

# Investigation of Corrosion Protection of Aluminium by Domperidone in Hydrochloric Acid Medium

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**ABSTRACT:** The corrosion protection of aluminium in hydrochloric acid medium using domperidone was studied by Weight loss, Galvanostatic polarization and Electrochemical impedance techniques. The results showed that the domperidone as a drug possessed good interaction on the metal surface and control both anodic and cathodic reactions. Studies pertaining to the determination of corrosion rate, effect of inhibitor concentration and temperature on percentage inhibition efficiency of the inhibitor. Both anodic and cathodic polarized potentials were measured under galvanostatic conditions. The corrosion current density, corrosion potentials, Tafel slopes and percentage inhibition efficiency were calculated. The corrosion protection was explained on the basis of adsorption of inhibitors on the metal surface. The interaction of the inhibitor on the metal surface was confirmed by FTIR spectra.

**KEYWORDS:** Corrosion of Aluminum, weightloss method, electrochemical method, corrosion inhibitors and percentage inhibition efficiency.

## I. INTRODUCTION

Structural components made from aluminium and its alloys are vital to the aerospace industry and are important in other areas of transportation and structural materials, such as building facades and window frames. Aluminium is remarkable for the metal low density and for its ability to resist corrosion due to the formation of a compact adherent passive oxide film on its surface [1].

In acidic solutions, aluminium reacts with water to form hydrogen, and in highly alkaline ones to form aluminates. Although aluminium surface covered with a protective passivating oxide film, but this film has an amphoteric and dissolves substantially when the metal surface exposed in acidic and basic solutions in pH 4-9 range [2, 3]. The study of corrosion behaviour of aluminium and its protection against corrosion in various corrosive environments is paramount importance, which attracts considerable attention because of the many applications of the metal [4].

Hydrochloric acid is an important pickling acid, which is widely used for removal of undesirable scales and rust present on the metal surface [5-7]. Inhibitors are often used in this process mainly to control the metal loss by dissolution and also acid consumption. In efforts made to mitigate aluminium corrosion, targeted to effectively isolate the metal surface from corrosive agents. This can be achieved by the use of corrosion inhibitors [8-11]. Many researchers developed inorganic substances such as phosphates, chromates, dichromate and arsenates have been found to be effective corrosion inhibitors of many metal. But the practice of corrosion inhibition is greatly influenced by new regulations that have been developed to check the use of toxic compounds and environmental damage resulting from the use of such compounds. Hence there is a trend to replace some widely used inhibitors such as chromates and cyanides because of their toxicity, environmental damage and pollution caused by these chemicals [12].

Large number of chemical inhibitors: organic compounds, pharmaceuticals drugs, dyes and even plant extracts are developed to control metal corrosion in acidic media. The roles of these compounds are adsorbed on the metal surface interact through hetero atoms like N, S, P and O in their functional and established a barrier between the metal and

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corrosive environment thereby reducing the rate of corrosion [13-15]. It has been observed that the inhibitor effect depends essentially on structure of the chemical compounds, the nature of the metal and the strength of aggressive medium [16]. Among several methods used in combating corrosion problems, the use of chemical inhibitors remains the most cost effective and practical method. From this point of view, a great number of investigators have conducted research work to find effective inhibitors for aluminum corrosion in harsh environments [18-20].

The present investigation undertaken to study the corrosion inhibition property of domperidone a pharmaceutical drug used as corrosion inhibitor for aluminium in hydrochloric acid medium. This compound contains nitrogen and oxygen atoms, conjugation and aromatic ring. This compound is readily soluble in water, and easily forms complexes with aluminium. Chemical and electrochemical methods are employed to study the corrosion inhibition ability of the compounds. Percentage inhibition efficiency and mechanism of inhibition have been investigated by weightloss, and Tafel extrapolation methods. The inhibition action of the inhibitor is explained based on the measurement of anodic and cathodic over potentials. Adsorption of inhibitor molecule on the metal surface has been investigated using FTIR technique.

