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RESEARCH TITLE

Effect of Temperatures on Mild Steel Electroplating Coating by Nickel

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Abstract

The primary objective of this study was to highlight the electroplating process of steel using nickel to enhance its fundamental mechanical and physical properties during the electroplating process. Several parameters were investigated, most importantly the solution temperature and current intensity. The goal was to increase corrosion resistance by adjusting the solution's pH. The thickness of the plating layers was calculated at different temperatures, and the results showed variations in plating thickness. The solution temperature, pH, and current intensity are among the most important electroplating parameters. this study evaluates the effect of temperature on the quality of nickel electroplating on mild steel. The results showed that increasing the temperature (from 25°C to 70°C) increases the nickel layer thickness from 0.0029 mm to 0.0202 mm, thus enhancing corrosion resistance. After a seawater corrosion test, nickel oxide (NiO) formed a protective layer, further improving corrosion protection.

Key Words: Electroplating, Nickel, Temperature.

عنوان البحث

تأثير درجات الحرارة على طلاء الفولاذ الطري باستخدام النيكل

المستخلص

كان الهدف الرئيسي لهذه الدراسة هو تسليط الضوء على عملية الطلاء الكهربائي للفولاذ باستخدام النيكل لتحسين خصائصه الميكانيكية والفيزيائية الأساسية أثناء عملية الطلاء. تم فحص العديد من المعايير، وأهمها درجة حرارة المحلول وشدة التيار. وكان الهدف هو زيادة مقاومة التآكل عن طريق ضبط درجة حموضة المحلول. تم حساب سمك طبقات الطلاء عند درجات حرارة مختلفة، وأظهرت النتائج اختلافات في سمك الطلاء. تُعد درجة حرارة المحلول ودرجة الحموضة وشدة التيار من أهم معايير الطلاء الكهربائي. تقيّم هذه الدراسة تأثير درجة الحرارة على جودة طلاء النيكل الكهربائي على الفولاذ الطري. أظهرت النتائج أن زيادة درجة الحرارة (من 25 درجة مئوية إلى 70 درجة مئوية) تزيد من سمك طبقة النيكل من 0.0029 مم إلى 0.0202 مم، مما يعزز مقاومة التآكل. بعد اختبار التآكل في مياه البحر، شكل أكسيد النيكل (NiO) طبقة واقية، مما زاد من تحسين الحماية من التآكل.

الكلمات المفتاحية: الطلاء الكهربائي، النيكل، درجة الحرارة.

1. Introduction

Mild Steel has excellent mechanical properties which can be exploited in a wide variety of applications[1,2].Mild Steel is susceptible to corrosion. Corrosion is a natural condition which is caused by electrochemical reactions between the metal and its environment, which is a dangerous and expensive problem [2,3]. In addition, corrosion can lead to environmental contamination, for example, leaking pipes and fuel tanks, which can affect the health of crops and drinking water and, therefore, wildlife and humans [4,5]

A common strategy to solve this issue is surface modification using thin protective metallic electroplating coating. There are many kinds of metallic electroplating coating, such as Ni and Cu coatings provide corrosion protection by applying a thin metal layer with more negative electrode potential than the metal substrate. The coatings are more corrosion resistant than the underlying metal substrate[6,7].

One of the crucial procedures in the metal industry is electroplating. The first goal of the electroplating process was to improve the mechanical and physical characteristics of base metals in order to increase their value [8.9.10]. During electroplating, the following parameters need to be controlled: bath temperature, pH of the bath, current. The coefficient of friction can be fixed via current density. Wear resistance may be increased by the bath's pH. The temperature of the bath can improve resistance to corrosion. The bath's particle concentration can improve the base metal's mechanical qualities and the internal stress can be decreased by particle size [11]. The primary electroplating parameters are the bath's temperature, pH, and current density. Secondary characteristics include particle size and concentration as well as electrolyte types [12].

Faraday's law and its equation govern electroplating. According to Faraday's law,

the amount of electricity is exactly proportionate to the chemical activity or decomposing power. which pass. Electrochemical equivalents are identical to and coincide with regular chemical equivalents. Moreover, the physical and metallurgical parameters are among the many elements that affect the rate of corrosion in metals [13]. The thickness of the layer is one of the physical elements that affects it, and electrolyte conductance is strongly correlated with layer thickness. The quantity and velocity of ions in electrolyte solutions are determined by electrolyte conductance; a high resistance results in a lower conductance [14].

