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Optimization of the Inhibitor Efficiency of a Triazole on Corrosion of Mild Steel in 1M HCl

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A B S T R A C T

In this work we have tried to find the best conditions to obtain maximum inhibitor efficiency of the triazole inhibitor on mild steel in a 1M HCl medium by following a response methodology. We have drawn up an experimental plan with three factors and two levels per factor in a simple way, without the use of specific software. The response (inhibitor efficiency) was evaluated by the gravimetric method. We have chosen the parameters most used in the corrosion field such as inhibitor concentration, immersion time and temperature. The results were found as the best inhibition condition of concentration of inhibitor 10^{-3} M, temperature of 30 °C and an immersion time of 24 h.

1. Introduction

The majority of the inhibitors used in acid medium are organic compounds containing of heteroatoms and of the aromatic cycles among these inhibitor: amines [1-4], mercaptans [5-6], aminothiols [7-9], thio-compounds [10], triazole [11-15], oxadiazoles [16-17], imidazol [18-20], thiazoles [21], phosphonate [22] and carboxylates [23]. Inhibitor Efficiency% depends on several parameters such as the concentration of the inhibitor, the temperature of the medium, the time of immersion.

The influences of these factors were tested by using the methodology of the experimental models [24]. We chose three factors with two levels thus 2^3= 8 possibilities. The model 2^k (K factors with 2 levels each one) is most widespread because being the least prohibitory at the financial level while remaining powerful. Among the advantages of the experimental designs are: Reduction amongst tests, Detection of the interactions between factors, modeling of the studied answer and an optimum precision of the results.

2. Experimental Methods

2.1 Inhibitor

The organic compounds (Hexaconazole), used as corrosion inhibitor, is a commercial product "Anvil". Brute Formula: $C_{14}H_{17}Cl_2N_3O$; Developer Formula: (RS)-2-(2,4-dichlorophenyl)1-(1H)-1,2,4-triazol-1-yl) hexane-2-ol (Fig. 1).

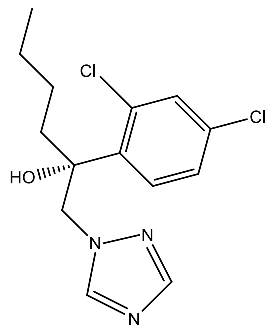

Fig. 1 The molecular structure of Hexaconazole

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2.2 Specimens

Mild steel specimens containing 0.09% P, 0.38% Si, 0.01 Al, 0.05 Manganese, 0.21% C, 0.05% sulphur and the remainder. Fe were used for the gravimetric and electrochemical measurements, these steel specimens were mechanically cut into 1 cm × 5 cm × 0.06 cm dimensions for weight loss experiment. For electrochemical experiments. The specimens were exposed a geometrical surface area of 1 cm^2 to the electrolyte .Prior to all measurements. Were mechanically polished on wet SiC paper (grade 120 -400–600-1200), rinsed with doubly distilled water, degreased ultrasonically in ethanol for 5 min and dried at room temperature.

2.3 Gravimetric Measurement

The weight loss of steel with and without the addition of different concentration of inhibitor was determined after immersion in acid over 6 h at 30 °C, the percentage inhibition efficiency (η%) was calculated from:

$$\eta\% = \frac{W_\circ - W}{W_\circ}$$

where W_0 and W are the values of the corrosion weight loss of steel after immersion in solutions without and with inhibitor respectively.

2.4 The Strategy of the Experimental Designs

2.4.1 Identification of the Factors

The three factor principals being able to influence the inhibitor efficiency are:

- The concentration of the inhibitor
- The temperature of the medium
- The time of immersion

Having decided to use two levels per factor, brainstorming indicates the values below (Table 1):

Table 1 The high and low levels of factors

Factor	Low level	High level
Concentration	10^{-6} M	10^{-3} M
Temperature	30 °C	60 °C
Time	6 h	24 h

2.4.2 Determining the Design of the Experimental Plan

The possible combinations three factors with two levels each are shown in the Table 2 below:

Table 2 The possible combinations with the signs

Combination	Concentration	Temperature	Time
1	-	-	-
2	+	-	-
3	-	+	-
4	+	+	-
5	-	-	+
6	+	-	+
7	-	+	+
8	+	+	+

We have 8 possibilities. "+" Indicates high levels (10^{-3} M for example for concentration or 60 °C for temperature) and «-" indicates low levels (6 hours for immersion time). After the determination of the signs + and - we replace them by their values (Table 3).

Table 3 The combinations with the values of the factors

Combination	Concentration	Temperature	Time
1	10^{-3} M	30 °C	6 h
2	10^{-6} M	30 °C	6 h
3	10^{-3} M	60 °C	6 h
4	10^{-6} M	60 °C	6 h
5	10^{-3} M	30 °C	24 h
6	10^{-6} M	30 °C	24 h
7	10^{-3} M	60 °C	24 h
8	10^{-6} M	60 °C	24 h

3. Results and Discussion

3.1 Determination of Response

For experiment 1, we determined the level of the inhibitor efficiency with a concentration of 10^{-3} M, a temperature of 30 °C and an immersion time level of 6 h. For experiment 2, we took a concentration of 10^{-6} M, a temperature of 30 °C and an immersion time of 6h and so on. The results obtained are given in Table 4.