## II. MATERIALS AND METHODS

The metal like Aluminium having the compositions C=0.05%, Mn = 0.35, P = 0.032, S= 0.033% and remainder Al= 99.552 % was used for the experimental investigations. Rectangular specimens of its dimensions 2 x 5 cm<sup>2</sup> were used for the weightloss measurements. Prior to weightloss measurement, the samples were degreased with the vapours of trichloroethylene followed by mechanical polishing with different grads of emery paper. The polished samples were washed with distilled water, dried and stored in desiccators. AR grade chemicals supplied by Sisco private limited, India were used for the preparation of solutions. The domperidone compound was used for corrosion inhibition studies. Chemical name and structure of the compound were shown figure 1.

**CHEMICAL NAME :** 3-[1-[3-(2-oxo-3H-benzimidazol-1-yl)propyl]piperidin-4-yl]-1H-benzimidazol-2-one.

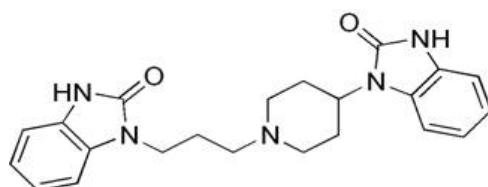


Fig.1. shows the structure of the domperidone.

The different concentration of domperidone compound is dissolved in 0.2M hydrochloric acid solution and the turbidity was removed by filtration and a clear solution taken for the corrosion inhibition studies.

### 2.1. Chemical method

#### Weightloss measurements

Weightloss measurements were performed by weighing the specimens before and after immersion in a 100 ml of acid solution at different time intervals in absence and presence of inhibitors. The same procedure was repeated for different concentration inhibitors and temperature of the test solution. Duplicate experiments were carried out in each case and the mean values of the weightloss were recorded. The corrosion rate ( $V_{corr}$ ) is determined using the relation:

$$V_{corr} = \frac{\Delta m}{St}$$

Where  $\Delta m$  is the mass loss (mg), S is an exposed area (cm<sup>2</sup>) and 't' is the immersion period (hours). The corrosion rate is expressed as mg cm<sup>-2</sup> h<sup>-1</sup>.

The percentage inhibition efficiency (%IE) was calculated using the relation:

$$\%IE = 1 - \frac{V_{corr}^1}{V_{corr}} \times 100$$

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Where  $V_{\text{corr}}$  is the corrosion rate of Aluminium in acid solution and  $V_{\text{corr}}^1$  is the corrosion rate of Aluminium in acid solution containing inhibitors.

## 2.2. Electrochemical method

### 2.2.1. Polarization measurements

The study of kinetics and mechanisms of electrode process is to obtain current-potential curves or polarization curves were performed in aqueous 0.2M HCl solution in presence and absence of the inhibitors by means of galvanostatic technique. A conventional three electrode cell consists of a Aluminium specimen exposed area of  $1 \text{ cm}^2$  as working electrode, saturated calomel and platinum were used as reference and auxiliary electrodes respectively. The cathodic and anodic polarization values were measured under galvanostatic conditions. In electrochemical method the corrosion current density ( $I_{\text{corr}}$ ) were determined by extrapolation of cathodic and anodic Tafel lines. Using corrosion current, percentage inhibition efficiency [%IE] was calculated using the formula:

$$\% \text{IE} = 1 - \frac{I_{\text{corr}}^1}{I_{\text{corr}}} \times 100$$

Where  $I_{\text{corr}}$  and  $I_{\text{corr}}^1$  were corrosion current density in absence and presence of the inhibitors respectively.

### 2.2.2. Electrochemical Impedance measurement

Electrochemical impedance measurements were carried out using an electrochemical system Frequency Response Analyzer (FRA). The results can be interpreted in terms of the equivalent circuit of the double layer, which has been used to model the metal-acid interface. Resistance polarization ( $R_p$ ) is inversely proportional to the corrosion current and was used to calculate the %IE from the following equation

$$\% \text{IE} = \frac{R_{p,i} - R_{p,o}^1}{R_{p,i}} \times 100$$

Where,  $R_p^1$  and  $R_{p,o}$  are the resistance polarization with and without the additives, respectively.

## III. RESULTS AND DISCUSSION

### 3.1. Weight Loss measurement

The corrosion rate and %IE in the presence and absence of domperidone in 0.2M HCl and immersion period 1 to 3 hour for aluminium at  $301 \pm 1\text{K}$  are presented in table 1. The results showed that the %IE increases with increase in the inhibitor concentration. The maximum %IE was found to be 89.06% in 0.2M HCl for 1 hour immersion period. Further increase in the inhibitor concentration, smaller degree of increase in inhibition was noticed. Therefore 0.0004M is considered as optimum inhibitor concentration. The results showed that the maximum %IE is found to be 92.11% with 0.0003M concentration at immersion period of 3hour. The %IE is increased with immersion time upto 3 hours and further increase in the immersion period, smaller degree of improvement was noticed. Therefore 3 hours immersion period was taken as optimum immersion time.

