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The Performance of Cathodic Protection with ICCP

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Abstract : This paper describes the anti-corrosion system on underwater structures of ships. Metals and alloys have several positions in the series such as immunity, corrosion and passivity. The iron potential has to change from the corrosion position to the anodic protection or cathodic protection for preventing corrosion by providing corrosion protection system such as ICCP(Impressed Current Cathodic Protection).

The purpose of ICCP system is to eliminate the rusting or corrosion, which occurs on metal immersed in water. The system includes a power supply unit, which consists of a transformer, a converter, a controller, etc. This paper presents the protection performance of ICCP under dynamic condition such as velocity.

The variation of potential and current density with time and environment factors are also described Finally, the experimental results will be explained and analysed.

Key words : Cathodic protection, Corrosion, Current density, ICCP, Hull

1. Introduction

In recent years there has been a growing interest in a wide variety of corrosion problems. ICCP of ships is always used in conjunction with protective coatings. The coatings are intended as primary protection, and ICCP is a backup in those areas where coating defects may be present.

Cathodic protection on corrodible hull needs a long time working and needs periodically the check-up and modifying protection conditions. During the operational life of the ship, the demand on the cathodic protection increases for protecting corrosion.

The underwater area of a ship is a large complex cathode with at least three components: painted steel, bare steel and bronze. They have different current density requirements for achieving the desired corrosion protection and respond differently to change in operational conditions such as seawater flow. Until recently, there was very little understanding of performance of impressed current cathodic systems under dynamic conditions and environment factors.

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This paper inspects the variation of the protection potential and current density with time, velocity and pH.

2. Principle of ICCP

ICCP for cathodic protection refers to the reduction or elimination of corrosion which can be achieved by forcing (impressing) current from the seawater into the metal surface. A metal also can be made cathodic by electrically connecting it to another metallic component in the same electrolyte through a source of DC current and the current flow to occur off the surface of added metallic component(anode), into the electrolyte and onto the metal. This metal is cathode.

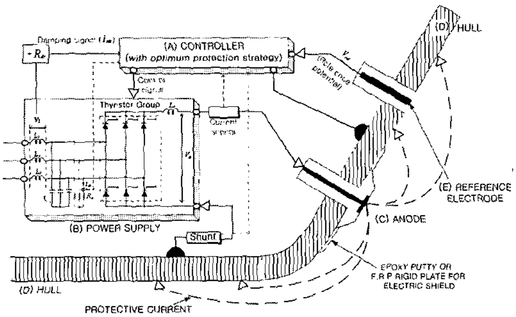
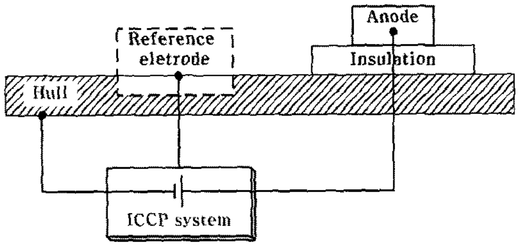
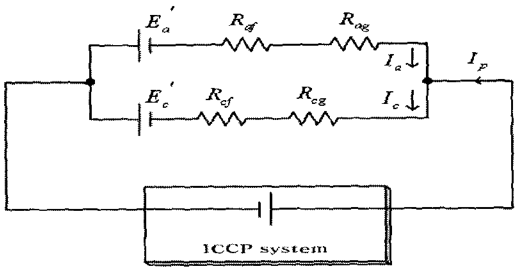


Fig. 1 Schematic of ICCP system for ship

Fig. 1 shows the schematic of the ICCP system for ship. There are five components required in the basic ICCP system. The controller (A) is connected to the reference electrode. The controller delivers a control signal to one or more power supplies (B). The anode (C) is mounted on the hull (D) and electrically insulated from it. Also, the reference electrode (E) is mounted through the hull (D) of the ship and is exposed to the seawater.