M. Kultamaa et al. employed zinc electroplating in 2021 to improve the corrosion resistance of porous metal injection-molded 440C stainless steel. The powder space holder method and the use of sodium chloride as a space holder material allowed for controlled porosity. Zinc was electroplated using three distinct electrolytes—zinc acetate, zinc sulfate, and zinc chloride to deposit the internal pore structure of porous 440C. According to our findings, corrosion resistance was greatly enhanced by all zinc depositions on porous 440C samples. Zinc acetate at 30 weight percent porosity showed the least amount of corrosion. The produced porous 440C samples covered with zinc may find use in harsh situations [15].

This study is experimental work with different temperatures 25,50 and70 0C at constant time and constant current density in order to study the effect of temperature on the quality of the samples were coated [16].

2. Material and methods:

In this study, mild steel samples were prepared in bulk. The samples were similar in shape, weight, and size. More than one sample was prepared, with the average reading taken. The mild steel samples were then cut into 1 cm x 4 cm x 1 mm shapes (with a surface area of 4 cm^2 per face), as shown in Figure 1.

2.1 Sample Preparation

The samples were cleaned by rubbing with carbon black sandpaper. and surface was cleaned with distilled water then sample was dried and allowed to cool, mild steel sample was weighed using a sensitive balance, and the initial weight was recorded as W1(g).

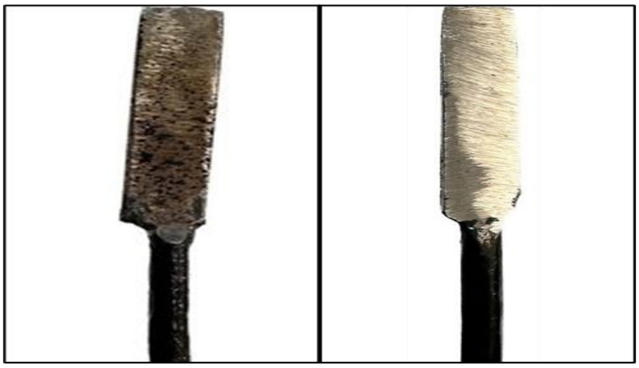

Figure 1: Samples before and after polishing.

2.2 Solutions Preparation

More solutions were prepared to test the corrosion and protection process before and after the coating processes that will be applied.

2.2.1 Nickel chloride solution

To prepare $NiCl_2$ solution wash and dry the beaker and place it on the magnetic mixer, Fill the 1000 ml-beaker with distilled water. after that Calculating the required amount of nickel chlorides and weighting the resulting quantity using an accurate balance.

Molarity = No. of moles / solution volume

Basis: molarity is 0.2M and solution volume is 1000ml

So, No. of solvent moles is 0.2 mole. By multiply number of moles in molecular weight of nickel chloride (237.69 g/gmol) can be obtain the required weight of solvent which is equal to 47.538 g.

weighted substance to the full beaker so that it gives the required concentration of the solution (0.2 M).

Figure 2: Nickel chloride solution.

The electroplating process involves two reactions, which occur at electrochemical the anode and cathode. The anode is usually made of nickel or an inert material, while the cathode is the metal substrate being plated.

The reactions can be represented as follows:

At the anode:

$$2Cl^- \longrightarrow Cl_2 + 2e^- \quad \text{......................1}$$

At the cathode:

$$Ni^{+2} + 2e^- \longrightarrow Ni \quad \text{......................2}$$

In the anode reaction, chloride ions are oxidized to produce chlorine gas and two electrons. These electrons flow through the external circuit to the cathode, where they reduce nickel ions to form metallic nickel. The overall reaction can be represented as follows:

$$Ni^{+2} + 2Cl^- \longrightarrow Ni + Cl_2 \quad \text{.............3}$$

2.3 Electroplate Coating Preparation

After preparing the samples and platinum, the mild steel and platinum are immersed in a beaker with 1000 ml of nickel chloride and potassium dichromate solution, and then connected to a DC power source with the mild steel as the cathode (-) and the platinum as the anode (+). The current and time are recorded. After 4 hours, the immersed sample is removed from the beaker, and the mild steel sample is weighed with a sensitive balance. The second weight, W2 (g), is recorded. The weight of the plating is the difference between W2 and W1[17].

