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Inhibition of corrosion of mild steel hull plates immersed in natural sea water by sandalwood oil extract of some natural products

ABSTRACT

The hull plates of the ship made of mild steel (MS) are always in contact with sea water are always in contact with aggressive ions such as chloride ions present in sea water. The corrosion resistance of the hull plates of the ship made of mild steel has been investigated by polarization study. Sandalwood oil extract containing 5 g each of Cardamom (disambiguation), Clove (disambiguation), Nutmeg, India Sambrani (loban), Chrysopogon zizanioides, commonly known as vetiver and Camphor was used as corrosion inhibitor along with Trisodium citrate (TSC), sodium dihydrogen phosphate (SDP) and Zn^{2+} . The corrosion resistance was measured in the absence and presence of various inhibitor systems: Trisodium citrate (TSC) 100 ppm+ Zn^{2+} 50ppm system, sodium dihydrogen phosphate (SDP) 100 ppm+ Zn^{2+} 50ppm system, Oil coated (3days) MS, Oil coated (3days) MS +TSC 100 ppm+ Zn^{2+} 50 ppm system and Oil coated (3days) MS +SDP 100 ppm+ Zn^{2+} 50 ppm system were used. It is observed that when mild steel is immersed in SW+TSC 100 ppm+ Zn^{2+} 50ppm system, the corrosion resistance of MS increases. When mild steel is immersed in SW+ SDP 100 ppm+ Zn^{2+} 50ppm system, the corrosion resistance of MS increases. When mild steel is immersed in Oil coated (3days) MS in Sea water system, the corrosion resistance of MS increases. When mild steel is immersed in Oil coated (3days) MS in SW+TSC 100 ppm+ Zn^{2+} 50ppm system, the corrosion resistance of MS increases. When mild steel is immersed in Oil coated (3 days) MS in SW+ SDP 100 ppm+ Zn^{2+} 50ppm system, the corrosion resistance of MS increases. This is revealed by the fact that there is increase in LPR value and decrease in corrosion current value. The corrosion potential is shifted to anodic side. This indicates that in this inhibitor system, the anodic reaction of metal dissolution is controlled predominantly. This implies that these inhibitor systems may be coated on mild steel surface used as hull plates to prevent corrosion of mild steel in sea water.

Keywords: corrosion inhibition, hull plates, mild steel, sea water, green inhibitors, electrochemical study.

1. INTRODUCTION

Hull plates made of mild steel are in contact with sea water all the time. So they undergo corrosion easily and severely. It is essential to protect them from corrosion. Several corrosion inhibitors have been used to control corrosion of metals and alloys in sea water [1-10].

Ahmad et al. [1] have reported synthesis, identification, theoretical and experimental studies for carbon steel corrosion inhibition in sea water for new urea and thiourea derivatives linkage to 5-Nitro Isatin Moiety. Isatin derivative is chosen as the best inhibitor by polarization study [1].

Influence of inhibitors on reinforced bar corrosion of coral aggregate seawater concrete has been investigated [2]. The effect of inhibitors on corrosion behavior of reinforced bar in coral aggregate seawater concrete (CASC) in artificial sea water was studied by means of linear polarization resistance method (LPR) and electrochemical impedance spectroscopy (EIS).

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Two inhibitors, calcium nitrite rust inhibitor (CN) and amino-alcohol rust inhibitor (AA) are used. The effect of inhibitors on corrosion behavior of reinforced bar in coral aggregate seawater concrete (CASC) in artificial sea water was studied by means of linear polarization resistance method (LPR) and electrochemical impedance spectroscopy (EIS) [2]. Corrosion studies of zinc coated steel parts in sea water have been made by Karthikeyan and Jeeva. The corrosion inhibition of zinc coated steel sheets immersed in 3.5% NaCl with sulfisoxazole (SSZ) has been reported by weight loss, potentiodynamic polarization, electrochemical impedance spectroscopy, hydrogen permeation studies and quantum mechanical studies. Polarization studies confirmed that the inhibition mode follows a mixed type. The adsorption of the compounds onto the zinc coated steel surface obeyed Langmuir adsorption isotherm [3]. Managing corrosion in desalination plants has been discussed by Schorr et al. To protect the desalination plant (DP) materials, industrial paints, polymeric coatings and rubber linings compatible with the DP fluids are applied. Cathodic protection with sacrificial anodic metals or impressed direct electrical current and corrosion inhibitors are supplied [4]. In marine conditions, especially in the Arctic, the problems of reliability and safety of marine corrosion protection systems are relevant. Reliability can be enhanced by corrosion inhibitors. Phosphating compound with anode inhibitors have been used by Plaskeeva and Trusov [5].

Duduna et al. [6] have compared various adsorption isotherm models for allium cepa as corrosion inhibitor on austenitic stainless steel in sea water. The sorption data of the allium cepa extract obeyed Langmuir, Freundlich, Temkin, El-Awady and Adejo Ekwenchi isotherm of which Langmuir Isotherm gave the best model fit [6]. Shen et al. have made a Study of pitting corrosion inhibition effect on aluminum alloy in seawater by biomineralized film. The electrochemical results showed that the radius of the impedance arc of the alloy immersed in seawater with bacteria increased gradually with time. The bacteria promoted the formation of the $\text{CaMg}(\text{CO}_3)_2$ film, which blocked seawater from the alloy and consequently, inhibited pitting corrosion [7]. Xu et al. have investigated steel rebar corrosion in artificial reef concrete with sulphoaluminate cement. It has been observed that a 2% dosage of corrosion inhibitor can significantly decrease the steel rebar corrosion in a new artificial reef concrete (NARC) to a similar corrosion

degree of ordinary artificial reef concrete (ARC) [8]. Colloidal ZrO_2 nanoparticles have been used for corrosion protection of AA2024 in synthetic sea water by Elbasuney et al. Inhibition efficiency of 93.6% was achieved. It was noted that ZrO_2 could act as cathodic inhibitor by suppressing the dealloying of the intermetallic particles [9]. Corrosion-induced morphological changes and the mechanism of A3003 aluminum alloy in model sea water containing gluconates and zinc ions have been investigated by Otani et al. The XPS results also suggest that zinc ions in the solutions bond to the oxide film of aluminum alloy and zinc ions enhance the corrosion inhibition ability of the protective films of gluconates for aluminum alloy in model sea water [10].

