Electrochemical Properties of Cathodic Protection System for Steel Members Using Al-Zn Base Sacrificial Anode

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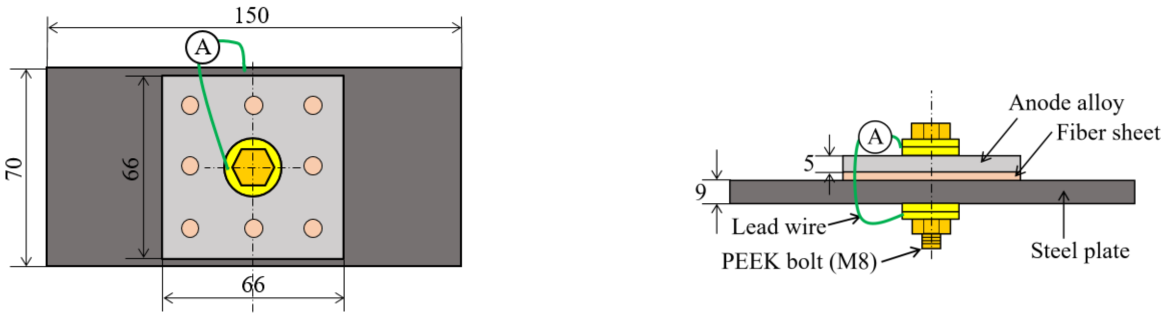
1. Introduction Sacrificial anode is one of the main methods for corrosion protection of steel structures. Corrosion problem tends to be more severe for steel structures in aggressive and humidity environments, such as steel bridge and oil storage tank at offshore place. Therefore, a new cathodic protection technique using sacrificial anodic alloy Al-3Zn (wt%) material was developed for steel structures in an aggressive atmosphere environment.

In this study, the electrochemical properties of alloy Al-3Zn and the specimens of cathodic protection system were investigated to reveal the effectiveness of this cathodic protection technique. Different concentration of electricity solution was applied to the electrochemical test. The activity of anode alloy and efficiency of cathodic protection system were demonstrated through spontaneous potential, polarization curves and galvanic coupling current of the samples.

2. Specimen and test method Test specimen of the system includes the components of carbon steel plate[1)] with dimensions of 150×70×9 mm, fiber sheet 66×66×3 mm, and anode alloy plate 66×66×5 mm. These components were fixed using a PEEK bolt at the center hole. The diameter of the eight circular holes cut was set as 6.5 mm, and alignment was arranged around the bolt hole, as shown in Fig.1. The galvanic coupling current between anode alloy and steel plate was measured by a zero-resistance ammeter, and lead wire was used to connect two types of metals to maintain short-circuit in the system.

During the electrochemical test, NaCl aq solution with different concentration of 0.1, 3.5, and 26.4 wt% was used as electrolyte. An Ag/AgCl electrode in saturated potassium chloride (Sat.KCl) solution was used as the reference electrode. The spontaneous potential (E_{corr}) of Al-3Zn was measured for 1200 s and reached to stable value. Then the anodic polarization curve was tested from 0.05 mV lower than E_{corr} to the required value with scanning speed of 20 mV/min, when platinum plate was used as counter electrode. Moreover, same electrochemical test process was conducted on the galvanic coupled specimens to investigate effect of anodic alloy Al-3Zn on the electrochemical properties of steel plate through the electrolyte in fiber sheet. The fiber sheet was absorbed with sufficient NaCl aq of 0.1, 3.5, and 26.4 wt% concentration in advance.



(a) Top view (b) Side view

Fig.1 Dimensions and components of specimen used in the electrochemical test (unit: mm)

3. Test results Fig.2 shows that E_{corr} of steel plate without anodic protection remain relatively stable around -675 to -695 mV as the concentration of NaCl aq increased from 0.1 wt% to saturated 26.4 wt%, whereas E_{corr} of Al-3Zn anode alloy tends to be more negative under the same electrolyte condition. E_{corr} of steel plate protected by anode alloy shift to negative direction and performing similar trend as Al-3Zn anode alloy under different concentration of NaCl aq. Both E_{corr} of anode alloy and protected steel plate have dropped dramatically before 3.5 wt% concentration and then decrease slowly with increasing NaCl aq concentration. In case of the fiber sheet absorbed 0.1 and 26.4 wt% NaCl aq, the negative shift on protected steel plate compares to steel plate without anode protection is 73 mV and 299mV respectively when Al-3Zn acts as anode. In general, potential shift of steel plate indicates the fiber sheet absorbed with sufficient NaCl aq performed as electrolyte in the specimen, hence providing a precondition for cathodic protection reaction in humid environment. Furthermore, the effective anti-corrosion potential[2)] for the steel members in a neutral environment being approximate -730 mV vs. Ag/AgCl, where specimens in this study were meet and exceed the effective anti-corrosion potential under various concentration of NaCl aq.

The galvanic coupling current density between steel and anode alloy shows in Fig.3. It can be seen from the figure that galvanic coupling current density tend to be larger along with the increasing of NaCl aq concentration, but at a slower rate as the concentration exceed 3.5 wt%. In addition, the current density[3)] required for electrochemical corrosion protection in seawater should be 10 $\mu A/cm^2$. In this study, the coupling current density of specimen rising from 29 $\mu A/cm^2$ to 44 $\mu A/cm^2$ as the concentration of NaCl aq increased from 0.1 wt% to 26.4 wt%, indicates this specimen meet the requirement for cathodic protection.

