence and presence of different concentrations of PASAC-1, PASAC 11 and Pasac13.

Analysis of the polarization curves from figures 1-3 indicates that at low overvoltages, the Tafel relationship are followed, showing that both anodic and cathodic reactions are activation-controlled. At higher overvoltages a limiting current appears on the anodic and cathodic polarization curves showing that, the transport of ions towards the electrode surface becomes the rate-determining step (concentration polarization). Analyzing the cathodic polarization curves from figures 1-3- it can be observed that, on the large range of the potential the brass electrodes behave very close to a passive behaviour. Practically, we can say that, in this potential range the electrode surface is passivated. We consider that, in this potential range, the cathodic reaction is hindered by the oxide film (passive film) from the electrode surface. In this potential range takes place the oxygen reduction cathodic reaction according to equation:



From polarization curves obtained by potentiodynamic method were calculated all kinetic corrosion parameters which are given in tables 3-4. As it can be seen, both cathodic and anodic reactions of brass electrode were inhibited with the increase of organic inhibitor concentration in cooling water system. The addition of PASAC13, PASAC11 and PASAC1 decreases the i_{corr} values significantly for all the studied concentrations due to increase in blocked fraction of the electrode surface by adsorption. This confirms that these inhibitors behave as a mixed inhibitor.

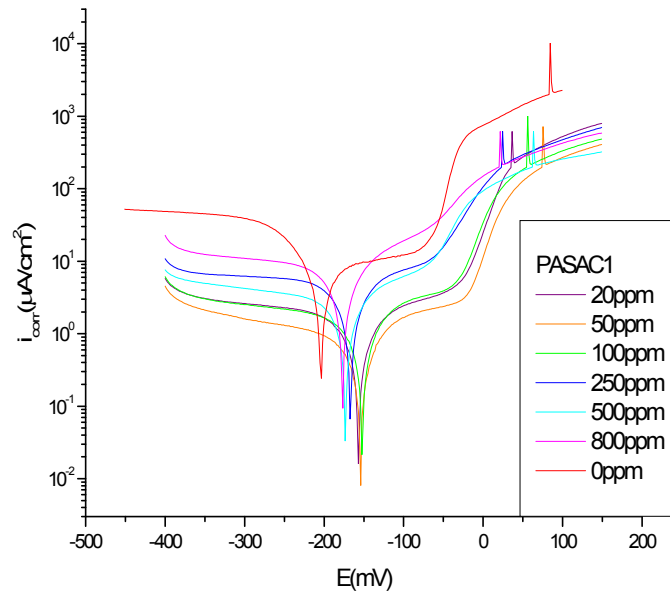


Figure 1 Polarization curves of brass in cooling water S_1 +Xppm PASAC-1 at temperature of 25⁰C

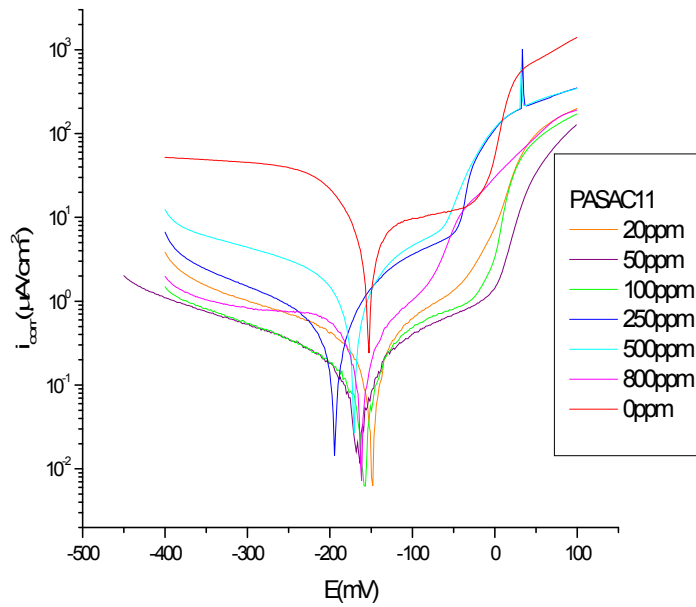


Figure 2 Polarization curves of brass in cooling water S_1 +Xppm PASAC-11 at temperature of 25⁰C

