CORROSION INHIBITION PERFORMANCE BY OCTYL-METHYLIMIDAZOLIUM-BROMIDE OMIBr ON API 5L X52 STEEL IN 1.0M H_2SO_4

By

Ahmad Imran Bin Azman

15913

Dissertation submitted in partial fulfillment of
the requirement for the
Bachelor of Engineering (Hons.)
(Mechanical)

JANUARY 2016

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TABLE OF CONTENTS

CERTIFICATION OF APPROVAL

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____

(Dr Saeid Kakooei)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK

January 2006

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

AHMAD IMRAN BIN AZMAN

ABSTRACT

In this study, Ionic Liquid Octyl-Methylimidazolium-Bromide OMIBr will be tested as corrosion inhibitor in 1.0M solution of sulfuric acid (H2SO4) on API 5L X52 using linear polarization method and electrochemical impedance method at temperatures 30◦, 50◦, and 70◦. From Linear Polarization method and Electrochemical Impedance spectroscopy, the polarization resistance and charge transfer resistance increases with injection of OMIBr which confirms the inhibition effect of OMIBr. From electrochemical test, the inhibition efficiency of OMIBr on API 5L x52 in 1.0M H_2SO_4 has been found to decrease with increasing temperature.

ACKNOWLEDGEMENT

I am using this opportunity to express my gratitude to everyone who supported me throughout the course of this FYP. I am thankful for their aspiring guidance, invaluably constructive criticism and friendly advice during the internship training. I am sincerely grateful to them for sharing their truthful and illuminating views on a number of issues related to the project.

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Thank you,
Ahmad Imran Bin Azman

CHAPTER 1
INTRODUCTION

1.1 Background

The API 5L X52 is a carbon steel widely used for pipeline transportation systems in the oil and gas industry. However, like any other steel, API 5L X52 is prone to corrosion when exposed to corrosive media like H_2SO_4 **.** There are several ways introduced by scientists to counter corrosion, one of it is using corrosion inhibitor. A corrosion inhibitor is a chemical compound that, when added to a liquid or gas, decreases the corrosion rate of a material. One of the corrosion inhibitor being used in the industry is calle, ionic liquids.

1.2 Problem Statement

Inhibitors like amide are known to have very good inhibition efficiency. However , due to its low boiling temperature and decomposition temperature, it tends to lose its corrosion inhibition performance at high temperatures. Ionic liquids have very high decomposition and boiling temperature up to 400-600 °C and is able to maintain its inhibition performance up to this range of temperature.

1.3 Objective

To investigate the corrosion inhibition performance of ionic liquid Octyl-Methylimidazolium-Bromide OMIBr on API 5L X52 steel at different temperature.

1.4 Scope of study

This project covers the compound synthesis for preparation of ionic liquid Octyl-Methylimidazolium-Bromide OMIBr which will be used as corrosion inhibitors. Inhibition efficiency and corrosion rate which are the goal parameters in the study will be obtained through electrochemical tests using the EIS and LPR method at different temperatures. SEM analysis will be used to confirm the inhibition influence of the ionic liquids on the surface metal through adsorption.

1.5 Significance of project

This project aims to prove the consistency in inhibition performance of Ionic liquid liquid Octyl-Methylimidazolium-Bromide OMIBr at different temperatures. Unlike other inhibitors like amide with low decomposition temperature will lose its inhibition performance at certain temperatures. However, ionic liquids have relatively high decomposition and boiling temperature and is capable of maintaining its inhibition performance even at high temperatures up to 400-700 °C.

CHAPTER 2
LITERATURE REVIEW

2.1 Corrosion on steel

The API 5L X52 is a steel widely used for pipeline transportation systems in the oil and gas industry. However, like any other steel, API 5L X52 is prone to corrosion when exposed to corrosive media like H_2SO_4 [1]. A material under corrosion attack will suffer in terms of mechanical properties where the yield strength, tensile strength, and ductility of steel will decrease [2] [3]. A structure weakened by corrosion will carry high risk of failure which will result in accidents .The corrosion phenomenon is damaging to the oil and gas industry where the majority of oil and gas installations are prone to corrosion [4]. Corrosion phenomenon can cause severe pollution to the environment as corrosion at pipelines or pressure vessels can cause leakage or discharge of harmful substances to the environment [5] .

2.2 Corrosion inhibitor

Scientists and researchers have found ways to inhibit corrosion attack by using corrosion inhibitor. Plenty of organic materials like Adenine, Sansevieria trifasciata extract and lawsonia have been used in the past and have been proven to inhibit corrosion by decreasing its corrosion rate [6] [7] [8]. The organic inhibitors which was found to be effective contain heteroatoms like O, N, S and multiple bonds in its molecules in which they are adsorbed on the metal surface [9].

2.3 Ionic Liquids

In recent years, studies on ionic liquids has captured a lot of attention due to its impressive characteristics like negligible vapour pressure [10], good conductivity [11] , high thermal stability , high electrochemical stability , solvation properties , and large liquidous range.

Ionic liquids have very high decomposition temperature up to 700 °C. This property makes ionic liquids highly efficient in corrosion inhibition even at high temperatures.

Physical and chemical properties of Ionic liquids, depends on cation anion combination [17] [18] [19] [20] . This means that the characteristic of the ionic liquid can be adjusted by altering its anion and cation combination for the desired application.

The application of ionic liquid incudes catalyst in reaction [12] , electropolymerization [13] , electrolytes for fuel cells [14] , extraction of metals [15] , and organic and catalytic reactions [16] .

2.4 Ionic liquids as corrosion inhibitor

A. Abdel-Gaber et al. 2013 in his study showed that ionic liquid (DTPB) has been found to work as an effective corrosion inhibitor through several electrochemical tests [22]. Many Ionic liquids of different cation and anion combination have been used as corrosion inhibitors, showing good inhibition performance. [21] [22] [23] [24]. These ionic liquids inhibit corrosion by decreasing the corrosion rate through adsorption process. The inhibition efficiency and adsorption process of each type of ionic liquid differs, which shows that different characteristics of ionic liquids exhibit different inhibition performances.

The inhibition process of ionic liquid occurs through adsorption where the molecules of the ionic liquid is adsorbed to the surface of the metal [24]. The adsorbed molecules on the metal surface forms a protective layer or film which prevents infiltrations of corrosion inducing ions like sulphate ions and chloride ions. Figure 1 shows the adsorption mechanism of a corrosion inhibitor through formation of protective layer. In figure 1(b) (c) , the corrosion protection of zinc is dependent on the oxide layer formed through passivation and defence mechanism of Zinc metal where it prevents the corrosion inducing molecules from reacting with Zinc metal. In figure 1(d) and (e) , after injection of a corrosion inhibitor , the molecules from the inhibitor are adsorbed to the surface of the metal , forming another protective layer. These double layers formed by oxide and inhibitor , prevents infiltration of Cl ions on the metal which could induce corrosion.

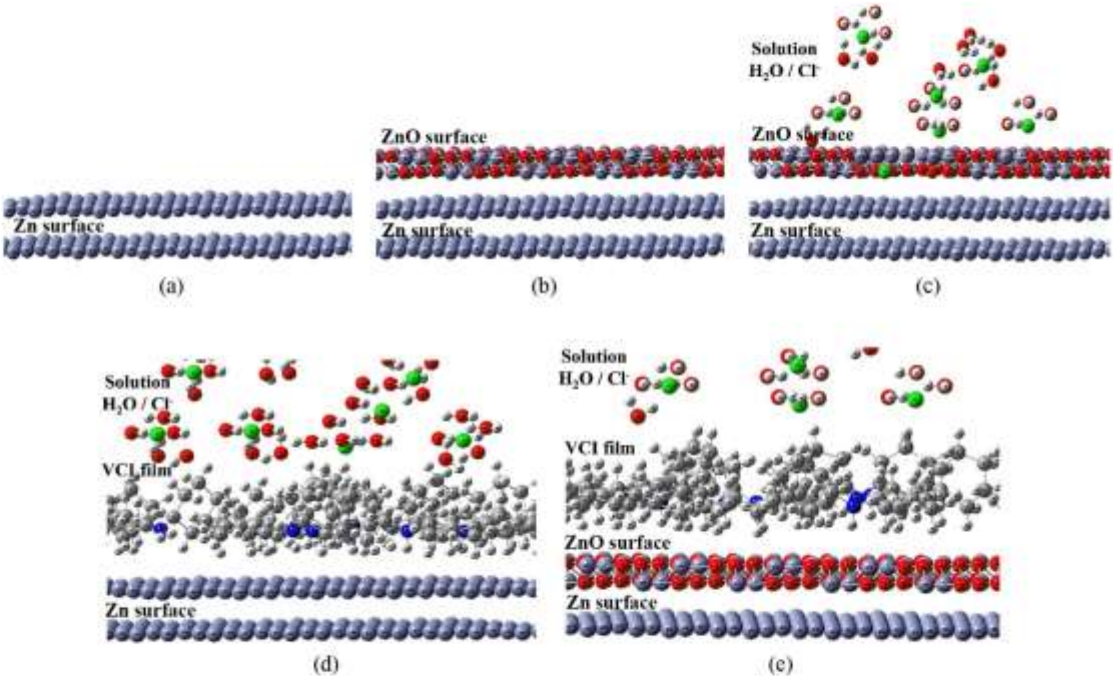


Figure 1: Corrosion protection through formation of protective film [24]

2.5 Effect of Alkyl Chain on inhibition efficiency

In a study made by Palomar Pardave et al. 2012, it was found longer alkyl chain gives better inhibition performance [25] [26].