Fig.4 shows the anodic polarization curves of anode alloy and specimen in 0.1, 3.5 and 26.4 wt% NaCl aq. For anode alloy and specimens, their current densities increased with gradual gradients as the potential approached noble region, and the trend of

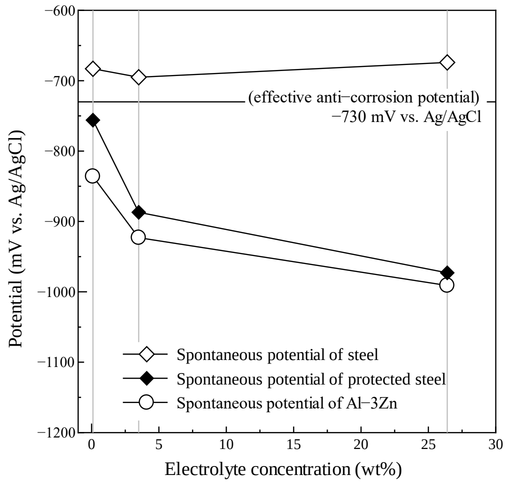


Fig.2 Spontaneous potential of samples in different NaCl aq concentration

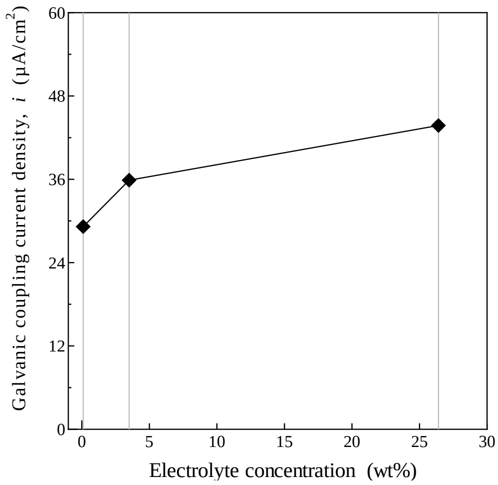
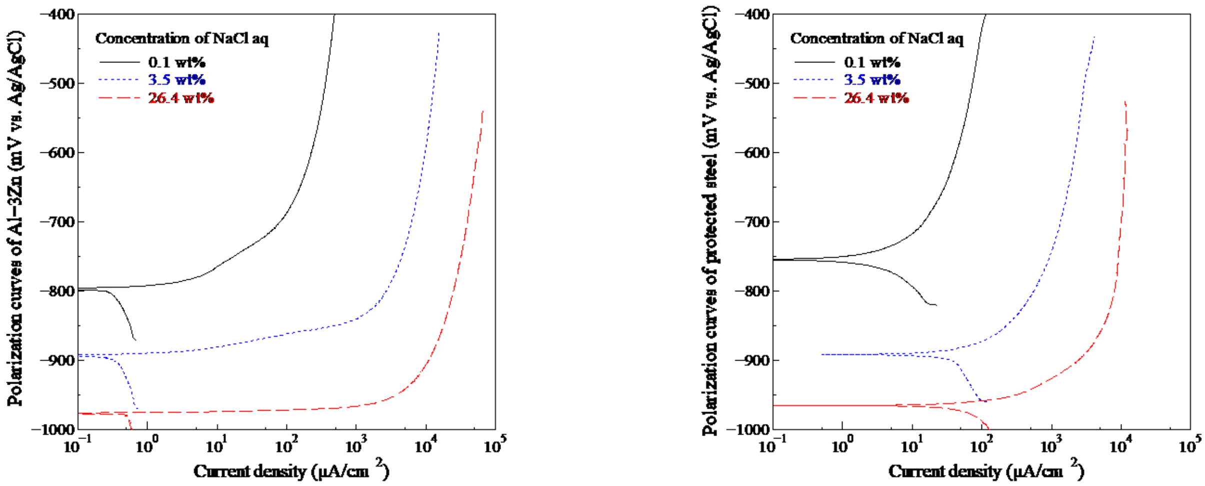


Fig.3 Galvanic coupling current density of specimens with different concentration of NaCl aq



(a) Polarization curve of Al-3Zn anode alloy (b) Polarization curve of protected steel plate

Fig.4 Polarization curve of samples under 0.1, 3.5 and 26.4 wt% NaCl aq

polarization curves are similar between anode alloy and protected steel plate immersed in the same concentration of electrolyte, indicate that anode alloy and steel plate formed a coupling system with fiber sheet and changed their electrochemical properties after assembled. For electrochemical properties of anode alloy as showed in Fig.4 (a), the passivation inhibition of alloy occurred in every concentration of NaCl aq, ensures that Al-3Zn anode alloy dissolving constantly in neutral chloride ionic solution hence worked as a functional sacrificial anode for steel. Corrosion current density of anode alloy stabilized in higher current density with rising overpotential, which indicates the anodic dissolution tends to be easier under high Cl^- concentration solution. For polarization curves of steel plate coupling with anode alloy as shown in Fig.4 (b), the current density slightly reduced compares to anode alloy in the same electrolyte, but the trend of polarization curves and galvanic values remain similar to the anode alloy, prove that electrochemical properties of steel plate affected by attached anode alloy.

4. Summary 1) Anti-corrosion potential of steel plate in this specimen meet the requirement for effective protection. 2) Galvanic coupling current density between anode alloy and steel plate was sufficient in various NaCl aq concentration. 3) Al-3Zn anode alloy affects the electrochemical properties of steel plate and provides constant protection despite increasing NaCl aq concentration.

Reference 1) Japanese Standards Association, Japanese Industrial Standard (JIS) G3106: Rolled Steels for Welded Structure, 2008. 2) S. Tamari, Corrosion problems and corrosion control, J. Soc. Mat. Sci., Japan., Vol.36, pp.636–641, 1987. 3) T. Ishihara, The Current Issue Case Histories in Corrosion Failures Analysis and Corrosion Diagnostics, Techno system, 2008.