Preparation and Electrochemical Properties of Water-borne Inorganic Zinc-rich Coating in Hydraulic Engineering Metal Structures

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Abstract: In order to develop more suitable anticorrosive coatings for hydraulic engineering metal structures, studies were carried out on the preparation and electrochemical properties of water-borne inorganic zinc-rich coatings in this paper. Through effective regulation of the type and dosage of silicate and zinc powder, modified water-borne inorganic zinc-rich coatings were prepared. Coupled with the enhanced anti-corrosion and electrochemical protection property, this modified new coating possesses a broader application prospect in hydraulic engineering metal structures.

Introduction

Metal structure is the core part of hydraulic structures, such as gates, trash racks, hoists, pressure steel pipes and so on. Since the friction by the sediments and corrosion in the water, corrosion prevention strategy has become to a necessary method to insure the critical parts of the structures would work better and longer . Anticorrosive coatings were the traditional solution for the corrosion problems of hydraulic engineering metal structures for their isolation effects and many other advantages, such as simple construction, easy operation, low cost and so on [1]. Great attention was paid to anticorrosion zinc-rich coatings for their superior performances both in shielding and electrochemical properties, which was expected to solve the corrosion problems in hydraulic environment [2].

According to the difference in film-forming materials, zinc-rich coatings are divided into two kinds. One kind is organic zinc-rich coatings which formed by epoxy resin, modified epoxy resin and other organic coating. The other kind is inorganic zinc-rich coatings, including the alcohol soluble inorganic zinc-rich coatings formed by alkyl ester silicate materials and water-borne inorganic zinc-rich coatings with silicate materials [3]. Over the past decades, water-borne inorganic zinc-rich coatings have attracted more attention for their excellent anticorrosion and environmental performances. However, a more stringent requirement on the corrosion resistance has been raised since the complex and specific environment in which hydraulic metal structures were applied. In this paper, the preparation of water-borne inorganic zinc-rich coating was studied. Besides, the influence of the type and dosage of zinc powder to the electrochemical protection property was also discussed. The result indicated that the optimal scheme of water-borne inorganic zinc-rich coatings has important significance and application value in the study of hydraulic metal structure corrosion resistance.

Experimental

Materials preparation. Silica-sol, along with a small amount of organic siloxane, were dissolved into the potassium silicate solution with different modulus. The high-modulus potassium silicate solution was prepared successfully after the solution was dispersed at the speed of 500r/min for about 240 minutes. Then the silicone-acrylate emulsion with the solid content of 30% was added into the above solution [4]. The modified potassium silicate solution was obtained after the solution was stirred at the temperature of 25 °C for about 40minutes. The obtained water-borne inorganic zinc-rich coatings were prepared after the modified film materials and sphere or flaky zinc powder was mixed according to the Standard HGT 3668-2009 Zinc-Rich Primer.

Electrochemical test. The electrochemical measurement system was composed with TD3720 potentiostat and IBM586 microcomputer. The corrosion resistance tests of 100 mm^2 membrane layers under different conditions were carried out in 3.5% NaCl solution at room temperature. In the tests, the working electrodes were coated specimens treated by zinc coating, while the reference electrode was calomel electrode and auxiliary electrodes was copper electrode. The electrochemical measurement system was set as scan rate at 60 mV/min, voltage at 0-5000 mV and 1000Ω of sample resistance.

Results and Discussion

Formulating

Potassium silicate was commonly used as the binder in water-borne inorganic zinc-rich coatings for its good film-forming, movement stable, soluble and low cost. Silica-sol, along with a small amount of curing catalyst was dissolved into the potassium silicate solution with volatile content at 30% - 40% and modulus at 6.0. The solution was dispersed at the speed of 500r/min at 40±5 ℃ for about 3 hours. In the late reaction, the viscosity of the solution should be constantly tested until the end of the reaction at 10 - 15mPa·s and turned to translucent solution. Finally, as shown in Table 1, de-foaming agent, the flowing agent, toughening agent and other auxiliaries were mixed in to the above solution under low speed mixing condition to obtain component A of water-borne inorganic zinc-rich coating (component B was zinc powder).

Table 1. Component A of water-borne inorganic zinc-rich coating

Raw material	Dosage (wt%)
Potassium silicate solution	70
Silica-sol	20
Anti-setting agent	5
Other auxiliaries	5

According to the method described in Experimental section, 9 samples were prepared with the differences in dosage and type of zinc powder. The corresponding sample numbers were listed in Table 2.