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Table 1: Corrosion rate & %IE of aluminium in 0.2 M HCl containing different concentration of inhibitor and immersion period 1 to 3 hours at 301 ± 1K.

Inh. Conc. [M]	1 hour		2 hour		3 hour	
	$V_{corr}$ ( $mg\ cm^{-2}\ h^{-1}$ )	%IE	$V_{corr}$ ( $mg\ cm^{-2}\ h^{-1}$ )	%IE	$V_{corr}$ ( $mg\ cm^{-2}\ h^{-1}$ )	%IE
Blank	0.750	----	1.350	----	1.750	----
0.0001	0.400	46.66	0.564	58.22	0.661	62.22
0.0002	0.209	72.13	0.290	78.51	0.257	85.31
0.0003	0.124	83.46	0.150	88.88	0.142	91.88
0.0004	0.082	89.06	0.117	91.33	0.138	92.11

### 3.2. Electrochemical methods.

#### 3.2.1. Polarization measurements

Figure 2 gives the anodic and cathodic polarization curves for aluminium in presence and absence of inhibitor in 0.2 M HCl. It is evident from the figure the anodic and cathodic curves are polarized nearly to the same extent and shows that the inhibitor is mixed type of corrosion inhibitor. The corrosion current density ( $I_{corr}$ ) was determined by extrapolating the cathodic and anodic Tafel lines. The cathodic & anodic curves tended towards a continuous linear shape at lower current densities. This effect could result from the presence of an organometallic protective layer on the electrode surface and decreased electron transfer rate at the interface. Thus the cathodic reaction would act substantially under charge transfer control [21].

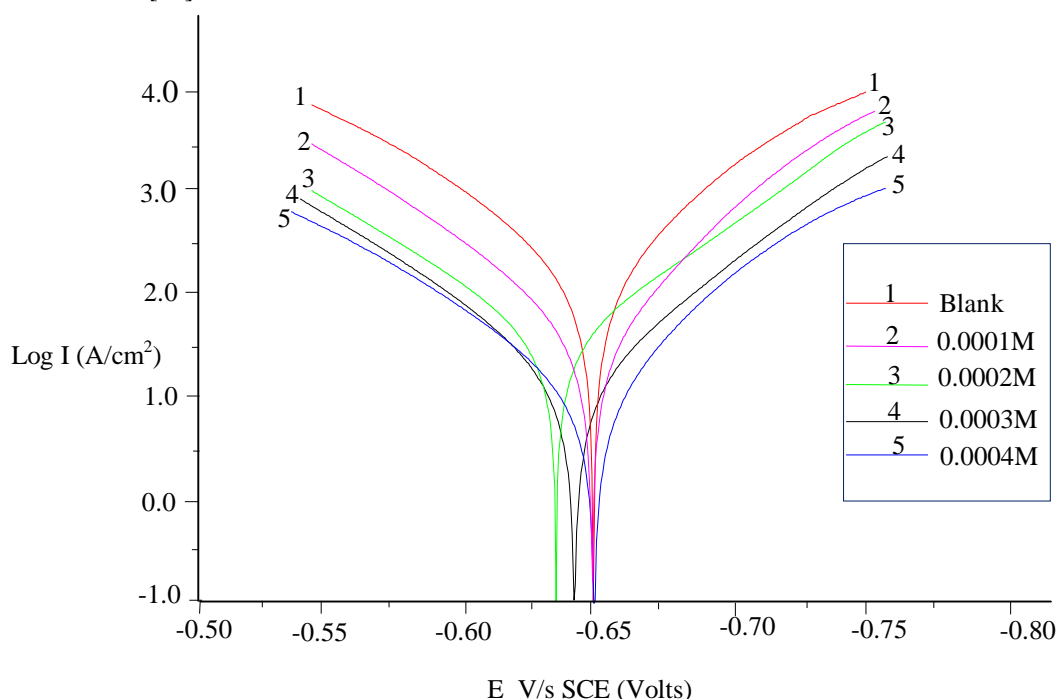


Fig. 2: Tafel plots for aluminium in 0.2M HCl in presence of different concentration of inhibitor at 301 ± 1K.