The present work is undertaken to investigate the inhibition of corrosion of mild steel hull plates immersed in natural sea water by sandalwood oil extract of some natural products, namely, Cardamom (disambiguation), Clove (disambiguation), Nutmeg, India Sambrani (loban), Chrysopogon zizanioides, commonly known as vetiver and Camphor. Also, Trisodium citrate (TSC), sodium dihydrogen phosphate (SDP) and Zn^{2+} are used as corrosion inhibitors. The inhibition effect has been studied by polarization study. The important parameters involved in this study are linear polarization resistance (LPR) corrosion potential (E_{corr}) and corrosion current (I_{corr}). It is better to understand the meaning of these terms.

Linear polarization resistance (LPR)

A linear polarization resistance (LPR) [11] test is a corrosion rate monitoring method and it can give an indication of the corrosion resistance of materials in an aqueous environment. LPR tests are performed both in the static condition and under reciprocating motion.

In LPR tests, potential is shifted from 50mV below E_{corr} (more negative than E_{corr}) to 50 mV more positive than E_{corr} . Current flow between the specimen and the counter electrode is monitored. A linear relationship of potential and current values can be observed. The linear polarization resistance (LPR) can be interpreted as the inverse of the corrosion rate at the time of measurement.

As the polarization curve close to the free corrosion potential can be assumed to be linear, the linear polarization resistance can be determined as the quotient of electrode potential shift and resulting current flow.

For LPR measurements, a three-electrode setup consisting of a working electrode, a counter electrode, and a reference electrode is required.

The linear polarization resistance strongly depends on the geometry of the corrosion system, i.e., the size of the working electrode, the distance between working electrode and reference electrode, and the position of the reference electrode.

Measurements on corroding systems—both corrosion current measurements and linear polarization resistance measurements—allow qualitative or semiquantitative determination on time-dependent changes in corrosion activity.

In a three-electrode probe, one electrode serves as a test specimen, the second as an auxiliary electrode and the third as a reference electrode against which the potential of the specimen is precisely controlled. The current flow is across the test electrode and the auxiliary electrode. Such a probe minimizes errors due to IR drop and is particularly suited for liquids having poor ionic conductivity.

Linear polarisation resistance (LPR) methods

Linear polarisation resistance (LPR) methods can be used to characterise a material medium pair by scanning the current–potential (i – E) domain. The linear polarisation resistance method consists of applying to the metal very small voltage variations (typically less than 30 mV) above and below its corrosion potential. Over this narrow range in the vicinity of the corrosion potential the current response obtained is linear. The polarisation resistance (R_p), defined as the slope of this current–potential curve, is therefore constant. According to the Stern–Geary equation (Stern and Geary, 1957), R_p is inversely proportional to the instantaneous corrosion rate, at least under certain conditions

$$R_p = B/i_{\text{cor}} \quad \text{when } B = (\beta_a \beta_c / 2.3(\beta_a + \beta_c))$$

where i_{cor} is the corrosion current and β_a and β_c the Tafel coefficients

Corrosion potential and corrosion current

The driving force for the flow of electrons is the difference in potential between the anode and the cathode. This process is most evident in the corrosion between two dissimilar metals (also known as bimetallic corrosion).

When a metal is immersed in a liquid (electrolyte), it adopts an electrode potential (also known as corrosion potential). The variance in potentials between the two metals results in a potential difference, which is responsible for the movement of electrons from the anode to the cathode.

The magnitude of the corrosion current in the system is proportional to the potential difference. That is, the greater the potential difference, the greater the corrosion current generated, and therefore the more severe the rate of corrosion at the anode.

In simple terms, corrosion potential is the characteristic or property of metal and nonmetal surfaces to lose electrons in the presence of an electrolyte. During the process of corrosion, two electrodes are formed spontaneously, a cathode and an anode.

Corrosion current and corrosion potential

The terms E_{oc} (Open Circuit Potential) and E_{corr} (Corrosion Potential) are usually interchangeable, but E_{oc} is preferred. The value of either the anodic or cathodic current at E_{oc} is called the Corrosion Current, I_{corr} . If we could measure I_{corr} , we could use it to calculate the corrosion rate of the metal.

The corrosion rate

Corrosion rate is the speed at which any metal in a specific environment deteriorates. It also can be defined as the amount of corrosion loss per year in thickness. The speed or rate of deterioration depends on the environmental conditions and the type and condition of the metal under reference.

Corrosion potential is a mixed potential (also an open-circuit potential or rest potential) at which the rate of anodic dissolution of the electrode equals the rate of cathodic reactions and there is no net current flowing in or out of the electrode. Corrosion current is the dissolution current at the corrosion potential.

2. EXPERIMENTAL

Composition of mild steel

The composition of mild steel used in this study is given in Table 1 (Done in steel company at Dindigul, Tamil Nadu, India). This mild steel is used in the construction of hull plates. The hull plates are in contact with sea water.

