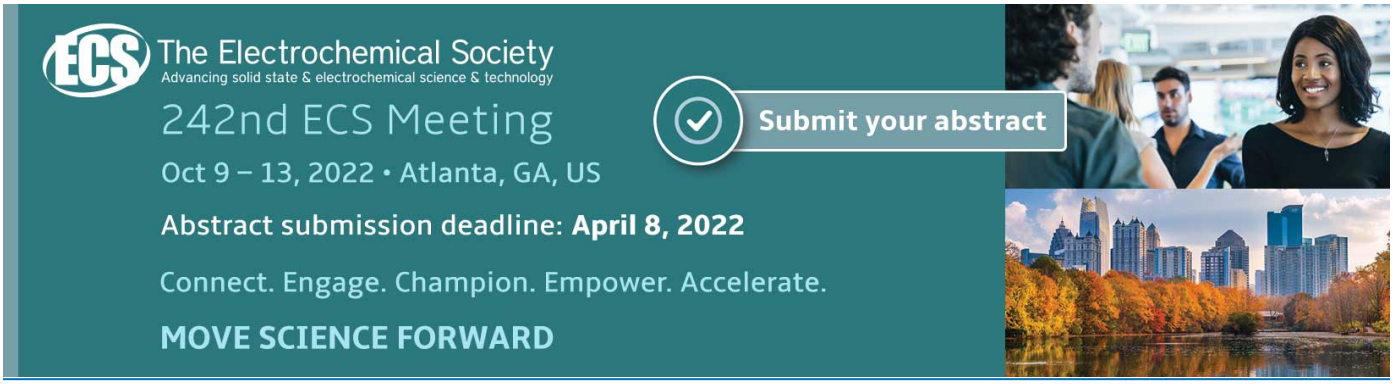
Effect of norcholine fluid derivative on the resilience of mild steel to electrochemical degradation in weak HCl media



Effect of norcholine fluid derivative on the resilience of mild steel to electrochemical degradation in weak HCl media

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Abstract. The resilience of mild steel to electrochemical degeneration in weak electrolyte corrosion (0.5 M HCl) was assessed at discrete concentrations of Norcholine derivatives by potentiodynamic polarization and open circuit potential analysis. Degradation rate of the steel substantially declined with augmentation of Norcholine concentration from 9.49 mm/y in control HCl (no Norcholine) to 0.27 mm/y at highest Norcholine value of 15%. The degradation rate at this inhibitor concentration correlates of 97.1% protection performance. Norcholine demonstrated cathodic inhibition effect from observation of the negative deviation in corrosion potential. Norcholine was also observed to indicate substantial passive reaction mechanism on the anodic polarization regions of the polarization graphs. This translates to evolution of non-porous layer on the steel exterior. Open circuit potential graphs indicate substantial variation between the inhibited and acid degraded graphs of the steel. Mathematical computations through analysis of variance demonstrates Norcholine concentration and potential tracking time are statistically important variation sources influencing the protection performance of Norcholine at values of 68.03% and 26.4%.

1. Introduction

Carbon steel exhibits universal utilization in most manufacturing and production plants due to its availability, cost, recyclability, ease of production and fabrication and being the most widely produced steel globally. However, the steel corrodes easily in mild aqueous environments. This is having been a major problem for scientist, engineers and industrialist sue to lack of comprehensive cost-effective replacements [1, 2]. The presence of corrosive anions such as SO_4^{2-}, Cl^- etc. in industrial operating conditions is a major problem for carbon steels limiting their operational lifespan. This is mostly common in industries where acidic solution is used various applications such as raw materials for the production of finished goods, intermediate compounds, acid production and industrial operations such as oil-well acidizing, acid descaling etc. [3-5]. HCl is extensively applied in dye production, manufacture of batteries, photoflash bulbs and in crude distillation overhead system. The low cost of carbon steel coupled with its extensive application necessitates the need for low cost corrosion prevention method. Chemical derivative known as corrosion inhibitors has seen applications universally in the protection of metallic alloys from the reaction effect of corrosive species. The harmful nature of most compounds also necessitates the need for sustainable compounds for corrosion inhibition [6]. Compounds composed molecules such as O, P, N and S etc. tends to adequately suppressing material degradation [7–9]. Organic