(a) block diagram



(b) equivalent circuit of local cell

Fig. 2 Circuit diagram for ICCP

The anodes and the reference electrodes must be very carefully mounted. The block diagram is shown in Fig. 2(a). Attached anodes provide the particular advantage of proprotionally low grounding resistance for the protection current.

Fig. 2(b) shows the equivalent circuit of local cell. This circuit can be explained the principle of ICCP. The protection condition of ICCP can be defined as the equation (1).

$$E_c' - E_a' + I_a(R_{af} + R_{ag}) + I_c(R_{cf} + R_{cg}) = 0 \quad (1)$$

Where, E_a' and E_c' are the polarization potential of local anode and cathode respectively. I_a is the anode current, I_c is the cathod current, R_{af} and R_{cf} are the surface resistance of local anode and cathode. R_{ag} and R_{cg} are the electrolyte resistance of local anode and cathode. The cathode protection with ICCP is given by

$$I_c = I_a + I_p \quad (2)$$

Where, I_p is the protection current.

In the case of perfect protection condition with ICCP ($I_a=0$, $I_c=I_p$), the equation (1) is modified as the equation (3).

$$E_a = E_c - \phi_c(I_p/A_c) + I_p(R_{cf} + R_{cg}) \quad (3)$$

Where E_a and E_c are the open circuit potential of local anode and cathode respectively. A_c is the area of local cathode. $\phi_c(I_p/A_c)$ can be expressed by the negative polarization. E_a is kept the protection potential by the ICCP system. For this purpose, the converter in ICCP is operated with the HE(Harmonic Elimination) algorithm. Also, this algorithm has to control the protection current and the harmonic component. The average output voltage of three phase full converter in ICCP is

$$E_{avo}(\alpha) = K \cdot \cos\alpha \quad (4)$$

Where α is the firing angle of converter, K is $3\sqrt{6}V/\pi$.

The firing angle of the converter has to be adjusted to keep the protection potential. The detail operation of the control algorithm of converter followed with reference to the flowchart of Fig. 3.

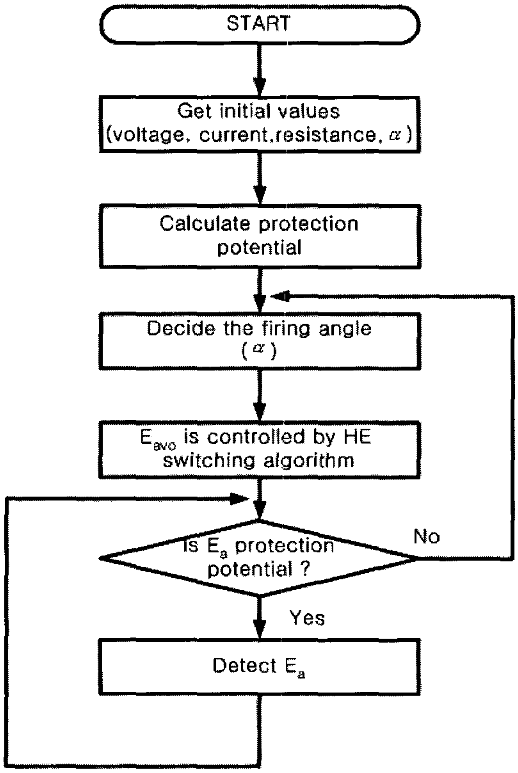


Fig. 3 Flowchart of control algorithm

3. Experimental Results

The potential of cathodic protection for steel structures in seawater is -780mV with respect to the seawater SSCE (Saturated Silver Chloride Electrode). Power supply system of ICCP has to be controlled to produce the required current for cathodic protection.

Practically -800mV/SSCE, instead of -780mV/SSCE, was given to compensate for field errors in a real environment.

The supplied protection current was adjusted by the converter of ICCP system to control the protection potential of -800mV/SSCE. Whenever the protection potential in accordance with environment factors and dynamic condition changed, it was controlled to keep -800mV/SSCE by ICCP system.