Table 4 The combinations with response

Combination	Concentration	Temperature	Time	The Inhibitor Efficiency%
1	10^{-3} M	30 °C	6 h	92
2	10^{-6} M	30 °C	6 h	82
3	10^{-3} M	60 °C	6 h	86
4	10^{-6} M	60 °C	6 h	80
5	10^{-3} M	30 °C	24 h	96
6	10^{-6} M	30 °C	24 h	83
7	10^{-3} M	60 °C	24 h	90
8	10^{-6} M	60 °C	24h	88

3.2 Analysis of the Results

There are 7 analyzes carried out as follows,

- Analysis of the impact concentration
- Analysis of the impact temperature
- Analysis of the impact time
- Analysis of the impact concentration and temperature
- Analysis of the impact temperature and time
- Analysis of the impact concentration and time
- Analysis of the impact concentration, temperature and time

To perform these analyzes, make a few simple calculations. The effect of the concentration factor on our response (The Inhibitor Efficiency) can be measured as follows: Sum of ys (responses) with high concentration (10^{-3} M) divided by 4 (since 4 "+" were used) minus the sum of yrs. with low concentration (10^{-6} M) divided by 4.

$$\frac{(92+86+96+90)}{4}-\frac{(82+80+83+88)}{4}=7.75$$

We can conclude, for the concentration factor, that when the concentration is at its high value (10^{-3} M) the inhibitory efficiency increases by 7.75%.

Analysis of the temperature factor gives:

$$\frac{(86+80+90+88)}{4}-\frac{(92+82+96+83)}{4}=-2.25$$

For the temperature factor, that when the temperature is at its high value (60 degrees) the inhibitor efficiency decreases by 2.25%.

Analysis of the time factor gives:

$$\frac{(96+83+90+88)}{4}-\frac{(92+82+86+80)}{4}=4.25$$

The temperature factor has a very small impact on the inhibitor efficiency and the time factor at a greater impact but much less than the concentration factor.

For reasons of space we have called the concentration factor A, the temperature factor B and the time factor C. AxB is therefore the combination of concentration and temperature factors.

The results of each combination are simply the mathematical results of the mixture of factors.

Thus, for AxB, the combination of concentration and temperature, the first combination gives "-" for the concentration and "-" for the temperature. The result AxB is "-" x "-" which gives us a "+" and so on (Tables 5 and 6).

Table 5 The combinations of the interactions between factors with the signs

Combination	Concentration	Temperature	Time	AxB	BxC	AxC	AxB xC
1	-	-	-	+	+	+	-
2	+	-	-	-	+	-	+
3	-	+	-	-	-	+	+
4	+	+	-	+	-	-	-
5	-	-	+	+	-	-	+
6	+	-	+	-	-	+	-
7	-	+	+	-	+	-	-
8	+	+	+	+	+	+	+

Table 6 The combinations of the interactions between factors with the values of the factors

Combination	Concentration	Temperature	Time	AxB	BxC	AxC	AxB xC	The inhibitor Efficiency %
1	10^{-3} M	30 °C	6 h	+	+	+	-	92
2	10^{-6} M	30 °C	6 h	-	+	-	+	82
3	10^{-3} M	60 °C	6 h	-	-	+	+	86
4	10^{-6} M	60 °C	6 h	+	-	-	-	80
5	10^{-3} M	30 °C	24 h	+	-	-	+	96
6	10^{-6} M	30 °C	24 h	-	-	+	-	83
7	10^{-3} M	60 °C	24 h	-	+	-	-	90
8	10^{-6} M	60 °C	24 h	+	+	+	+	88

Analysis of the AxB combination

$$\frac{(92+80+96+88)}{4}-\frac{(82+86+83+90)}{4}=3.75$$

Analysis of the BxC combination

$$\frac{(92+82+90+88)}{4}-\frac{(86+80+96+83)}{4}=1.75$$

Analysis of the AxC combination

$$\frac{(92+86+83+88)}{4}-\frac{(82+80+96+90)}{4}=0.25$$

Analysis of the AxBxC combination

$$\frac{(82+86+96+88)}{4}-\frac{(92+80+83+90)}{4}=1.75$$

The effects of the combinations have been grouped in the Table 7 and Fig. 2.

Table 7 The effects of the combinations

Factor	Effect
Concentration - A	+ 7.75
Temperature - B	- 2.25
Time - C	+ 4,25
AxB	+ 3.75
BxC	+ 1.75
AxC	+ 0.25
AxBxC	+ 1.75

From the results we noticed that the factor with the most influence is concentration. This factor is much higher than the others and then, the immersion time.

Thus, it will be essential to control the concentration and time (for example by applying a maximum concentration and controlling the time) and to maximize the inhibitor efficiency.

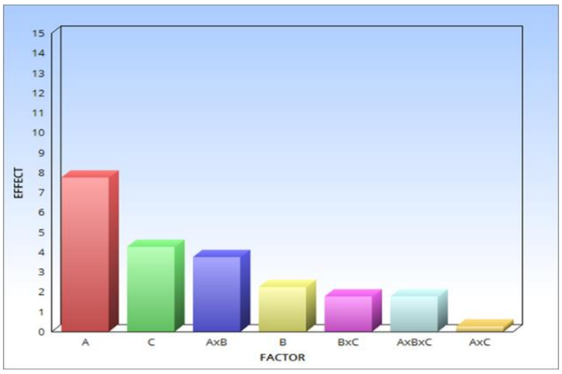

Fig. 2 Histogram shows the effect of each combination

4. Conclusion

The response methodology was used to find out the best conditions by means of hexaconazole as corrosion inhibitor of mild steel in 1 M HCl. The strategy of the experimental designs which we have followed provides the results as (concentration of inhibitor 10^{-3} M, a temperature of 30 °C and an immersion time of 24 h) to find the best conditions to obtain the maximum inhibitor efficiency.

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