The accelerated corrosion of carbon steel in air-solution alternating condition

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Abstract

In Fukushima Daiichi nuclear power station, cooling water is constantly injected into the reactor pressure vessels (RPVs) for cooling the fuel debris after the severe accidents in March 2011. Inner components of the primary containment vessels (PCVs) was observed by remote-controlled robots and the observation showed that carbon steels of the PCVs wall above the contaminated water level was exposed to an air-solution alternating condition. In the present study, an alternating corrosion test of carbon steel which simulated the air-solution alternating condition was carried out. The surface observations after the test showed that the rust layer formed on the steel after the tests in the alternating condition was thicker than that of the steel rotated always in solution. The corrosion rate of carbon steel in the alternating condition was more than three times larger than that of the steel rotated always in solution. A thin water film was confirmed on the steel when the specimen exposed to the air during the tests. This suggests that the accelerated corrosion of the steel in the alternating condition would be caused by the thin water film on the steel during the tests.

Keywords

Nuclear corrosion, Water film, Carbon steel, AES, Raman

Introduction

In Fukushima Daiichi nuclear power station, cooling water is constantly injected into the reactor pressure vessels (RPVs) for cooling the fuel debris after the severe accidents in March 2011. Inner components of the primary containment vessels (PCVs) was observed by remote-controlled robots and the observation showed that carbon steels of the PCVs wall above the contaminated water level was exposed to an air-solution alternating condition. Previous studies [1], [2] have reported that the corrosion rate of carbon steel is accelerated in case of the steel with thin water film exposed in air under the an air-solution alternating condition. This suggests that the corrosion rate of carbon steel will be accelerated in the air-solution alternating condition. However, the corrosion rate of the steel on the corrosion tests which simulated the air-solution alternating condition has not been clarified. In the present study, an alternating corrosion test of carbon steel which simulated the air-solution alternating condition was carried out.

Experimental methods

The carbon steel was alternately exposed to air and solution for 144 h by rotating in a water tank which was not completely filled with solution. The surface morphology of the specimen after the tests were observed by digital camera and optical microscope, and the corrosion rate of the steel in the alternating condition was obtained from mass loss measurement. The cross-sectional observation and analysis for the iron rust layer formed on the specimen were carried out by a scanning electron microscopy (SEM) and an Auger electron spectroscopy (AES).

Results and discussions

The cross-sectional SEM images show that the rust layer formed on the steel after the tests in the alternating condition was thicker than that of the steel rotated always in solution. (Fig. 1) The corrosion rate of carbon steel in the alternating condition was more than three times larger than that of the steel rotated always in solution. A thin water film was confirmed on the steel when the specimen exposed to the air during the tests. It has been reported that the mass transfer of dissolved oxygen to the carbon steel surface is accelerated in case of the carbon steel covered by a thin water film and corrosion of carbon steel is accelerated by the acceleration of oxygen reduction reaction (cathodic reaction) [3]. This suggests that the accelerated corrosion of the steel in the alternating condition would be caused by the thin water film on the steel during the tests.

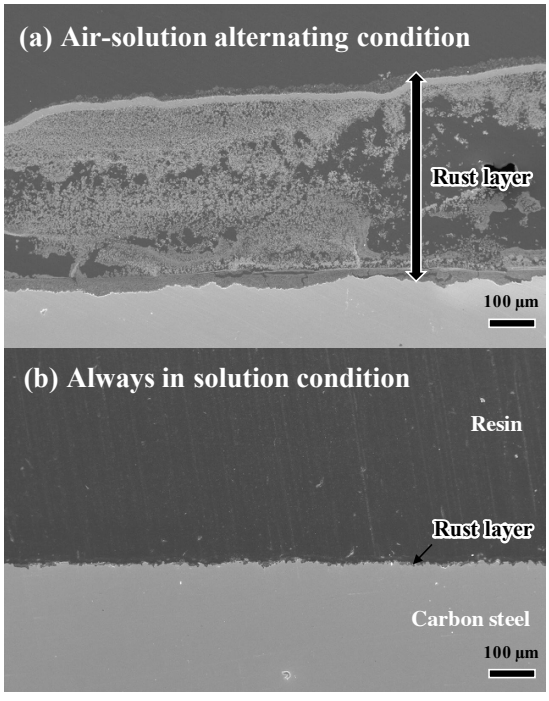

Fig. 1 Cross-sectional SEM images of the rust layer formed (a) in the alternating condition. (b) always in solutions.

Conclusion

The corrosion rate and corrosion behavior of the steel in the air-solution alternating condition was investigated by the alternating corrosion test with surface and cross-sectional observations and analyses.

1) The rust layer formed on the steel after the tests in the alternating condition was thicker than that of the steel rotated always in solution.
2) The corrosion rate of carbon steel in the alternating condition was more than three times larger than that of the steel rotated always in solution.
3) The accelerated corrosion of the steel in the alternating condition would be caused by the thin water film on the steel during the tests.

References

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