Table 2. Samples with different dosage and type of zinc powder*

Sample	S1	S2	S3	S4	S5	S6	F1	F2	F3
Solid content of zinc powder	40 (S)	50 (S)	60 (S)	70 （S）	80 （S）	90 （S）	40 (S)	50 (S)	60 (S)

*Note：F—flaky zinc, S—spherical zinc.

Influence of spherical zinc solid content to the electrochemical properties.

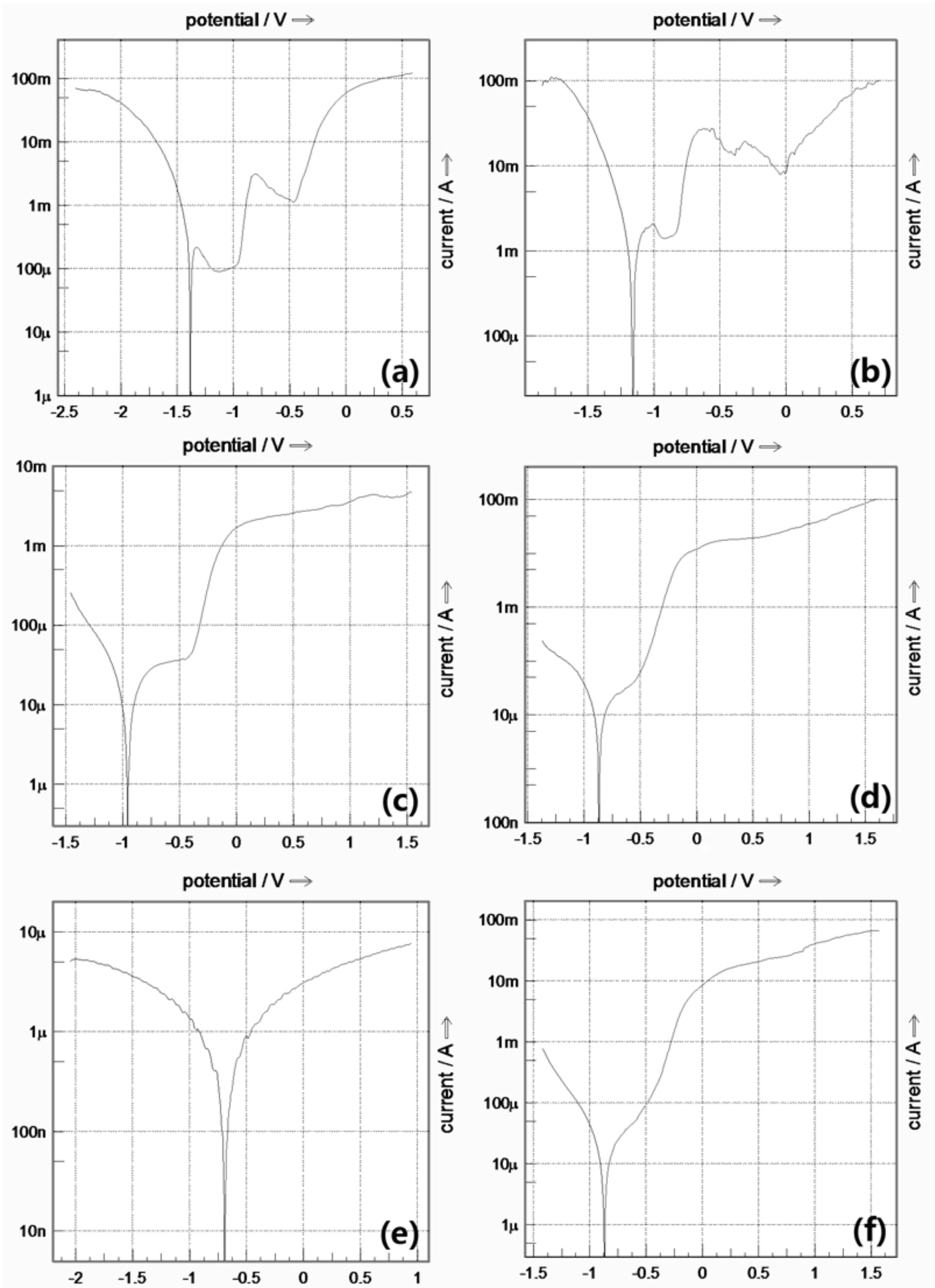

Fig 1. Polarization curves of coatings at different solid content of spherical zinc coatings (a-S1, b-S2, c-S3, d-S4, e-S5, f-S6).

