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SIMULATION ANALYSIS OF ELECTROPLATING ZINC BASED ON COMSOL

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There are many uncertain factors in the test process of electroplating zinc. The establishment of control standards in the research process can reduce the workload and shorten the test cycle. Based on the electrochemical module developed by COMSOL multi-physics software, this study uses the computer ‘s powerful computing power and the existing perfect theoretical system to simulate the experiment. The results show that the potential at the anode plate is higher, the potential at the cathode plate is lower, and the potential distribution in the middle area of the two plates is relatively uniform. When the plating time is 10 min, the outer surface of the galvanized part is basically coated with a relatively uniform zinc coating, which is about 2μm. Due to the large local current density in each edge area of the sample, the plating layer is relatively thick, but the difference is not large.

Keywords: X80, welded joint, COMSOL, zinc coating electroplating, sediment thickness;

INTRODUCTION

With the service environment of oil and gas pipelines in extreme areas becoming more and more harsh, in order to protect pipeline steel from corrosion, various methods have been developed, such as coating [1,2], anodic oxidation and galvanizing [3]. Zinc is widely used in pipeline steel protection as a highly active metal [4]. The service life of zinc-coated steel can be as long as several decades. However, the content of electroplating zinc test is too complicated. There are often many uncertain factors in the test process. Therefore, the establishment of a control standard in the study can reduce the workload and shorten the test cycle. Therefore, based on COMSOL multi-physics software and the electrochemical module developed based on electrode dynamics theory, this paper uses the powerful computing power of computer and the existing perfect theoretical system to simulate the experiment and obtain relatively accurate electroplating data.

SIMULATION

Firstly, the geometric model of equal proportion is established in the model. The analysis conditions, such as initial concentration, system temperature, etc., were set. Then the grid is divided.

Finally, the established model is solved. The mathematical model is discretized into a finite number of elements, and the boundary conditions and initial conditions of the finite element analysis are used to solve the linear or nonlinear equations.

Figure 1 is a three-dimensional simulation physical model based on COMSOL multi-physics software, which is modeled as 1: 1 of the actual electroplating equipment. The size of the plating bath is 175 × 175 × 60mm. The cathode is X80 pipeline steel welded joint with a size of 50 × 50 × 18.4 mm. The anode is zinc sheet, and the overall area of the anode is 2.5 times the area of the cathode welded joint.

Figure 2 is the grid division of the established three-dimensional simulation physical model, with a total of 17 661 grids. The grid volume is 0,002182 m^3. The weld area is refined due to its unevenness. The simulation uses the Nernst-Planck electrochemical distribution interface of the ‘ three current distribution ‘ in the COMSOL electroplating module, fully considering the trans-

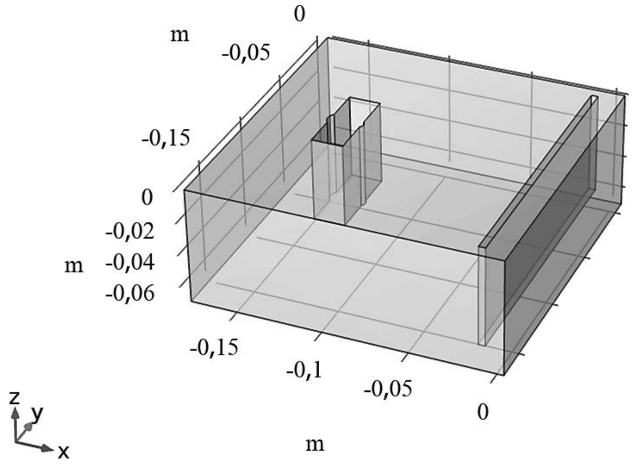

Figure 1 Electroplating device model diagram

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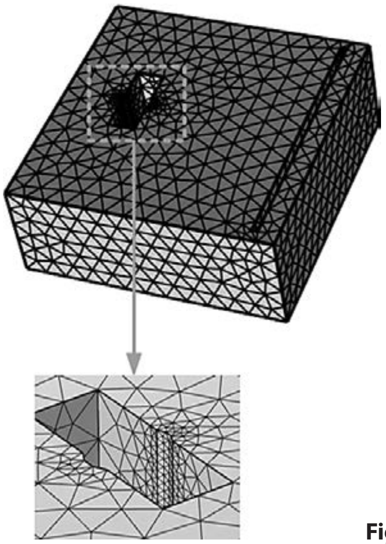

Figure 2 Grid division

Table 1 **Parameter setting**

Name	Expression
Cinit	500/mol/(m^3)
T0	298/K
i0_ref	250/A/m^2
phis_anode	0135/V
phis_cathode	-0,135/V
alpha_a	1,5/1
z_Zn	2/1
z_Cl	-1/1
D_Zn	2e-9/m^2/s
D_Cl	D_Zn

fer of material through diffusion, electromigration and convection, and obtaining the change of electrolyte concentration in the electrochemical process. Parameter settings are shown in Table 1.

