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Corrosion of Zinc Coated Steel in Magnetically Treated 3% Sodium Chloride Solution

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The dissolution amount of Zn plate was 0.058 mg/cm^2 in the non-magnetically treated solution, and was 0.059 mg/cm^2 in the magnetically treated solution after 24 hours of immersion. The magnetic treatment had no effect to corrosion of Zn plate as pH on surface was not recognized the difference. The addition of Zn(Ⅱ) ion in the solution was prepared to the effects of corrosion and dissolution of Fe. The regularity was not obtained the effect of the magnetic treatment on the dissolution of Fe plate.

Keywords *: ferrous ion, ferric ion, zinc ion, 3% NaCl solution, magnetic treatment*

1. Introduction

Iron gathers rust readily, effects of magnetic effect on water was reported.[1] The change from red rust to black rust was faster, and usually inhibited the corrosion. The generation of Zn and Zn alloy coatings on the steel is one of the most important processing techniques, and used to protect steel components exposed to corrosive environments. Zn coatings are predominantly used to improve the aqueous corrosion of steel by two methods, barrier and galvanic protections.

The Zn surface rapidly forms a thin film of $Zn(OH)_2$, this film transforms into white rust which is $Zn_4CO_3(OH)\cdot H_2O$ or $Zn_5(CO_3)_2(OH)_6$ in an atmosphere of air.[2] Or, different corrosion products, $Zn_5(OH)_8Cl_2\cdot H_2O$ formed in 3 % NaCl solution.[3] Corrosion products in seawater,[4] effect of chloride ion on Zn passivity[5),6)] and Zn coating Fe[7] were reported.

Magnetic treatment water inhibited the corrosion of iron.[1] The magnetic field effect on the current oscillations in the anodic Zn dissolution was reported.[8] The studies of magnetic effects on corrosion of Zn and Zn coating Fe were little.

In this work, the effect of Zn ion on the corrosion of Fe plate was determined.

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2. Experimental procedure

The procedure described same as previous report.[1] Zn plated Fe plate used commercially. Corrosion area was 10 cm^2.

3. Result and discussion

Effect of immersion time on the pH on the surface is shown in Fig. 1. pH was 4.8 in magnetic treated solution,

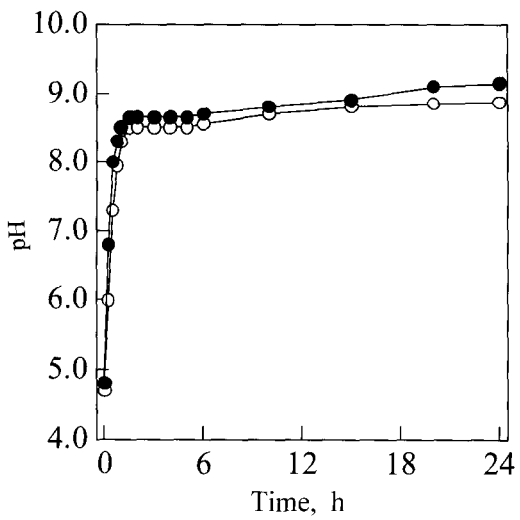

Fig. 1. pH on Zn surface
Magnetic treatment: ○ ; Non-magnetic treatment, ● ; Magnetic treatment

4.7 in non magnetic treated solution. Zn immersed in test solution, pH rapidly changed in the alkaline side in initial stage of immersion. pH was increased to 8.5 after about 2 hours of immersion. pH was stabilized to 8.9 in the non-magnetically solution and 9.1 in the magnetically treated solution after 24 hours of immersion. The magnetic treatment had not little effect to corrosion of Zn plate. It was concluded that the cathodic reaction was the oxidizing and reducing environments. In the oxidizing environment,

$$O_2 + 4H^+ + 4e^- \rightarrow 2H_2O \quad \text{(Acid)} \qquad (1)$$

$$^1/_2O_2 + H_2O + 2e^- \rightarrow 2OH^- \quad \text{(Alkaline)}$$

$$E_0 = 0.401V \text{ vs. NHE} \qquad (2)$$

In the reducing environment,

$$2H^+ + 2e^- \rightarrow H_2 \quad \text{(Acid)} \qquad (3)$$

$$2H_2O + 2e^- \rightarrow H_2 + 2OH^- \quad \text{(Alkaline)} \qquad (4)$$

When pH was from 6 to 12, corrosion potential was in the passivity region.