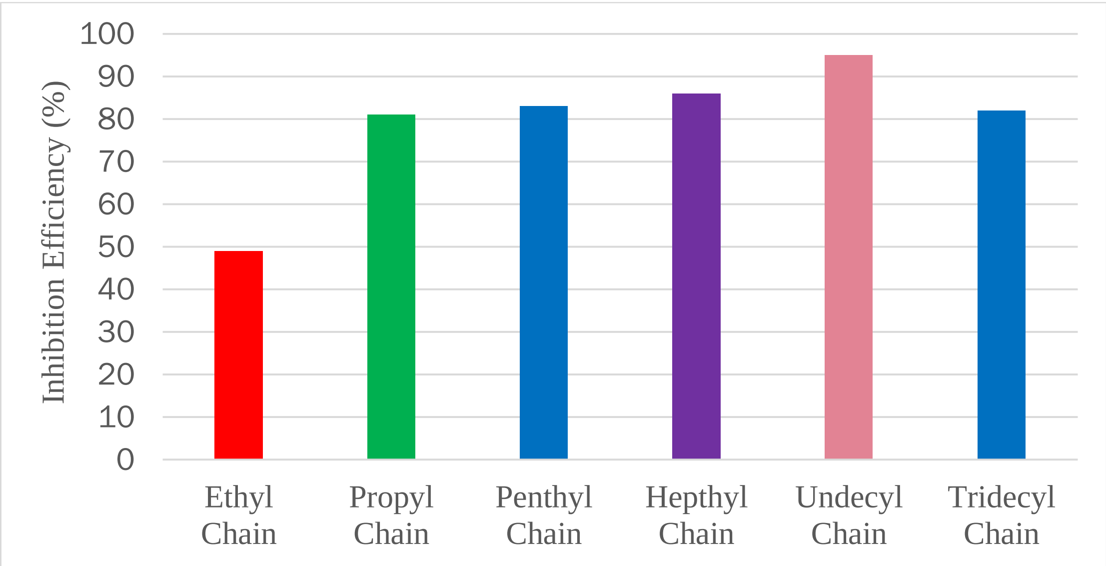


Figure 2: Inhibition efficiency of ionic liquids of different alkyl group

Figure 1 shows that inhibition efficiency of the compounds first increases up to the undecyl spacer chain and then decreases at tridecyl chain. This dependence can be explained as a result of the flexibility and the possibility that the alkyl chain bends over itself.

Furthermore, it was found that the inhibition efficiency increases with increasing the carbon chain length of the alkyl connecting with N_3 of imidazolium ring [27].

Ionic Liquid of Imidazole type have good corrosion inhibition properties [28] [29] [30] [31]. In this study, ionic liquid Octyl-Methylimidazolium-Bromide OMIBr, an imidazole type ionic liquid with the iodide anion (I^-), will be used to study its corrosion inhibition performance on API 5L X52 in 1.0M H_2SO_4.

2.6 Optimum Concentration

In a study made by Octavio Olivares et al. 2014 on effect of concentration of imidazole type ionic liquid on inhibition efficiency in H_2SO_4, where four different concentrations were studied which were 25 ppm , 50 ppm , 75 ppm and 100 ppm it was found that ionic liquid at concentration 100 ppm showed the highest inhibition efficiency [24]. Figure 3 below shows the relation of inhibition efficiency with concentration of inhibitor.

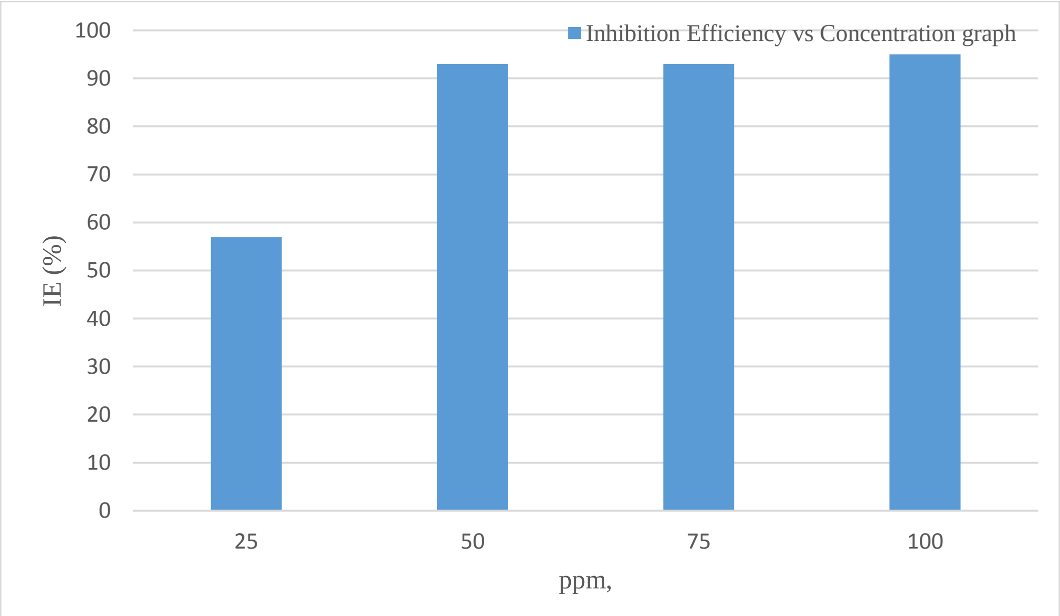


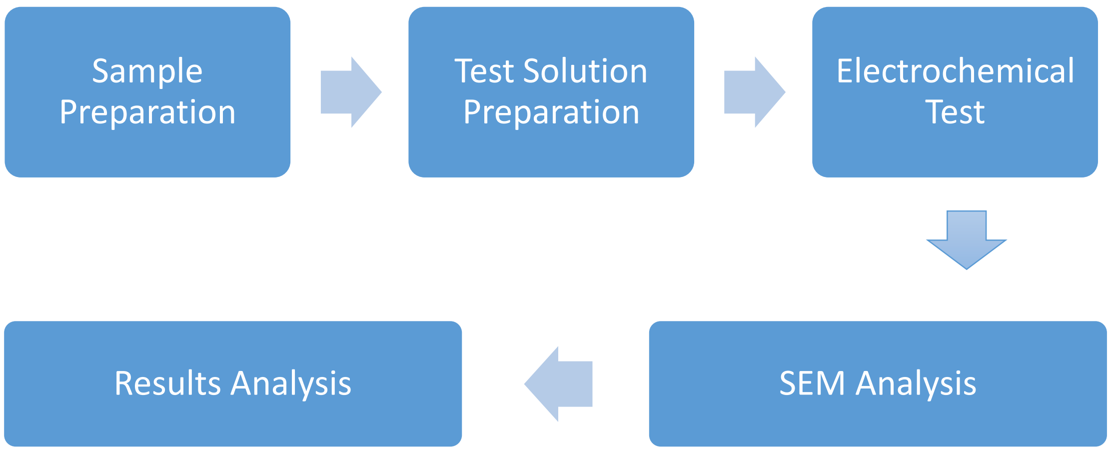
Figure 3: Inhibition efficiency vs Concentration Graph

2.7 Effect of temperature on reaction rates

The rate of reaction increases as temperature increases due to a disproportion of large increase in the number of high energy collisions. For most reactions, for every temperature increment of 10°C, the rate of reaction doubles [32].