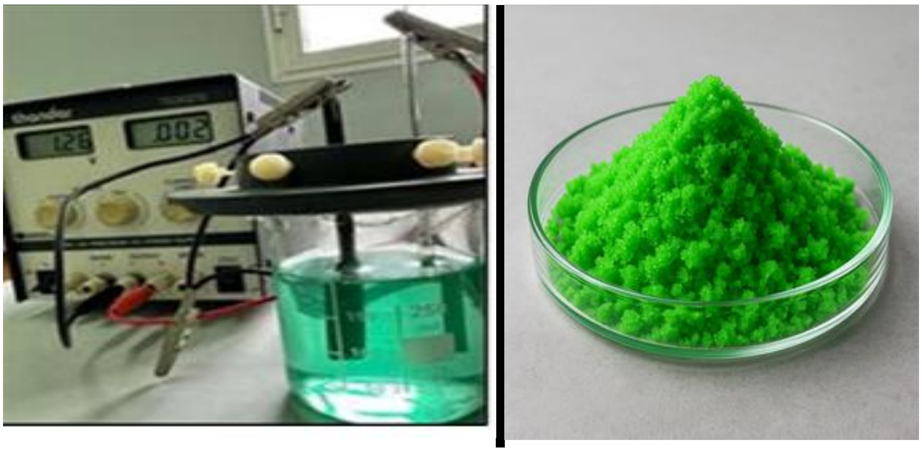

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Figure 3: Criteria electroplate coating

2.4 Corrosion Rate Measurement

1. Clean the sample surface by rubbing with Black Carbon Sandpaper (P100 and P400 grand).
2. Surface cleaning by distilled water.
3. Drying the sample by dryer and wait until it is cool.
4. Weight the sample of mild steel in a sensitive balance, and recording the first weight W_1(g).
5. Immersed the mild steel sample in beaker with 200 ml of Nickel chloride solution and record the current time after each sample.
6. Weight the mild steel sample in a sensitive balance, and record the second weight W_2(g).
7. Calculate the wight difference between W_1 and W_2.
8. Calculate the coating thickness for all samples from equation

$$\text{Thickness } (mm) = \frac{\Delta W}{A*\rho*V} \quad \text{.............................4}$$

Where: ΔW: weight difference between W_1 and W_2.

ρ : Density of metal coating at bath coating temperature

A : Area of mild steel sample

V :Volume of mild steel sample

2.5 Specimen Examination

Immersed the coated samples in 200 ml of a sea water beaker and recording the current time, After specific time (2 days). Remove the immersed samples from the beaker. Weight the sample by a sensitive balance, and record the weight W2. The loss in weight is difference between W1 and W2.

The weight loss (g) = $W_1 - W_2$

Figure 4: Mild steel after corrosion

3. Results and Discussion

3.1 Mild Steel coated by Nickel (Ni) :

The samples were coated at different temperature, constant current density (0.25A) and constant concentration (0.2M) in order to study the effect of temperatures 25,50 and70 ^{0}C on the quality of coating.

Tables (2a 2b 2c). show the results of Nickel plated mild steel samples at temperature (25. 50 . 70) ^{0}C

Table 2a : mild steel sample coated by Nickel at (25 ^{0}C)

NO	t(min)	I(A)	V(v)	w_1(g)	w_2(g)	Δw
1	30	0.25	5	24.0677	24.1045	0.0368
2	30	0.25	5	22.4548	22.4923	0.0375
3	30	0.25	5	19.4668	19.5168	0.05

Table 2b: mild steel sample coated by Nickel at (50 ^{0}C)

NO	t(min)	I(A)	V(v)	w_1(g)	w_2(g)	Δw
1	30	0.25	5	22.9828	23.1505	0.1677
2	30	0.25	5	22.7542	22.9823	0.2281
3	30	0.25	5	21.8919	22.1221	0.2302

Table 2c: Mild Steel Sample Coated by Nickel at (70^{0}C)

NO	t(min)	I(A)	V(v)	w_1(g)	w_2(g)	Δw
1	30	0.25	5	18.9405	19.1802	0.2397
2	30	0.25	5	17.3229	17.6099	0.2870
3	30	0.25	5	19.1614	19.4988	0.3374

Table 2d shows the average thickness results of Nickel plated mild steel samples at temperature (25,50,70^{0}C)

NO	T(^{0}C)	t(min)	I(A)	V(v)	Δw	th (mm)
1	25	30	0.25	5	0.0414	0.0029
2	50	30	0.25	5	0.2087	0.01464
3	70	30	0.25	5	0.2880	0.0202