Table 1. Composition of mild steel

Tabela 1. Sastav mekog čelika

Element	Average, %	Abs. Std. Dev.	Ref. Std. Dev.	1	2
C	0.101	0.0014	1.4	0.102	0.1
Si	0.055	0.0021	3.89	0.053	0.056
Mn	1.629	0.0057	0.35	1.633	1.625
P	0.0087	0.0003	3.25	0.0085	0.0089
S	0.0028	0.0003	10.1	0.0026	0.003
Cr	0.036	0.0014	3.93	0.037	0.035
Mo	0.0086	0.00007	0.83	0.0086	0.0085
Ni	0.033	0.0007	2.18	0.033	0.32
Cu	0.0063	0.00007	1.13	0.0062	0.0063
Al	0.044	0.0014	3.21	0.043	0.045
As	0.0011	0	0	0.0011	0.011
B	0.0027	0.0005	18.68	<0.00010	<0.00010
Bi	<0.00010	0.00002	84.85	<0.0025	0.003
Ce	0.0032	0.0013	42.65	0.0041	0.0022
Co	0.011	0	0	0.011	0.011
Mg	0.0003	0	0	0.0003	0.0003
Nb	0.03	0.0007	2.4	0.029	0.03
Pb	0.0081	0.0013	15.71	0.0072	0.009
Sb	0.004	0.0004	8.95	0.0037	0.0042
Sn	0.0034	0	0	0.0034	0.0034
Ta	0.03	0.0071	23.57	0.025	0.035
La	0.0071	0	0	0.0071	0.0071
Ti	0.0035	0	0	0.0035	0.0035
V	0.138	0.0014	1.02	0.137	0.139
W	0.071	0.0078	11.03	0.076	0.065
Zn	0.0024	0	0	0.0024	0.0024
Zr	0.0051	0.0002	0.2	0.0052	0.0049
Se	<0.0005	0.0001	4.42	<0.0005	<0.0005
N	0.0093	0.00007	0.76	0.0092	0.0093
Ca	0.0014	0.0001	10.1	0.0013	0.0015
Te	0.0026	0.0025	97.91	<0.0010	0.0044
Fe	97.74	0	0	97.74	97.74

Sea water

The corrosion resistance of mild steel in sea water was investigated, before oil coating and after oil coating. The composition of sea water used in this study is given in Table 2. Sea water was collected in Bay of Bengal, located at Kanampadi, East Coast Road, Chennai, India (near AMET University, Kanampadi, East Coast Road, Chennai, India).

Table 2. Composition of sea water used in this study

Tabela 2. Sastav morske vode korišćene u ovoj studiji

S. No.	Physical Examination	Acceptable Limit	Permissible limit	Sample Value
1	Colour	–	–	Unobjectionable
2	Odour	Unobjectionable		Unobjectionable
3	Turbidity NT Units	1	5	0.2
4	Total Dissolved Solids mg/l	500	2000	29400
5	Electrical Conductivity micro mho/cm	–	–	42000
6	pH	6.5–8.5	6.5–8.5	7.46
7	pH Alkalinity as CaCO ₃	–	0	0
8	Total Alkalinity as CaCO ₃	200	600	140
9	Total Hardness as CaCO ₃	200	600	4000
10	Calcium as Ca	75	200	1200
11	Manganese as Mn	30	100	240
12	Iron as Fe	0.1	1	0
13	Magnesium as Mg	0.1	0.3	NT
14	Free Ammonia as NH ₃	0.5	0.5	0.48
15	Nitrite as NO ₂	0.5	0.5	0.104
16	Nitrate as NO ₃	45	45	25
17	Chloride as Cl	250	1000	15000
18	Fluoride as F	1	1.5	1.8
19	Sulphate as SO ₄	200	400	1170
20	Phosphate as PO ₄	0.5	0.5	1.47
21	Tids Test 4hrs as O ₂	–	–	NT

Preparation of inhibitor (Oil containing extracts of plant materials)

5 g Each of Cardamom (disambiguation), Clove (disambiguation), Nutmeg, India Sambrani (loban), Chrysopogon zizanioides, commonly known as vetiver and Camphor were boiled along with sandalwood oil for 15 minutes in an iron vessel. The suspended impurities were removed by filtration. The total volume of the oil extract of the above ingredients was 100 ml. This oil extract of the plant materials was used in the present study as corrosion inhibitor.

The main active ingredients of the above materials[12] are given in Table 3, and their structures are shown in Figure 1.

Table 3. Ingredients of natural products

Tabela 3. Sastojci prirodnih proizvoda

S. No	Natural products	Ingredients
1	Cardamom	α-terpineol, myrcene, 1,8-cineol
2	Clove	Eugenol
3	Nutmeg	Myristicin, tremyristicin, myristic acid
4	India Sambrani (loban)	Benzoin
5	Vetiver	α-vetivone, β-vetivone, khusimol
6	Camphor	(+)-Camphor, (-)-Camphor
7	sandalwood oil	α-santalol, β-santalol

