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Technical Report

Study on the Splash Zone Corrosion Protection of Carbon Steel by Sacrificial Anode

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The reason that sacrificial anode can not work properly in the area of splashed zone is that there is no stable electrolytes around the metalwork to enable the anode to function. In this paper the water absorbing capacity of materials was evaluated in order to select a suitable material that can be applied to the splash zone to form a stable electrolyte layer. Then the effect of sacrificial anode on the splash zone corrosion was studied by field exposure and cyclic wet and dry method.

Keywords: Splash zone, corrosion protection, sacrificial anode

1. INTRODUCTION

At present, alternative corrosion protection methods in splashed zone are composite Zn-Al alloy/organic coating [1], Ni-Cu alloy coating [2,3] and heavy-duty coating [4,5] etc. The corrosion protection effect of composite Zn-Al alloy/organic coating is the combination of the cathodic protection of Zn-Al alloy coating and isolation of corrosive environment by organic coating. This technique has better protection effect and longer service life, but the Zn-Al/organic coating operation requires strict operation conditions and careful surface pretreatment. Therefore it was not suitable for the repair of failed coating in marine environment.

It was reported that Ni-Cu alloy coatings protection method could give reliable protection to steelwork and reduce the corrosion rate to a very small scale [2, 3]. Its service life corresponds to that of the oil and gas fields. This method had been applied in the Morecambe Gulf. Obviously Ni-Cu alloy coating is for long-term protection. Same as Zn-Al alloy/organic coating, it also requires strict operation conditions and careful surface pretreatment and not suitable for the repair of marine structures.

Heavy-duty coatings have also been developed [4, 5]. Better surface treatment was necessary to maintain a longer service life.

If sacrificial anode can work properly in marine splash zone, it will be an important alternative to solve the anti-corrosion problem. The reason that sacrificial anode can not work properly in the area of splashed zone is that there is no stable electrolytes around the metalwork to enable the anode to function. If stable seawater film can be formed on the surface of splash zone metal structure, the sacrificial anode will be able to be used to protect the structure. If a kind of material that have a good property of absorbing and preserving the splashed seawater can be chosen, it can be wrapped around the structure to enable the sacrificial anode to function. In this paper the water absorbing capacity of materials was evaluated, and then the effect of sacrificial anode on the splash zone corrosion with the wrapping of selected seawater preserving material was studied by field exposure and cyclic wet and dry method.

2. EXPERIMENTAL

2.1 Material and specimen

The metallic material used was carbon steel with a chemical composition (wt%) as follows, C:0.15, Mn:1.46, Si:0.38, O:0.002, P:0.011, S:0.005, N: 0.0022, Fe balance. The samples that used for cathodic protection current measurement were machined to 100mm× 50mm× 2mm. Steel rods of ϕ30mm×1000mm were used for field exposure tests. The surfaces of these samples were grinded with emery papers up to 600# grade followed by thorough rinsing in acetone and de-ionized water. Pure zinc wire of ϕ2mm was used as sacrificial anode. Four kinds of fabrics, cotton, linen, dacron and chemical fiber were tested for the seawater absorbing capacity. Fresh seawater from Qingdao bay, China was used as the corrosion media.

2.2 Vertical seawater absorption test

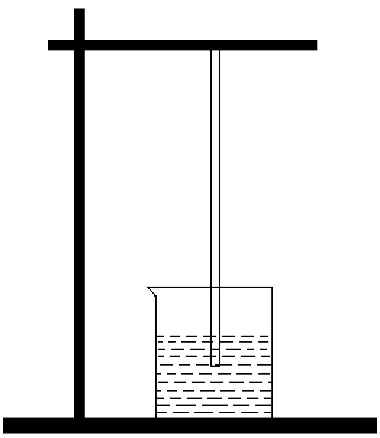

Figure 1. Schematic of water absorption test

Four kinds of material were tailored to strips of 100cm×2cm. One end of strips was hung to a horizontal stand, and the other side was soaked in a beaker filled with seawater as shown in Figure 1. After 24h, the wetting feature of strips was observed and the length of wetted section was recorded.

