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Evaluation of Corrosion Inhibition of Low-Carbon Steel Using Chamomile Plant Extract

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ABSTRACT: The investigation focused on elucidating the corrosion inhibition mechanism of chamomile extract, serving as an environmentally sustainable inhibitor, across various concentrations (0.2, 0.4, 0.6, 0.8, 1.0 w/v %) applied to carbon steel immersed in a 0.6 M NaCl variations in temperature affect the solution. (303, 313, 323, 333 K). The analytical approach involved Assessment of weight reduction metrics complemented by sophisticated techniques, Scanning Electron Microscopy (SEM), Gas Chromatography-Mass Spectrometry (GC-MS), and Energy Dispersive X-ray Spectroscopy (EDS) were used to analyze the carbon steel surface with and without the extract. The principal aim was to conduct a detailed examination of the development of a layer of adsorption layer. The obtained results consistently validated a positive correlation between inhibition efficiency and extract concentration. SEM imaging visually substantiated a more extensive protective film at higher inhibitor concentrations, and EDS analysis corroborated these findings by detailing the elemental composition of the adsorbed layer. The observed reduction in inhibition efficiency with elevated temperatures suggests a thermodynamic effect, where increased temperatures diminish the adsorption of the inhibitor onto the metal surface. This comprehensive investigation establishes the potential of chamomile extract as an eco-friendly inhibitor for effectively mitigating corrosion on carbon steel in corrosive environments. The pinnacle of inhibition efficiency, reaching 96.55%, was achieved at the concentration of the inhibitor.

Keywords: Corrosion Inhibition, Corrosion evaluation, Low Carbon Steel, Chamomile Extract.

1. INTRODUCTION

Low carbon steel, prized for its superior structural and mechanical attributes, technological value, and widespread industrial applications, encounters significant challenges in corrosive environments, particularly those involving acid solutions (1). Industries, spanning salt pickling to petrochemical processes, grapple with the complex issue of corrosion in low carbon steel (2). To counteract this, approaches to prevent corrosion include the application of protective layers and the utilization of materials resistant to corrosion and environmental control measures, with material and production method choices influenced by environmental and economic considerations. Corrosion inhibitors play a pivotal role in mitigating low carbon steel corrosion in salt settings, with major industries encompassing sectors such as petroleum refinement, exploration of oil and gas, water treatment processes, chemical production, and the addition of products., driving substantial demand. The efficacy of inhibitors hinges on their ability to absorb onto metal surfaces, achieved through physisorption, chemisorption, or a combination of both processes (3-5). The organic adsorption type inhibitors formulation employs diverse chemical functionalities, notably those featuring electronegative functional groups, crucial for effective adsorption on the metal surface (6). Organic compounds containing electronegative functional groups, as well as heteroatoms like S, P, N, and O, and π electrons in triple and conjugated double bonds, are very effective in preventing corrosion. This is because they easily attach to metal surfaces (7). Regrettably, a substantial proportion of presently employed corrosion inhibitors within industrial contexts are characterized by elevated costs, pronounced toxicity, and environmental peril (8). The imposition of stringent environmental standards in recent years has redirected

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the focus of researchers towards the development of alternative corrosion inhibitors that are non-toxic and environmentally benign (9).

Plant extracts, distinguished for their abundance in naturally synthesized organic compounds, have emerged as significant contributors to this pursuit, given their eco-friendly, bio-compatible, and renewable attributes (10). Ongoing scientific investigations have scrutinized various plant extracts, encompassing polyphenolic compounds, tannins, alkaloids, and carbohydrates, for their inhibitory potential (11).

Matric area is scientifically known as chamomile (12). It is widely accepted throughout Europe, Asia, Africa, North America, and South America, where it thrives along roads, valleys and close to homes, earning it the traditional nickname "field chamomile" due to its prevalence in grassy landscapes (13). Chamomile is an ancient plant remedy used to treat a variety of ailments. (14). It facilitates enhanced sleep through its antioxidant content and provides toothache relief (15). It effectively relieves nervous tension, treats shortness of breath, liver colic, and cystitis. Its bioactive compounds Azulene and Bisabol contribute to its analgesic and anti-inflammatory properties (16).

2. MATERIALS AND METHODES

2.1 SAMPLES PREPARATION

Carbon steel samples utilized in this study have the following composition (Table 1). Samples for weight loss measures were cut into 3cm × 1.5cm x 2mm pieces. To smooth the metal surface of carbon steel samples, several grades of SiC paper were used, followed by washing with distilled water and drying with a cloth.