$$Zn + \rightarrow Zn^{2+} + 2e^- \quad E_0 = 0.878 \text{ V vs. NHE} \qquad (5)$$

The pH of solution of different concentrations, Zn (Ⅱ), resulting from the dissolution of such as oxide or hydroxide ion in pure water is governed by equation

$$\log Zn(Ⅱ) = \log([OH^-]\text{-}10^{-7}) \qquad (6)$$

If pH was 8.8, Zn(Ⅱ) ion was 0.3 mg $Zn(OH)_2$ /dm^3. This results was differed to dissolution amount (Zn(Ⅱ) ion: 5.8 mg/dm^3). It was concluded that test solution was NaCl solution and to the existence of $Zn(OH)^+$ ion or varieties of precipitation products.

Effect of immersion time on the rest potential of Zn plate is shown in Fig. 2. The rest potential shifted to base direction rectilinearly in the magnetically and non-magnetically treated solutions. It was estimated that magnetic treatment had not little effects.

After 2~3 hours of immersion, the rest potential reached approximately -1.01V in the magnetically treated solution and -1.02 V vs. Ag.AgCl in the non-magnetically treated solution, thereafter potential was stabilized.

The progress of the dissolution was rapidly as the potential change speed was larger in the early stage. The rest potential was the base potential comparing with equilibrium potential of Zn. The mechanism of dissolution

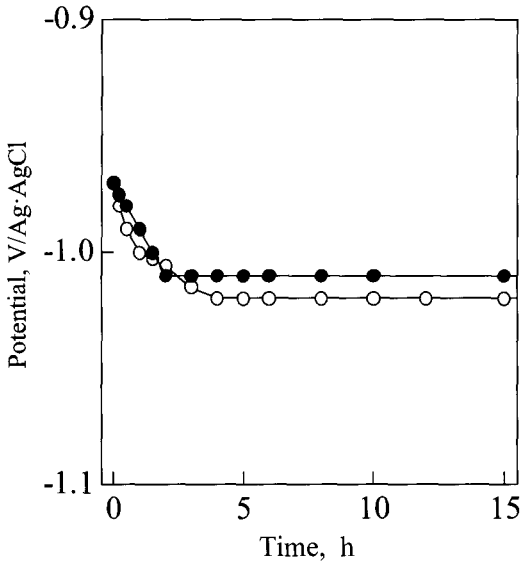

Fig. 2. Rest potential

was comprised two steps; the first stage related selective dissolution and the second stage was the uniform dissolution. The anodic partial reaction is the dissolution of Zn. The corrosion of Zn with the evolution of hydrogen may be expressed.[3),5)] Some $Zn(OH)_2$ solid began to precipitate on the surface at a value of pH around 7.2 after 0.5 h of immersion.[6),8)] The precipitation is a maximum for a pH in the region of 10. Finally, the $Zn(OH)_2$ formed redissolutions and its dissolution is complete for pH value of about 13. In the relatively, it was concerned for the Zn^{2+}- $Zn(OH)_2$ equilibrium in low pH range, as follows;

$$Zn + \rightarrow Zn^{2+} + 2e^- \quad E_0 = 0.878 \text{ V vs. NHE} \qquad (5)$$

$$2H^+ + 2e^- \rightarrow H_2 \qquad (3)$$

$$Zn + 2OH^- \rightarrow Zn(OH)_2 + 2e^-$$

$$E_0 = -1.248 \text{ V vs. NHE} \qquad (7)$$

$$Zn(OH)_2 + 2H^+ \rightarrow Zn^{2+} + 2H_2O \qquad (8)$$

$$Zn^{2+} + 2OH^- \rightarrow Zn(OH)_2$$

$$K_{sp} = [Zn^{2+}][OH^-]^2 = 7.0 \times 10^{-18} \qquad (9)$$

Magnetic treatment effects were not quite effective to Zn plate, because anodic polarization curves were almost no recognizable difference.