CHAPTER 3
METHODOLOGY

The project consists of five main processes which are sample preparation , test solution preparation , electrochemical test, SEM analysis and results analysis.



3.1 Sample Preparation

The sample used in this experiment is API 5L X52 carbon steel. Below are the physical and chemical properties of API 5L X52.

Table 1: Chemical Composition of API 5L X52

Chemical Composition	C (%)	Mn (%)	P (%)	S (%)	Si (%)	Ti (%)	Nb (%)	V (%)
API5L X52	0.16	1.65	0.020	0.01	0.45	0.04	0.05	0.07

Table 2: Mechanical Properties of API 5L X52

Mechanical Properties	Tensile Strength, MPa	Yield Strength, Mpa	Elongation, %

API 5L X52	455.05	358.53	21

The sample preparation process is done by preparing 6 specimens of 10 mm (length) x 10mm (width) x 5mm (height) by milling and cutting. Figure 4 shows the samples preapred through machining.

Figure 4: Six samples of 10mm x 10mm x 5mm

The samples were then mounted using epoxy resin and each connected to a copper wire as figure 5 below.

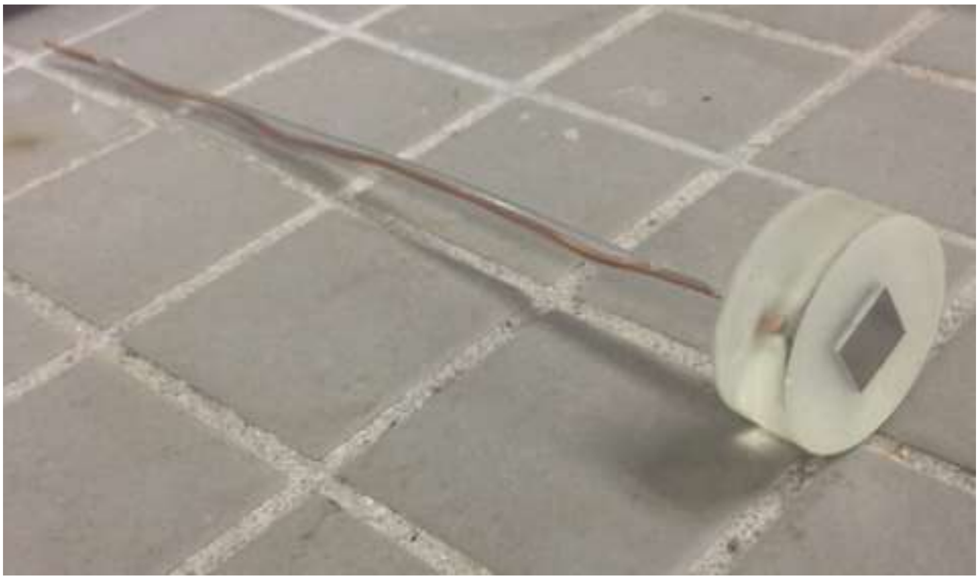


Figure 5: Mounted specimen connected to copper wire

The samples were polished with abrasives grit paper number 80,240,320, 600 until a shiny, flat and smooth surface is achieved and degreased with acetone and rinsed. Figure 6 below shows the specimens being grinded with abrasives paper.

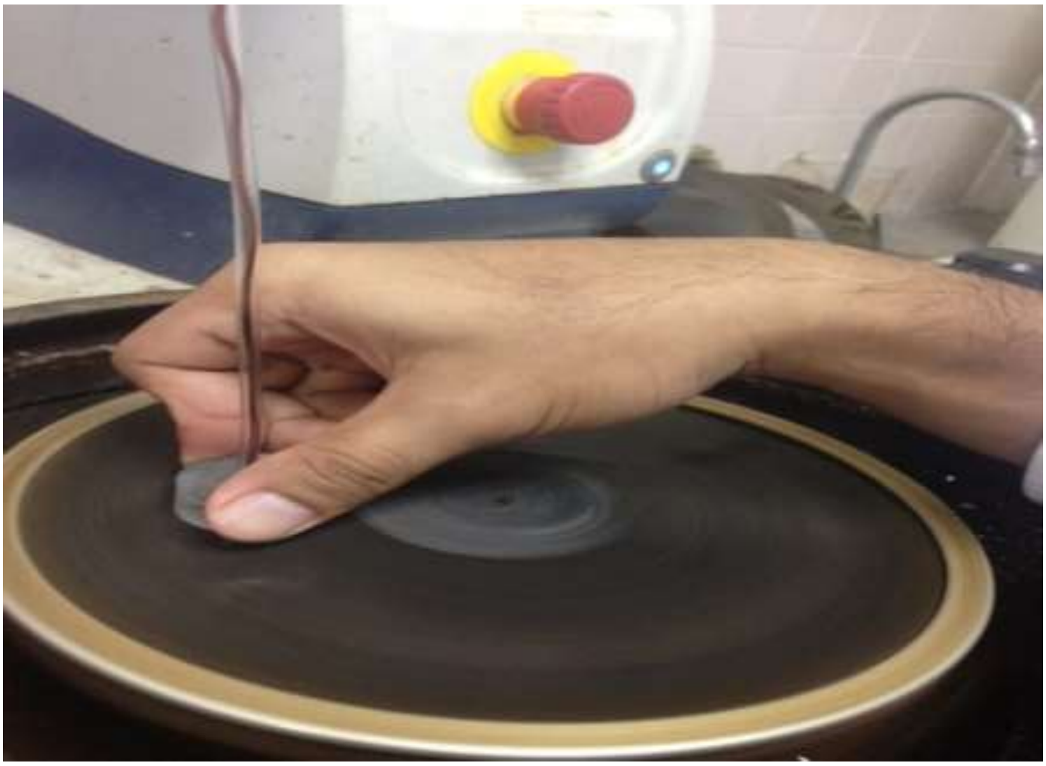


Figure 6: Grinding specimen

3.2 Preparation of Test solutions

Six test solutions are prepared in this project where 3 are uninhibited while 3 are inhibited with Ionic Liquid OMIBr at 100ppm. 1.0M H_2SO_4 is used as corrosive media.

3.2.1 Uninhibited test solution

To prepare 1.0M H_2SO_4 , the following calculations are used.

$$\left[\frac{(w\%\ x\ d)}{MW}\right] x\ 10 = Molarity$$

Density, d = 1.84 g/ml

Weight percentage = 95.0 %

Formula Weight, MW = 98.08 g/mol

$$\left[\frac{(95\ x\ 1.84)}{98.08}\right] x\ 10 = 17.822\ M$$

From above equation , Molarity = 17.822M

$$H_2SO_4\ \frac{mL}{L} = \frac{1(1.0M)}{17.822M} = 56.11\ \frac{mL}{L}$$

56.11mL is needed for 1L solution. For 2L solution , 112.22 mL H_2SO_4 is needed. 112.22 mL H_2SO_4 was poured into a 2L beaker , and filled to 2L with distilled water while being stirred continuously.

3.2.1 Inhibited test solution

To prepare a 100ppm OMIBr solution, the following calculations are involved.

$$100ppm\ x\ 0.001\frac{g}{l} = 0.1\frac{g}{l}$$

$$0.1\frac{g}{l} \div 275.23\frac{g}{mol} = 3.63\ x\ 10^{-4}M$$

To prepare a concentration of 3.63 x 10^{-4} M, 200mg of OMIBr was first weighed using an analytical balance , and then poured into a 2L beaker. The beaker was then filled with 112.22mL H_2SO_4. The solution was then filled to 2L with distilled water while continuously stirred.

3.3 Electrochemical test preparation

Prior to conducting electrochemical test, the test solutions were first purged for 30 minutes with carbon dioxide to evacuate room air like nitrogen or oxygen to prevent oxidation reaction in the test solution. After purging, the specimen was then transferred to a three electrode cell connected to a potentiostat. The electrode specifications are:

i. Working Electrode = API 5L x52
ii. Reference electrode = Ag-AgCl
iii. Auxiliary Electrode = Stainless steel

3.4 Electrochemical test

The electrochemical tests used in this project are Electrochemical Impedance Spectroscopy and Linear Polarization Resistance.

3.4.1 Electrochemical Impedance Spectroscopy

Electrochemical Impedance Spectroscopy is a method used to measure the dielectric properties of a medium as a function of frequency. From this method , the corrosion rate and inhibition efficiency can be obtained through Nyquist plot as Figure 7 below.