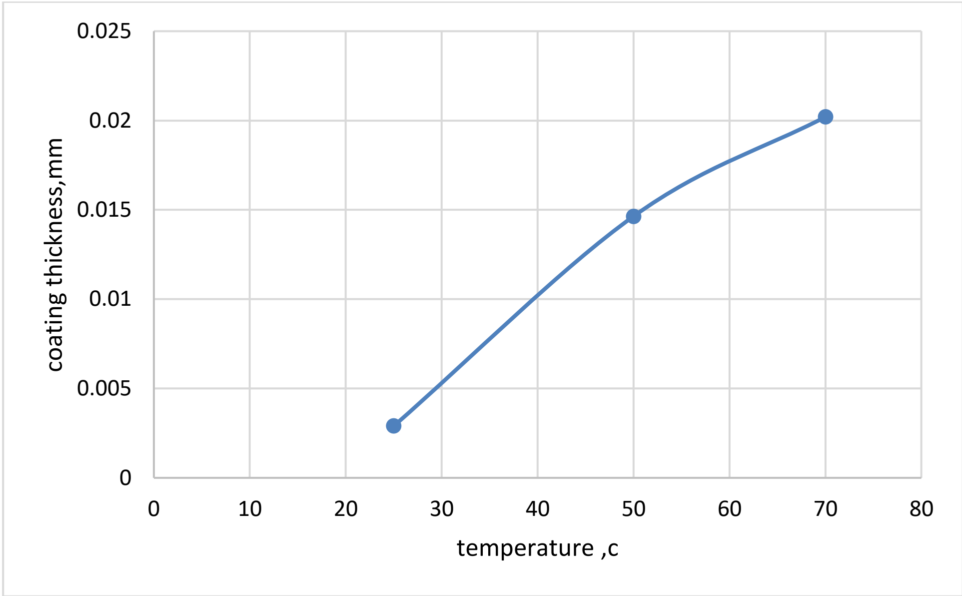

Figure 5: The relationship between Temperature and Coating Nickel thickness

Data graph shows the Nickel thickness of the paint is directly proportional to the temperature, because increasing the temperature helps to accelerate the supply of ions the metal surface.

Figure 6. sample of mild steel coated by nickel

3.2 Corrosion test of mild steel before coating in sea water environment:

In this test, mild steel samples were tested in seawater for two days to study the weight lost during the two days and compare them with the samples that were coated and placed in sea water for two days and study the effect of coating on the protection of mild steel from corrosion

Table 5. Corrosion of mild steel without Protection

NO	w_1(g)	w_2(g)	Weight losses
1	25.4130	25.4090	0.0040

Two samples of mild steel were tested in sea water for two days. It was found that the sample decreased by a rate of 0.0040 g , These sample will be compared with the coated sample, and the effect of the coating layer on protecting of the mild steel .

befor After

Figure 7: sample of mild steel befor immersion in sea water

3.3 Corrosion test of mild steel after coating in sea water environment:

Nickel coated samples were tested in seawater for two days to study their effect on the corrosion protection of mild steel, table 6. showed the average results of nickel plated sample in sea water for two days were taken.

Table 6. coating layer test in sea water at 25C^0

NO	Coating layer	Weight losses(g) $= w_1 - w_2$
1	Ni	-0.012467 **w2 > w1**

from the table that the nickel-plated samples increased their weight losses > **w1)** after two days of immersion in sea water, Nickel oxide (NiO) can form as a passive corrosion layer in seawater environments fig (8), which helped to protect the mild steel in sea water . It can be concluded from this that the best coating is nickel for the strength of the oxide layer, but in general, mild steel is much better protected than mild steel without protection..

Figure.(8)

3.4 Calculation of Nickel Oxide Thickness in sea water environment:

By using eq (4)

Nickel Oxide Thickness in sea water:

$$\text{Thickness } (mm) = \frac{0.0243}{4 * 6.67 * 0.4} = 0.0228\, mm$$

4. Conclusion
   1- Nickel Electroplating coating offers many benefits, including increased corrosion protection of mild steel in sea water.
   2- The influence of temperature on rate of growth of thickness is increased, leading to more corrosion resistance.
   3- Oxide film of nickel forms, a thin passive oxide film in seawater environments that initially protects against corrosion. [18].

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