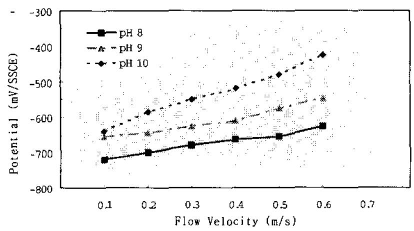


Fig. 4 Potential variation with pH and velocity

Fig. 4 shows potential as a function of velocity at different pH. The potential increased with increasing pH. Also, the current density variation is described by Fig. 5. The current density decreased with increasing pH.

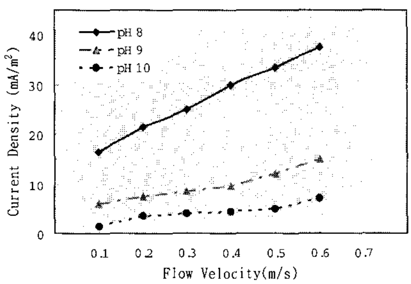


Fig. 5 Current density variation with pH and velocity

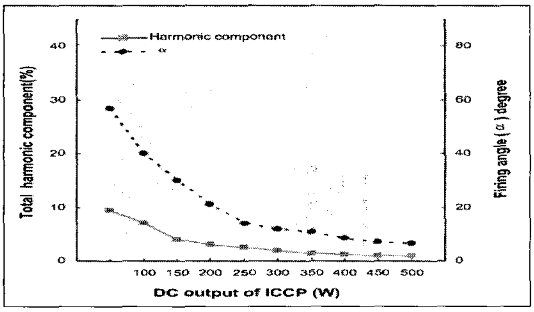


Fig. 6 Harmonic component and α in accordance with output

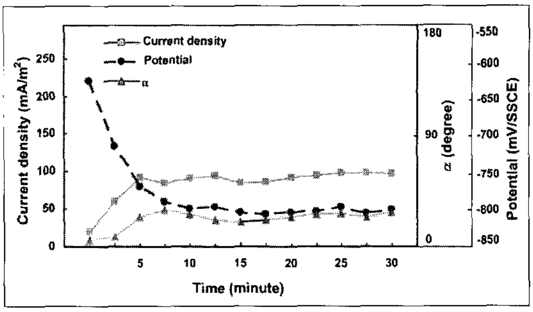


Fig. 7 Variation of potential, current density and with α time

Fig. 6 shows the harmonic component and the firing angle(α) in accordance with DC output of ICCP system. The firing angle is controlled from 0° to about 60°. The output increased with decreasing the firing angle. The harmonic component is decreased with increasing the output. In this paper, the harmonic component is about 7% at 250W.

The variation of potential, current density and α with time is shown in Fig. 7. The current density was about 100mA/m² after 5 minutes. The protection potential was controlled with α to keep -800mV/SSCE. The protection potential was kept about -800mV/SSCE after 10 minutes. The difference of potential, current density and α is small after 10 minutes.

4. Conclusions

The corrosion potential is influenced by the environmental factors and dynamic conditions. The current density and potential are varied with velocity and pH. In this paper, we describe the influence of design factors for ICCP through the experiments and the output performance of converter in accordance with the firing angle. For the high performance of ICCP, the ICCP control algorithm for ship has to include the marine environment factors, dynamic condition and switching strategy for converter.

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He was born in Kyung-Nam, Korea. He received the B. E. degree in Marine Engineering from Korea Maritime University in 1983. Since 1983, he has been with the Zodiac(England Company) including early 4 years of System Engineer. He received the M.E. and Ph. D.degrees from Korea Maritime University, Pusan, Korea in 1989 and 1996, respectively. He had been with the Agency for Defense Development(ADD) as a researcher from 1989 to 1992. From 1992 to 1996, he was an Assistant Professor in the Department of Industrial Safety Engineering at Yangsan College. In 1996, he joined the Division of Mechatronics Engineering at Korea Maritime University. His research interests include electrical drive systems, robot control and PC-based Control applications.