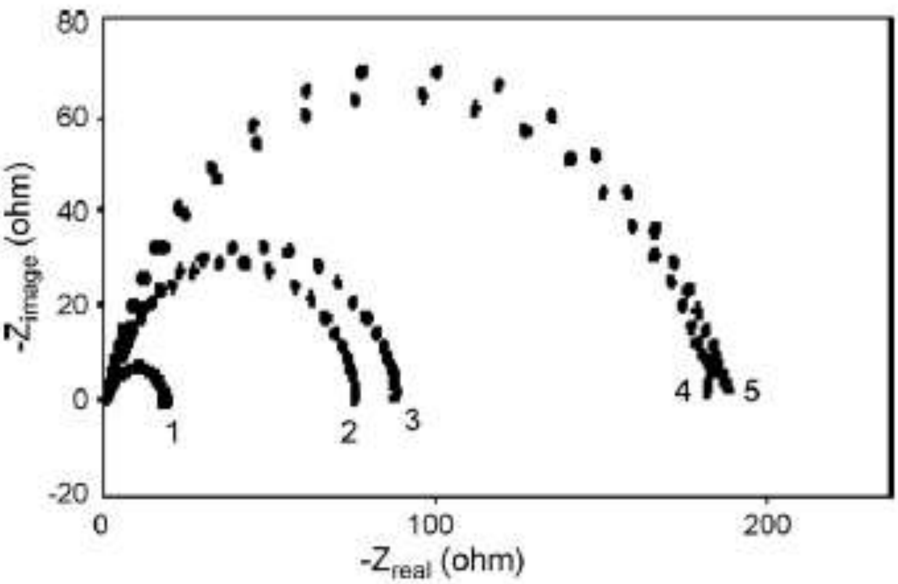


Figure 7: Nyquist plot [24]

For every reaction, It takes energy to remove electrons from a metal electrode and join them with the protons to produce hydrogen. Thus, the process of transferring electrons from the electrode to the hydrogen ions in has a certain resistance associated with it called charge resistance. This charge resistance is the main parameter needed for determining corrosion inhibition performance. An increase in charge transfer resistance shows increasing inhibition effect. Using the values obtained from this Nyquist plot , the inhibition efficiency can be calculated using formula :

$$IE(\%) = \frac{R_t^{-1} - R_{t(inh)}^{-1}}{R_t^{-1}} \; x \; 100$$

3.4.2 Linear Polarization Resistance

Linear polarization resistance is a technique of increasing or decreasing the potential of an electrode in order to polarize it. Whenever the potential of an electrode is forced away from it's value at open circuit, that is referred to as polarizing the electrode. When an electrode is polarized, it can cause current to flow via electrochemical reactions that occur at the electrode surface. This output current is an important parameter which can be used to evaluate its inhibition performance.

The important parameter from LPR technique that is essential to calculate corrosion rate and inhibition efficiency is the polarization resistance. Polarization resistance is a type resistance which resist the process of a polarization reaction. This polarization resistance hinders a reaction from occurring. The reaction which is involved here is corrosion reaction which involves both oxidation and reduction reaction. With an increase in polarization reaction , the corrosion rate decreases since polarization resistance is indirectly proportional to corrosion rate.

Thus in this project, a high polarization resistance is favourable upon injection of OMIBr. This polarization resistance can be obtained by calculating the gradient of potential vs current density graph as figure 7 below. The polarization resistance of the sample is recorded every hour and the inhibition efficiency of OMIBr at every hour can be calculated by using formula below

$$IE = \frac{R_{P_{inh}} - R_{P_0}}{R_{P_{inh}}}$$

GANTT CHART

FYP 1		Weeks													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	FYP Title Selection	■													
2	Consultation with SV		■	■	■	■	■	■	■	■	■	■	■	■	■
3	Literature Study		■	■	■	■	■	■	■	■					
4	Methodology Identification 1) Experiment procedure 2) Listing of items and equipment needed 3) Calculating costs										■	■			
5	Proposal Defence presentation									■	■				
6	Submission of Interim Report														■

FYP 2		Weeks													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Consultation with SV	■	■	■	■	■	■	■	■	■	■	■	■	■	■
2	Consult HOD of CCR for approval of lab and equipment			■	■	■	■								
3	Prepare sample by machining							■	■						
4	Preparation of test solution through mixture of OMIBr, distilled water and H2SO4									■					
5	Conduct electrochemical test to study inhibition performance of OMIBr										■	■	■	■	
6	Data gathering and analysis										■	■	■	■	
7	Report writing and VIVA													■	■

CHAPTER 4

RESULTS & DISCUSSION

4.1 Electrochemical Impedance Spectroscopy

Figure 8 and 9 shows the Nyquist plot of the test solution at 30°. From figure 10, it can be seen that the impedance increases with injection of inhibitor. This confirms the inhibition performance of OMIBr which takes place through adsorption.