The Fe surface appears when the dissolution of Zn progresses. Corrosion process of Fe-Zn galvanic couple was anodic reaction with corrosion of Zn ($Zn + \rightarrow Zn^{2+} + 2e^-$) and reduction of oxygen ($^1/_2O_2 + H_2O + 2e^- \rightarrow 2OH^-$). Zn(Ⅱ) ion formed $Zn(OH)_2 + 2H^+$. Potentials of

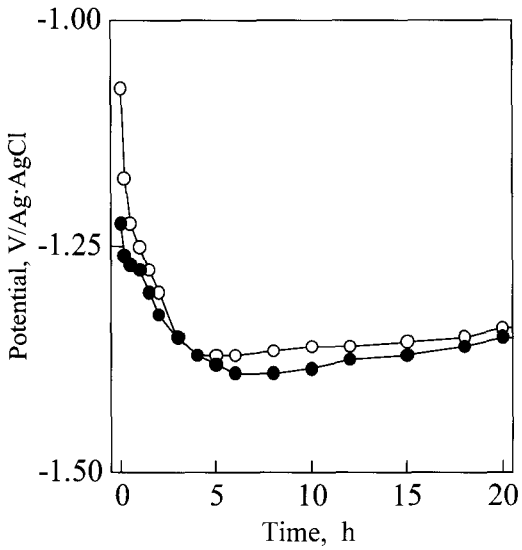

Fig. 3. Potential of Zn electrode on Fe-Zn cell
Magnetic treatment: ○; Non-magnetic treatment, ●; Magnetic treatment

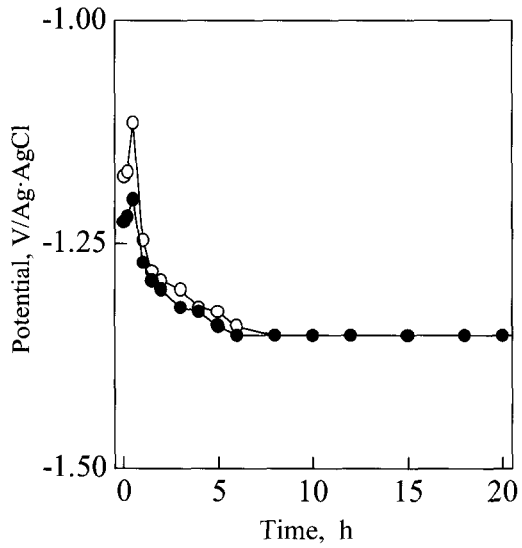

Fig. 4. Potential of Fe electrode on Fe-Zn cell
Magnetic treatment: ○; Non-magnetic treatment, ●; Magnetic treatment

Fe and Zn electrodes are shown in Fig. 3 and 4. Potential of Fe electrode reduced to Zn electrode potential and stabilized at -1.35V vs. Ag.AgCl in the magnetically and non-magnetically treated solutions. Potential of Zn electrode showed peaks at -1.37 V in the non-magnetically treated solution and at -1.39 V in the magnetically solution, thereafter potentials shifted to noble direction. Zn was a sacrifice electrode, dissolution of Fe inhibited. However inhibition effect of magnetic treatment was unknown for dissolution of Fe or Zn plate.