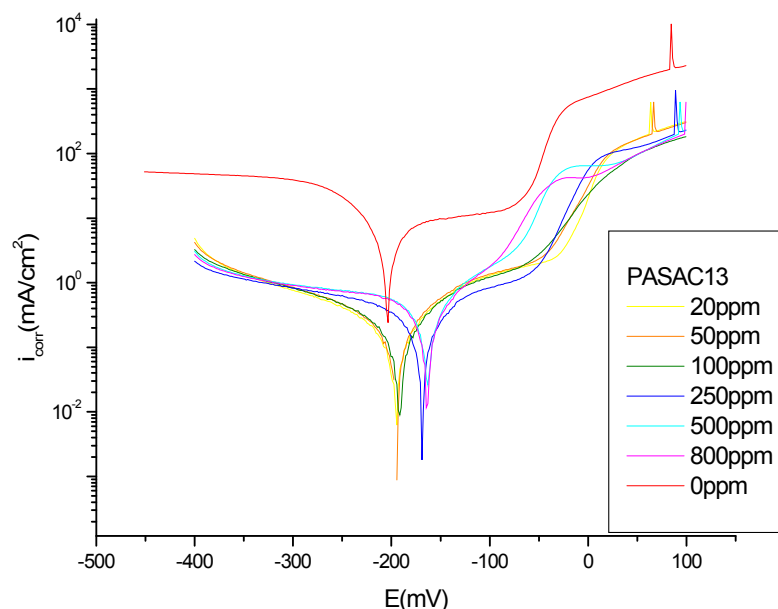


Figure 3 Polarization curves of brass in cooling water S_1 +Xppm PASAC-13 at temperature of 25°C

The electrochemical parameters derived from the polarization curves at different concentrations are given in tables 3-4. Analyzing these tables, it can be observed that, the addition of the organic inhibitor to the amounts shown in the tables 3-5 leads in all the cases to inhibition of the corrosion process. This fact can be explained taking into account the effects of organic compounds on the electrochemical properties of the brass. It can be observed from tables 3-5 that, the inhibitor PASAC13 and Pasac11 has a higher efficiency for corrosion system brass+S1 than for PASAC1 in same condition. Analyzing in comparison the corrosion rate of organic inhibitors, in the same condition, one can see that, the PSAC-13 had a higher efficiency for corrosion system brass in S1 and PASAC11 had a very good efficiency for same system and Pasac1 had a good efficiency. Sometimes on the anodic curves appears oxidation peaks followed by the narrow passive range and a decrease of the current density (this behaviour can be explained due to formation of oxo-hydroxo-complexes of Cu). The maximum efficiency is obtained at the inhibitor concentration for PASAC 13 is 20ppm and 100ppm, for PASAC11 is 100ppm and for PASAC1 is 50ppm.

Table 3 Kinetic corrosion parameters of brass in cooling industrial water type S_1 in presence and absence of organic inhibitor type PASAC-1 at temperature of 25 °C

Inhibitor) (ppm)	i_{corr} ($\mu A/cm^2$)	R_p $K\Omega/cm^2$	R_{mpy}	$P_{mm/year}$	K_g g/m^2h	E (%)	$-E_{corr}$ (mV)	b_a (mV)	$-b_c$ (mV)	θ
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0	5.31	2.92	2.60	0.066	0.064	-	207	186	76	
20	1.225	20.93	0.65	0.0164	0.016	77	160	193	296	0.77
50	0.915	34.17	0.45	0.0113	0.011	83	157	134	291	0.83
100	1.16	19.95	0.567	0.0144	0.014	78	155	147	305	0.78
250	2.662	6.97	1.301	0.033	0.032	50	167	135	196	0.50
500	2.59	9.86	1.267	0.032	0.031	51	175	189	293	0.51
800	2.34	10.05	1.145	0.029	0.028	56	174	187	206	0.56

Table 4 Kinetic corrosion parameters of brass in cooling industrial water type S₁ in presence and absence of organic inhibitor type PASAC-11 at temperature of 25 °C

Inhibitor) (ppm)	i _{corr} (μA/cm ²)	R _p KΩ/cm ²	R _{mpy}	P _{mm/year}	K _g g/m ² h	E (%)	E _{corr} (mV)	b _a (mV)	b _c (mV)	θ
0	5.31	2.92	2.60	0.066	0.064	-	207	186	76	
20	0.151	89.92	0.074	0.0018	0.0018	96	151	117	196	0.96
50	0.126	181.26	0.061	0.0016	0.0015	97	168	127	186	0.97
100	0.116	170.25	0.056	0.0014	0.0014	98	162	89	183	0.98
250	0.449	43.88	0.219	0.0055	0.0054	91	197	87	184	0.91
500	1.158	17.52	0.567	0.0144	0.014	78	172	111	172	0.78
800	0.296	62.19	0.145	0.0037	0.0036	94	163	113	142	0.94

Table 5 Kinetic corrosion parameters of brass in cooling industrial water type S₁ in presence and absence of organic inhibitor type PASAC-13 at temperature of 25 °C

Inhibitor) (ppm)	i _{corr} (μA/cm ²)	R _p KΩ/cm ²	R _{mpy}	P _{mm/year}	K _g g/m ² h	E (%)	-E _{corr} (mV)	b _a (mV)	-b _c (mV)	θ
0	5.31	2.92	2.60	0.066	0.064	-	207	186	76	
20	0.167	106	0.081	0.002	0.002	97	199	92	137	0.97
50	0.194	96	0.091	0.0023	0.0022	96	198	95	145	0.96
100	0.185	98	0.09	0.0022	0.0022	96.5	195	96	146	0.96.5
250	0.280	78.6	0.137	0.0034	0.0033	95	172	136	224	0.95
500	0.462	47.38	0.226	0.0057	0.0056	91	166	109	205	0.91
800	0.330	51.36	0.161	0.0041	0.0039	94	167	87	180	0.94

The variation curves of the corrosion current density and efficiency function of the inhibitor concentration are presented in figures 4. From figures, one can see much better the influence of these parameters on the polarization behaviour of the brass in cooling water system.

