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Corrosion Resistance of Zn and Cu Coated Steel Pipes as a Substitute for Cu Pipe in an Air Conditioner System

Jae-Gyeong Shin, Chan-Jin Park†, and Sung-Kil Hong

Department of Materials Science and Engineering, Chonnam National University, 300, Yongbong-dong, Buk-gu, Gwangju 500-757, Korea

We investigated the corrosion resistance of Zn and Cu coated steel pipes as a substitute for Cu pipe in an air-conditioner system. In addition, the galvanic corrosion tendency between two dissimilar metal parts was studied. The corrosion resistance of the Cu electroplated steel was similar to that of Cu, while the corrosion rate of the Zn electro- galvanized and the galvalume (Zn-55 % Al) coated steels was much higher and not suitable for Cu substitute in artificial sea water and acidic rain environments. Furthermore, the galvanic difference between Cu electroplated steel and Cu was so small that the Cu coated steel pipe can be used as a substitute for Cu pipe in an air-conditioner system.

Keywords *: coated steel, copper, galvanic corrosion, air-conditioner*

1. Introduction

Due to recent extraordinary hot summers, there has been an increased world-wide demand for air-conditioners. In particular, the portion of Korean goods in world air-conditioner market has increased remarkably. Korean air-conditioners are preferred due to their luxury design, excellent performance and reasonable price.

Recently, the price of copper pipes for air-conditioner has increased significantly. The increase in copper price induces the increase in the price of final product. Therefore, there have been efforts to find a cheaper substitute for copper pipe in air-conditioner system. Steel pipes coated with Zn or Cu can be a good candidate due to their good corrosion resistance.[1] Cu pipes are mainly used in outdoor part of air-conditioner system. In particular, the pipes may be highly affected by corrosion in coastal or industrial areas.

The objective of this work is to investigate the corrosion resistance of Zn and Cu coated steel pipes and the galvanic tendency between two dissimilar metal parts in artificial sea water and acidic rain environments.

2. Experimental

We used pure Cu, Cu electroplated steel, Zn electro-galvanized steel, and galvalume (Zn-55 % Al) steel pipes for tests. For simplicity, they are named as Cu, E Cu, E Galva and Galva, respectively. Some pipes were cut into parts and masked using silicone with an exposure area of 1 cm^2. Then, all specimens were rinsed with acetone and deionized water.

For potentiodynamic tests, a cell is composed of a metal pipe of interest as the working electrode, a Pt wire as the counter electrode, and a saturated calomel electrode (SCE) as the reference electrode. Potentiodynamic tests were conducted in a 3.5 % NaCl solution and an artificial acidic rain with pH 4.8 at a scan rate of 0.5 mV/sec.

Galvanic corrosion tests between two dissimilar pipe specimens were carried out using zero resistance ammeter (ZRA).[2),3)] In particular, filler metals (Cu-5 % Ag and Cu-30 % Ag) that is generally used for brazing Cu pipes were also tested. The higher the absolute value of galvanic current, the severer the galvanic corrosion between two working electrodes.

In addition, cyclic corrosion tests were conducted for 10 cycles at 35 ^{o}C using 5 % NaCl solution to investigate the atmospheric corrosion behavior of the pipes. 1 cycle is composed of the salt spray of 5 % NaCl for 8 h and the rest period for 16 h.

3. Results and discussion

The possible factors that can induce corrosion of the pipes for outdoor part of air-conditioner system can be floating sea water spray in coastal area or acidic rain in-

† Corresponding author: parkcj@chonnam.ac.kr

dustrial region.[4)-8)] Thus, the potentiodynamic tests were conducted in an artificial acidic rain with pH 4.8 and a 3.5 % NaCl solution. Fig. 1 shows the polarization curves and the obtained corrosion potential (E_{corr}) and corrosion current density (i_{corr}) in an artificial acidic rain with pH 4.8. The corrosion potential of E Galva and Galva is near -600 mV_{SCE}, while that of Cu and E Cu is close to 0 V_{SCE}. In addition, the corrosion current density of Zn coated steels (E Galva and Galva) was much higher than that of Cu. It is noticeable that the corrosion potential and current density of E Cu is similar to those of Cu.

Fig. 2 shows the polarization curves and the obtained corrosion potential and current density in 3.5 % NaCl solution. Similarly to the previous results, the corrosion

