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Use of Experimental Designs to Evaluate the Influence of a triazole on the Corrosion of ordinary Steel in HCl (1 M) Environment

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ABSTRACT: *The present study attempted to investigate the best conditions for the use of Bromuconazole as corrosion inhibitor of ordinary steel in 1 M HCl through the use of the surface response methodology. In this work 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. The results were analyzed and discussed.*

Keywords*: corrosion inhibition, experimental designs, gravimetric method, steel.*

I. INTRODUCTION

Carbon steel has been widely used as tubing material for condensers and heat exchangers in various cooling water systems because of their resistance to corrosion. Ordinary steel materials are extensively used to fabricate structures and components exposed to sea water and petroleum production and refining.

One of the most important methods in corrosion protection is the utilization of organic inhibitors [1-3]. In general, the organic compounds have demonstrated a great effectiveness in inhibiting the aqueous corrosion of many metals and alloys [4-10].The inhibiting action of those organic compounds is usually attributed to interactions with metallic surface by adsorption. The adsorption of inhibitors takes place through heteroatoms such as oxygen, phosphorus and sulphur or aromatic rings containing polar groups and π electrons [11].

Inhibitor Efficiency % depends on several parameters such as the concentration of the inhibitor, the temperature of the medium, the time of immersion… In this paper, the influences of these factors were tested by using the methodology of the experimental models [12]. 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.

II. EXPERIMENTAL DETAILS

2.1. Inhibitor:

The organic compounds (Bromuconazole), used as corrosion inhibitor, is a commercial product "Vectra".

• Brute Formula C13 H12 BrCl2 N3 O

• Developer Formula: 1 – ((4 – Bromo – 2 – (2, 4 –dichlorophenyle tetra hydro- 2 – furanyle) methyl) – 1 H – 1, 2, 4, - triazole

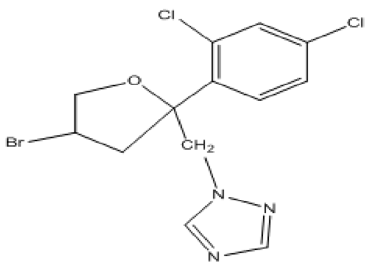

Fig.1: the molecular formula of Bromuconazole.

2.2. Specimens

Ordinary steel specimens containing 0.11% C , 0.24 % Si , 0.47% Mn , 0.12% Cr , 0.02% Mo , 0.1% Ni , 0.03% Al , Co< 0.0012% ,Cu 0.14% ,V < 0.003% , W 0.06% and the remainder Fe was used as the substrate, these steel specimens were mechanically cut into 1cm × 5 cm × 0.06 cm dimensions for weight loss experiment .Prior to all measurements. Were mechanically polished on wet SiC paper (grade 120 - 400 – 600 - 1200), rinsed with doubly distilled water, degreased 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 W0 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. Establish the objective of the experiment

Our objective is to maximize the inhibitor efficiency.

2.4.2. Identification of the factors

We determined that the three factors 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: The high and low levels of factors

Factor	Low level	High level
Concentration	10-5 M	10-3 M
Temperature	30 °C	60 °C
Time	24 h	48 h

2.4.3. Determining the design of the experimental plan

So we have three factors with two levels each. The possible combinations are shown in the table 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 (24 hours for immersion time)

2.4.4. Proceed with the experiment

After the determination of the signs + and - we replace them by their values

Table.3: The combinations with the values of the factors

combination	Concentration	Temperature	Time
1	10-5 M	30 °C	24 h
2	10-3 M	30 °C	24 h
3	10-5 M	60 °C	24 h
4	10-3 M	60 °C	24 h
5	10-5 M	30 °C	48 h
6	10-3 M	30 °C	48 h
7	10-5 M	60 °C	48 h
8	10-3 M	60 °C	48 h

III. RESULTS AND DISCUSSION

3.1. Determination of response

For experiment 1, we will determine the level of the inhibitor efficiency with a concentration of 10-5 M, a temperature of 30 °C and an immersion time level of 24 h. For experiment 2, we will take a concentration of 10-3 M, a temperature of 30 °C and an immersion time of 24 h 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	10-5 M	30 °C	24 h	83
2	10-3 M	30 °C	24 h	92
3	10-5 M	60 °C	24 h	80
4	10-3 M	60 °C	24 h	90
5	10-5 M	30 °C	48 h	87
6	10-3 M	30 °C	48 h	97
7	10-5 M	60 °C	48 h	80
8	10-3 M	60 °C	48 h	96

3.2. Analysis of the results

We will carry out 7 analyzes:

- 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 ys with low concentration (10-5 M) divided by 4.

$$\frac{(92+90+97+96)}{4}-\frac{(83+80+87+80)}{4}=11.25$$

We can conclude, for the concentration factor, that when the concentration is at its high value (10-3 M) the inhibitory efficiency increases by 11.25%.