The boundary condition of the electroplating simulation is to add the three times electroplating module as the physical field constraint in the whole simulation area, and add the average current density on the cathode surface as the load constraint. The specific boundary conditions are as follows: add the three times electroplating module as the physical field of the simulation, and set the initial experimental parameters. And the diffusion coefficient, mobility, conductivity, number of participating charges, electrochemical equivalent coefficient and other related parameters of ions in the model. Adding the above conditions and applying the anode edge surface, the anode edge and the zinc sheet surface can simulate the thickness of the simulated coating.

The boundary condition of electroplating simulation is to add the electroplating three times module as the physical field constraint in the whole simulation area, and add the average current density as the load constraint on the cathode surface. The flow rate of each ion in the electroplating solution can be calculated by the Nernst-Planck equation shown in equation (1-1).

$$N = -D\nabla c - zuFc\nabla\varnothing \qquad (1\text{-}1)$$

Among them, N is the ion flow rate, D is the diffusion coefficient, c is the electrolyte concentration, z is the number of charges carried by the ions, and u is Ion mobility, F is the Faraday constant, Φ is the electrolyte potential, ∇ is the Hamiltonian operator.

SIMULATION RESULTS AND ANALYSIS

After using COMSOL software to simulate the galvanizing process of X80 welded joint, the electrolyte potential and electrolyte current density streamline of multi-section were obtained, and the change of total electrode thickness was also shown. The direction of electron flow is from negative to positive, so the cathode gets electrons and the anode loses electrons.