2.2 Corrosive medium preparation

To evaluate the corrosion study, a 0.6 M NaCl solution was created by distilled water.

2.3 Inhibitor preparation

Chamomile plant powder was cleaned with distilled water to remove soil and dust residue. Then, 10 g was extracted by boiling in water for 3 hours. The extracted plant's water was evaporated to create a 200 mL concentrated solution following filtration. The plant extract inhibited carbon steel at varying doses (2, 4, 6, 8, and 10) mL L^{-1} and temperatures (303, 313, and 323 K).

2.4 Experiment on corrosion

Investigation of the inhibitory effects of chamomile plant extract on carbon corrosion. The steel was analyzed using the weight loss technique in a 0.6 M NaCl solution. The analysis was conducted after immersing the steel for 4 hours at various temperatures. Precious the levels of inhibitory efficiency (IE%) and corrosion rate (CR) were measured. Samples of carbon steel were gathered. The object is measured in weight after it has been submerged in 50 milliliters of corrosive substances.

The medium exhibits distinct characteristics in both absence and presence of inhibitor concentrations. The samples underwent a cleaning process. After rinsing the water with distilled water, the water was dried using paper towels and then measured using a precise scale.

The corrosion rate **CR** The values were deduced based on the provided given:

$$\mathbf{CR} = \frac{\Delta\ \mathbf{W}}{\mathbf{A\ x\ t}}$$

The chemical composition of carbon steel sample

C %	Si %	Mn %	P %	S %	Cr %	Mo %	Ni %	Cu %	Al %
0.193	0.442	9.75	0.0409	0.0143	9.00	0.0186	0.956	0.817	0.001

Where ΔW is the weight loss (g) is determined by the total area (m^2) of the carbon steel sample and the immersion duration (day).

The calculation of inhibition efficiency was conducted by applying the subsequent relationship:

$$IE\ \% = \frac{\mathbf{CR\ uninh.} - \mathbf{CR\ inh.}}{\mathbf{CR\ uninh}}\ x\ \mathbf{100}$$

In this context, **CR_union** and **CR_inh** represent the corrosion rates of carbon steel samples were measured both in the absence and presence of the inhibitor.

2.5 GC-mass analysis

Gas chromatography-mass spectrometry (GC-MS) is indeed a powerful analytical technique that combines the separation capabilities of gas chromatography with the detection and quantification capabilities of mass spectrometry. Gas chromatography separates the components of a sample mixture, while mass spectrometry identifies and quantifies these components based on their mass-to-charge ratio. This technique finds extensive applications in environmental analysis, forensic science, pharmaceuticals, and many other fields due to its versatility and sensitivity (17).

2.6 Sem analysis

The morphology of the carbon steel was examined using scanning electron microscopy (SEM). The SEM micrographs were captured to examine the protective layer. The objective is to assess the effects of an inhibitor on the morphology of a sample surface while exposed to a saline corrosive solution, and to identify any changes compared to when the inhibitor is not present (18).

2.7 Eds analysis

The EDS spectra indicated the presence of chlorine, sodium, and oxygen in varying proportions on the surface of the carbon steel. The specimens were submerged in a 50 mL solution of the sample was immersed in a 0.6 M NaCl solution for a duration of 3 hours, both with and without the highest concentration of inhibitor in the corrosive solution. Scanning electron microscopy (SEM) and energy-dispersive X-ray spectroscopy (EDS) were performed using a Tescan-Mira3 scanning electron microscope from France (19).

3. RESULTS AND DESCUSSION

3.1 Sem analysis

SEM micrographs were obtained to examine the condition of the carbon steel surface before and after exposure to a 0.6 M NaCl solution, both in the absence and presence of chamomile extract as an inhibitor. The polished surface of carbon steel prior to immersion revealed a pristine condition, while Fig. 2b depicts heavy corrosion on the immersed surface in the absence of the inhibitor. Conversely, in the presence of the inhibitor, the corrosion rate decreased, leading to a smoother surface due to the formation of a protective layer. This observation is consistent with findings reported by Morad and El-Dean (2006).