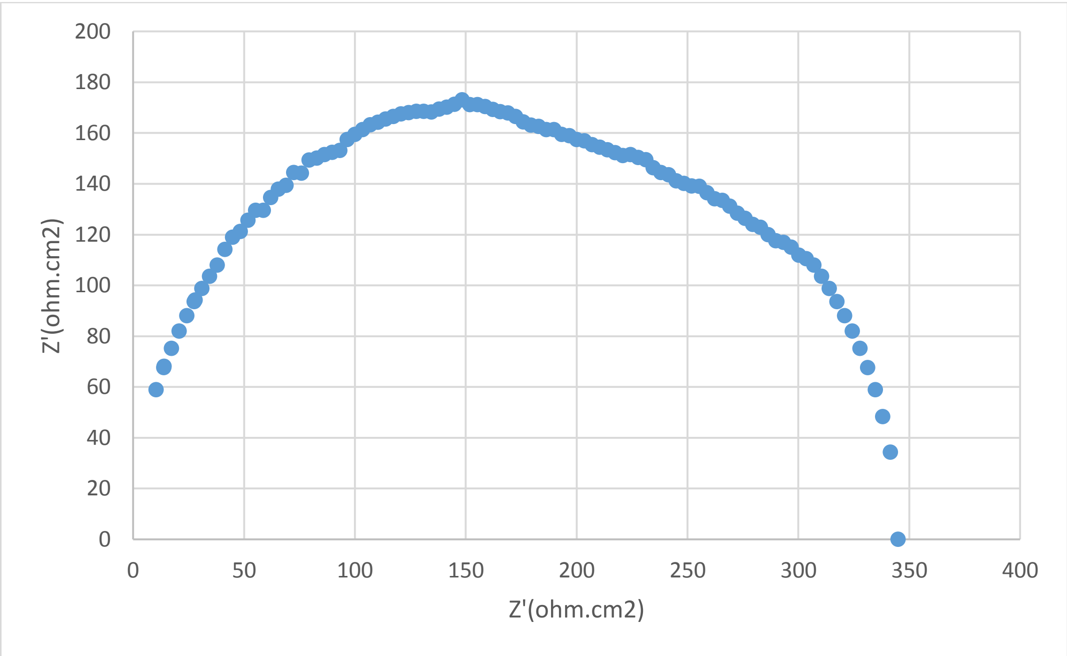


Figure 8: Nyquist plot at blank solution at 30°

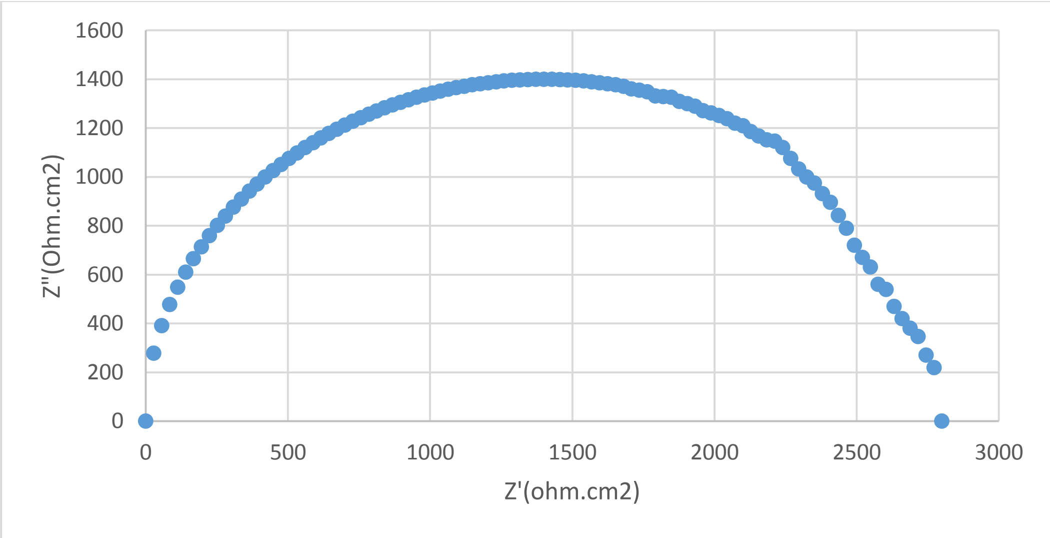
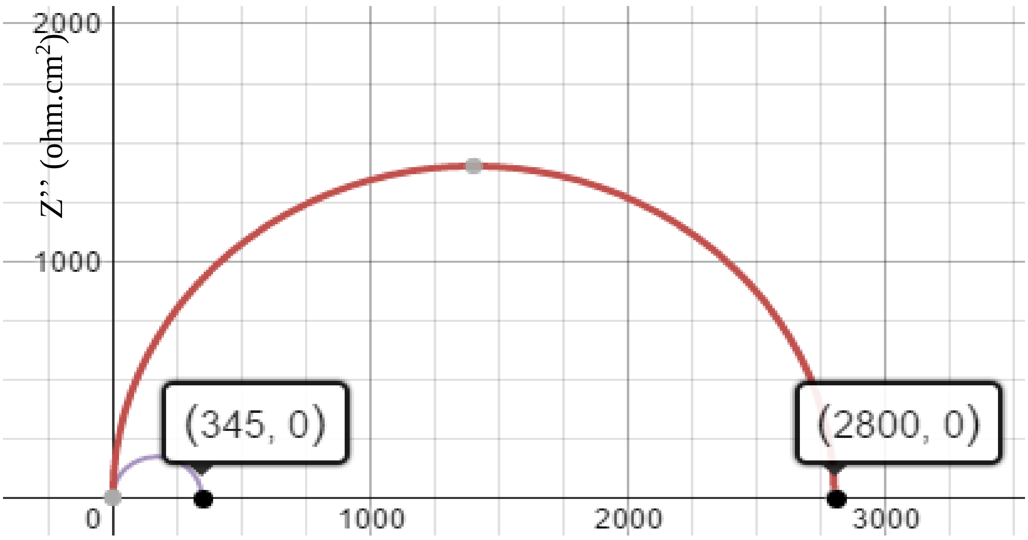


Figure 9: Nyquist plot of inhibited solution at 30°

Figure 10 below shows the best line of fit for uninhibited and inhibited test solution at 30°



Z’ (ohm.cm^2)

Figure 10: Nyquist plot of uninhibited and inhibited test solution at 30°C

4.1.1 Inhibition efficiency at 30°

The corrosion was calculated using equation x.

$$IE(\%) = \frac{R_t^{-1} - R_{t(inh)}^{-1}}{R_t^{-1}}\ x\ 100$$

$$R_t^{-1} = \frac{1}{26.3} = 0.038 \text{ ohm.cm}^2$$

$$R_{t(inh)}^{-1} = \frac{1}{193} = 5.18\ x\ 10^{-3} \text{ ohm.cm}^2$$

$$IE(\%) = \frac{(0.038) - (5.18\ x\ 10^{-3})}{(0.038)}\ x\ 100\% = 86.37\%$$

The inhibition efficiency of the inhibitor at test solution 30°C by Nyquist plot is 87.69%.

Figure 11, 12 and 13 shows the Nyquist plot of the test solution at 50°. From figure 13, it can be seen that the impedance increases with injection of inhibitor. This confirms the inhibition performance of OMIBr which takes place through adsorption.

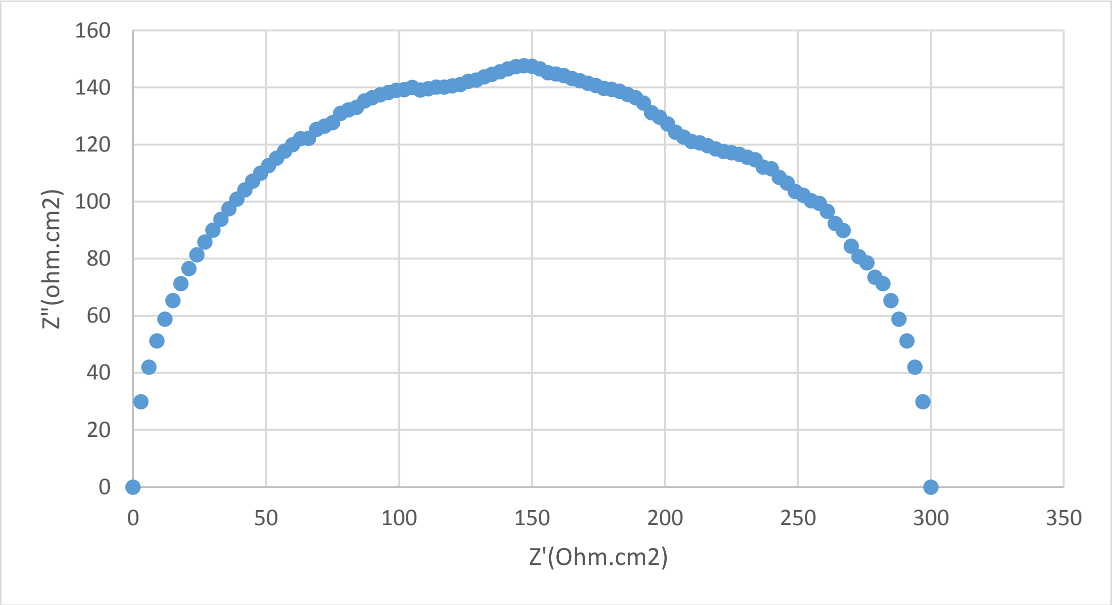


Figure 11: Nyquist plot of blank solution at 50°

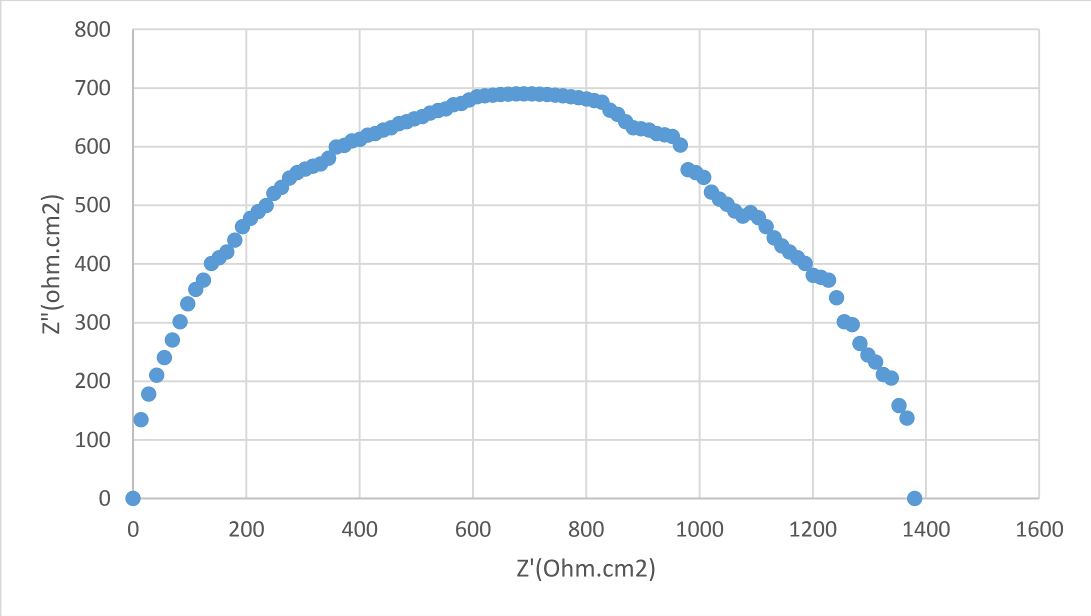


Figure 12: Nyquist plot of inhibited solution at 50°

Figure 13 below shows the best line of fit for Nyquist plot of the test solution at 50°.