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The corrosion parameters obtained by polarisation method were presented in the table 2. The results showed that the maximum % IE was found to be 87.82 % at 0.0004M concentration of inhibitor at  $301 \pm 1$  K. The %IE obtained from the polarization technique was in good agreement with those obtained from weight loss experiment.

Table 2: Corrosion parameters obtained from polarization measurements for aluminium in 0.2M HCl containing various concentration of inhibitor at  $301 \pm 1$  K.

Conc. of Inhibitor [M]	$E_{corr}$ (V)	$I_{corr}$ ( $A\ cm^{-2}$ )	$B_c$ V/dec	$B_a$ V/dec	%IE
Blank	-0.668	187.4	-0.078	-0.052	-
0.0001	-0.663	109.1	-0.083	0.045	41.78
0.0002	-0.657	57.67	-0.085	0.053	69.22
0.0003	-0.658	40.74	-0.087	0.041	78.26
0.0004	-0.653	22.83	-0.086	0.039	87.82

### 3.2.2. Electrochemical Impedance Method

The corrosion behavior of aluminium in 0.2 M HCl solution in the presence of domperidone was investigated by EIS at  $301 \pm 1$  K. Figure 3 shows a typical set of Nyquist plots for aluminium in HCl in the absence and presence of various concentrations of inhibitor. The impedance response of aluminium in uninhibited HCl is significantly changed after addition of domperidone to the corrosive medium. The semicircle radii depend on concentration of added inhibitor. The diameter of the capacitive loop increased with increasing concentration of domperidone. Resistance polarization ( $R_p$ ) is inversely proportional to the corrosion current density and was used to calculate the %IE.

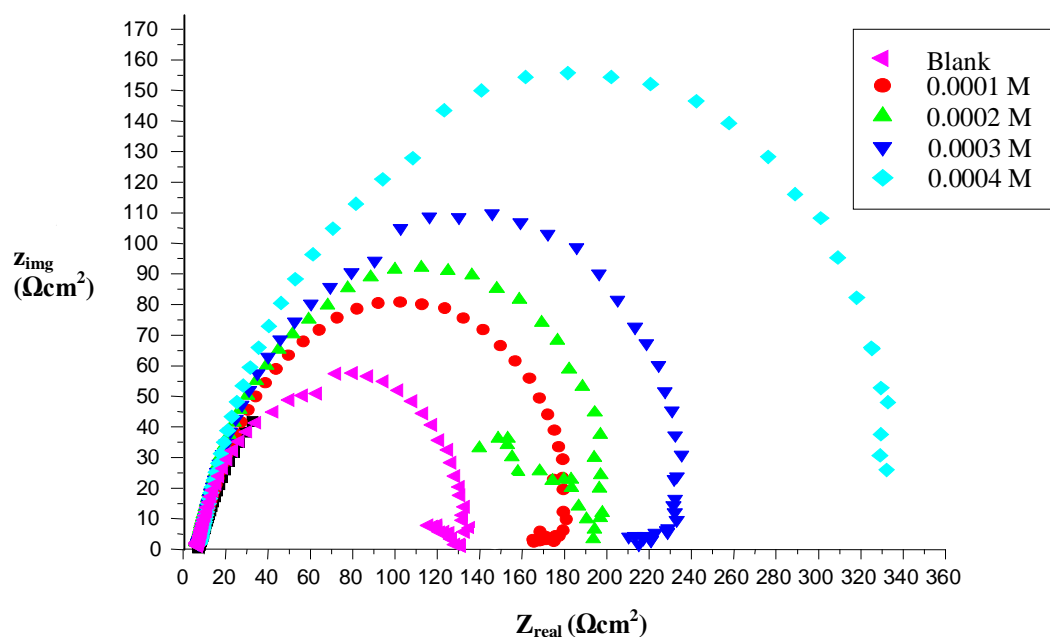


Fig. 2: Nyquist Plots for aluminium in HCl in the absence and presence of different inhibitor concentration at  $301 \pm 1$  K.

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Impedance parameters for aluminium in HCl with and without inhibitors are given in table 3. The  $R_p$  & %IE values increased with additive concentration and the capacitance values (CPE) decreased, indicating the formation of a surface film [22].