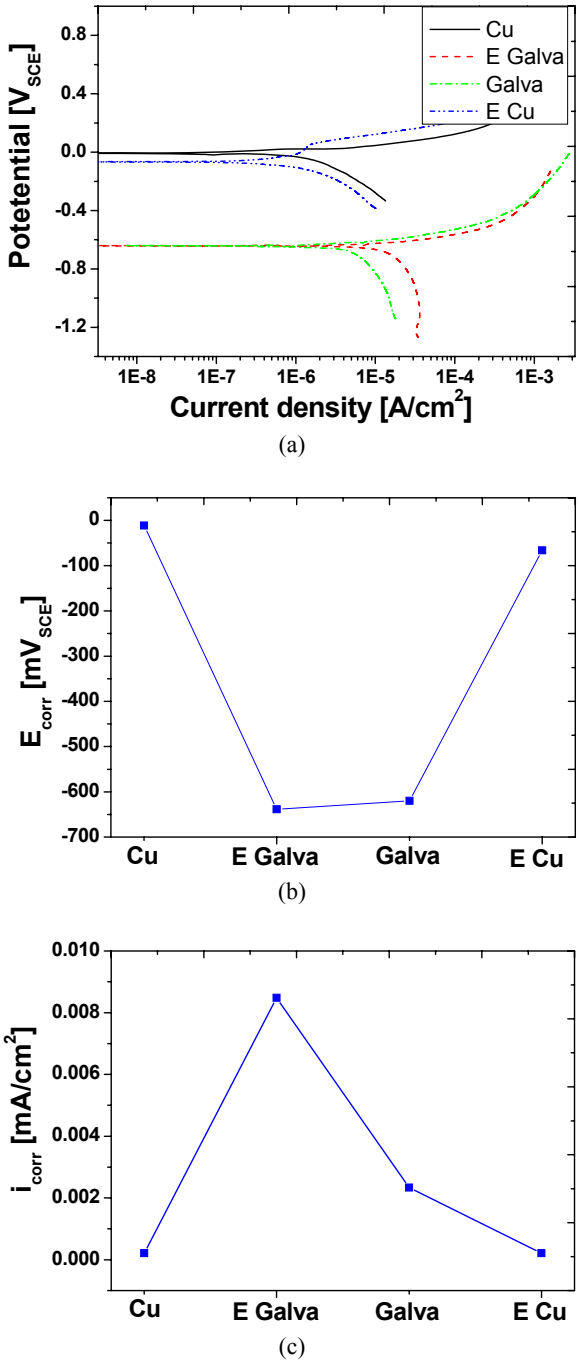


Fig. 1. (a) Polarization curves of the metal pipes and the measured (b) corrosion potential and (c) corrosion current density in an artificial acidic rain with pH 4.8.

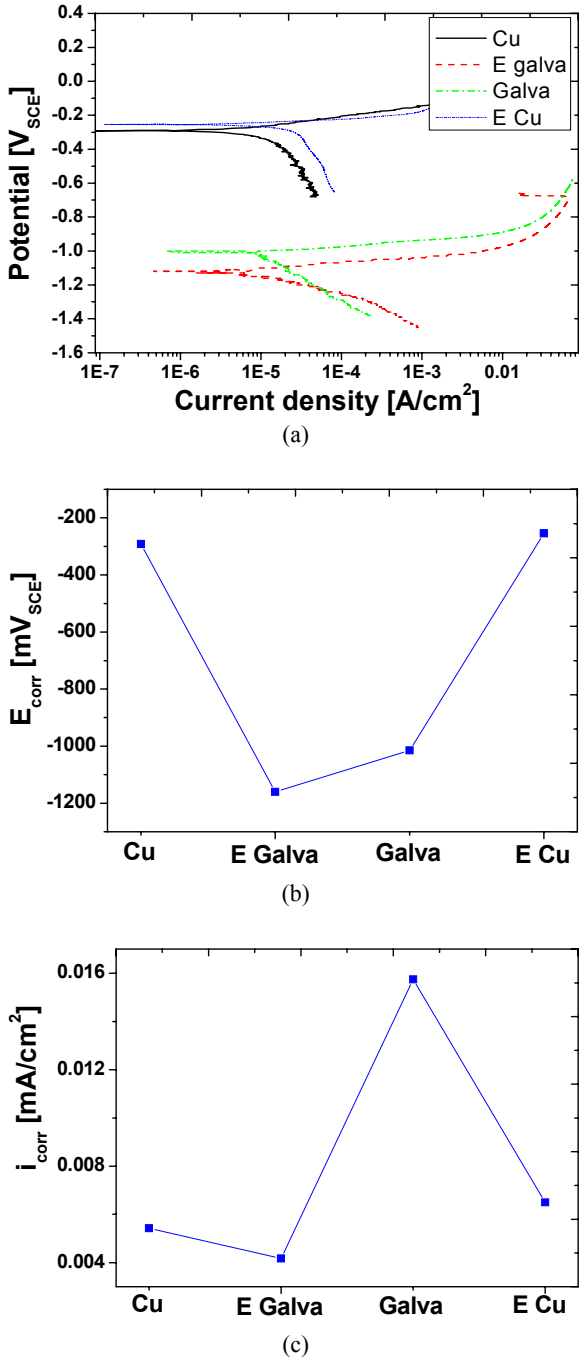
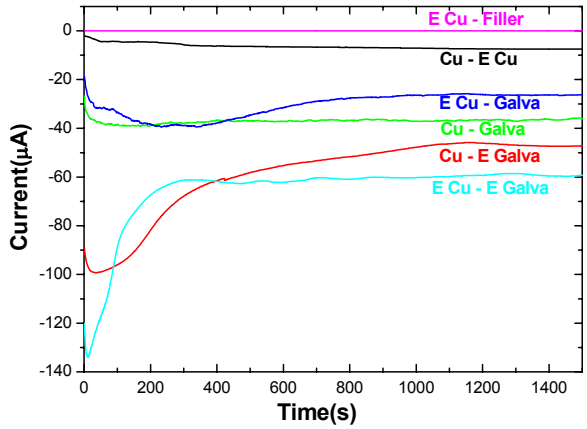