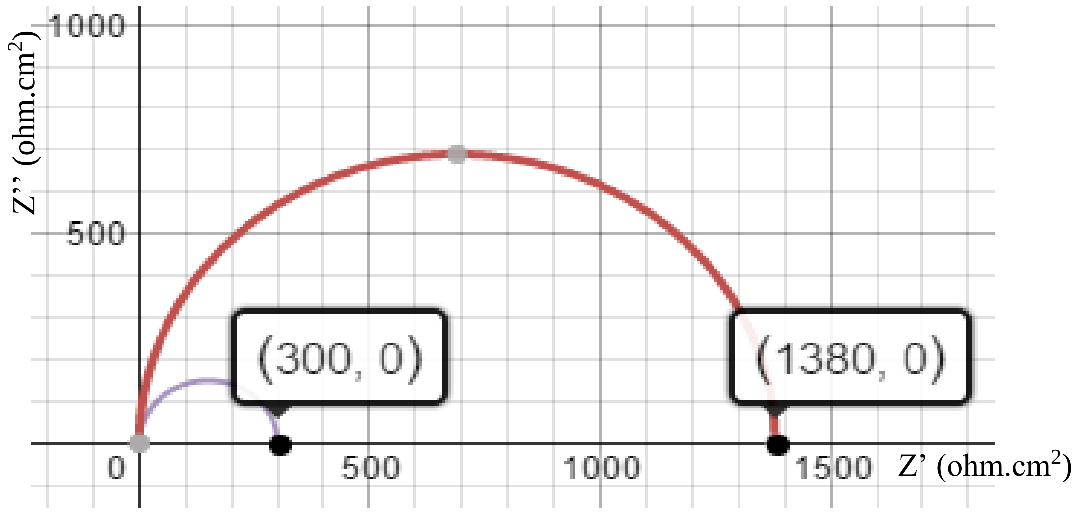


Figure 13: Nyquist plot of uninhibited and inhibited solution at 50°

4.1.2 Inhibition Efficiency at 50°

$$IE(\%) = \frac{R_t^{-1} - R_{t(inh)}^{-1}}{R_t^{-1}} \; x \; 100$$

$$R_t^{-1} = \frac{1}{23.4} = 0.043 \text{ ohm.cm}^2$$

$$R_{t(inh)}^{-1} = \frac{1}{193} = 5.18\ x\ 10^{-3} \text{ ohm.cm}^2$$

$$IE(\%) = \frac{(0.043) - (5.18\ x\ 10^{-3})}{(0.043)}\ x\ 100\% = 76.51\%$$

The inhibition efficiency of the inhibitor at test solution 30°C by Nyquist plot is 76.51%.

From figure 14 ,15 and 16, it can be seen that the impedance increases with injection of inhibitor. This confirms the inhibition performance of OMIBr which takes place through adsorption.

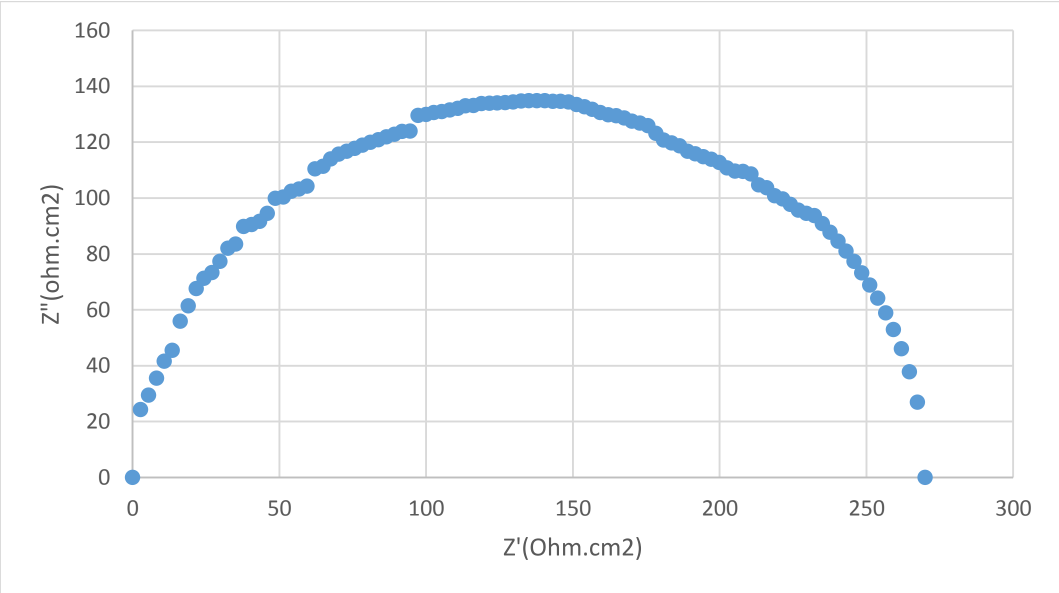


Figure 14: Nyquist plot of blank solution at 70°

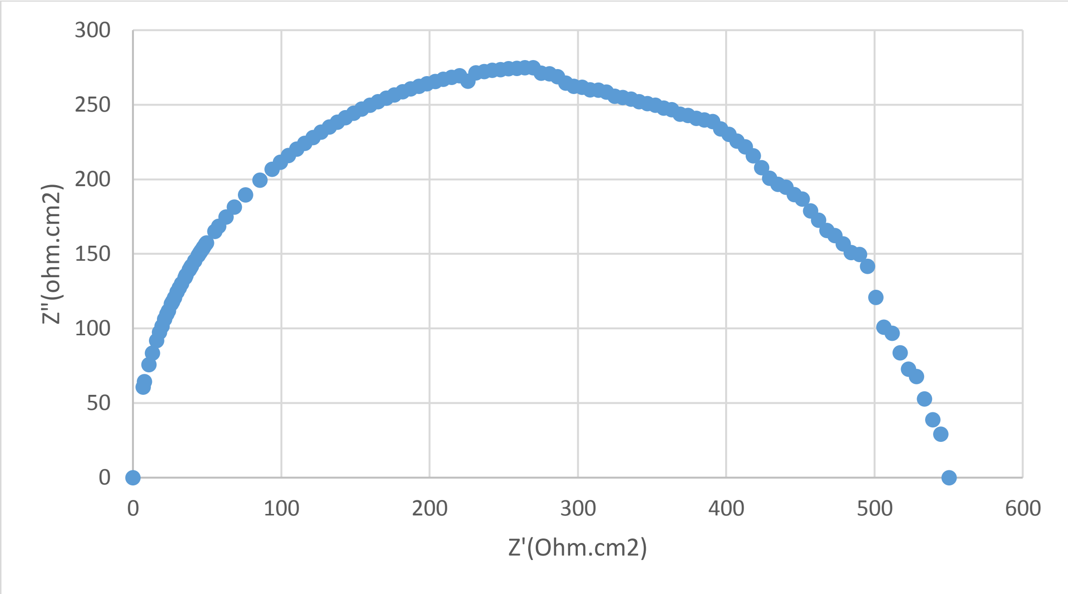


Figure 15: Nyquist plot of inhibited solution at 70°

Figure 16 below shows best line of fit Nyquist plot of the test solution at 70°

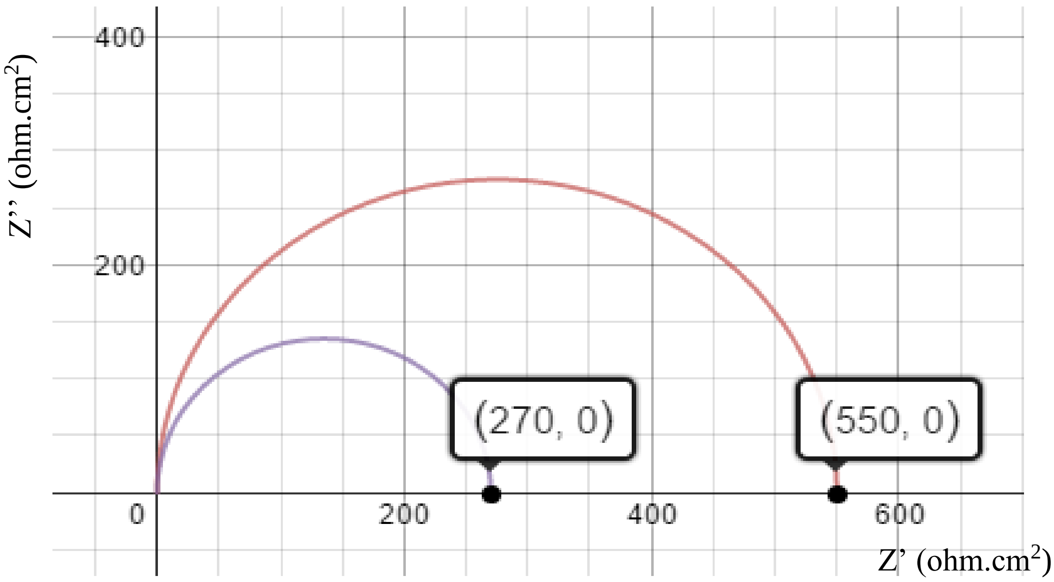


Figure 16 : Nyquist plot of uninhibited and inhibited test solution at 70°

4.1.2 Inhibition efficiency at 70°

$$IE(\%) = \frac{R_t^{-1} - R_{t(inh)}^{-1}}{R_t^{-1}} \; x \; 100\%$$

$$R_t^{-1} = \frac{1}{19} = 0.053 \text{ ohm.cm}^2$$

$$R_{t(inh)}^{-1} = \frac{1}{42.1} = 0.024 \text{ ohm.cm}^2$$

$$IE(\%) = \frac{(0.053) - (0..024)}{(0.053)} \ x \ 100\% = 54.87\%$$

The inhibition efficiency of the inhibitor at test solution 30°C by Nyquist plot is 54.78%.