Figure 1 demonstrated the electrochemical test results of potassium silicate zinc-rich coating with different solid content of sphere zinc powder. As shown in Figure 1, the polarization potential tended to increase with the increase of solid content, which suggested a better electrochemical protection performance of the coating. As we can see, zinc powder relatively loosely wrapped in the zinc-rich coating when the solid content of zinc powder was too low. In this way, the only function of zinc-rich coating was shielding but without electrochemical protection. This electrochemical protection function of zinc powder would able to show up when the zinc powder reached at certain content and connected with the metal base in the external environment to form a corrosion cell.

With the increase of zinc powder content, a more uniform dense structure could be built in the zinc-rich coating when the solid content was in the range of 40% to 80%. As a result, the polarization potential at this range was 1.4 V, 1.2, 1.2V, 0.85 V and 0.7 V, respectively. This increment in polarization potential demonstrated that the electrochemical protection performance improved with the increase of zinc powder content. However, the anti-corrosion performances of the water-borne inorganic zinc-rich coating deteriorated severely when the solid content was more than 80%. This was due to too much zinc powder would lead to coating foaming in the humid environment where hydraulic metal structures were applied. On the other hand, the accumulation of excess zinc powder on the surface would easy to fall off under the action of external force. Local corrosion occurred on these coating defects as shown in Figure 2. Besides, the viscosity of the coating was also determined by the solid content. Too much or too little zinc powder would both be the challenges for the application technology of water-borne inorganic zinc-rich coatings [5].

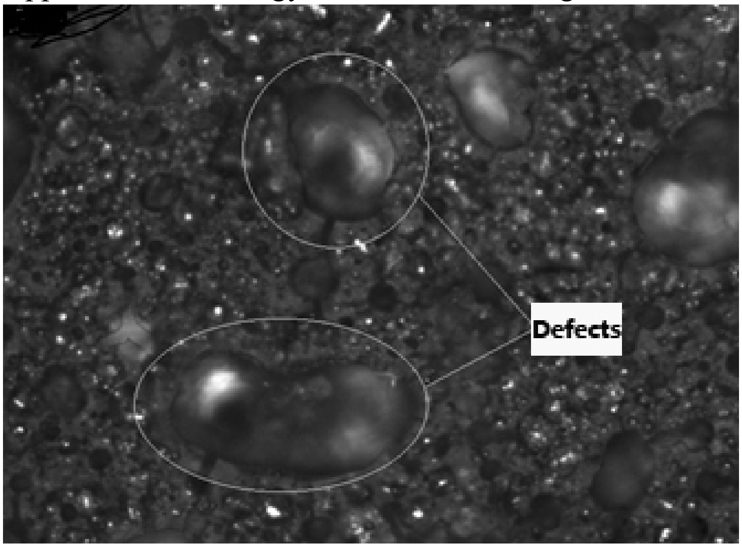

Fig 2. Defect of coatings caused by the high solid content of zinc

Influence of flaky zinc solid content to the electrochemical properties.

Spherical zinc is used wildly in water-borne inorganic zinc-rich coatings for its simple production and price moderate. However, the coatings are easy to contract during curing process since the poor disparity of spherical zinc in water-borne inorganic zinc-rich coatings [6]. Compared to spherical zinc, there are some advantages to flaky zinc in theory as the following aspects [7]. Firstly, the high radius-thickness ratio of flaky zinc leads to a better settlement-resistance property than spherical zinc. Therefore, the inhomogeneity of zinc powder distribution during coating construction would greatly reduce [8]. Secondly, the interaction between spherical zinc particles is in the form of point to point contact while it is face to face structure in flaky zinc. This face to face structure greatly increased electrical contact area of zinc powder as well as more electric flux in the corrosion cell. As consequence, the electrochemical protection performance of water-borne inorganic zinc-rich coatings was magnified after modifying flaky zinc. In addition, a longer seepage path of corrosive medium in flaky zinc coatings could result in much less water and ion permeation in the coating. In this way, the anti-corrosion performance of modified water-borne inorganic zinc-rich coatings was enhanced by flaky zinc [9].