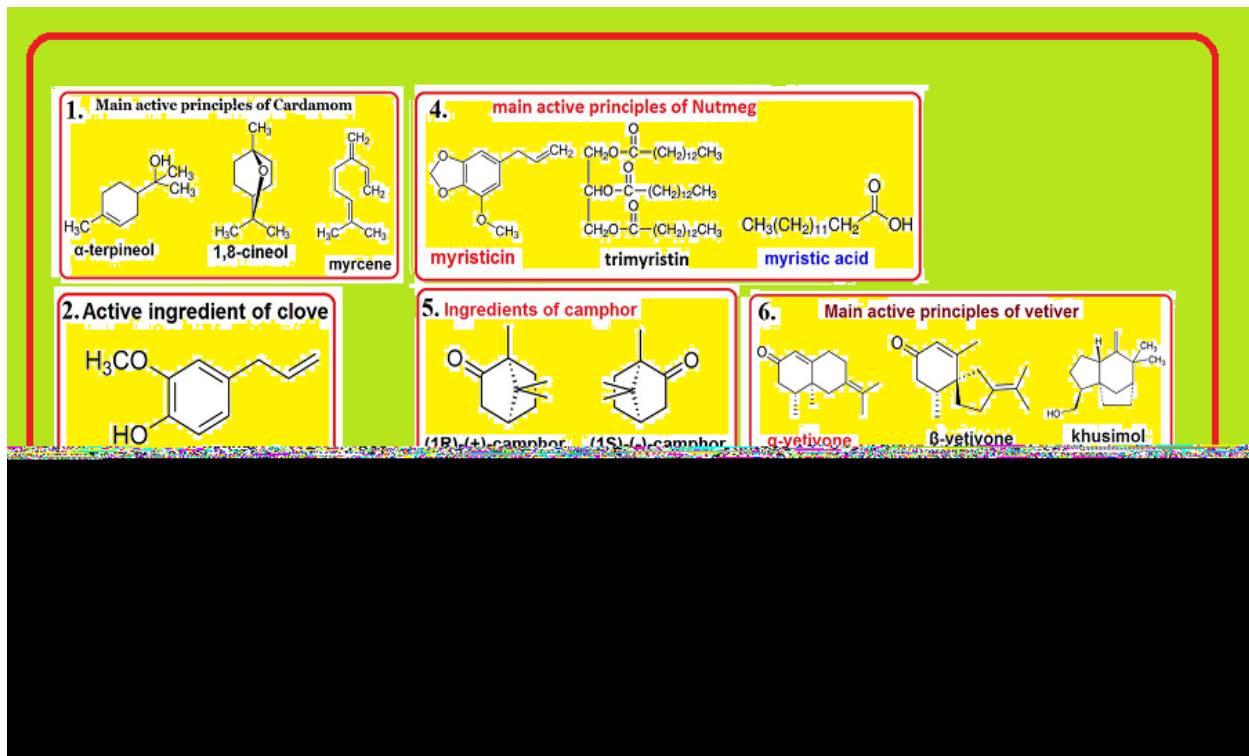


Figure 1. Ingredients of natural products: 1 – active principles of cardamom; 2 – active principles of clove; 3 – active principles of loban; 4 – active principles of nutmeg; 5 – active principles of camphor; 6 – active principles of vetiver; 7 – active principles of sandalwood oil.

Slika 1. Sastojci prirodnih proizvoda: 1 – aktivni delovi kardamoma; 2 – aktivni delovi karanfilića; 3 – aktivni delovi lobana; 4 – aktivni delovi muskatnog oraščića; 5 – aktivni delovi kamfora; 6 – aktivni delovi vetivera; 7 – aktivni delovi ulja sandalovine.

Electrochemical study

In the present work the corrosion resistance of mild steel specimens immersed in various test solutions was measured by Polarization study.

Polarization study

Polarization studies were carried out in a CHI Electrochemical work station model 660A. It was provided with automatic iR compensation facility. A three electrode cell assembly was used (Figure 2). The working electrode was mild steel. A SCE was the reference electrode. Platinum was the counter electrode. From polarization study, corrosion parameters such as corrosion potential (E_{corr}), corrosion current (I_{corr}), Tafel slopes anodic = b_a and cathodic = b_c and LPR (linear polarisation resistance) values were derived. The scan rate (V/S) was 0.01. Hold time at (E_{fcs}) was zero and quiet time (s) was 2.