It is obvious from the figures that all these compounds inhibit the corrosion of brass in cooling water system at all concentrations used in this study.

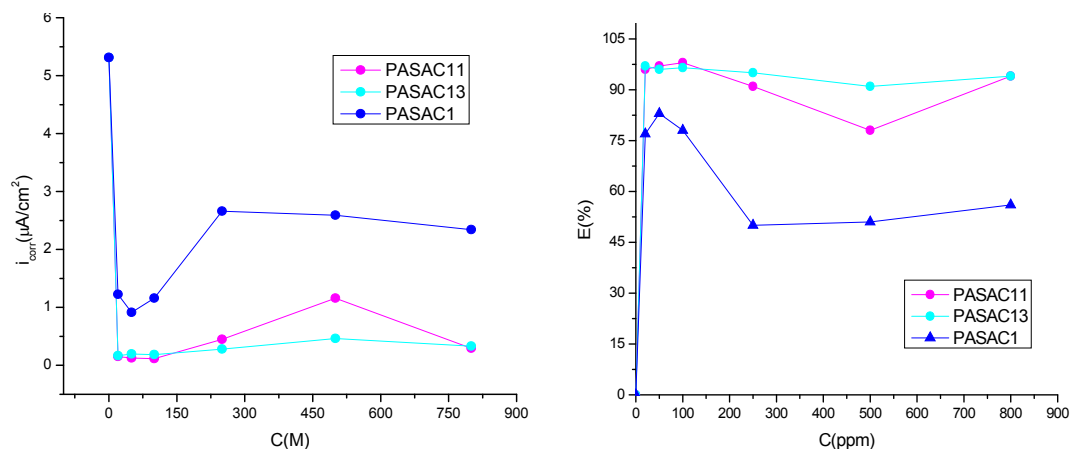


Figure 4 The influence of the inhibitors PASAC11, PASAC13 and PASAC1 concentration on the corrosion rate and efficiency of the brass in cooling water type S1 at 25°C.

We presume that, the higher inhibitor efficiency is a consequence of the adsorption process. To quantify the effect of inhibitor concentration on the corrosion rate, it is common to fit the rate data to equilibrium adsorption expressions, such as Langmuir equation: $\theta / (1 - \theta) = KC$, where θ is the fraction of surface coverage by the inhibitor and K is the equilibrium constant for the adsorption reaction. θ is given by: $\theta = (i_{corr} - i_{inh}) / i_{corr}$ where i_{inh} and i_{corr} are the corrosion rates in industrial cooling water S1 with and without inhibitor. Usage of the Langmuir treatment is often justified with the argument that inhibition must involve adsorption.

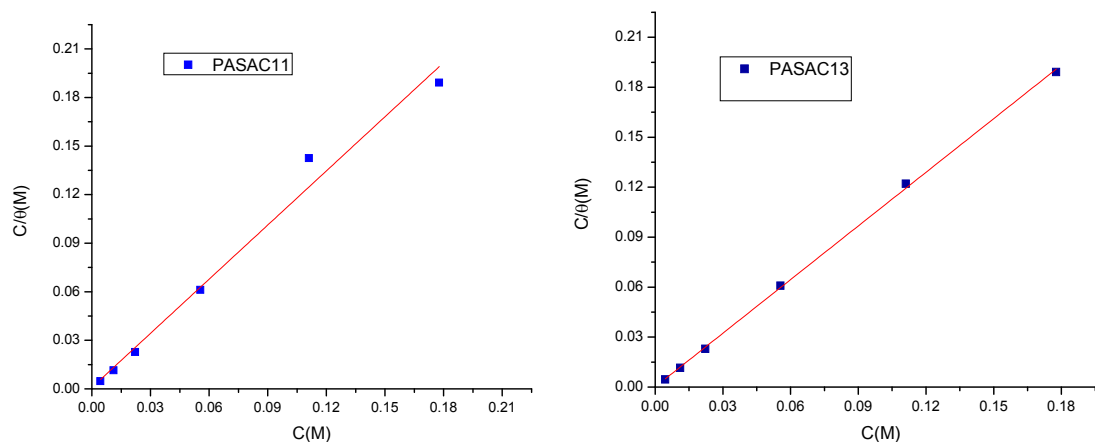


Figure 5 Langmuir plot for PASAC 11 and PASAC 13 on brass in S1 at different inhibitor concentrations

In this study, the Langmuir isotherm is plotted against C, when a linear relationship is obtained for each inhibitor and a slope of near unity for each compound indicated approximate

Langmuir behaviour (see Figure 5). Further, we shall try to show what kind type of adsorption process takes place on the electrode surface.

