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Evaluation of the corrosion resistance of the galvanized SS400 steel in NaCl solutions

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1. Introduction

A typical CANDU plant generates about 5,000 spent fuel bundles annually, which are stored in a spent fuel pool. Because the storage capacity of a spent pool is 10 years of spent fuel bundles, the Silo type storage modules are used to store the extra fuel bundles. In a multi-unit site like Wolsong, the extra space needed for the Silo type storage modules are ever increasing with the operating years. Therefore a more space effective storage system is necessary to accommodate all the extra spent fuels from the four CANDU units at site. A new dry storage system, MACSTOR/KN-400 (M/KN-400) that is based upon MACSTOR design concept was developed. M/KN-400 will be built at the seaside in Wolsong site and galvanized carbon steel will be used for storage cylinder material to protect from the corrosion.

Generally, galvanized carbon steels, in which the Zn layer on the surface acts as a sacrificial anode, are known to have good corrosion resistance in the atmospheric or aqueous conditions. However, in the brine condition containing chloride ions or steam environment, the Zn layer can be damaged. Therefore, considering the seaside atmosphere in which the storage system are located, the integrity of the storage cylinder is likely to be affected by the corrosion caused by the salt included in the atmosphere [1, 2].

In this study, electrochemical corrosion tests were performed on the galvanized carbon steels to estimate the corrosion resistance of the storage cylinder.

2. Experimental procedure

2.1 Test specimen

The material of the storage sylinder of M/KN-400 was selected based on MACSTOR design material of Canada, CAN/CSA G40.21-M 300W. The test material, SS400 carbon steel was chosen from candidate materials. Table 1 shows the chemical composition of SS400 carbon steel. SS400 carbon steel of 1200 × 2400 mm^2 and 1 mm thickness sheet was cut into 310 × 150 mm^2 for ease of coating, welding and treatment. For Zn coating, specimen sheet was cleaned in a 20% HCl solution. After that, specimen sheet was dipped in the Zn melting bath of 450℃ for 3 minutes and was cooled. The Zn coating thickness was measured as about 150 ㎛ by coating thickness measuring instrument.

Table 1. Chemical composition of SS400 carbon steel

	Fe	C	Si	Mn	P	S
Wt%	Bal.	0.169	0.010	0.730	0.013	0.008

2.2 Test procedure

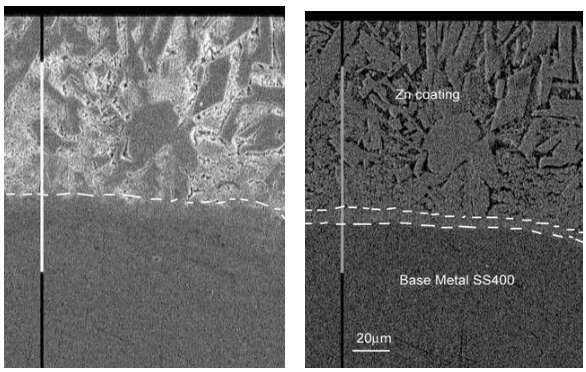
The microstructure of Zn coating was observed using SEM. The SEM observation was carried out with back scattered electron image mode and secondary electron image mode.

From electrochemical test, the corrosion resistance was measured and equivalent corrosion rate was calculated with temperature and aging time.

3. Results and discussions

3.1 Test results

From SEM observation (Figure 1), the thickness of Zn coating was about 150 ㎛ and it was similar that measured from coating surface by measuring instrument. From secondary electron image, many cavities were observed. These cavities might be formed by rapid cooling rate. The rapid cooling rate of Zn seemed to interrupt the decrease of cavities.



(a) (b)

Figure 1. SEM observation results; (a) secondary electron image (b) back scattered electron image

And there are two layers of Zn coating was observed form the back scattered electron image. The thickness of the first layer of Zn coating was about 10 ㎛ and there are no cavities observed. This layer may be gamma phase layer [3], or an alloy of Zn and Fe.

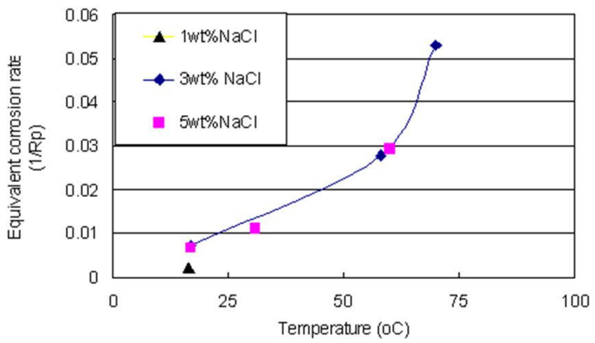


Figure 2. Temperature effect of corrosion of Zn coated SS400 in NaCl solution

From EIS test results with test temperature, the equivalent corrosion rate increased with increasing temperature (Figure 2). But there were little differences with the concentration of NaCl. Between 60℃ and 70℃, the equivalent corrosion rate increased rapidly. That means that the temperature at 60℃ is boundary region of Zn corrosion reaction activity increase. At that temperature, the corrosion resistance of Zn coating started to decrease rapidly.

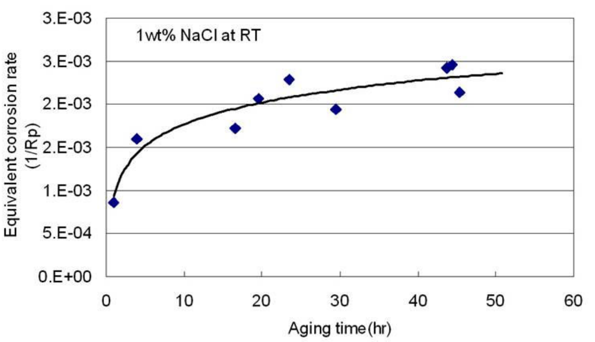


Figure 3. Aging time effect of corrosion of Zn coated SS400 in 1 wt% NaCl solution

From EIS test results with aging time of Zn coated SS400 in 1 wt% NaCl solution, the equivalent corrosion rate increased with aging time (Figure 3). Generally, in the first stage of Zn coating corrosion, Zn dissolves as Zn^{2+} at an active site (anode) and thick corrosion products (mainly $ZnCl_2{\cdot}4Zn(OH)_2$) are found until porous corrosion product reaches to Fe-Zn alloy. And these corrosion products seem not to act as a barrier layer for mass transports of O_2 and dissolved Zn^{2+} [4]. In this case, the surface seemed to be covered with Zn corrosion products of the first stage. And the NaCl solution seemed to soak into the originally formed cavities of Zn coating after Zn coating dissolving, and the surface area increase. This process seemed to be main cause of increase of equivalent corrosion rate. And equivalent corrosion rate after that more aging test performed may be saturated or decrease when the Zn corrosion process reaches to second stage, Fe-Zn alloy layer starts to corrode.

4. Conclusion

The corrosion test and microstructure observation test were performed with Zn coated SS400 carbon steel and the following results were confirmed.

1. From microstructure observation test results, many cavities were detected in the secondary electron image. And two layers of Zn coating was observed in the back scattering electron image. These layers made from differences cooling rate on surface.
2. The equivalent corrosion rate increased with increasing temperature. The equivalent corrosion rate increased rapidly between 60℃ and 70℃.
3. The equivalent corrosion rate increased with aging time in 1 wt% NaCl solution. The reason seemed to that the Zn corrosion products seem not to act as a barrier layer for mass transports of O_2 and dissolved Zn^{2+} and NaCl solution soaks into the originally formed cavities of Zn and the surface area increase.

Acknowledgement

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