In this paper, we compared the electrochemical performances of water-borne inorganic zinc-rich coatings with flaky zinc powder and sphere zinc powder. As shown in Figure 3, the polarization potential could reach -0.7 V when the solid content of flaky zinc was about 50%, which was in the same level of electrochemical protection performance with 80% solid content of sphere zinc. This result not only demonstrated the superiority of flaky zinc which discussed above, but also revealed that the utilization of resources could be improved by using flaky zinc.In addition, peeling off of the excess zinc and anti-corrosion performance deterioration also occurred when the solid content of flaky zinc was more than 60% with the similar way of sphere zinc-rich coating [10].

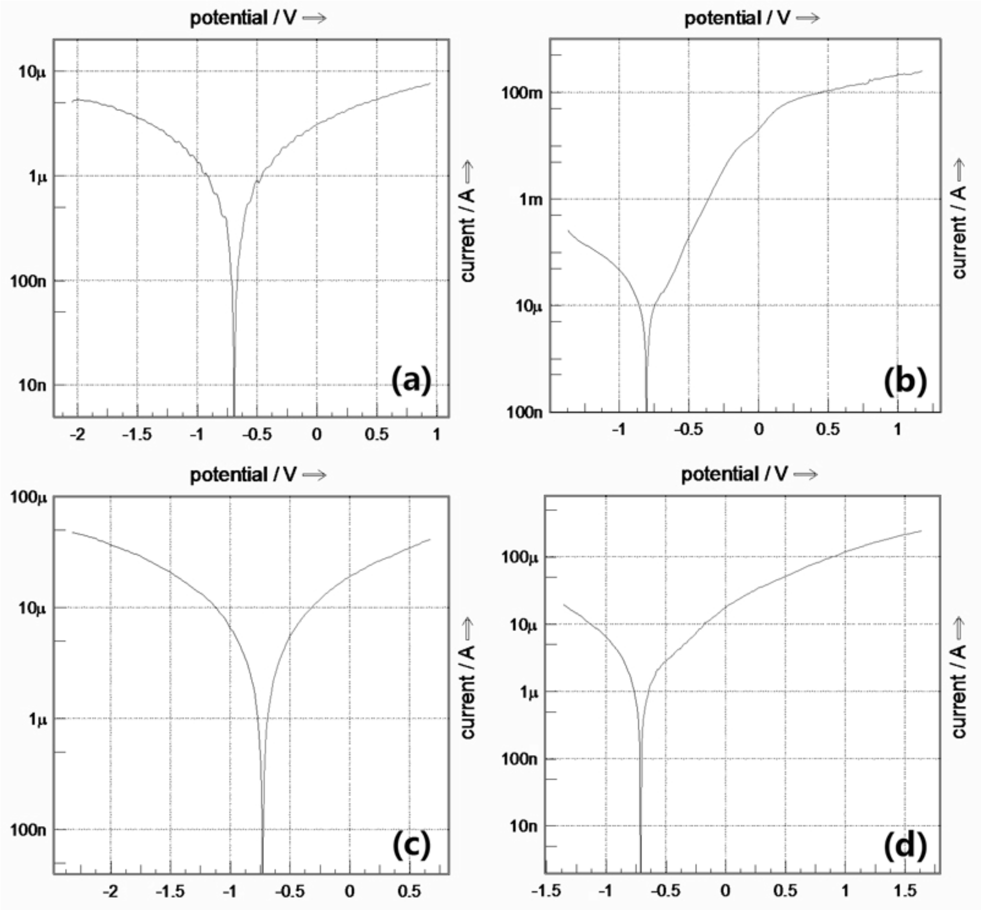

Fig 3. Polarization curves of zinc coatings (a-S5, b-F1, c-F2, d-F3).

Conclusion

In this paper, the preparation of water-borne inorganic zinc-rich coating was studied. Besides, the influence of the type and dosage of zinc powder to the electrochemical protection property was also discussed. The result indicated that flaky zinc powder was more cost effective and environmental than spherical zinc powder since zinc-rich coating with flaky zinc powder achieved the same anti-corrosion property (polarization potential at -0.72 V) while the dosage was 25% less than spherical zinc powder. It can be concluded that the optimal scheme of water-borne inorganic zinc-rich coatings has important significance and application value in the study of hydraulic metal structure corrosion resistance.

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