

Galvanic corrosion behavior between CFRP and steel under the water film condition

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1. Introduction In recent years, CFRP has been widely used for steel structure reinforcement. One of the main disadvantages of using CFRP composites to reinforce and repair steel structures is the lack of knowledge about the galvanic corrosion behavior between CFRP and steel. Galvanic corrosion occurs at the interface between CFRP and steel structures, reducing the durability of the structure. In this research, the influence of different water film thicknesses and two contact types (flat surface contact and cross-section contact) on CFRP and steel galvanic corrosion behavior was studied.

2. Test method All the CFRP plates were made by Mitsubishi GM 520. The size of the CFRP plate is $15 \times 15 \times 2$ mm. The electrode is made of SM490A steel and the electrode area is 1 mm^2 . Two electrodes are buried in epoxy resin, cured at room temperature (25°C) for 24h, the distance between the two electrodes is 10 mm. The surfaces of the electrodes are sanded with sandpaper from #400 to #1000, then wiping the surface of the electrodes with acetone solution to remove impurities and grease. The aqueous film thickness was controlled using the apparatus as shown in Fig.1 (a). The electrode and the measuring terminal of the electronic micrometer were connected by a multimeter. The multimeter detected a weak resistance when the terminal contacts the electrode surface. Currently, return the indication of the electronic micrometer to zero, slowly rotate the measuring terminal to 0.5 mm for fixation, and then slowly add saltwater to the water tank. When the surface of the saltwater touches the measuring terminal of the electronic micrometer, the multimeter detects the resistance again. At this time, the water film setting is completed.

The experiments were conducted in the 3.5 mass% NaCl aqueous solution under room temperature 25°C . Two kinds of water film thicknesses (0.5 mm and 10 mm) were set for this experiment. ZRA (Zero Resistance Ammeter) method was used to measure the corrosion current for 48 h while Ag/AgCl/sat. KCl was used as the reference electrode. As shown in Fig.1 (b), the reference electrode is placed near the working electrode (WE). During the test, to prevent the CFRP from detaching from the electrode surface due to buoyancy, the four corners of the CFRP board were fixed on the resin around the electrode with transparent tape. After the test, uncover the CFRP from the electrode surface, remove the corrosion products, wash with acetone, and photograph the electrode surface state with an optical microscope. For each water film thickness, two tests were carried out in different contact methods between the CFRP and the electrode: 1) flat surface of CFRP in contact with the electrode, 2) cross-section of CFRP in contact with the electrode, the surface properties of CFRP as shown in Fig.1 (c). For the section contact, several carbon fiber plates are made into cubes with adhesive and then one side of the section is cut into a $15 \times 15 \times 2$ mm plate. In addition to this, the open circuit potential of the electrodes was measured under the different contact conditions.

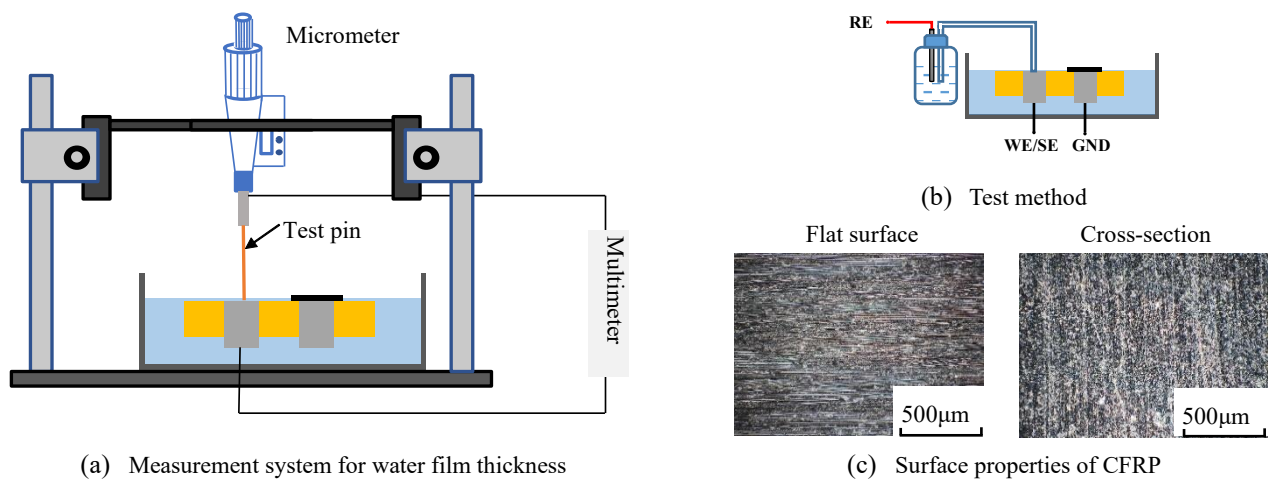


Fig.1 Measurement system and test methods

3. Test results Fig.2 shows steel electrodes' open circuit potential with and without CFRP contact. The result shows the open circuit potential of steel is tend to increase by the influence of the CFRP. Of these, the CFRP cross-sectional contact has the greatest effect, it is increasing the open circuit potential by approximately 50 mV compared to the case of steel immersed in a 10 mm thick electrolyte. Fig.3 shows the test results when the CFRP flat surface is in contact with the electrode, and it can be seen from the current results that current density is positive when the water film thickness is 0.5 mm, but it is negative when the water film thickness is 10 mm. When the thickness of the water film is 0.5 mm, the oxygen in the air is dissolved in the water film, and the working electrode is subjected to oxygen absorption corrosion. Therefore, the initial corrosion current density is very large in the first 12 h and then decreases rapidly. This is due to the rapid consumption of oxygen at the interface between CFRP and steel. The change of corrosion current density is relatively stable between 12 and 36 h, the corrosion formed on the electrode surface hinders the oxygen absorption corrosion of the electrode to a certain extent, and the corrosion reaction reaches the