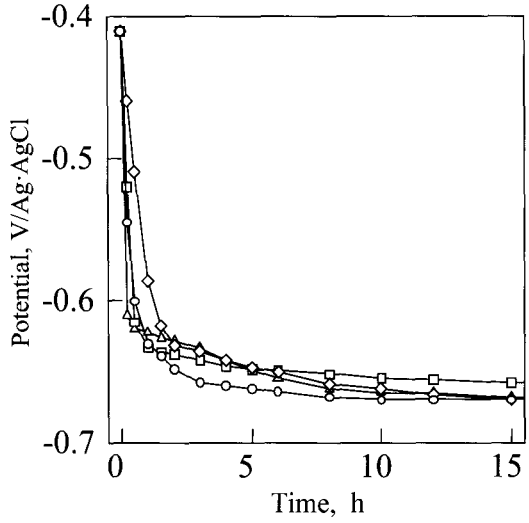

Fig. 5. Effect of Zn (Ⅱ) ion on the rest potential of Fe plate in non-magnetically treated solution
Concentration: ○; non, △; 20ppm, □; 50ppm, ◇; 100ppm

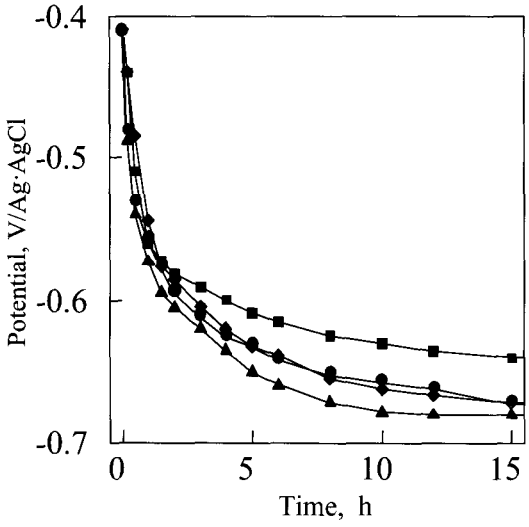

Fig. 6. Effect of Zn (Ⅱ) ion on the rest potential of Fe plate in magnetically treated solution
Concentration: ●; non, ▲; 20ppm, ■; 50ppm, ◆; 100ppm

Effect of Zn(Ⅱ) ion on the rest potentials of Fe plate is shown in Fig. 5 and 6. The rest potentials shifted in the based direction with time, and stabilized at approximate -0.67 V vs. Ag.AgCl. In the magnetically treated solution, the time which required become a steady state was longer comparing with that in the non-magnetically treated solution.

Effect of Zn(Ⅱ) and Fe(Ⅱ) ions on the rest potentials of Fe plate is shown in Fig. 7 and 8. The rest potentials shifted in the based direction with time. In the non-magnetically solution containing 50 ppm Fe(Ⅱ) ion, 20 ppm Zn(Ⅱ) ion was more affected and inhibited. How-

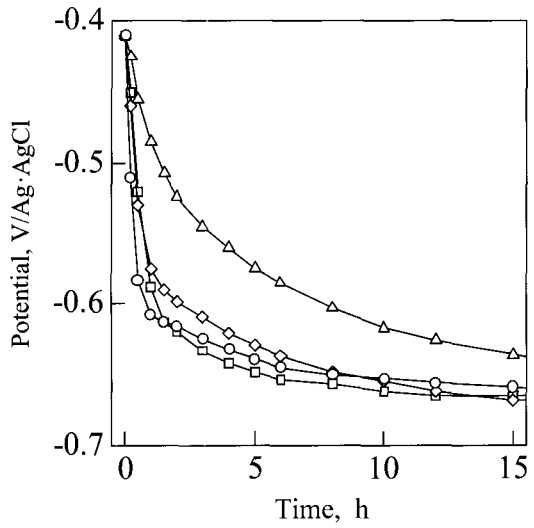

Fig. 7. Effect of Zn (Ⅱ) ion on the rest potential of Fe plate in non-magnetically treated solution containing 50 ppm Fe (Ⅱ) ion
Concentration: ○; non, △; 20ppm, □; 50ppm, ◇; 100ppm