The adsorption equilibrium constant (K_{ads}) is related to the standard free energy of reaction (ΔG_{ads}°) by the equation: $\ln K_{ads} = -(\Delta G_{ads}^{\circ} / RT)$.

The obtained values ΔG_{ads}° up to -20KJmol^{-1} or lower are consistent with electrostatic interaction between the charged molecules (in our case, the inhibitor molecules) and the charged electrode surface (physical adsorption see table 6), while those more negative than -40KJmol^{-1} , involve charge sharing or transfer from the inhibitor molecules to the metal surface to form a co-coordinative type of bond (chemisorptions).[28-30]

Table 6.The values of K_{ads} and ΔG_{ads}° for studied systems

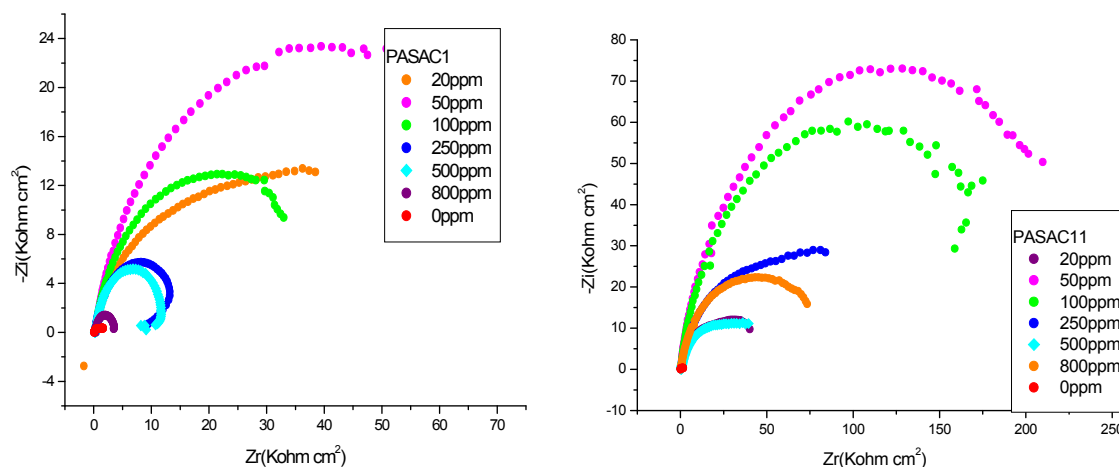
The system	Type of metallic material	Values of K_{ads} , M^{-1}	Values of ΔG_{ads}° KJmol^{-1}	Type of adsorption
Cooling water type S_1 +PASAC 1	Brass	1.088×10^2	-12.447	Physical adsorption
Cooling water type S_1 +PASAC 11	Brass	1.171×10^3	-17.497	Physical adsorption
Cooling water type S_1 +PASAC 13	Brass	7.366×10^3	-22.051	Physical adsorption and chemisorption

The corrosion of brass in cooling water system in the absence and presence of PASAC 1, PASAC 11 and PASAC13 were investigated by EIS. Impedance measurements were performed at open circuit potential on the frequency range between 100 kHz and 40 mHz with an AC wave of ± 10 mV (peak-to-peak) and the impedance data were obtained at a rate of 10 points per decade change in frequency.

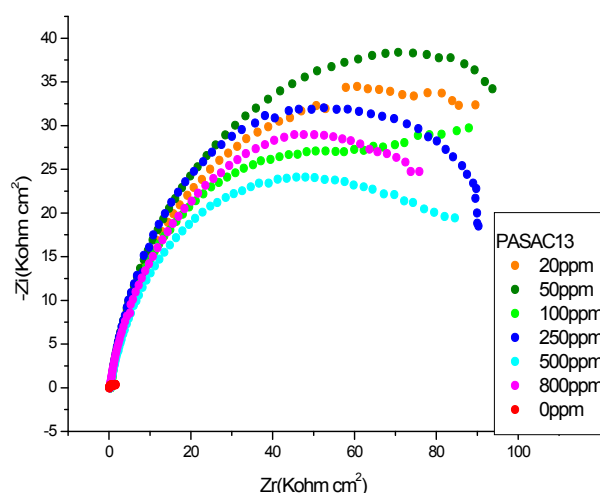
Nyquist plots for brass obtained at the interface in the presence of inhibitors at optimum concentration are given in figure 6. All impedance spectra exhibit one capacitive loop and the diameter of the semicircles increases on increasing the inhibitor concentration suggesting that the formed inhibitive film was strengthened by the addition of inhibitors. However, these diagrams are not perfect semicircles and this fact is attributed to frequency dispersion. The semicircular appearance shows that the corrosion of steel is controlled by charge transfer and the presence of inhibitor does not change the mechanism of dissolution.