2.3 Water transportation test

Strips of fabrics were placed into plastic U pipes with two ends of strips exposing outside. One end was put into a container filled with seawater and the other end into an empty container as shown in Figure 2.

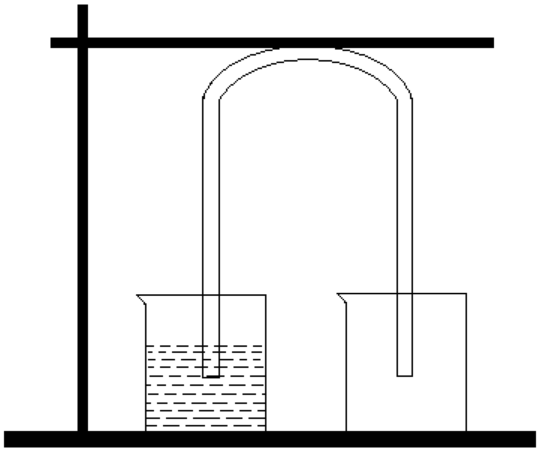

Figure 2. Schematic of water transportation test

The middle of the plastic pipe was fixed to a horizontal stand. After 72h, the originally empty container was observed and the amount of seawater transported through the strips was measured.

2.4 Measurement of cathodic protection current under cyclic wet/dry conditions

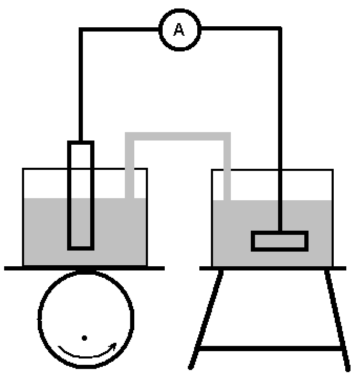

Figure 3. Apparatus for the measurement of cathodic protection current

A lead was soldered to one end of the steel specimen and then sealed. As shown in Figure 3, two beakers were filled with seawater and was connected with a salt bridge. The specimen was hung in one container and the sacrificial anode was placed in another. The movement of an eccentric disc under one beaker makes the beaker moves up and down and results in a cyclic wet/dry condition for the specimen. The cathodic protection current was measured while the eccentric disc was rotating for the specimen with and without the wrapping of fabrics.

2.5 Field exposure tests

A steel rod of ϕ30mm×1000mm was enlaced with pure zinc wire and one end of the wire was fully connected with the rod, then the rod was securely wrapped with a layer of linen. The protected rod and a bare surfaced rod were then placed at splash zone in a Qingdao marine corrosion field exposure site for one year.

The corrosion was evaluated by measuring the diameter change of the rods. When measuring, the rod was divided into segments; each segment was 10 cm apart. Nodes were marked one by one on the rod from the top to the bottom. At every node, the diameter of the rod was measured four times with a vernier caliper at 90 degree interval to obtain four numerical diameter values. The mean value of the diameter was reported.

3. RESULTS AND DISCUSSION

3.1 Vertical seawater absorption test

Table 1. The length of wetted section of strips after 24h

Fabrics	linen	dacron	cotton	Chemical fibre
Wetted length	24.5cm	14.0cm	0.0cm	2.0cm

Table 1 shows the results of the vertical seawater absorption test. Of the four kinds of fabrics, linen has the best seawater absorbing capacity. The seawater does not go up at all for cotton after 24h. The phenomenon suggests that linen is the best among the four kinds of fabrics that maybe used for seawater absorption to enable sacrificial anode's function of cathodic protection at splash zone.

3.2 Water transportation test

After 72h, some water existed only in the beaker below the linen strip and the quantity was 6.3790g. The other three beakers remained empty. This result proved further that linen has the best seawater absorbing capacity.