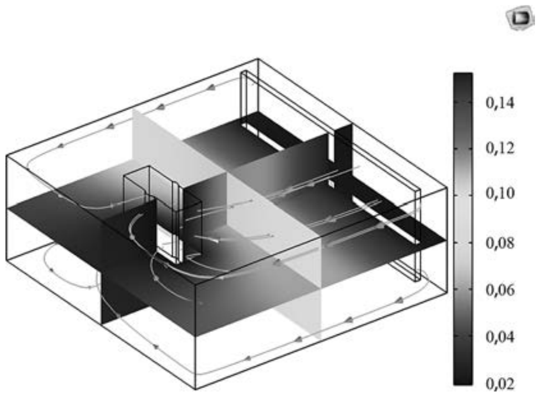

Figure 3 Multi-section electrolyte potential /V

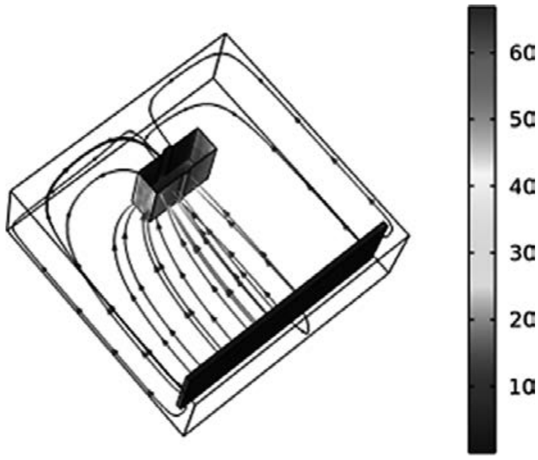

Figure 4 Electrolyte current density streamline /A/m^2

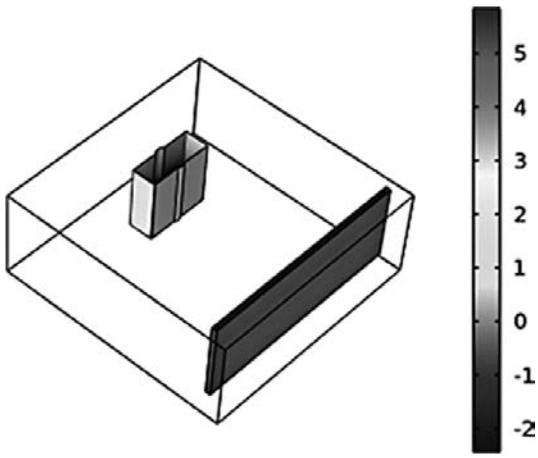

Figure 5 Total electrode thickness variation /μm

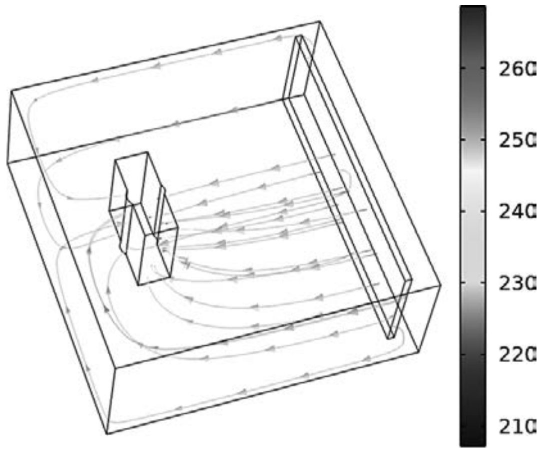

Figure 6 The Zn streamline of substance /mol/m^3

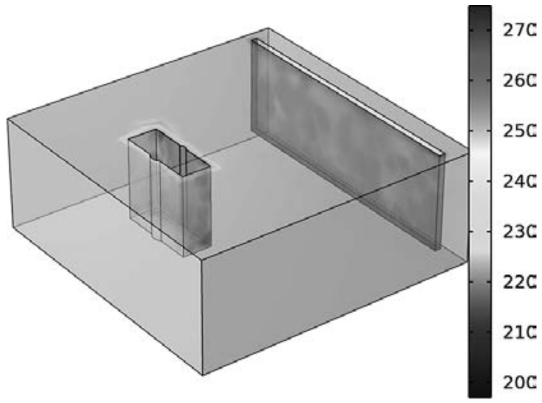

Figure 7 Substance Zn concentration surface /mol/m^3

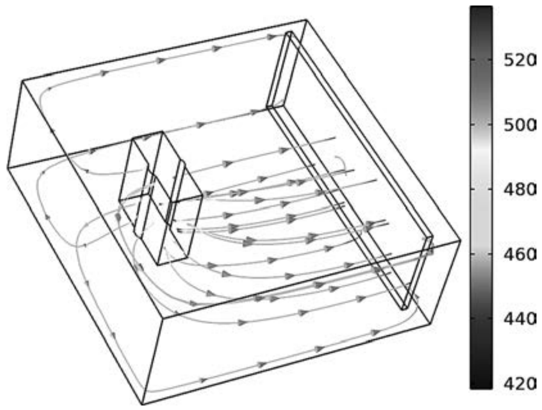

Figure 8 Substance Cl concentration surface /mol/m^3

Figure 3 is the multi-section electrolyte potential. From Figure 3, it can be seen that the electrolyte potential distribution shows that the potential at the anode plate is higher, the potential at the cathode plate is lower, and the potential distribution in the middle area of the two plates is relatively uniform.

The electrolyte concentration at the cathode plate gradually decreases from the upper boundary to the lower boundary. The reason for this trend may be that some zinc ions are produced by the electrolysis of the anode plate, and a large number of metal ions are deposited on the lower boundary of the cathode plate.

Figure 4 is the electrolyte current density streamline. Figure 5 shows the change of the total thickness of the electrode, and the plating time is 10 min. The color of the legend represents the value of thickness. From Figure 5 and Figure 4, it can be seen that the outer surface of the whole galvanized part is basically plated with a relatively uniform zinc coating, which is about 2μm. However, due to the large local current density in each edge area of the sample, the plating layer is relatively thick, but the difference is not large. The factors affecting the thickness of the coating are the local current density and potential of the electrode, and the current density has a great influence on the coating, which determines the thickness of the coating.

Figure 6 shows the streamline trend of material Zn, and it can be seen from the figure 6 and 7 that zinc is uniformly attached to the sample. Figure 8 shows the streamline trend of material Cl. The electrodeposition at this time is also very uniform.

Acknowledgments

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CONCLUSION

Through the simulation test conditions, such as the geometric structure of the electroplating tank, current density and electrodeposition thickness, etc., the quality of electrogalvanized zinc was determined, and the results were consistent with the actual test. The results show that the potential at the anode plate is higher, the potential at the cathode plate is lower, and the potential distribution in the middle area of the two plates is relatively uniform. When the plating time is 10 min, the outer surface of the galvanized part is basically coated with a relatively uniform zinc coating, which is about 2μm. Due to the large local current density in each edge area of the sample, the plating layer is relatively thick, but the difference is not large.

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Note: The responsible translator for English language is M.M. LI -North China University of Science and Technology, China