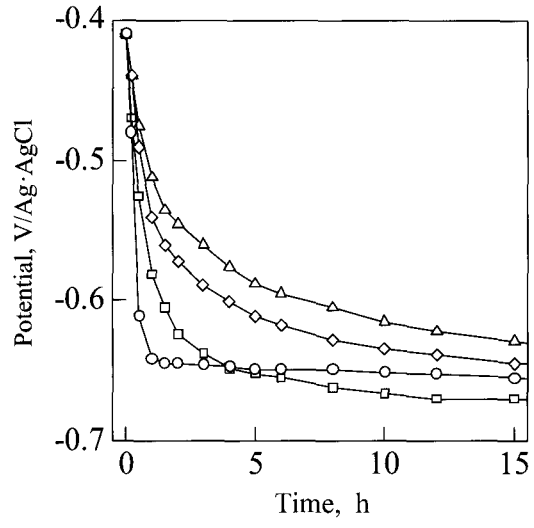

Fig. 9. Effect of Zn (Ⅱ) ion on the rest potential of Fe plate in non-magnetically treated solution containing 50 ppm Fe (Ⅲ) ion
Concentration: ○; non, △; 20ppm, □; 50ppm, ◇; 100ppm

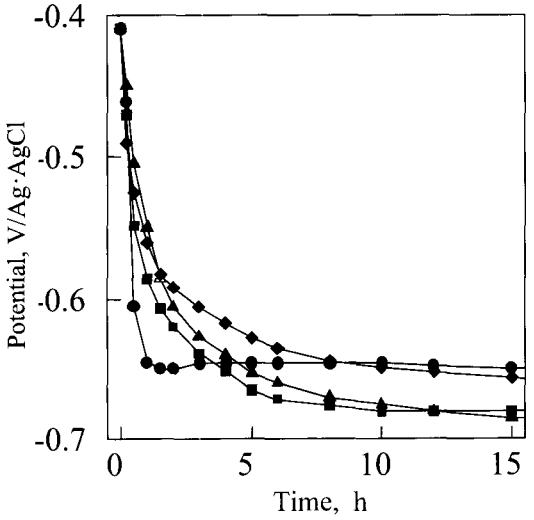

Fig. 8. Effect of Zn (Ⅱ) ion on the rest potential of Fe plate in magnetically treated solution containing 50 ppm Fe (Ⅱ) ion
Concentration: ●; non, ▲; 20ppm, ■; 50ppm, ◆; 100ppm

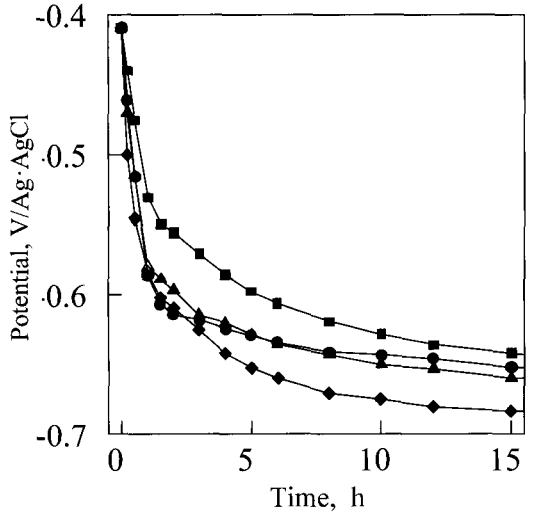

Fig. 10. Effect of Zn (Ⅱ) ion on the rest potential of Fe plate in magnetically treated solution containing 50 ppm Fe (Ⅲ) ion
Concentration: ●; non, ▲; 20ppm, ■; 50ppm, ◆; 100ppm

ever, magnetic treatment had not little effects.

Effect of Zn (Ⅱ)and Fe(Ⅱ) ions on the rest potentials of Fe plate is shown in Fig. 9 and 10. The rest potentials shifted in the based direction with time. Magnetic treatment had not little effects.

Effect of Zn (Ⅱ), Fe(Ⅱ) and Fe(Ⅲ) ions on the rest potentials of Fe plate is shown in Fig. 11 and 12. The rest potentials shifted in the based direction with time. Magnetic treatment had not little effects. From the potential-pH diagram, the corrosion products could not be determined as pH was about 6.5 and the potential was -0.65 V vs. Ag.AgCl. The rest potentials were differed with trace amount of Fe ions. In the non-magnetically treated solution, the stationary potentials were noble comparing with that of containing Fe ion. It was concluded that the trace amount of Fe(Ⅱ) and Fe(Ⅲ) ions in the solution affected to corrosion and dissolution of Fe plate.