compounds generally prevent corrosion reaction processes through adsorption mechanisms which inhibit the electrolytic transport and degradation reaction of anions on the steel [10-17]. The structural dimension and adsorption mechanism of the compound are also important in determining effective corrosion inhibiting organic compounds [18-22]. This article studies the corrosion suppression properties of Norcholine on the degradation of low carbon steel in dilute HCl solution.

2. Experimental methods

Mild steel (MS) rod bought in Lagos, Nigeria has a diametric dimension of 14.5 mm. The steel was machined into 7 test exhibits with minimal length of 6 mm and cleansed with distilled H_2O and C_3H_6O. Norcholine (NHL), a light-yellow liquid was procured from Sigma Aldrich company in the United States. The fluid derivative has a molecular formular and molar mass of $C_4H_{11}NO$ and 89.14 g mol^{-1}. NHL was prepared in volumetric concentration from 2.5% to 15% in 200 mL of 0.5 M HCl solution. Analar grade NaCl was added at 3.5% concentration per 200 mL of acid/inhibitor solution. Potentiodynamic polarization test was done using a ternary terminal configuration (Pt counter terminal, MS specimen terminal and Ag/AgCl standard terminal) immersed in the acid-inhibitor solution within a specialized container, and linked to Autolab PGSTAT 30 potentiostatic device and monitoring computer for real-time plotting. The plots were recorded from -1.5V to +1.5 mV at scanning rate of 0.0015V/s. Open circuit potential analysis was performed using the same potentiostat with two terminal configurations (MS specimen terminal and Ag/AgCl standard terminal) linked to a computer and monitored for 288 h at 48 h interval. 2-factor single level statistical test (ANOVA F - test) was employed to assess the statistical relevance of NHL concentration and potential tracking time (independent variables) on the inhibition performance of Norcholine at confidence level of 95% (significance level of $\alpha = 0.05$).

3. Results and discussion

3.1 Potentiodynamic polarization studies

Graphical representations depicting the electrochemical behaviour of MS in 0.5 M HCl at specific NHL solution is shown in Fig. 1 Table 1 depicts the outputs from the graphs. Corrosion rate of MS at 0% NHL is observed to be 9.47 mm/y due to the redox reaction mechanisms induced by chloride species. The chloride caused the anodic degradation of MS surface resulting in accelerated degeneration of the steel. Addition of NHL at 2.5% concentration significantly decreased the degradation rate of MS to 3.85 mm/y which corresponds to protection performance of 59.35%. At 15% NHL concentration the degradation rate is 0.27 mm/y correlating to protection performance of 97.1%. More augmentation of NHL concentration aided continuous decrease in corrosion rate and substantial rise in protection performance, till 0.27 mm/y and 97.10% at 15% NHL concentration. Decrease in degradation rate analogous to rise in NHL concentration is because of increase in NHL molecules which suppressed the chloride acceleration oxidation-reduction reaction processes. The corrosion potential transited significantly in the cathodic direction relative to the potential of MS at 0% NHL beyond the threshold 85mV signifying NHL is a cathodic inhibitor. Secondly it shows NH compound suppresses corrosion of MS through selective precipitation on active sites and modification of the corrosive medium. The cathodic portion of the polarization plot from 7.5% NHl concentration shows the cathodic inhibition process occurs under activation control. Simultaneously, the anodic portion of the polarization plot shows significant passivation behaviour due to stifling of the corrosion reaction mechanism and accumulation of protonated NHL molecules on MS surface.

