CHAPTER 8
CONCLUSIONS
OVERALL CONCLUSIONS FROM THE THESIS

The investigation of 3 monomeric and 7 gemini surfactants as corrosion inhibitors was conducted in 1M HCl/3.5% NaCl solution to judge their inhibition ability and adsorption characteristics with MS. Many important experimental techniques like gravimetric measurement, PDP measurement and EIS were employed to study the inhibition effect of these synthesized inhibitors at various concentrations and temperatures (30°C, 40°C, 50°C and 60°C). The evaluation of the adsorption behavior of these monomeric and gemini surfactants was accomplished by calculating the values of thermodynamic parameters like $K_{\text{ads}}$, $\Delta G^{\circ}_{\text{ads}}$, $\Delta H^{\circ}_{\text{ads}}$ and $\Delta S^{\circ}_{\text{ads}}$ and activation parameter like $E_a$, $\Delta H^*$ and $\Delta S^*$. PDP measurements were carried out to study the adsorptive nature of the inhibitors and their activeness towards cathodic and anodic areas on the metal surface. The corrosion parameters such as $R_{\text{ct}}$, $C_{\text{dl}}$ and corrosion inhibition efficiencies of the inhibitors were determined by EIS. FT-IR and UV-Vis. spectroscopic techniques were used to study the binding of inhibitors on MS surface. The surface morphologies of the corroded steel were studied using AFM and SEM-EDX analysis. Quantum chemical calculations and MD simulation study were also done to corroborate the experimental findings.

The followings conclusions are drawn from the present study:

8.1 Evaluation of Surface Active Properties

To get insight into the interfacial adsorption of the studied surfactant, CMC values along with other physico-chemical parameters such as $\pi_{\text{CMC}}$, $\Gamma_{\text{max}}$, $A_{\text{min}}$, $\Delta G^{\circ}_{\text{mic}}$ and $\Delta G^{\circ}_{\text{ads}}$ were calculated and discussed. The trend observed in the lowering of CMCs of studied surfactants in 1M HCl and 3.5% NaCl solutions, at 30°C, were as follows:

1M HCl solution

$$(\text{C}_{12}\text{Cys}) < 12\text{-E}2-12 < 14\text{-E}2-14 \equiv 2(\text{C}_{12}\text{Cys}) < 16\text{-E}2-16 < 14\text{-Py} < 16\text{-Py}$$

3.5% NaCl solution

$$\text{Glu}(10) < \text{Glu}(12) < \text{Glu}(12)-2\text{-Glu}(12)$$

8.2 Weight Loss Study

All the studied ten inhibitors showed great inhibition efficiencies for MS corrosion in the studied corrosive solutions. The corrosion inhibition effect of the surfactants was found to be dependent on their concentration as well as the
temperature of the test solution. Inhibition efficiencies invariably increased with increase in their concentration and temperature implying chemical mode of adsorption. Further, inhibition effect of some of the gemini surfactants such as m-E2-m and Glu(12)-2-Glu(12) were studied in presence of salt additives and inhibition efficiencies were observed to increase synergistically. The order of inhibition efficiencies in presence of different inhibitors as obtained by gravimetric analysis is as follows:

**1M HCl solution**

16-E2-16 > 16-Py > 2(C12Cys) > 14-E2-14 > 14-Py > 12-E2-12 > (C12Cys)

**3.5% NaCl solution**

Glu(12)-2-Glu(12) > Glu(12) > Glu(10)

**8.3 Adsorption Isotherm and Thermodynamic and Activation Parameters**

The adsorption of the evaluated inhibitors on MS surface obeyed Langmuir adsorption isotherm at all the studied temperatures. The thermodynamic and activation parameters suggested that the adsorption of inhibitors on the MS surface was spontaneous and predominantly chemical in nature.

**8.4 Potentiodynamic Polarization Measurements**

All the investigated compounds acted as mixed-type inhibitors controlling both the cathodic and anodic reactions for MS corrosion in 1M HCl and 3.5% NaCl solution. The variation in inhibition efficiencies followed the identical trend as observed in weight loss measurements.

**8.5 Electrochemical Impedance Measurements**

EIS results show that an increase in inhibitors concentration increases $R_{ct}$ and $C_{dl}$ values owing to the increased thickness of adsorbed layer. The inhibition efficiency of the studied inhibitors varied in similar fashion as observed in weight loss and potentiodynamic polarization measurements.

**8.6 Spectroscopic Studies**

UV-Visible and FT-IR results confirmed the interaction of inhibitors with the MS surface in inhibited 1M HCl/3.5% NaCl solution.
8.7 Surface Analytical Studies

AFM/SEM/EDX results showed a visible difference in the morphologies of the uninhibited and the inhibited system suggesting the formation of a protective film on the MS surface by the adsorbed inhibitors molecules.

8.8 Theoretical Studies

The quantum chemical analysis assisted in understanding the mechanism of adsorption of the studied surfactants on a molecular level.

8.8 Monte Carlo Simulation Study

The interaction between the investigated inhibitors with the Fe (110) surface was carried out to locate the low energy adsorption configuration and the electron transfer process that takes place at the steel/electrolyte interface.

SCOPE FOR FUTURE WORK

The present work has led to the development of some new monomeric and gemini surfactants as green corrosion inhibitors for MS in 1M HCl/3.5% NaCl solution. The addition of salts in small concentration to some of the gemini surfactants has further led to the improvement of their inhibition efficiencies. However, in order to make these gemini surfactants more versatile and robust the following is proposed for future consideration.

- To evaluate the studied inhibitors/inhibiting formulations for other active metals/corrosive medium.
- The studied surfactants may be used in preparation of inhibitor loaded conducting polymer based coatings for which virtually no reference is available.
- A combination of two or more surfactants may be tested for MS and other metal corrosion in the studied corrosive media.