The corrosion potential and corrosion current density, E_{cor} and I_{cor} were affected by magnetic treatment and by Zn(Ⅱ) ion addition. But the progress of corrosion products were changed as time passed.

Dissolution amount of Zn was 0.058 mg/cm^2 in

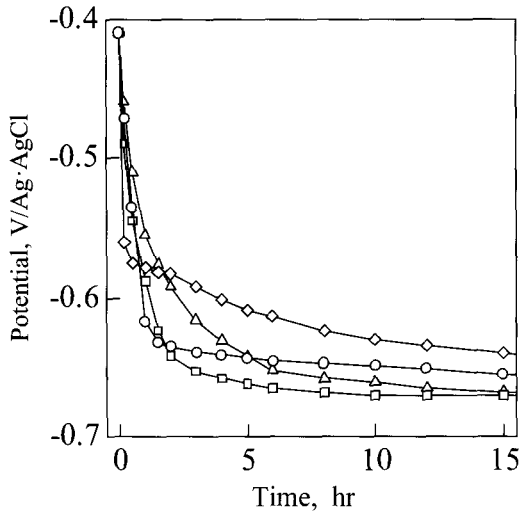

Fig. 11. Effect of Zn (Ⅱ) ion on the rest potential of Fe plate in non-magnetically treated solution containing 25 ppm Fe (Ⅱ) and 25 ppm Fe (Ⅲ) ions
Concentration: ○; non, △; 20ppm, □; 50ppm, ◇; 100ppm

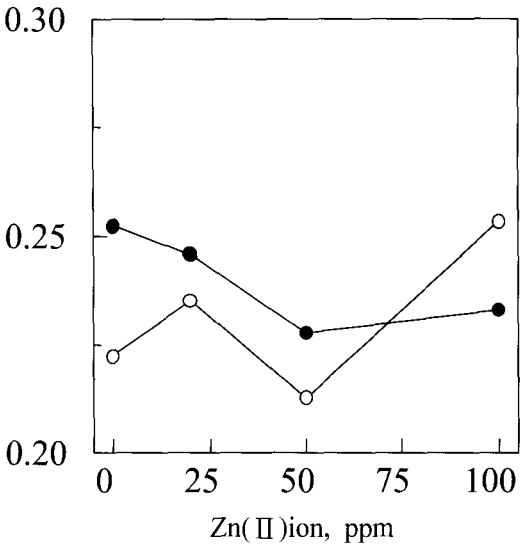

Fig. 13. Effect of Zn (Ⅱ) ion on the dissolution amount
○: Non-magnetic treatment, ●: Magnetic treatment

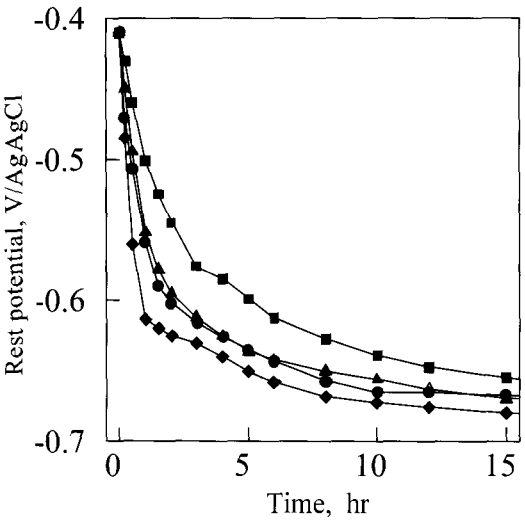

Fig. 12. Effect of Zn (Ⅱ) ion on the rest potential of Fe plate in magnetically treated solution containing 25 ppm Fe (Ⅱ) and 25 ppm Fe (Ⅲ) ions
Concentration: ●; non, ▲; 20ppm, ■; 50ppm, ◆; 100ppm