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equilibrium state. At 36 h, due to the natural evaporation of water and the increase of corrosive substances on the electrode surface, the water film thickness decreases and the corrosion current density gradually tends to zero. Under the condition that the water film thickness is 10mm, the corrosion current density is large within the first 3 h of the test. However, due to the thick water film, the oxygen consumed in the water cannot be supplemented in time, and then the current density gradually decreases. **Fig.4** shows the test results when the cross-section of CFRP is in contact with the electrode. It has the same trend as the test results of plane contact under 10 mm water film. A larger corrosion current will be generated in the water film environment of 0.5 mm.

The surface states of the steel electrodes after the test are shown in **Fig.5**. The surface states of the two working electrodes with different water film thicknesses and contact methods are different. As shown in **Fig.5 (a)**, in the condition of flat surface contact, the working electrode with the water film thickness of 0.5 mm has more than 70% of the area was corroded, while the working electrode with the water film thickness of 10 mm has less than 40% of the area was corroded. Both water film thicknesses showed the same spot-like corrosion on the GND electrode surface due to the CFRP plate's contact between steel and exposed carbon fiber. As shown in **Fig.5 (b)**, in the condition of cross-section contact, the whole surface of the working electrode under 0.5 mm water film was corroded, but the corrosion area of the 10 mm water film was about 75%. Compare the corrosion area ratio of the flat surface contact and cross-section contact, the larger corrosion area shows the higher corrosion tendency, it is because the cross-section of carbon fiber has stronger electrochemical activity than the cylinder surface^[1].

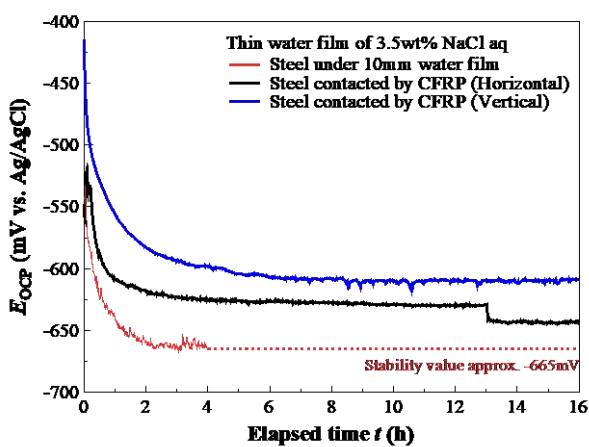


Fig.2 Test result of OCP

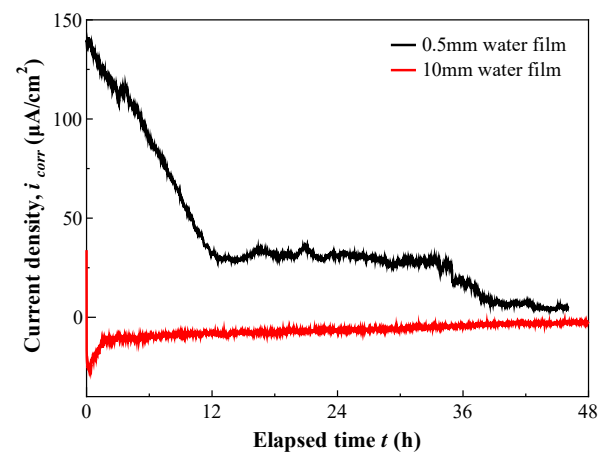


Fig.3 Test result of the flat surface of CFRP in contact with the electrode

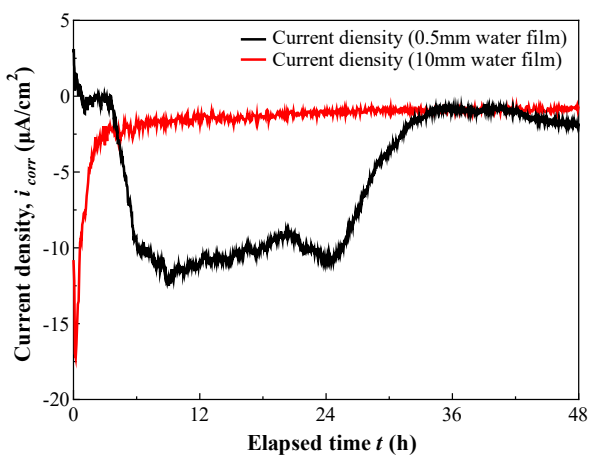


Fig.4 Test result of the cross-section of CFRP in contact with the electrode



0.5mm water film thickness 10mm water film thickness

(a) Electrode photo of flat surface contact



0.5mm water film thickness 10mm water film thickness

(b) Electrode photo of cross-section contact

Fig.5 Electrode photo of different contact types

4. Conclusion 1) In the environment of thin water film, oxygen is more likely to enter the water and participate in the corrosion reaction, so it is more likely to cause serious corrosion behavior compared to thick water film. 2) Cross-sections of carbon fiber have more active electrochemical properties, so electrodes are more susceptible to galvanic corrosion when in contact with the cross-section of CFRP.

References [1] C. Zhang, X. Chen, G.L. Song, D. Zheng, Z. Feng, Y. Guo and X. Huang, Two-dimensional Anisotropic Electrochemical Behavior of carbon fiber. *Electrochimica Acta*, 2019, Vol. 326, 135005.