Table 3: Electrochemical impedance parameters for aluminium in 0.2M HCl in the presence and absence of inhibitor at  $301 \pm 1$  K.

Inhibitor Con.[M]	$R_p$ ( $\Omega \text{ cm}^2$ )	$C_{dl}$ ( $\mu\text{F cm}^{-2}$ )	%IE
Blank	122.5	177.0	-
0.0001	200.1	123.8	38.77
0.0002	381.0	100.6	67.85
0.0003	499.6	60.8	75.48
0.0004	846.5	52.41	85.53

### 3.3. Effect of Temperature

Effect of temperature on corrosion rate and percentage inhibition efficiency of the inhibitor was carried out at three different temperatures by weight loss method. Table 4 gives the values of corrosion rate & %IE in 0.2M HCl solution containing optimum concentration of the inhibitor. The results revealed that the corrosion of aluminium increased in acid solution and also the acid containing inhibitor with increase in temperature of 301 K, 311 K and 321 K. This is due to increase in transport action of  $H^+$  ions to the electrode surface and subsequent reduction of  $H^+$  ions. The reduction reaction in presence of inhibitor is minimum, indicated there is a formation of passive film on the electrode surface compare to the uninhibited system.

Table 4: Corrosion rate and %IE of aluminium in 0.2M HCl at different temperatures.

Temperature (K)	Corrosion Rate ( $\text{mg cm}^{-2} \text{ h}^{-1}$ )		%IE
	Blank	Inhibitor	
301K	1.35	0.143	89.41%
311K	2.55	0.392	84.63%
321K	4.30	0.880	79.53%

### 3.4. Nature of adsorption isotherm

The values of surface coverage  $\theta$  were evaluated using the values of % IE resulted from the weight loss in 0.2M HCl. A plot of  $\log(\theta/1-\theta)$  v/s  $\log C$ , a straight line is obtained, it indicate that corrosion control take place via adsorption process. The adsorption of the inhibitor molecule on aluminium surface obeys Langmuir adsorption isotherm [23].

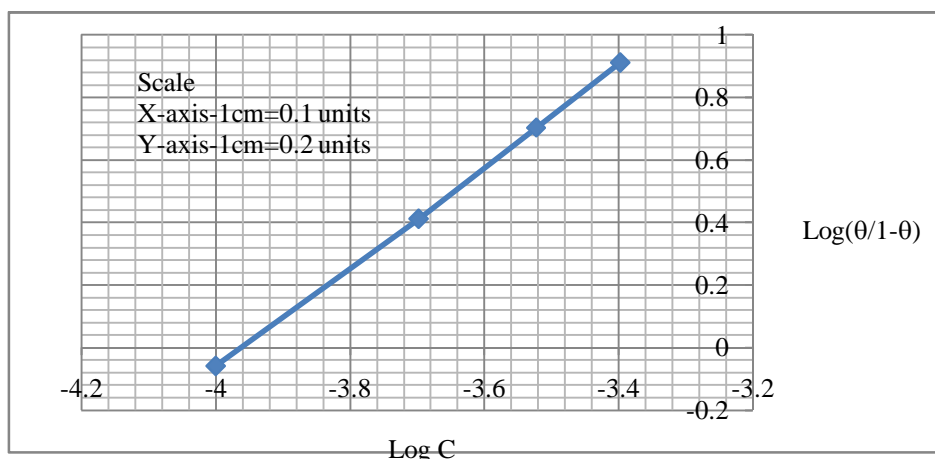


Fig. 4: Langmuir adsorption isotherm for aluminium in 0.2M HCl containing various concentration of inhibitor from weight loss study.

Activation energy was calculated from the slope of a straight lines obtained by plotting the graph of  $\log (V_{\text{corr}})$  vs  $\log 1/T$  as shown in the figure 5a & 5b.