3.3 Measurement of cathodic protection current under cyclic wet/dry conditions

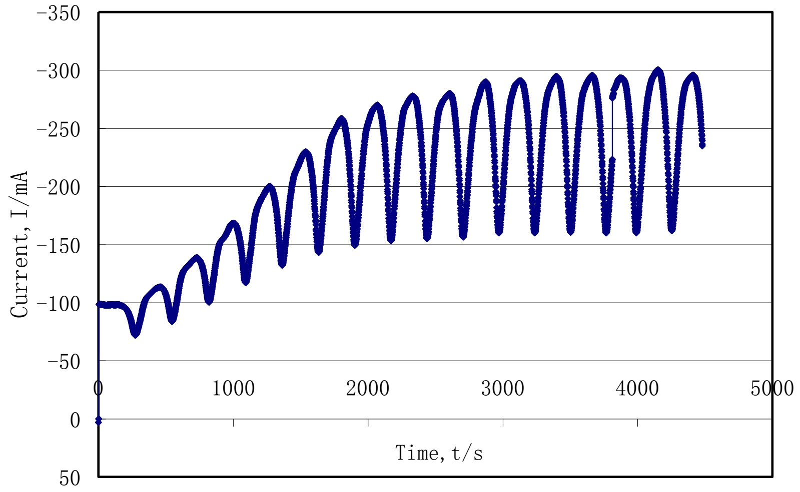

Figure 4. Cathodic protection current change with the bare specimen moving in and out the seawater

Figure 4 shows the cathodic protection current change with the bare specimen moving in and out the seawater. The current fluctuates tremendously, showing that the effect of sacrificial anode reduces while the specimen is drying out.

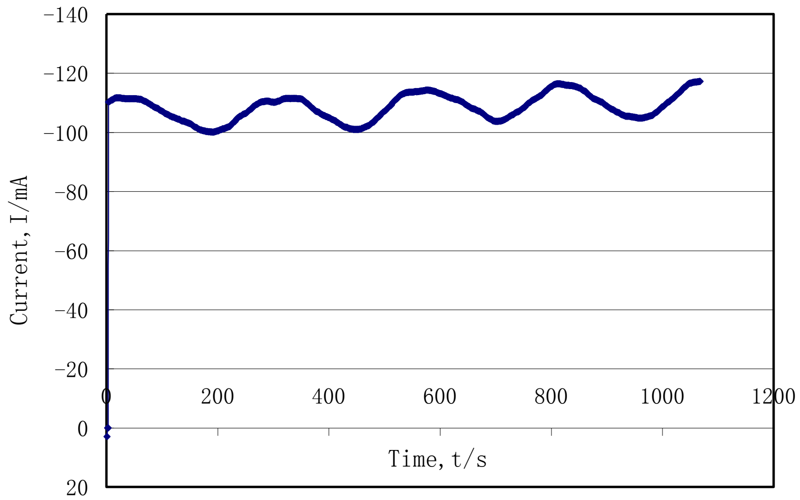

Figure 5. Cathodic protection current change with the bare specimen moving in and out the seawater when it was wrapped with one layer of linen

Figure 5 shows the cathodic protection current change when the specimen was wrapped with one layer of linen. The fluctuation of current is greatly reduced. Obviously, because linen has the ability of preserving seawater when the specimen is moving out the seawater, the sacrificial anode still function as a result of continuous electrolyte layer forming around the specimen.