Analysis of the temperature factor gives:

$$\frac{(80+90+80+96)}{4}-\frac{(83+92+87+97)}{4}=-3.25$$

For the temperature factor, that when the temperature is at its high value (60 degrees) the inhibitor efficiency decreases by 3.25%.

Analysis of the time factor gives:

$$\frac{(87+97+80+96)}{4}-\frac{(83+92+80+90)}{4}=3.75$$

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.

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	10-5 M	30 °C	24 h	+	+	+	-	83
2	10-3 M	30 °C	24 h	-	+	-	+	92
3	10-5 M	60 °C	24 h	-	-	+	+	80
4	10-3 M	60 °C	24 h	+	-	-	-	90
5	10-5 M	30 °C	48 h	+	-	-	+	87
6	10-3 M	30 °C	48 h	-	-	+	-	97
7	10-5 M	60 °C	48 h	-	+	-	-	80
8	10-3 M	60 °C	48 h	+	+	+	+	96

Analysis of the AxB combination

$$\frac{(83+90+87+96)}{4}-\frac{(92+80+97+80)}{4}=1.75$$

Analysis of the BxC combination

$$\frac{(83+92+80+96)}{4}-\frac{(80+90+87+97)}{4}=-0.75$$

Analysis of the AxC combination

$$\frac{(83+80+97+96)}{4}-\frac{(92+90+87+80)}{4}=1.75$$

Analysis of the AxBxC combination

$$\frac{(92+80+87+96)}{4}-\frac{(83+90+97+80)}{4}=1.25$$

The effects of the combinations have been grouped in the table 7 and figure 2

Table.7: The effects of the combinations

Factor	effect
Concentration - A	+ 11.25
Temperature - B	- 3.25
Time - C	+ 3.75
AxB	+ 1.75
BxC	- 0.75
AxC	+1.75
AxBxC	+ 1.25

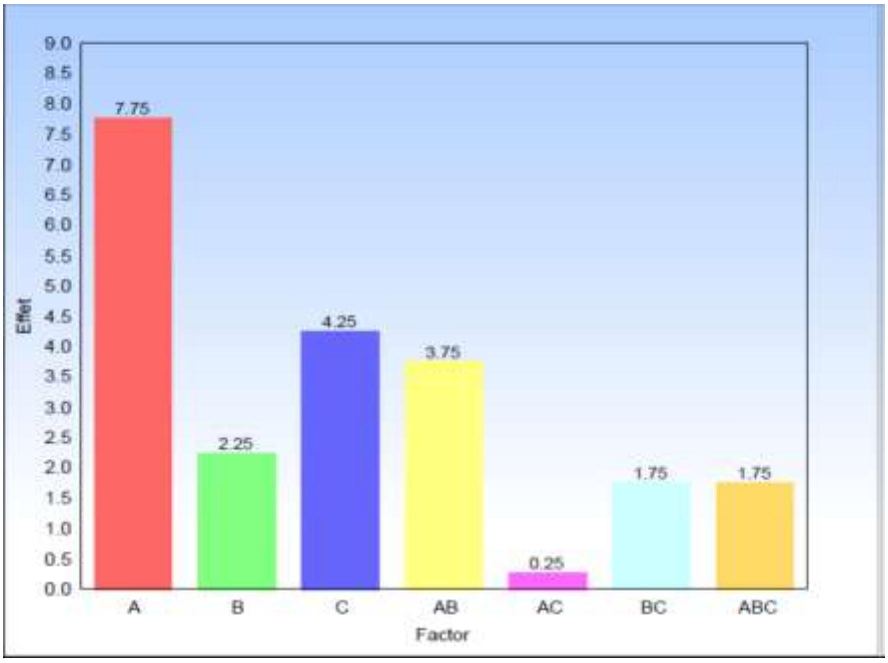

Fig.2: Histogram shows the effect of each combination

From the results we notice that the factor with the most influence is concentration. This factor is much higher than the others. 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.

IV. CONCLUSION

- Bromuconazole is a very good inhibitor in 1M HCL.
- The experiment design methodology allowed us to reduce the number of tests.
- The strategy of the experimental designs which we have followed will allow us to find the best conditions to obtain the maximum inhibitor efficiency.

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