Figures 6 also indicates that the diameters of the capacitance loops in the presence of 50ppm PASAC1+Brass-S1, 50ppm and 100ppm PASAC11+Brass-S1 and for 50ppm PASAC13+Brass-SC1 are bigger than those in the absence of organic inhibitors, suggesting that has good anticorrosion performance on the brass in S1

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Figure 6 The Nyquist plot for brass in S1 with and without organic inhibitor

255 Bode diagrams presented in figures 7-9 are in accordance with Nyquist diagrams. It can be
256 observed that in absence of organic inhibitor the electrode presents one time constant
257 corresponding to a phase angle of about 30° at medium and low frequencies, this fact indicates an
258 inductive behaviour with low diffusive tendency. On the contrary, in the presence of the organic
259 inhibitor, on the curve-phase angle versus log frequency appears a maximum very well defined
260 corresponding to a phase angle of about 75° which means that in this case the electrode has a
261 strong capacitive behaviour, according with the results obtained by electrochemical polarization
262 and in concordance with the Nyquist diagrams.

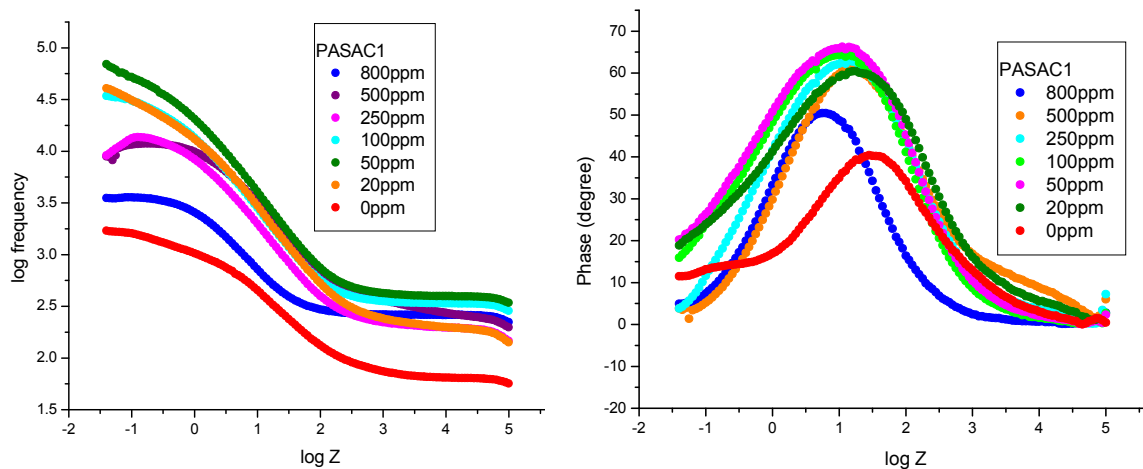


Figure 7 The Bode plot for brass in S1 with and without organic inhibitor PASAC-1

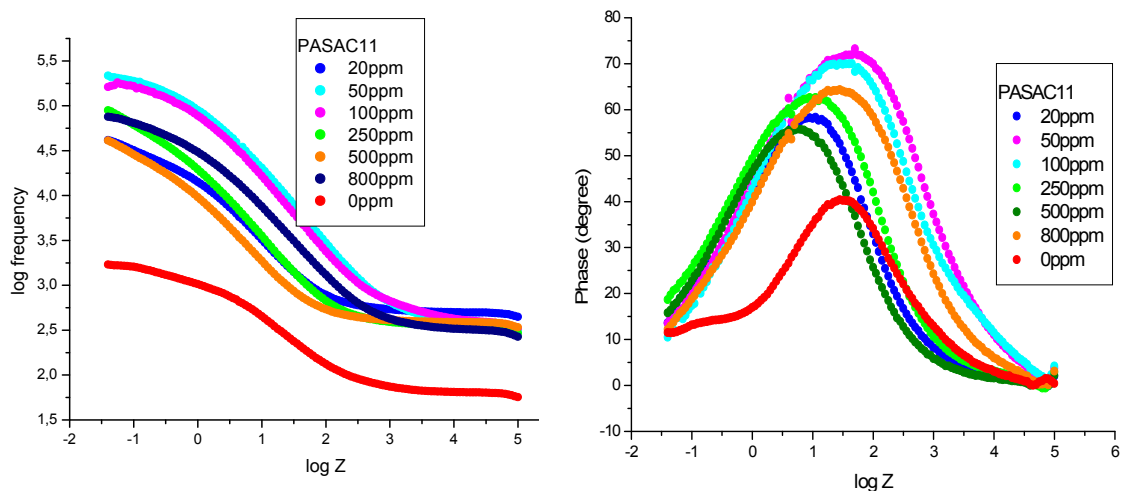


Figure 8 The Bode plot for brass in S1 with and without organic inhibitor PASAC-11