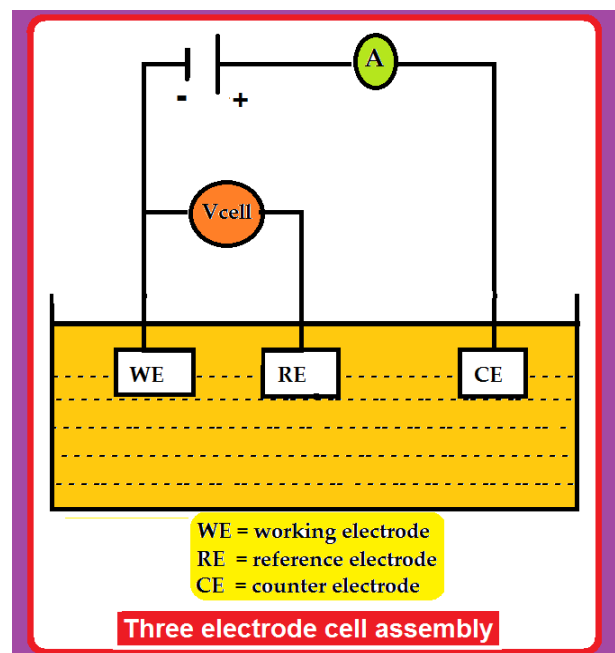


Figure 2. Three electrode cell assembly

Slika 2. Sklop ćelije sa tri elektrode

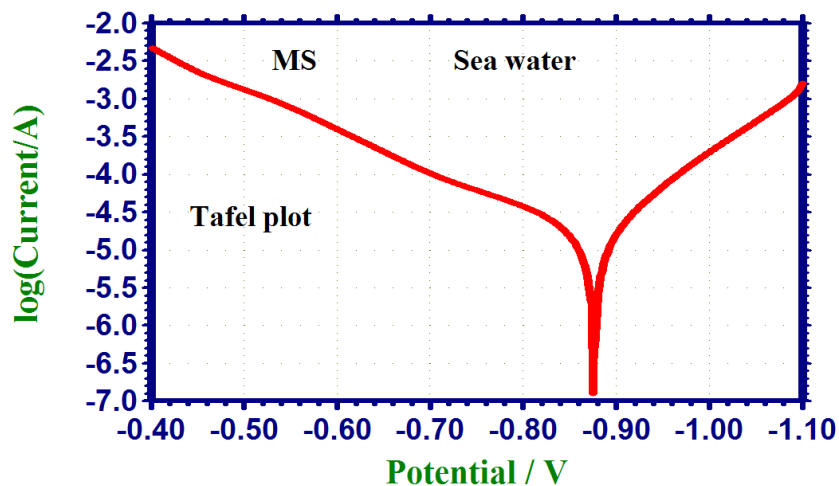


Figure 4. Tafel plot of mild steel immersed in sea water

Slika 4. Tafel kriva za meki čelik uronjen u morsku vodu

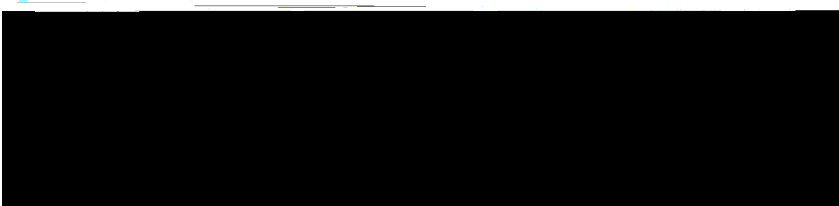
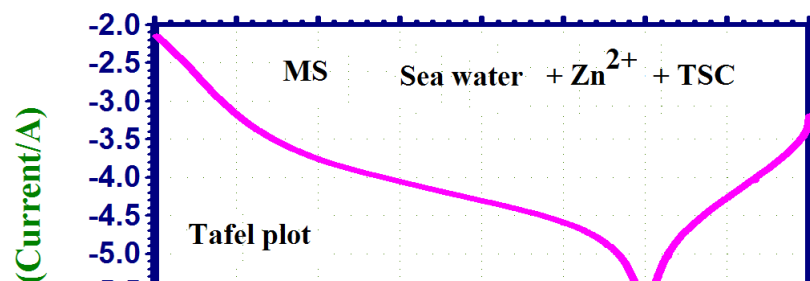


Figure 5. Tafel plot of mild steel immersed in sea water + TSC + Zn^{2+}

Slika 5. Tafel-ova kriva za meki čelik uronjen u morsku vodu + TSC + Zn^{2+}

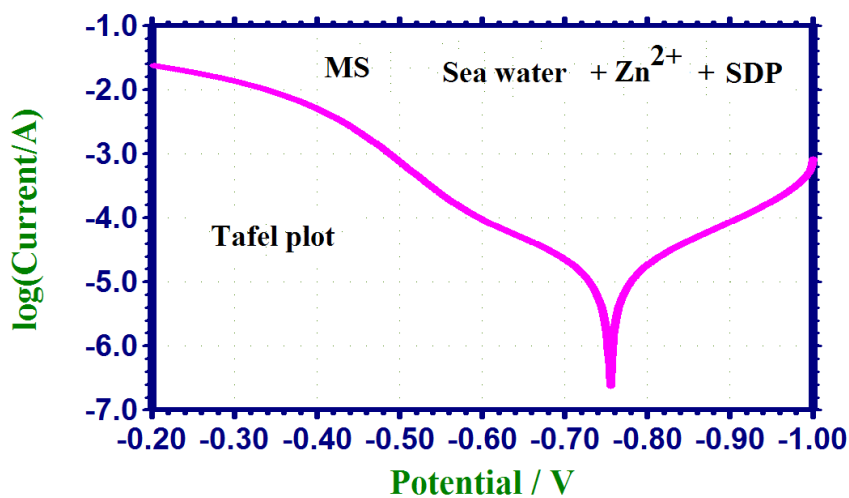


Figure 6. Tafel plot of mild steel immersed in sea water + SDP + Zn^{2+}

Slika 6. Tafelova kriva za meki čelik uronjen u morsku vodu + SDP + Zn^{2+}

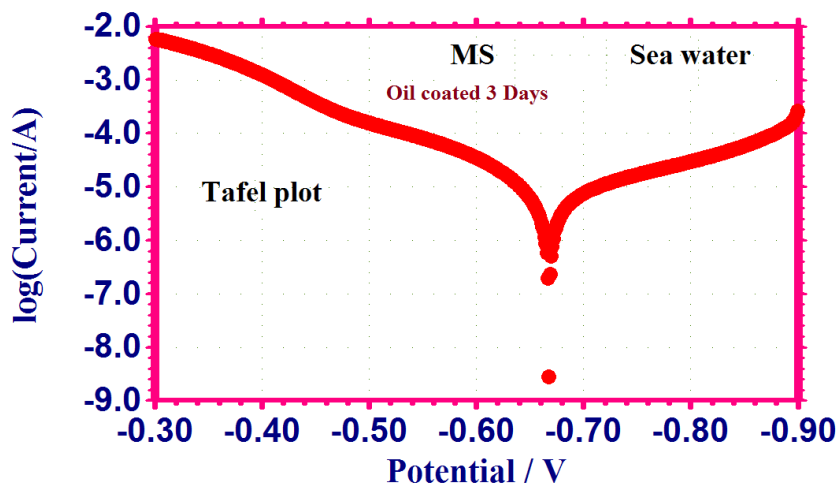


Figure 7. Tafel plot of oil coated (3 Days) mild steel immersed in sea water

Slika 7. Tafelova kriva za meki čelik obloženog uljem (3 dana) uronjen u morsku vodu

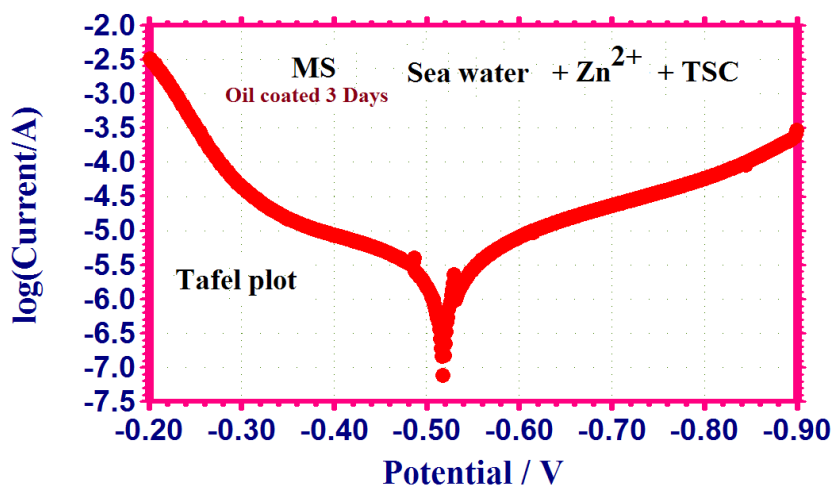


Figure 8. Tafel plot of oil coated (3 Days) mild steel immersed in sea water + TSC + Zn²⁺