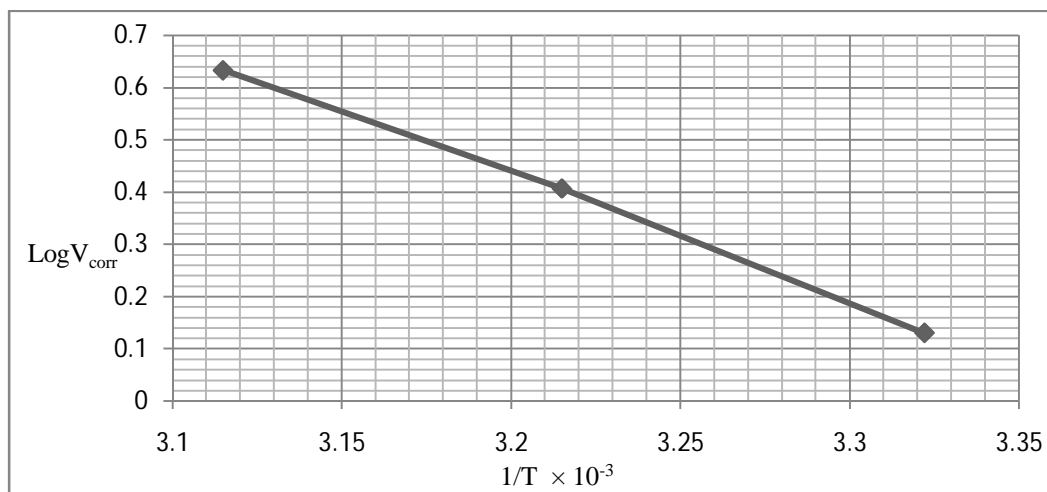


Figure 5a: Activation energy of corrosion of aluminium in 0.2M HCl.

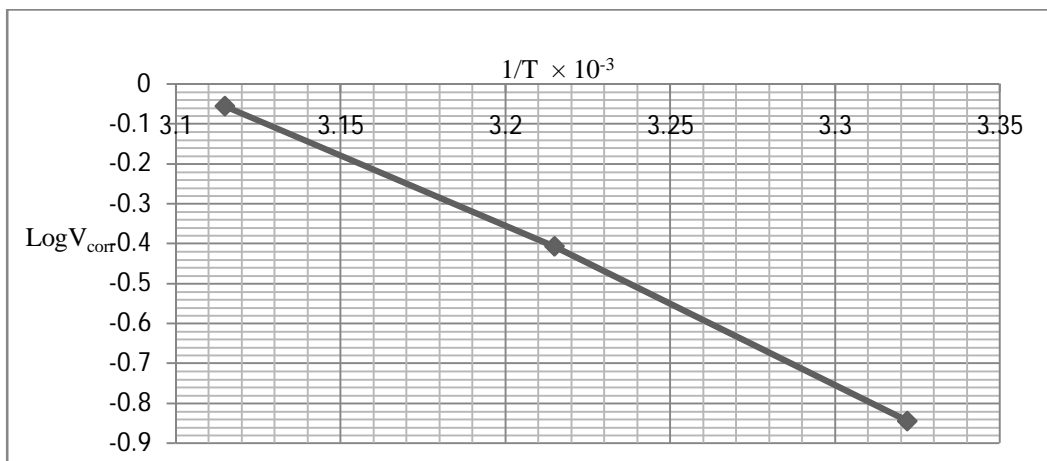


Figure 5b: Activation energy of corrosion of aluminium in 0.2M HCl containing inhibitor.

The results showed that the activation energy for corrosion of Aluminium in 0.2 M HCl is found to be  $19.03 \text{ kJ mol}^{-1}$  and in presence of inhibitor is  $29.93 \text{ kJ mol}^{-1}$ . The corrosion of aluminium required more activation energy ( $E_a$ ) in presence of inhibitor; it reveals the surface of the metal covered with inhibitor and decreases the rate of corrosion.

### 3.5. Fourier Transform Infrared Spectroscopic studies (FTIR)

FTIR studies were performed to confirm the adsorption of inhibitors on aluminium surface. Figure 6a shows the FTIR spectrum of the pure sample of domperidone and the Figure 6b shows the spectrum of scrapped compound from the corroded metal surface. The peaks at  $3432.11 \text{ cm}^{-1}$  is characteristic peak corresponding to the stretching vibration of the  $-N-H$  bond of the amino group. This peak modified to  $3440.48 \text{ cm}^{-1}$  in the spectrum of the sample collected from the metal surface. Several peaks in Figure 6a (domain:  $1691.20$  to  $1116.59 \text{ cm}^{-1}$ ) are modified / disappeared in Figure 6b



(domain:  $1634.61$  to  $1112.18$   $\text{cm}^{-1}$ ). This disappearance/modification of these bands indicates the establishment of chemical bonds between nitrogen and oxygen atoms of the compound to the metal surface [24].