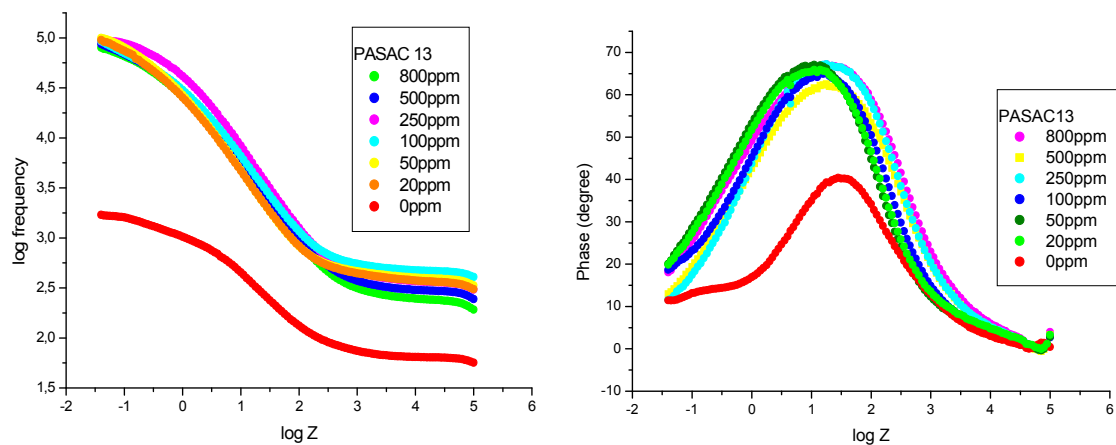


Figure 9 The Bode plot for brass in SC1 with and without organic inhibitor PASAC-13

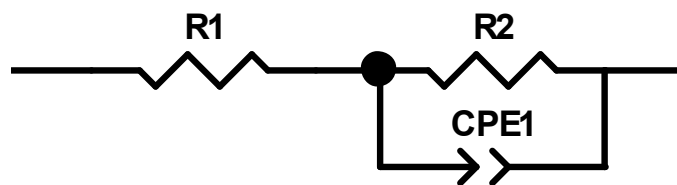


Figure 10 Equivalent circuit

All the obtained plots show only one semicircle and they were fitted using one time constant equivalent mode with capacitance (C), the charge transfer resistance (R_{ct}) and R_s solution resistance. The lower capacitance values for systems: SC1+Brass with PASAC-11, PASAC-13 and PASAC-1, indicate the inhomogeneity of the metal surface roughened due to corrosion. The Cdl values decreases once with the increasing of the inhibitor concentration and reaches very low values for the optimum concentrations of inhibitors for all the studied systems indicating the reduction of charges accumulated in the double layer due to the formation of adsorbed inhibitor layer.

In this study, FT-IR spectrometry was used to identify whether there was adsorption and to provide new bonding information on the brass surface after immersion in the cooling water system containing organic inhibitors [23-28]. All spectra in these experiments were obtained at a resolution 4cm^{-1} in the region $4000\text{-}650\text{ cm}^{-1}$.

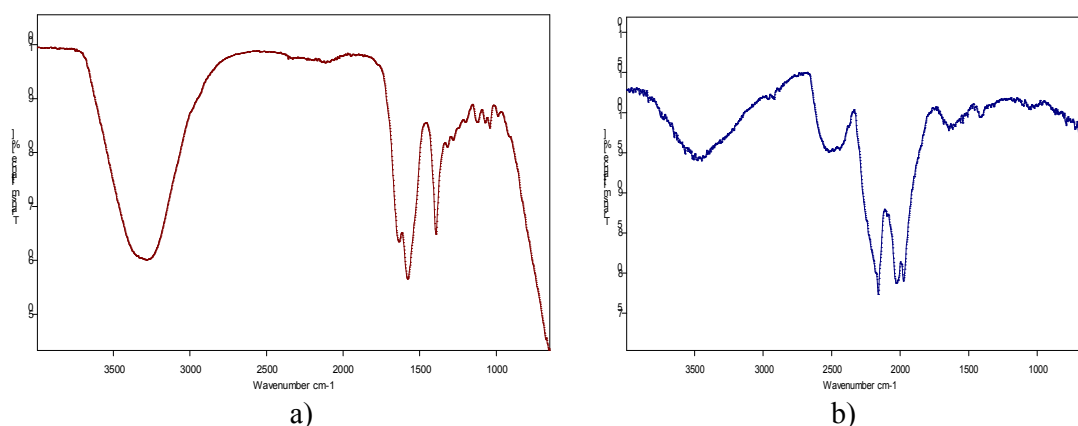


Figure 11 FT-IR spectra of (a) PASAC11 and (b) Brass+100 ppm PASAC11+S1

The FT-IR spectrum of organic polymer PASAC11 and brass immersed in cooling water S1 containing 100ppm PASAC11 is shown in figure 11a and 11b. The FT-IR spectra of adsorbed protective layer formed on the surface after immersion in S1 containing optimum concentration of inhibitor 100ppm PASAC11 is shown in figure 11b. As can be seen all important peaks in

pure compounds appeared in adsorption layer on the electrode surface. The band around 3350 cm^{-1} is attributed to O-H stretching, which indicates that the protective film contains H_2O . The peak around 2780 cm^{-1} are assigned to C-H stretching vibration, the peaks at 1540 and 1413 cm^{-1} corresponds to the C=O and N-H.. The presence of C-N, C-O is indicated by their stretching modes at 1100 and 900 cm^{-1} . This is already confirmed from the Langmuir adsorption isotherm studies.