Table 1. Data for potentiodynamic polarization of MS in 0.5 M HCl solution at specific NHL concentration

Inhibitor Conc. (%)	Inhibitor Conc. (M)	Corrosion Rate (mm/y)	Inhibition Efficiency (%)	Corrosion Current density (A/cm²)	Corrosion Potential (V)	Polarization Resistance, R_p (Ω)	Cathodic Tafel Slope, B_c (V/dec)	Anodic Tafel Slope, B_a (V/dec)
0	0	9.49	0	8.31E-04	-0.360	25.99	-0.102	0.419
2.5	2.80E-04	3.85	59.35	3.37E-04	-0.429	53.79	-0.090	0.292
5	5.60E-04	3.16	66.61	2.77E-04	-0.763	116.90	-0.251	0.374
7.5	8.40E-04	2.61	72.41	2.29E-04	-0.853	188.83	-0.102	0.325
10	1.12E-03	1.86	80.40	1.63E-04	-0.859	298.36	-0.192	0.335
12.5	1.40E-03	0.55	94.19	4.82E-05	-0.858	403.78	-0.147	0.290
15	1.68E-03	0.27	97.10	2.41E-05	-0.872	547.61	-0.059	0.105

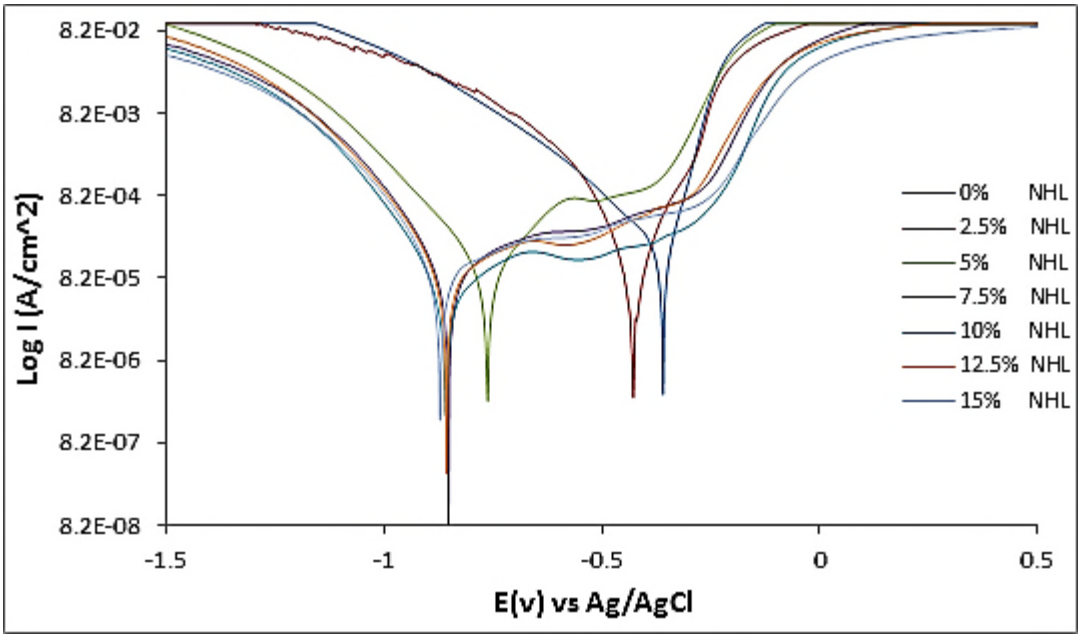

Figure. 1 Graphical representation of the potentiodynamic polarization behavior of in 0.5 M HCl solution at specific NHL concentration