Table 3 below shows the charge transfer resistance and inhibition efficiencies at temperatures 30°, 50° and 70° using Eletrochemical Impedance Spectroscopy method. From table 3 , it can be seen that the impedance increases with injection of inhibitor. This confirms the inhibition performance of OMIBr which takes place through adsorption. However, as temperature increases, the Rt decreases which explains why the inhibition efficiency decreases. This decrement of IE with temperature can be explained due to desorption of CI molecules from the steel due to high working temperature. The increased temperature caused the CI molecules to move restlessly and gets detached from the steel surface.

Table 3: Inhibition efficiency and charge transfer resistance at temperature 30°,50° and 70°

Temperature	R_t (ohm.cm^2)	$R_{t(inh)}$ (ohm.cm^2)	IE (%)
30	26.3	193	86.37
50	23.4	99.6	76.51
70	19	42.1	54.87

4.2 Linear Polarization Resistance

From figure 17, it can be seen that the polarization resistance Rt increases with injection of OMIBr which proves the inhibition performance of OMIBr. The polarization resistance Rt of inhibited test solution steadily increases with time. This shows that at working temperature of 30°C , OMIBr molecules is consistently being adsorbed to the steel surface, acting as protective film which prevents attack from sulphate ions.

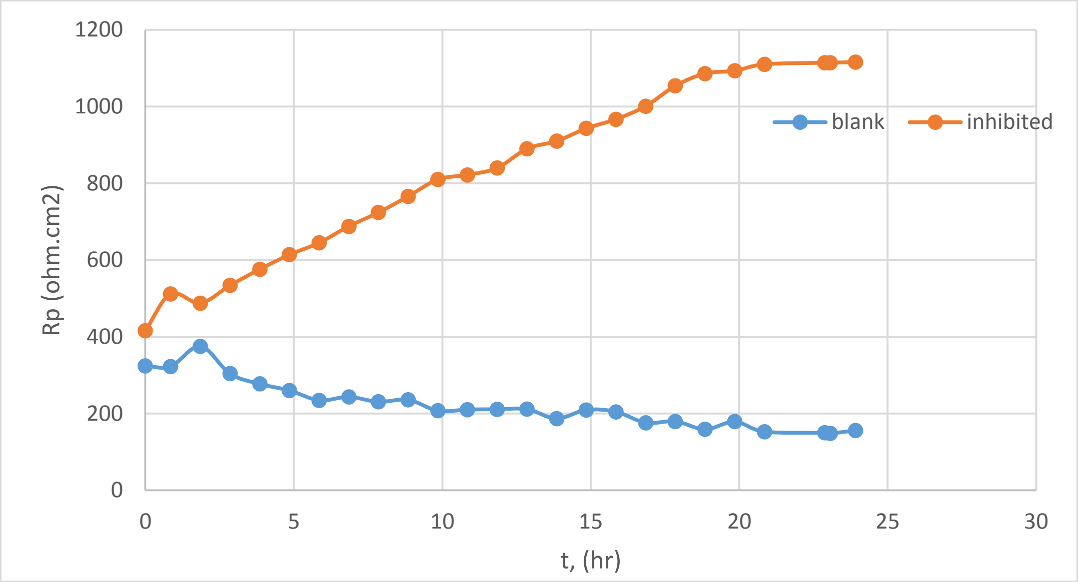


Figure 17: Polarization resistance vs immersion time at 30°C

4.2.1 Inhibition efficiency of OMIBr at 30°C

Highest inhibition performance occurred at 21 hours where:

R_{po}=153.07 ohm.cm2

R_{pinh}=1114 ohm.cm2

$$IE(\%) = \frac{R_{p_{inh}} - R_{p_o}}{R_{p_{inh}}} \; x\ 100\%$$

$$IE(\%) = \frac{1114-148.39}{1114} \; x\ 100\% = 86.67\%$$

Inhibition efficiency of OMIBr at 30°C using Linear polarization technique is 86.26%.

From figure 18 below, it can be seen that the polarization resistance Rt increases with injection of OMIBr which proves the inhibition performance of OMIBr . For 50°C solution, the Rt first increases, but later decreases after 13 hours of immersion.. This behaviour can be explained due to the high temperature which increases the rate of reaction. The CI molecules gets steadily adsorbed onto the steel surface at first, but after a certain exposure time to high working temperature , the OMIBr molecules moves restlessly due to high rate of reaction and gets detached from the steel surface which explains the decrement of Rt.

At figure 18, it can be seen that there are inconsistent fluctuations of polarization resistance which occurred between 15-20 hours. These fluctuations proves that even though CI molecules are being detached from the steel surface due to high temperature, the inhibition action of the CI through adsorption of OMIBr molecules is still present.

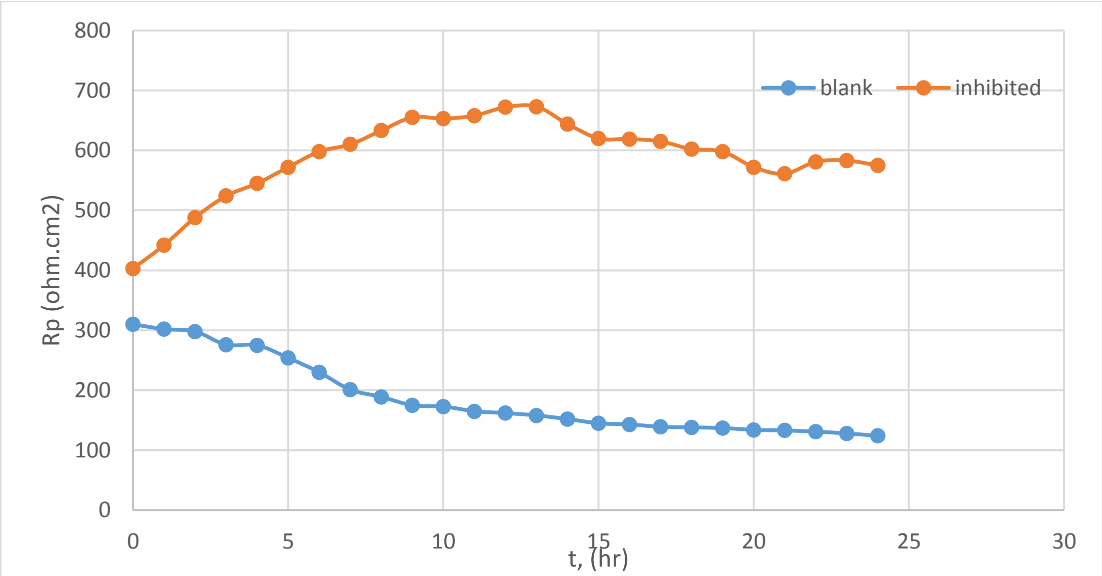


Figure 18: Polarization Resistance vs immersion time graph at 50°C

4.2.2 **Inhibition efficiency of OMIBr at 50**°C

Highest inhibition performance occurred at 23 hours where:

R_{po}=128 ohm.cm^2

R_{pinh}=583 ohm.cm^2

$$IE(\%) = \frac{R_{p_{inh}} - R_{p_o}}{R_{p_{inh}}} \; x \; 100\%$$

$$IE(\%) = \frac{583-128}{583} \; x \; 100\% = 78.04\%$$

For 70°C solution as in figure 19 below , the Rt decrement is sooner which occurs at 10 hours. This behaviour can be explained due to the high temperature which increases the rate of reaction. The CI molecules gets steadily adsorbed onto the steel surface at first, but after a certain exposure time to high working temperature , the OMIBr molecules moves restlessly due to high rate of reaction and gets detached from the steel surface which explains the decrement of Rt.