Fig. 2. (a) Polarization curves of the metal pipes and the measured (b) corrosion potential and (c) corrosion current density in 3.5 % NaCl solution.

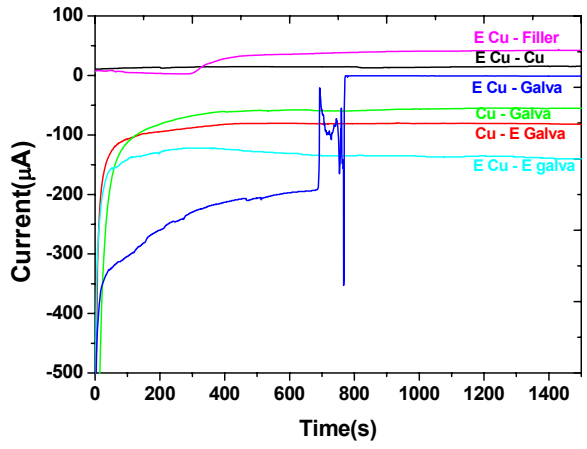
potential of Zn coated steels exhibited lower values than that of Cu and E Cu. However, the corrosion current density of E Cu was smaller even than Cu. In contrast, the current density of Galva was higher than others. It is strange that two Zn coated steels exhibits different corrosion behaviors. This phenomenon is due presumably to surface condition of the pipes. Galva had many scratches on surface which might be formed during hot dipping process or handling, while the E Galva showed smooth surface. Corrosion resistance of coated steel appears to be highly affected by its surface condition particularly in chloride solution.

In air-conditioner system, there can be many joints between dissimilar metals. In particular, the formation of the joint between the Cu pipe of indoor part and the substitute pipe for Cu of outdoor part is inevitable. Thus, we measured the galvanic corrosion tendency between two dissimilar metal couples. Fig. 3 shows the galvanic current via zero resistance ammeter (ZRA) between two different working electrodes in an artificial acidic rain and NaCl solution. On the whole, the galvanic current measured in 3.5 % NaCl solution was higher than that in artificial acidic rain. Galvanic current between Zn coated steels (E Galva and Galva) and Cu was measured to be higher than that between E Cu and Cu. This result indicates that galvanic corrosion may not become a problem if E Cu is used as a substitute for Cu pipe. In contrast, galvanic corrosion can occur when Zn coated steel pipes and Cu pipe are electrically connected.

Fig. 4 shows the appearance of Cu and coated steel joints, which were brazed using filler metals, after cyclic corrosion test for 10 cycles. The rust of each metal is characterized by its own color. Bluish green is for Cu, white for Zn, and reddish brown for Fe. The joints between Cu and Zn coated steel pipes were highly corroded. Accordingly, reddish brown rust for Fe was found in large areas. In contrast, the E Cu and Cu joint exhibits less brown rust compared with Cu-Zn coated joints. From the results, it is considered that E Cu pipe can be safely used as a substitute for Cu pipe and less prone to galvanic corrosion than Zn coated steel pipes.



(a)

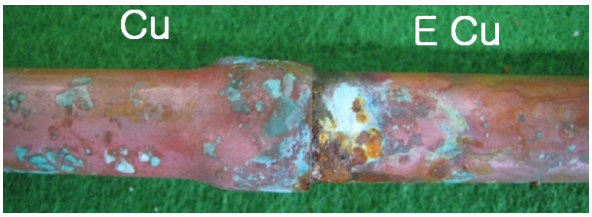


(b)

Fig. 3. Galvanic current via zero resistance ammeter (ZRA) between various metal couples.

(a)

(b)



(c)

Fig. 4. Appearance of (a) Cu-E Cu, (b) Cu-Galva, and (c) Cu-E Cu joints, brazed using filler metals, after cyclic corrosion tests for 10 cycles. Cu-30 % Ag filler was used for (a) and (b), and Cu-10%Ag filler was for (c).

4. Conclusions

The corrosion resistance of the Cu electroplated steel was similar to that of Cu, while the corrosion rate of the Zn electro-galvanized and the galvalume (Zn-55 % Al) coated steels was much higher and not suitable for Cu substitute in artificial sea water and acidic rain environments. Furthermore, the galvanic difference between Cu electroplated steel and Cu was so small that the Cu coated steel pipe can used as a substitute for Cu pipe in an air-conditioner system.

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