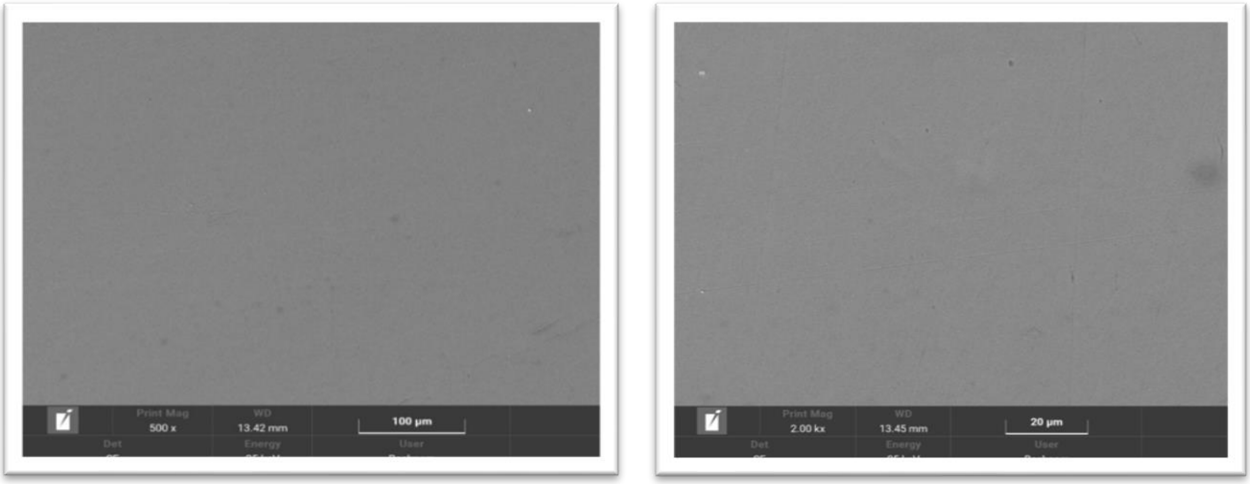

FIGURE 1. - SEM micrograph of carbon steel surface before the immersion in 0.6 M NaCl solution

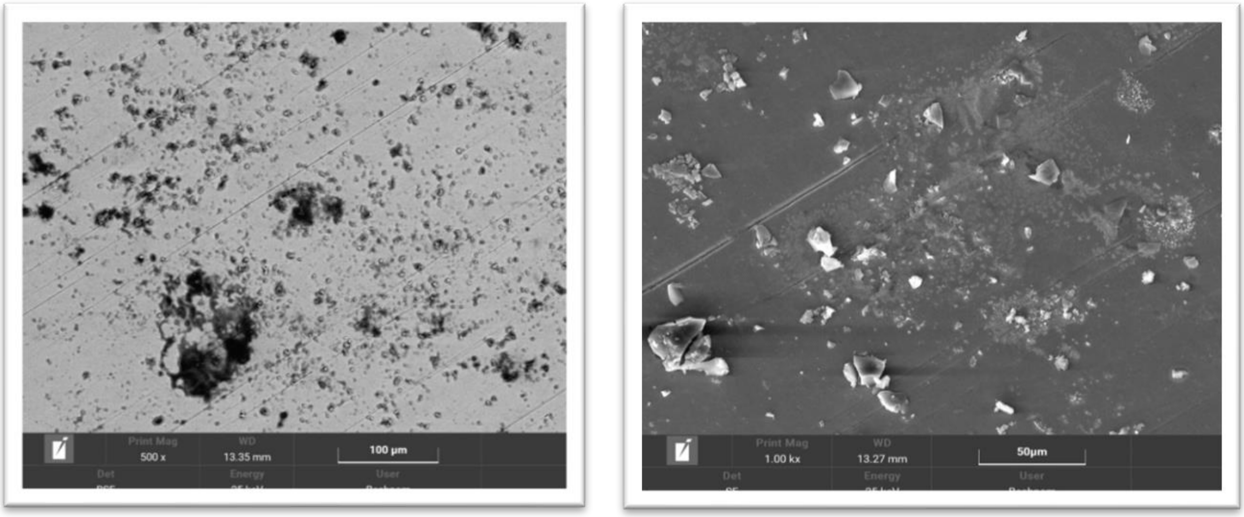

FIGURE 2. - SEM micrograph of carbon steel surface after the immersion in 0.6 M NaCl solution