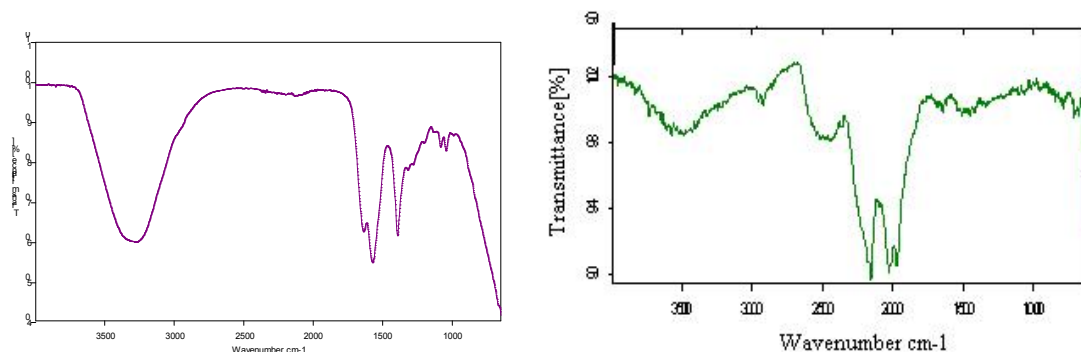


Figure 12 FT-IR spectra of (a) PASAC13 and (b) Brass+20 ppm PASAC13+S1

The FT-IR spectrum of pure organic polymer PASAC 13 is depicted in figure 12a and the FT-IR spectrum obtained for the brass immersed in cooling water systems type S1 containing 20ppm PASAC13 inhibitor organic is presented in figure 12b. A broad peak at 3200 cm^{-1} indicates the presence of the C-H bond of the PASAC13 and the presence of C=O, N-H, C-H is indicated by their stretching modes at region 1642, 1491, 1325 to 1210 cm^{-1} respectively. The FT-IR spectra obtained for the brass immersed in cooling water systems type S1 containing 100ppm PASAC13 inhibitor organic is presented in figure 12b. A broad band in the range from 3340 cm^{-1} is attributed to C-H, the appearance of the peak in region 1520 cm^{-1} is assigned to N-H symmetric stretching vibration. The band around 3500 cm^{-1} is attributed to O-H stretching, which indicates that the protective film contains H_2O . The peaks for C-N stretching modes can be assigned in the region around 1450 cm^{-1} . The bands 1200 cm^{-1} and 1050 cm^{-1} are attributed to C-O and C-N.

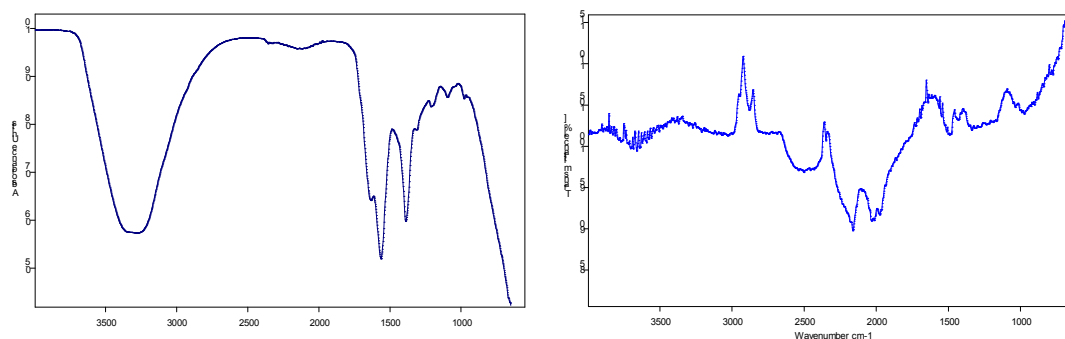
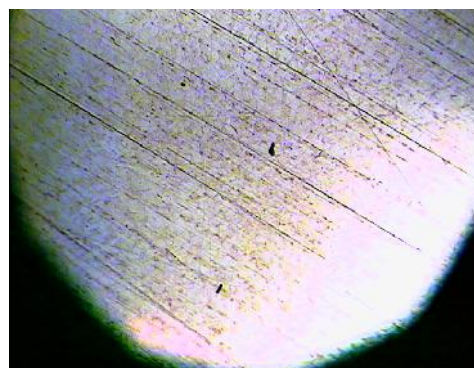


Figure 13 FT-IR spectra of (a) PASAC1 and (b) Brass+50 ppm PASAC1+S1

The transmission FT-IR spectra obtained of pure organic polymer PASAC 1 and for the brass immersed in cooling water systems type S1 containing 50ppm PASAC1 inhibitor organic is presented in figures 13a and 13b. This shows the characteristics the bands for the adsorbed PASAC1 on the electrode surface. A weak band in the range from 3300 cm^{-1} is attributed to C-H. The medium band approximately 1582 cm^{-1} is assigned to N-H symmetric stretching vibration. The peaks for C-N stretching modes can be assigned in the region around 1396 cm^{-1} . The bands 1200 cm^{-1} and 1020 cm^{-1} are attributed to C-O and C-N.