Slika 8. Tafel-ova kriva za meki čelik obloženog uljem (3 dana) uronjenog u morsku vodu + TSC + Zn²⁺

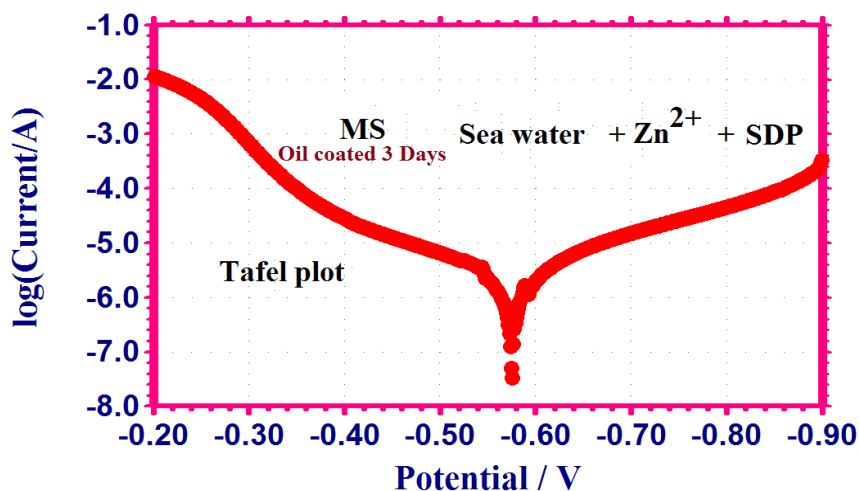


Figure 9. Tafel plot of oil coated (3 Days) mild steel immersed in sea water + SDP + Zn²⁺

Slika 9. Tafel-ova kriva za meki čelik obloženog uljem (3 dana) uronjenog u morsku vodu + SDP + Zn²⁺

It is observed from Table 4, that when mild steel is immersed in sea water the corrosion potential is -875 mV vs SCE. The LPR value is 1630 Ohm.cm². The corrosion current is 1.918x10⁻⁵ A/cm²

MS in SW+TSC 100 ppm + Zn²⁺ 50 ppm system

When mild steel is immersed in SW+TSC 100 ppm+ Zn²⁺ 50 ppm system, the corrosion resistance of MS increases. This is revealed by the fact that there is increase in LPR value and decrease in corrosion current value. The corrosion potential is shifted to anodic side. This indicates that in this inhibitor system, the anodic reaction of metal dissolution is controlled predominantly.

MS in SW+ SDP 100 ppm + Zn²⁺ 50 ppm system

When mild steel is immersed in SW+ SDP 100 ppm+ Zn²⁺ 50 ppm system, the corrosion resistance of MS increases. This is revealed by the fact that there is increase in LPR value and decrease in corrosion current value. The corrosion potential is shifted to anodic side. This indicates that in this inhibitor system, the anodic reaction of metal dissolution is controlled predominantly.

Oil coated (3days) MS in Sea water

When mild steel is immersed in Oil coated (3days) MS in Sea water system , the corrosion resistance of MS increases. This is revealed by the fact that there is increase in LPR value and decrease in corrosion current value. The corrosion potential is shifted to anodic side. This indicates that in this inhibitor system, the anodic reaction of metal dissolution is controlled predominantly.

Oil coated (3 days) MS in SW + TSC 100 ppm + Zn²⁺ 50ppm

When mild steel is immersed in Oil coated (3days) MS in SW+TSC 100 ppm+ Zn²⁺ 50ppm system , the corrosion resistance of MS increases. This is revealed by the fact that there is increase in LPR value and decrease in corrosion current value. The corrosion potential is shifted to anodic side. This indicates that in this inhibitor system, the anodic reaction of metal dissolution is controlled predominantly.

Oil coated (3days) MS in SW + SDP100 ppm + Zn²⁺ 50ppm

When mild steel is immersed in Oil coated (3days) MS in SW+ SDP 100 ppm+ Zn²⁺ 50ppm system , the corrosion resistance of MS increases. This is revealed by the fact that there is increase in LPR value and decrease in corrosion current value. The corrosion potential is shifted to anodic side. This indicates that in this inhibitor system, the anodic reaction of metal dissolution is controlled predominantly.

The corrosion potential values, the LPR values and corrosion current values of mild steel immersed in various test solutions are compared in Figures 10-12 respectively.

Implication

These inhibitor systems may be coated on mild steel surface used as hull plates to prevent corrosion of mild steel in sea water.

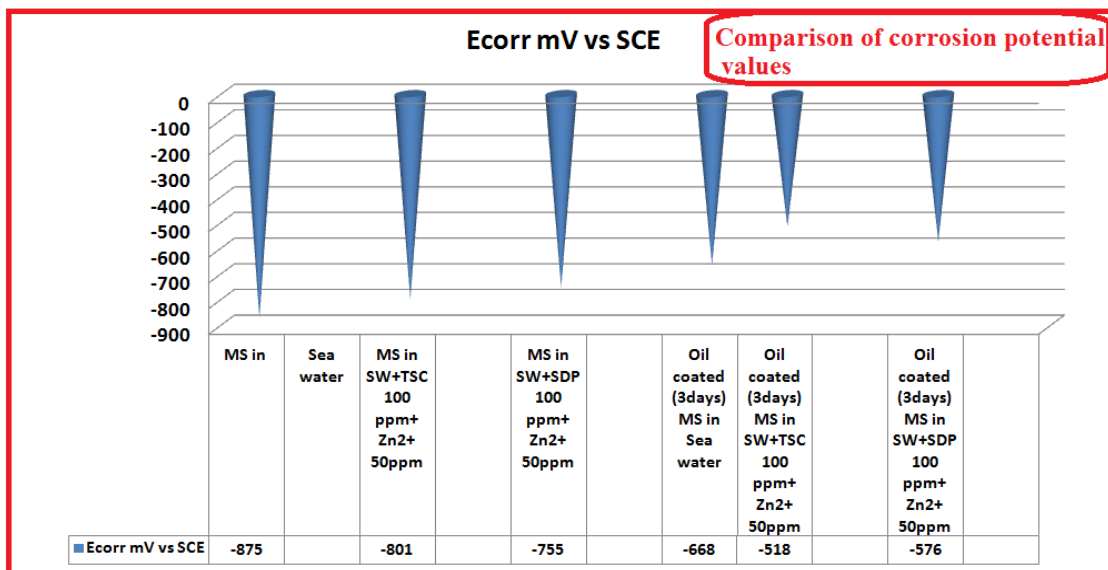


Figure 10. Comparison of corrosion potentials of mild steel immersed in various test solutions