3.2 Open circuit potential analysis

The open-circuit potential plots MS corrosion is shown in Fig. 2. General equilibrium potential of about was attained at 1 h of exposure in HCl solution at all NHL concentrations. Anodic potential shift occurred with increase in NHL concentration. This is because of the presence of adequate ionized NHL molecules which adsorbed unto MS surface forming chemical complexes that stifled further interfacial reaction and chloride adsorption detrimental to MS. MS attained mean steady state corrosion potential value ~306 mV at 10% NHL concentration. The potential plot slightly differs with respect to NHL concentration. At 2.5% - 5% NHL concentration, the thermodynamic tendency to corrode is high. At 7.5% NHL concentration, the tendency to corrode is intermediate while at 10% - 15%, the corrosion tendency is very low signifying strong dependence of NHL performance on concentration. The corrosion potential plot of MS at 0% NHL was significantly cathodic throughout due to active deterioration of the steel surface by chloride anions. Generally, the plots at specific NHL concentration were thermodynamically stable while the anodic shift with respect to NHL concentration signifies enhancement of the protective properties NHL compound due to molecular adehesion of NHL cations unto the steel exterior and maintains the potential values in the passive potential region of the plot.

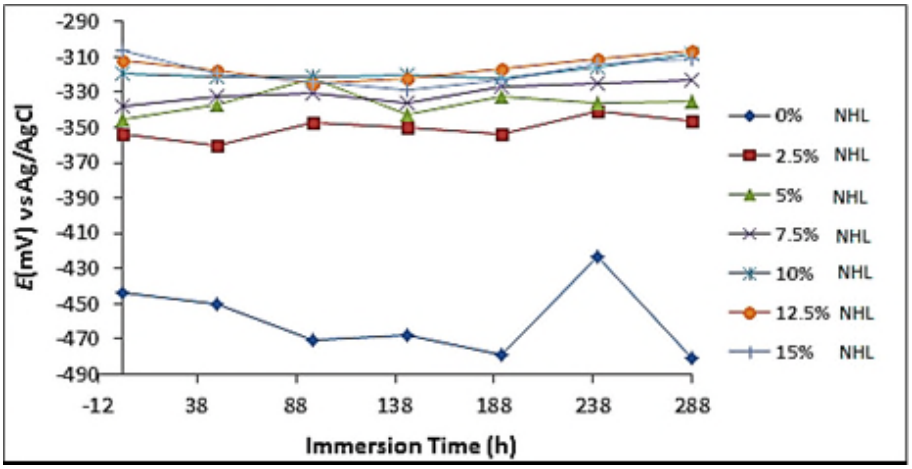

Figure. 2 Plot of corrosion potential against potential tracking time for MS in 0.5 M HCl at specific NHL concentrations

3.3 Statistical analysis

ANOVA data indicating the mathematical relevance of exposure time and NHL concentration on the corrosion protection effect of NHL shows both variables influence the performance of NHL at different levels. However, the percentage importance of NHL concentration stands at 68.03% compared to the potential tracking time which stands at 26.4%. The F-values depicted at 28.28 and 11.70 are significantly more than the significance factor ($\alpha = 0.05$). The results expresses NHL concentration and observation time are significant independent variables which affects the protection effect of NHL on MS.

Table 2. Statistical analysis (ANOVA) for NHL inhibition performance on MS at 95% confidence level

Source of Variation	Mean Square Ratio	Significance F	F (%)
NHL Concentration	28.28	2.71	68.03
Exposure Time	11.70	2.87	26.4

4. Conclusion

Norcholine effectively inhibited mild steel degeneration in dilute HCl solution with respect to its concentration. The compound exhibited cathodic inhibition properties. Norcholine initiated passivation reaction processes on the polarization plots of mild steel at specific concentration of norcholine. In the absence of Norcholine, open circuit potential graphs for mild steel reaction were substantially more electronegative than the plots at various concentrations of norcholine. The electrochemical mechanism of norcholine was physiochemical and which thereafter deviated to chemisorption adsorption at higher norcholine concentrates in consonance with Langmuir and Freundlich isotherms illustrations. The inhibitor molecules selectively precipitate on the reactive areas of the steel exterior in consonance with cathodic inhibition reaction.

Acknowledgement

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