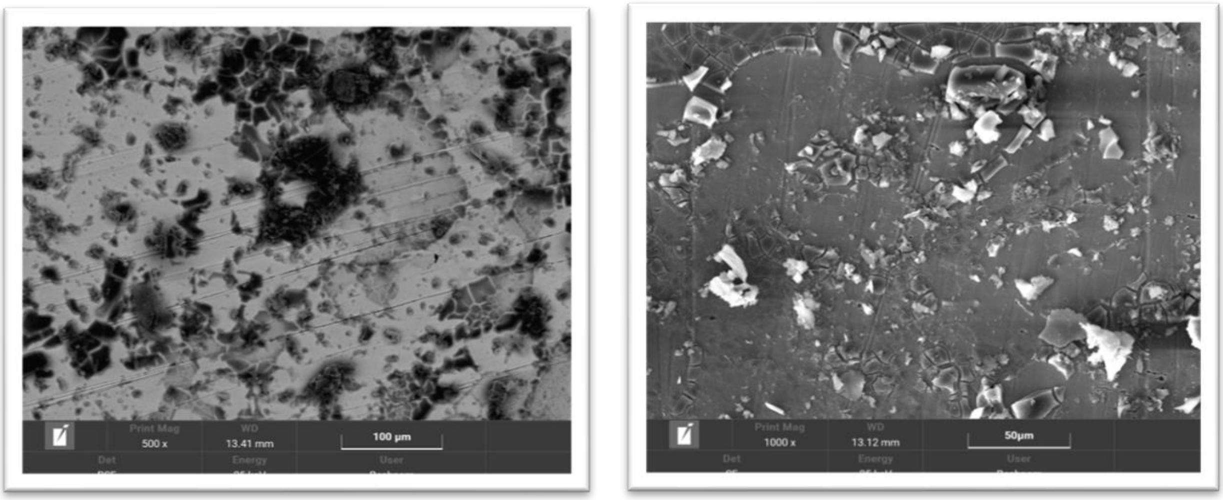

FIGURE 3. - SEM micrograph of carbon steel surface in presence of the chamomile with 0.6 M NaCl solution

3.2 Eds analysis

The EDS (Energy Dispersive X-ray Spectroscopy) analysis was performed to determine the elemental composition of low carbon steel submerged in a 0.6 M NaCl solution, with and without the inhibitor. Without the inhibitor, a significant oxygen concentration of 18.2% was detected, presumably caused by the oxidation of the alloy's surface. Conversely, the inhibitor's presence led to a decrease in chlorine concentration, suggesting the formation of a protective layer. The augmentation in the concentration of oxygen is ascribed to oxygen atoms, originating from the inhibitor molecules, that act as donors.

Table (1):

elements	C	O	Al	Si	Cr	Mn	Fe	Ni	Cu
Wt % without NaCl	**4.34**	**0.48**	**0.07**	**0.61**	**8.72**	**9.56**	**74.20**	**1.39**	**0.63**
Wt % with NaCl	**5.73**	**1.19**	**0.29**	**0.55**	**8.49**	**9.35**	**72.17**	**1.45**	**0.78**
Inhibitor	**4.50**	**1.63**	**0.18**	**0.60**	**8.69**	**9.43**	**72.99**	**1.32**	**0.67**