3.4 Field exposure tests

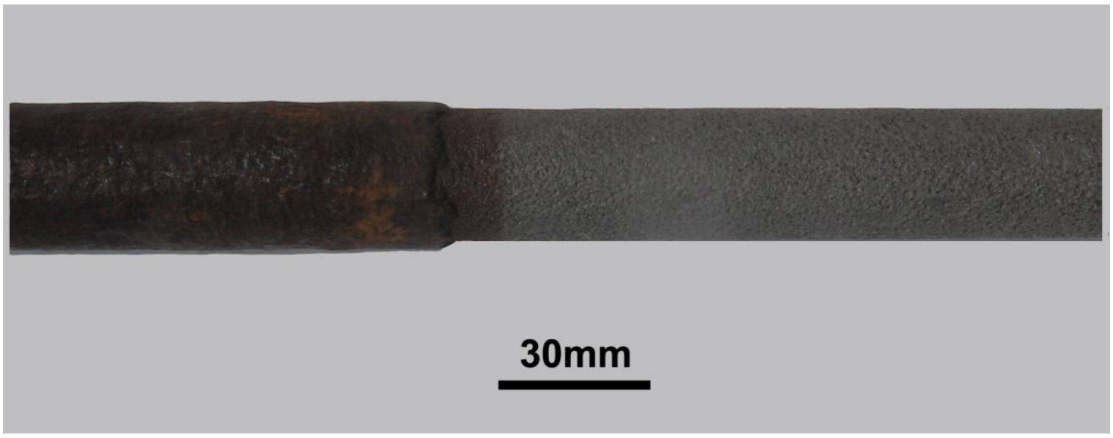

Figure 6. Morphology of bare surfaced rod after one year's exposure at splash zone, left is the upper half without removal of rust; right is the lower half, with rust removed.

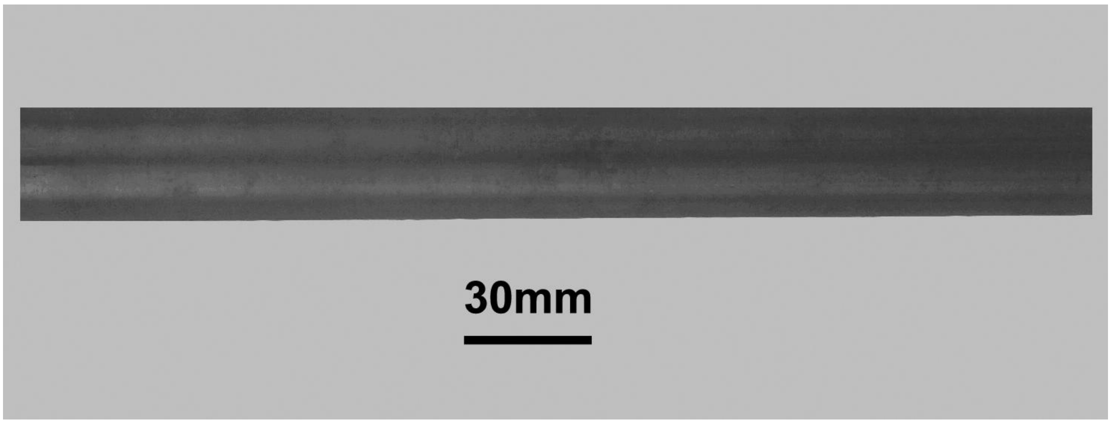

Figure 7. Morphology of a rod enlaced with pure zinc wire and wrapped with a layer of linen after one year's exposure at splash zone

Figure 6 shows the morphology of bare surfaced rod after one year's exposure at splash zone, left is the upper half without removal of rust; right is the lower half, with rust removed. The severity of corrosion in splash zone is clearly shown. The corrosion rate of bare surfaced rod is 0.2920 mm/a. Figure 7 shows the morphology of a rod enlaced with pure zinc wire and wrapped with a layer of linen after one year's exposure at splash zone. After removing of wrapped layer of linen and pure zinc wire, a fairly protected smooth surface was seen. The corrosion rate of sacrificial anode protected rod is 0.00375 mm/a. The protection efficiency by sacrificial anode in marine splash zone is 98.7%. The approach has the advantages for the instant repair of deteriorating structures.

4. CONCLUSION

Linen has better water absorbing capacity compared with cotton, dacron and chemical fiber and it can be used as the material helping electrolyte layer forming on the steel structure in splash zone. The protection efficiency by sacrificial anode in marine splash zone is high and it is an alternative of splash zone corrosion protection techniques.

ACKNOWLEDGEMENT
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