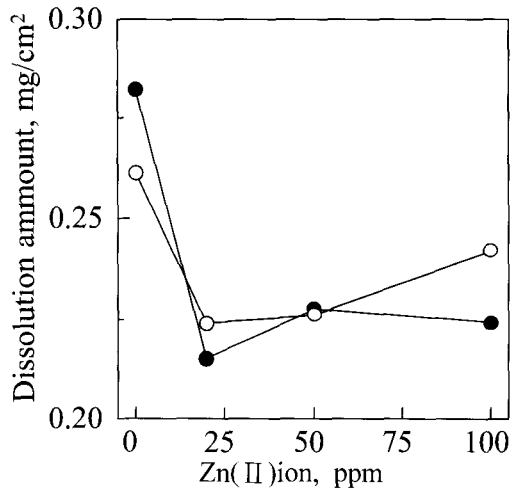

Fig. 14. Effect of Zn (Ⅱ) ion on the dissolution amount containing 50 ppm Fe (Ⅱ) ion
○: Non-magnetic treatment, ●: Magnetic treatment

non-magnetically treated solution, and was 0.059 mg/cm^2 in magnetically treated solution after 24 h of immersion. Magnetic treatment had not little effects. Effect of Zn ion on the dissolution of Fe plate is shown in Fig. 13~16. Addition of Zn (Ⅱ) ion in solution was prepared to effects of corrosion and dissolution of Fe. The regularity was not obtained the effect of the magnetic treatment on the dissolution of Fe plate.

4. Conclusions

Addition of Zn (Ⅱ) ion in solution was prepared to effects of corrosion and dissolution of Fe plate. The regularity was not obtained the effect of the magnetic treatment on the dissolution of Fe plate.

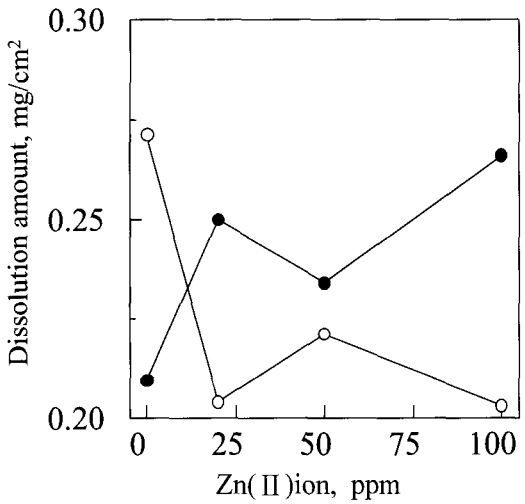

Fig. 15. Effect of Zn (Ⅱ) ion on the dissolution amount containing 50 ppm Fe (Ⅲ) ion
○: Non-magnetic treatment, ●: Magnetic treatment

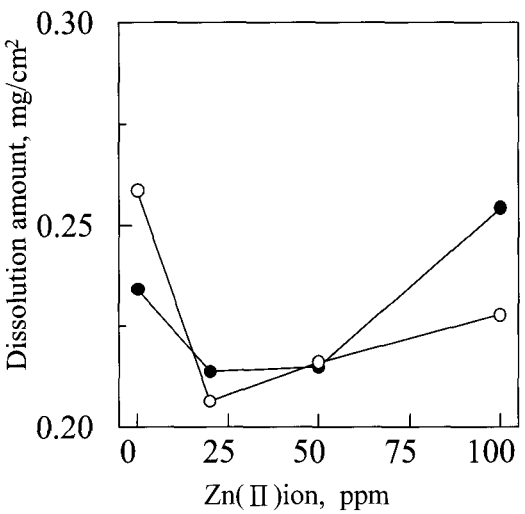

Fig. 16. Effect of Zn (Ⅱ) ion on the dissolution amount containing 25 ppm Fe (Ⅱ) and 25 ppm Fe (Ⅲ) ions
○: Non-magnetic treatment, ●: Magnetic treatment

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