The increase in corrosion rate at test solution 500°C and 70°C can also be explained due to high rate of reaction due to high temperature. A high rate of reaction means that the corrosion reaction between Fe2+ and SO_4^{2-} occurs faster, which eventually leads to a higher corrosion rate at shorter time. The high rate of reaction also causes the film formed by OMIBr on the steel surface, to detach quicker, which leads to infiltration of sulphate ions.

Figure 19 below shows that there are inconsistent fluctuations of polarization resistance which occurred between 15-20 hours. These fluctuations proves that even though CI molecules are being detached from the steel surface due to high temperature, the inhibition action of the CI through adsorption of OMIBr molecules is still present.

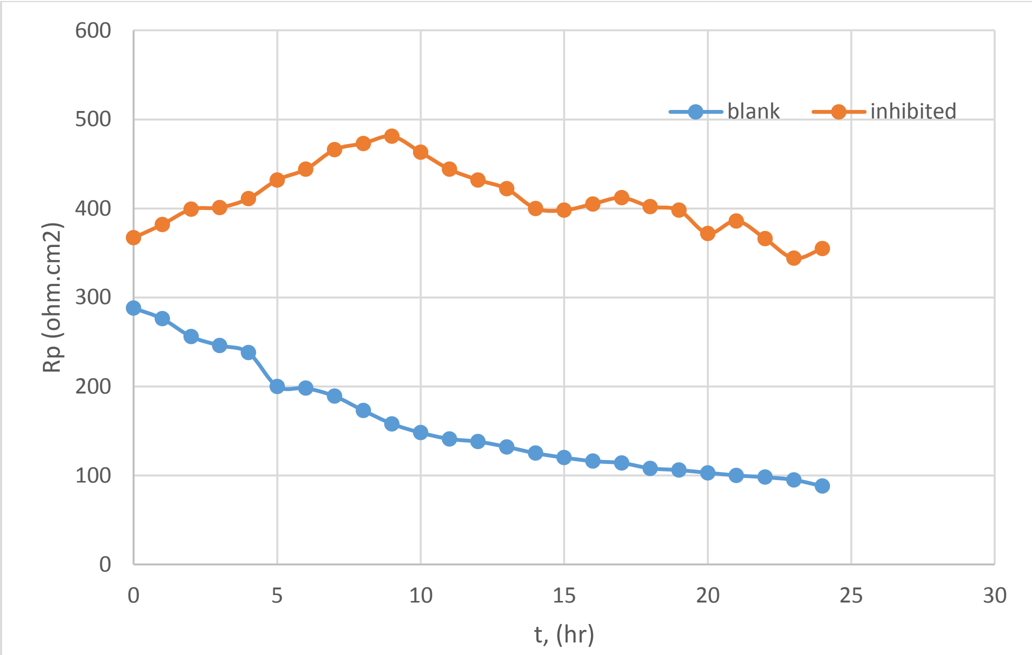


Figure 19: Polarization resistance vs immersion time graph at 70°C

4.2.3 Inhibition efficiency of OMIBr at 70°C

Highest inhibition performance occurred at 9 hours where:

R_{po}=481 ohm.cm^2

R_{pinh}=158 ohm.cm^2

$$IE(\%) = \frac{R_{p_{inh}} - R_{p_o}}{R_{p_{inh}}} x\ 100\%$$

$$IE(\%) = \frac{481-158}{481} x\ 100\% = 55.59\%$$

Inhibition efficiency of OMIBr at 70°C using Linear polarization technique is 55.59%.

From the electrochemical tests done, it was proven that OMIBr works as corrosion inhibitor in H_2SO_4, The inhibition efficiency of Ionic Liquid OMIBr in H2SO4 as in table 4 are 86.67% , 78.04% and 55.59% at temperatures 30°C , 50°C , and 70°C respectively.

Table 4: Inhibition Efficiency of OMIBr on API 5L x52 in H_2SO_4 at temperature 30°C, 50°C, and 70°C

Temperature (°C)	Polarization Resistance, R_p (Ohm.cm^2)	Polarization Resistance, R_{pinh} (Ohm.cm^2)	Inhibition Efficiency (%)
30	153.07	1114	86.67
50	128	583	78.04
70	158	481	55.59

Figure 20 below shows the inhibition efficiency of OMIBr at temperature 30°C, 50°C, and 70°C. The inhibition efficiency decreases as temperature increases. Inhibition of ionic liquid OMIBr on API 5L x52 takes place through adsorption of the Corrosion inhibitor molecules to the metal surface which acts as a film. This film prevents any infiltration of SO_4^{2-} ions and and H_3O^+ ions on the steel surface which could induce a corrosion reaction on steel surface. OMIBr doesn't only inhibit corrosion by forming layers on steel surface, but also by occupying empty spaces on the steel surface first before sulphate ions. These empty spaces, when occupied by sulphate ions, will induce corrosion. This filling these empty spaces with OMIBr molecules will block further infiltration of sulphate ions.

The decrement of inhibition efficiency with temperature can be explained due to desorption of the inhibitor molecules from the metal surface due to high working temperature .Even though there was a decrease in inhibition efficiency with increase in temperature, the inhibition effect of OMIBr is still present. This is because, the molecules structure of ionic liquid OMIBr doesn't break, decompose or vaporize due to its high decomposition temperature which is 450 °C. The molecules are still continuously adsorbed to the steel surface despite a portion of it being detached due to high temperature.

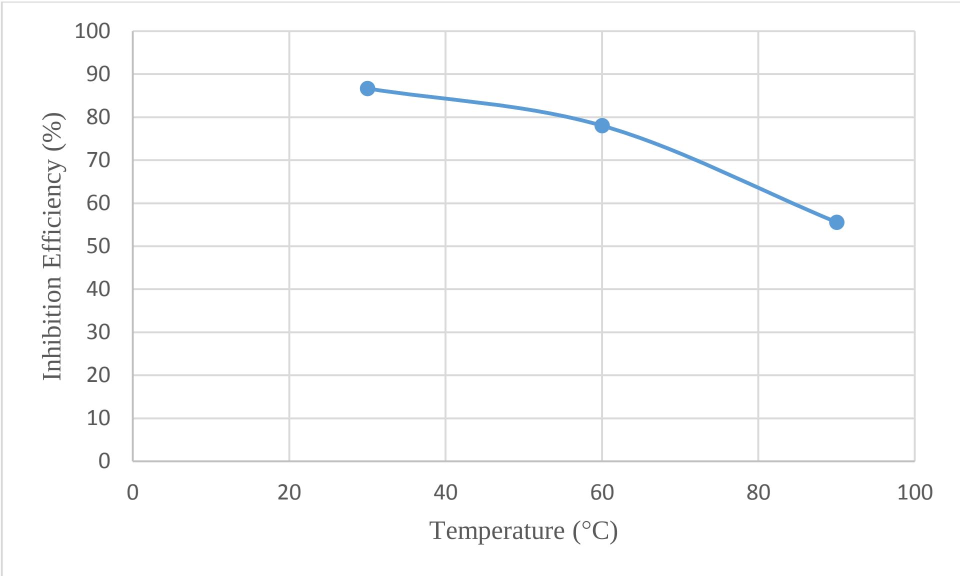


Figure 20: Temperature (°C) vs Inhibition Efficiency (%)

CHAPTER 5
CONCLUSION AND RECOMMENDATION

Corrosion rates decreases with injection of OMIBr, proving that OMIBr acts as good corrosion inhibitor on API 5L x52 in 1.0M H_2SO_4. Inhibition of OMIBr occurred through formation of protective layer, and occupation of OMIBr molecules in empty vacant sites on steel surface, preventing attack from sulphate ions. Inhibition efficiency of OMIBr at temperatures 30°C, 50°C and 70°C are 86.67%, 78.04% and 55.59% respectively. Inhibition efficiency decreases as temperature increases, due to desorption of OMIBr molecules from metal surface at high temperatures. Even though there are losses in efficiency, the inhibition performance of OMIBr is still present and maintains relatively high .This is due to high decomposition temperature of OMIBr, which makes it possible for its molecules to withstand temperature at 30°C , 50°C and 70°C without experiencing any breaking down of molecules and decomposition of microstructure.

A few recommendations I would like to make for future work are:

1. Conduct a similar experiment but using a commercial inhibitor like amides, to compare its corrosion performance with ionic liquid OMIBr.
2. Maintain same experiment parameters, but use different metal like A106 Gr B, to investigate the relation of different metal composition with inhibition performance.
3. Study the inhibition performance of OMIBr in HCl.

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