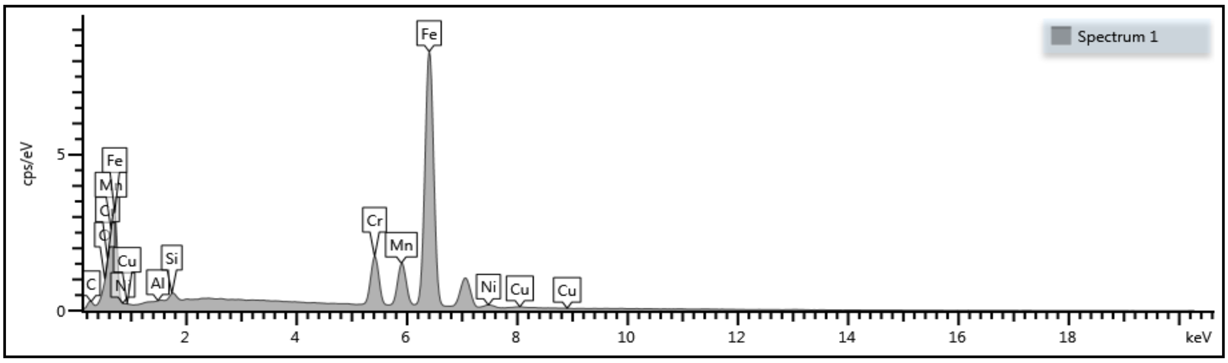

FIGURE 4. - **EDS spectrum of carbon steel surface without NaCl**

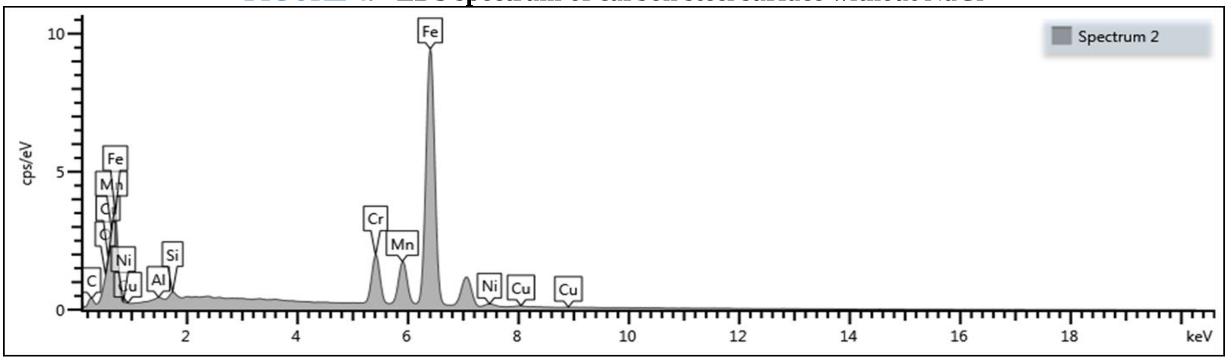

FIGURE 5. - **EDS spectrum of carbon steel surface with NaCl**

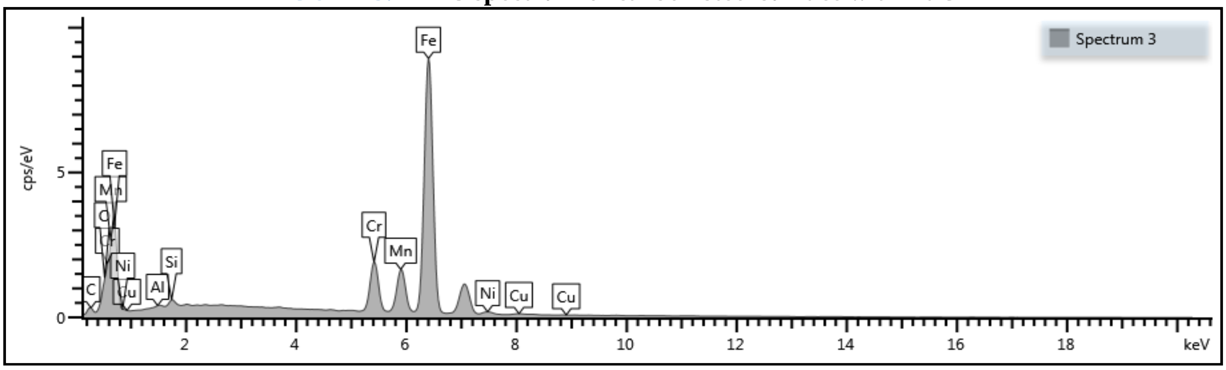

FIGURE 6. - **EDS spectrum of carbon steel surface chamomile extract with NaCl**

3.3 GC-MS analysis

was performed to screen and determine the presence of different active compounds in the sample, such as terpenoids and flavonoids, as well as other phytochemicals. This analysis contributes to the understanding of the therapeutic properties and biological activities of chamomile extract.

Table (2): Chemical compounds found in chamomile extract.

Compound name	Result	Units
Oleic acid $C_{18}H_{34}O_2$	15	%
Palmitic acid $C_{16}H_{32}O_2$	13	%
Caprylic acid $C_{16}H_{32}O_2$	13	%
Stearic acid $C_{16}H_{32}O_2$	11	%
Linalool $C_{10}H_{18}O$	0.26	ppb
Caryophyllene $C_{15}H_{24}$	0.08	ppb
Carvacrol $C_{10}H_{14}O$	0.16	ppb
B-pinene	0.085	ppb
B-myrcene	0.092	ppb
α-pinene	0.076	ppb
Thymol $C_{10}H_{14}O$	0.11	ppb

Table (3): Chemical compounds found in chamomile extract with NaCl.