Slika 10. Poređenje potencijala korozije mekog čelika uronjenog u različita ispitivana rastvora

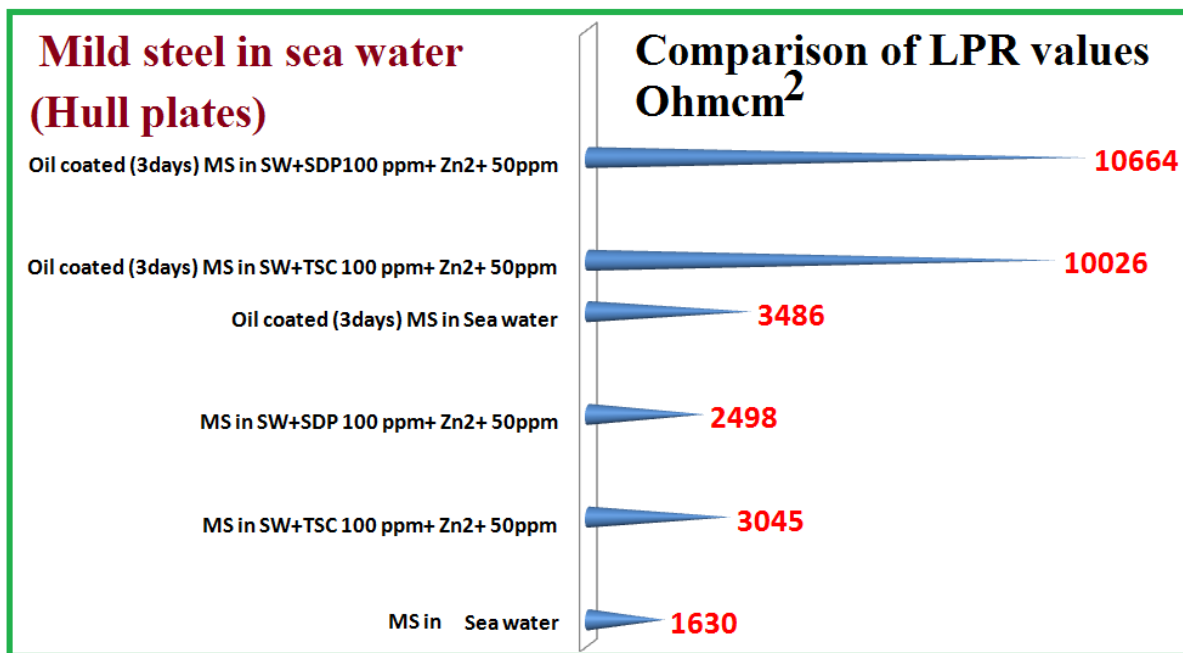


Figure11 . Comparison of LPR values

Slika 11. Poređenje vrednosti LPR

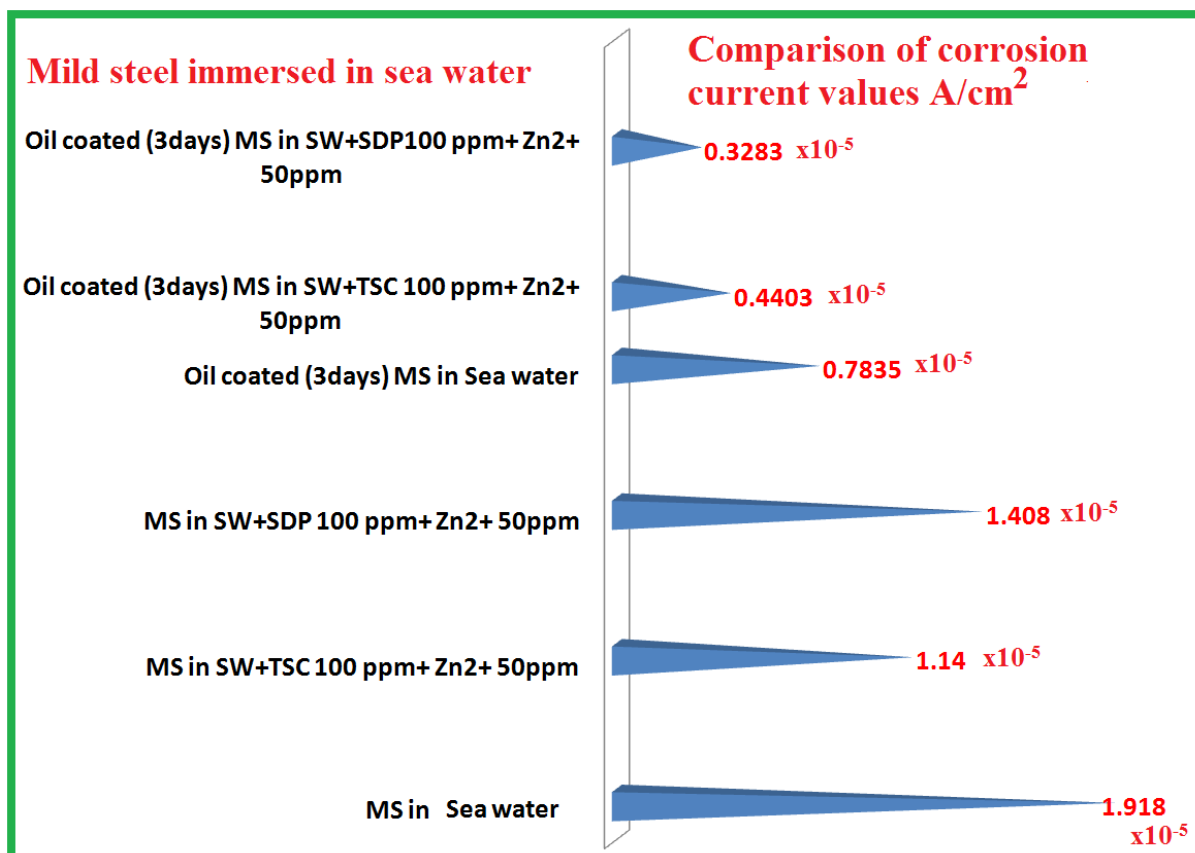


Figure12 . Comparison of corrosion current values

Slika 12. Poređenje vrednosti struja korozije

4. CONCLUSIONS

The hull plates of the ship made of mild steel (MS) are always in contact with sea water are always in contact with aggressive ions such as chloride ions present in sea water. The corrosion resistance of the hull plates of the ship made of mild steel has been investigated by polarization study. Sandalwood oil extract containing 5 g each of Cardamom (disambiguation), Clove (disambiguation), Nutmeg, India Sambrani (loban), Chrysopogon zizanioides, commonly known as vetiver and Camphor was used as corrosion inhibitor along with Trisodium citrate (TSC), sodium dihydrogen phosphate (SDP) and Zn^{2+} . The corrosion resistance was measured in the absence and presence of various inhibitor systems.

- Trisodium citrate (TSC) 100 ppm + Zn^{2+} 50ppm system, sodium dihydrogen phosphate (SDP) 100 ppm + Zn^{2+} 50ppm system, Oil coated (3days) MS, Oil coated (3days) MS +TSC 100 ppm + Zn^{2+} 50 ppm system and Oil coated (3days) MS +SDP100 ppm + Zn^{2+} 50 ppm system were used.
- It is observed that when mild steel is immersed in SW+TSC 100 ppm + Zn^{2+} 50ppm system , the corrosion resistance of MS increases.
- When mild steel is immersed in SW+ SDP 100 ppm + Zn^{2+} 50ppm system , the corrosion resistance of MS increases.
- When mild steel is immersed in Oil coated (3days) MS in Sea water system , the corrosion resistance of MS increases.
- When mild steel is immersed in Oil coated (3days) MS in SW+TSC 100 ppm + Zn^{2+} 50ppm system , the corrosion resistance of MS increases.
- When mild steel is immersed in Oil coated (3days) MS in SW+ SDP 100 ppm + Zn^{2+} 50ppm system , the corrosion resistance of MS increases.
- This is revealed by the fact that there is increase in LPR value and decrease in corrosion current value.
- The corrosion potential is shifted to anodic side. This indicates that in this inhibitor system, the anodic reaction of metal dissolution is controlled predominantly.