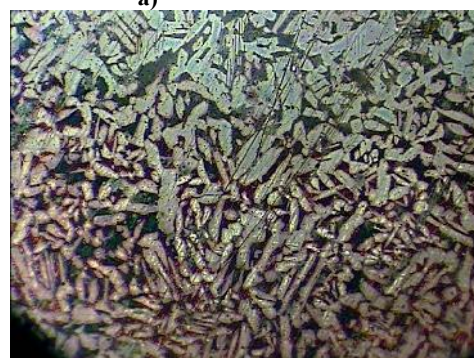
In figure 14 are given a few micrographies obtained by us for the following systems: brass +S1 before and after a certain immersion in cooling water type S1 with and without organic inhibitor. Analyzing in comparison the figures 14b, 14c, 14d and 14e-f, it can be observed that, on the surface of micrographies there are the adsorbed films of inhibitor and corrosion products and that, these films are thicker if the inhibitor concentration are higher. These films behave like a barrier between corrosive medium and metal surface and as a consequence the corrosion process is inhibited - see in comparison the figures 14(a, b, c, d, e and f).[32-35]



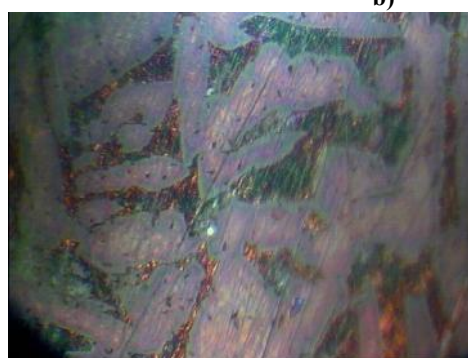
Brass polished
a)



Brass+S1
b)



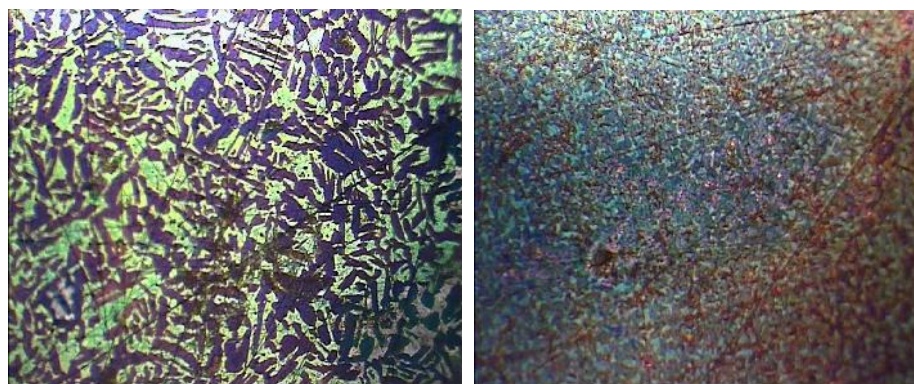
Brass+50ppm PASAC-11+S1



Brass+100ppm PASAC-11+S1

c)

d)



Brass+20ppm PASAC-13+S1

e)

Brass+50ppm PASAC-10+S1

f)

Figure 14 Micrographies of the brass in cooling water type S1 with and without organic inhibitor PASAC-11, PASAC13 and PASAC-1

Analyzing in comparison the figures 14(a-f), it can be observed that, the corrosive attack is much more accentuated in the case of brass+ water type S1 system than in the case of brass+ water type S1 +Xppm inhibitor system. This finding is in good concordance with the results obtained by electrochemical method –see tables 3-5 and the polarization curves from figures 1-3.

CONCLUSIONS

In the studied corrosion systems at low overvoltages, the corrosion process is under activation control, while at high overvoltages is controlled by diffusion.

The addition of organic inhibitors led in all the cases to the inhibition of the corrosion process.

The new organic polymers which were obtained by us have presented a good inhibitory action and a significant efficiency for decreasing of the rate corrosion.

The organic inhibitors were adsorbed on the brass surface according to a Langmuir isotherm. The values of the adsorption constant determined from the plot of Langmuir isotherm pointed out that, in these cases there is a mixture of physical and chemical adsorption of organic inhibitors.

The adsorption of all organic inhibitors investigated follows the Langmuir isotherm and the FT-IR, results also reveals the adsorption of inhibitor molecule on the electrode surface and blocking the active sites.

PASAC11, PASAC13 and PASAC1 inhibit both anodic and cathodic reactions by adsorption on the brass surface and hence behave like mixed type inhibitor.

In all of the cases, the organic inhibitor type PASAC-13 and PASAC11 had a higher efficiency; PASAC-1 had a good efficiency.

The inhibition efficiency follows the order: PASAC13>PASAC11>PASAC1

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