Compound name	Result	Units
Oleic acid $C_{18}H_{34}O_2$	18	%
Palmitic acid $C_{16}H_{32}O_2$	16	%
Caprylic acid $C_{16}H_{32}O_2$	2	%
Stearic acid $C_{16}H_{32}O_2$	15	%
Linalool $C_{10}H_{18}O$	0.083	ppb
Caryophyllene $C_{15}H_{24}$	0.012	ppb
Carvacrol $C_{10}H_{14}O$	0.14	ppb
B-pinene	0.11	ppb
B-myrcene	0.14	ppb
α-pinene	0.095	ppb
Thymol $C_{10}H_{14}O$	0.091	ppb

3.4 Corrosion evaluation

It is observed that the rate of corrosion increases with the increase in the concentration of the corrosion and inhibition medium of the plant extract at the temperatures studied.

In general, the rate of corrosion speed increased when the temperature increased when compared to the same concentration of inhibitor. On the other hand, it was also observed that the percentage of inhibition efficiency increased when the concentration of the inhibitor increased at each temperature, and the reason is due to blocking the corrosion sites, which leads to reducing the lost weight. Therefore, the decrease in the inhibition efficiency values when the temperature increases is due to the increased dissolution of the alloy, as the chamomile plant extract had a greater inhibition efficiency rate 96% at 303 K. It was also found that the inhibition efficiency decreases when the temperature increases for the same concentration of inhibitor, which indicates that the effect of temperature is greater in the corrosion process than the effect of the inhibitor.

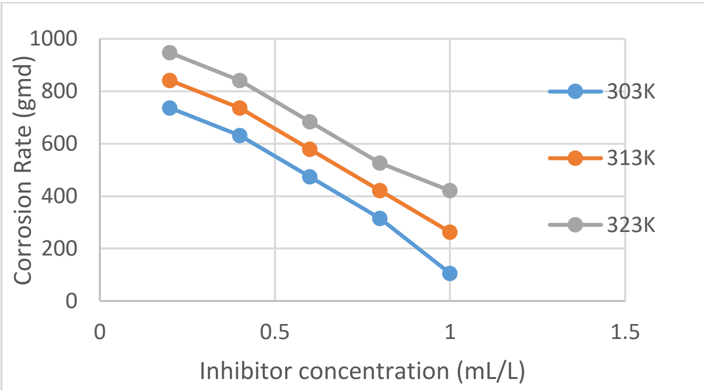

FIGURE 7. - Corrosion rate of the studied steel versus the concentration of chamomile plant extract in saline medium.

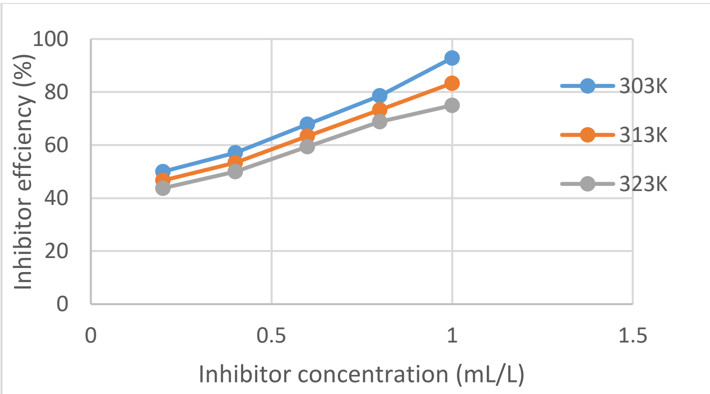

FIGURE 8. - Inhibition effciency chamomile of diffrent concentration of plant extract versus studied steel the in saline medium.

4. CONCLUSION

The carbon steel is immersed in a 0.6 M NaCl solution in the absence of any other materials. An inquiry has been made about examining chamomile leaf extract.formation of an adsorption layer on top metal surface. The damping efficiency improves proportionally as it increases. The concentration of the extract fluctuates. Where the temperature rises to 333 Kelvin. Moreover, the highest level of damping efficiency has been achieved. The concentration of chamomile plant extract was 1 ml/L, which represents 96.55% of the total. After conducting several tests using FTIR, SEM, and EDS, the above results were obtained.

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