- This implies that these inhibitor systems may be coated on mild steel surface used as hull plates to prevent corrosion of mild steel in sea water.

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IZVOD

SPREČAVANJE KOROZIJE PLOČA OD MEKOG ČELIKA POTOPLJENIH U MORSKU VODU EKSTRAKTOM ULJA NEKIH PRIRODNIH PROIZVODA

Ploče trupa broda od mekog čelika (MČ) su uvek u kontaktu sa morskom vodom i uvek su u kontaktu sa agresivnim jonima, kao što su hloridni joni prisutni u morskoj vodi. Otpornost na koroziju ploča trupa broda od mekog čelika je istražen proučavanjem polarizacije. Ekstrakt ulja sandalovine, koji sadrži po 5 g kardamoma, karanfilića, muskatnog oraščića, Indija Sambrani (loban), Chrysopogon zizanioides, poznatijeg kao vetiver i kamfor, korišćen je kao inhibitor korozije zajedno sa trinatrijum citratom, natrijum dihidrogenom fosfat i Zn^{2+} . Otpornost na koroziju je merena u odsustvu i prisustvu različitih inhibitornih sistema: Trinatrijum citrat (TSC) 100 ppm+ Zn^{2+} 50 ppm sistem, natrijum dihidrogen fosfat (SDP) 100 ppm+ Zn^{2+} 50 ppm sistem, obložen uljem (3 dana) MČ, uljem premazan (3 dana) MČ +TSC 100 ppm+ sistem obložen Zn^{2+} 5 ppm+ sistem MS +SDP100 ppm+ Zn^{2+} 50 ppm. Primećeno je da kada je meki čelik uronjen u sistem SV+TSC 100 ppm + Zn^{2+} 50ppm, otpornost MČ na koroziju se povećava. Kada je meki čelik uronjen u sistem SV+ SDP 100 ppm + Zn^{2+} 50 ppm, otpornost MČ na koroziju se povećava. Kada se meki čelik uroni u MS obložen uljem (3 dana) u sistem morske vode, otpornost MČ na koroziju se povećava. Kada se meki čelik uroni u MS obložen uljem (3 dana) u sistem SV+TSC 100 ppm + Zn^{2+} 50ppm, otpornost MČ na koroziju se povećava. Kada se meki čelik uroni u MS obložen uljem (3 dana) u sistem SV+ SDP 100 ppm + Zn^{2+} 50 ppm, otpornost MČ na koroziju se povećava. Ovo se objašnjava činjenicom da dolazi do povećanja vrednosti LPR i smanjenja vrednosti struje korozije. Potencijal korozije se pomera na anodnu stranu. Ovo ukazuje da se u ovom sistemu inhibitora pretežno kontroliše anodna reakcija rastvaranja metala. Ovo implicira da se ovi sistemi inhibitora mogu obložiti na površinu od mekog čelika koji se koristi kao ploče trupa da bi se sprečila korozija mekog čelika u morskoj vodi.

Ključne reči: inhibicija korozije, ploče trupa, meki čelik, morska voda, zeleni inhibitori, elektrohemijaska studija.

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