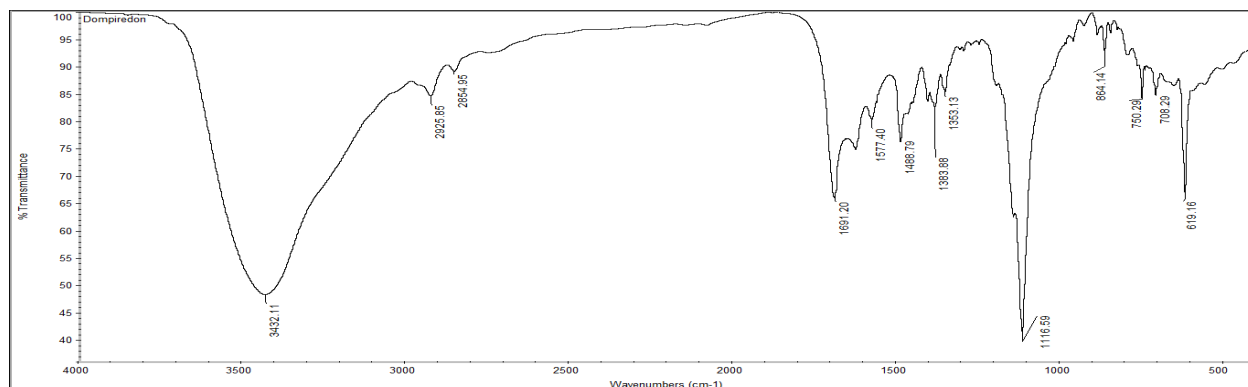


Fig.6: FTIR spectrum of Domperidone compound.

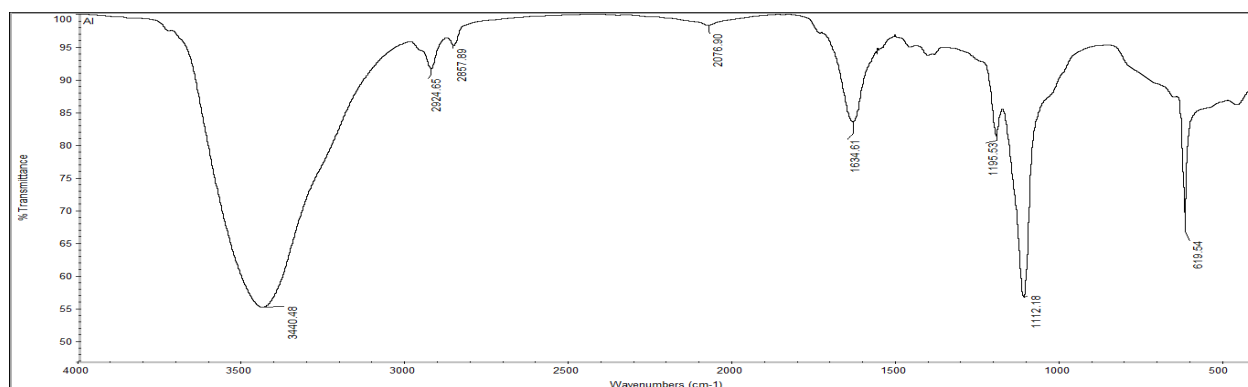


Fig.6b: FTIR spectrum of adsorbed compound scrapped from the corroded Aluminium surface

#### IV. CONCLUSION

The chemical and electrochemical corrosion studies shows that the domperidone control the dissolution of aluminium to a greater extent in 0.2M HCl at  $301 \pm K$ . The percentage inhibition efficiency depends on the inhibitor concentration, immersion period and temperature of the medium and molecular structure of the compound. The inhibitor controls the rate of both anodic & cathodic reactions and acts as a mixed type inhibitor. The corrosion inhibition takes place via adsorption of the inhibitor and obeys Langmuir's adsorption isotherm. FTIR studies revealed that, domperidone interact on the metal surface through hetro atoms present in the compound and form a barrier between the metal – solution interface and isolate the electrode surface from the corrosive medium. The domperidone compound is soluble in water, non toxic and can be used as effective corrosion inhibitor for aluminium in acid medium.

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