【Article】

A Study on Antifouling Technique through Seawater Electrolyzing Reaction on Ship Hull Surface

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Abstract

The antifouling technique through seawater electrolysis for ship hulls may be realized by an antifouling system consisting of a power unit and the electro-conductive film. In the electric field formed by such an antifouling system, besides that both the electro-conductive film layer sub-region and the seawater sub-region are included, polarization occurs on the interface between electro-conductive film layer and seawater. Therefore, based on the Interface Electro-Double Layer theory, a numerical simulation technique using both of the finite element method and the boundary element method jointly was developed.

An excellent efficiency of the antifouling system using electro-conductive film was demonstrated with a long term antifouling test, and the validity of the developed numerical simulation method was verified by its applications to a small size passenger boat, for which the antifouling system was undertaken and the antifouling efficiency test was performed.

Introduction

As a preventing measure of marine organisms growth on the surface of a ship hull, self-polishing copolymer (SPC) type antifouling paint with TriButy Tin (TBT) compound copolymer had demonstrated effective performance. However, utilization of the TBT antifouling paint has been restrained from 1990 because it would result in pollution of marine environment. Therefore, an antifouling technique by seawater electrolyzing reaction, has been developed[1)]

For the application of this antifouling technique to a ship hull, insulating layer should be painted on the surface submerged in seawater and an electro-conductive film layer should be then coated over the insulating layer. Through the electro-conductive film layer, certain electric current is sent over the submerged surface of a ship hull, and seawater is electrolyzed to form a layer of hypochlorous ions (ClO^-) over the submerged surface with the electric current. Therefore, growth of marine organism on a ship

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hull would be prevented.

In order to keep the antifouling state satisfactory, current density for seawater electrolyzing reaction over the submerged surface of a ship hull should exceed certain lower limit value. On the other hand, the electro-conductive film ages early with the increase of current density. Therefore, an expected electro-conductive film layer should make the current density distribution be as even as possible over the submerged surface.

For the electro-conductive film layer, the high conductivity as well as being resistant to electrolyzing are demanded. For these purposes, an electro-conductive film layer may be consisted of an under layer over the insulating paint with a high conductivity and an electrolyzing endurance upper layer contacting with seawater. Moreover, some metallic foils connected to a power supply unit are buried at certain intervals in the high conductivity under layer to heighten the conductivity of the electro-conductive film layer.

In order to design such an antifouling system for a large ship with a submerged surface area of some ten thousands square meters, it is necessary to make the relationship between current density distribution and construction of the electro-conductive film layer clear firstly, and then to propose a reasonable electro-conductive film layer.

In this research, aiming at the optimum design of an antifouling system for a ship hull, a numerical simulation method for the potential field, which includes electro-conductive film layer sub-region and seawater sub-region, formed by an antifouling system is developed. In the developed numerical method, based on the Interface Electro-Double Layer theory, the electric behavior on the interface between electro-conductive film layer and seawater is handled by using polarization characteristics of the electrolyzing endurance layer in seawater, and the overall potential field formed by an antifouling system would be analyzed collectively using the finite element method (FEM) and the boundary element method (BEM) jointly.

Moreover, the developed numerical simulation method is applied to a small-size passenger boat, on which the antifouling system was undertaken for antifouling efficiency test, and the validity of the developed numerical simulation method is verified by comparing with measurements.

The principle of the antifouling technique and the construction of an electro-conductive film layer

The principle of the antifouling technique applied to a ship hull is shown in **Fig.1**. As an antifouling system, the electro-conductive film layer is constructed on the outside surface of the starboard and that of the port of a ship hull shell separately with the insulating paint coated on the center area of the ship hull shell, and therefore electric current is sent with a power unit by taking the electro-conductive film layer on the starboard and that on the port as both kinds of electrode (Cathode and Anode). On the surface of anodic side of the electro-conductive film layer, hypochlorous ions (ClO^-) are formed through the electrolyzing reaction of seawater and growth of marine organisms would be then prevented. Prevention of growth of marine organisms on both sides of a ship hull, however, can be realized by changing the electro-conductive film layers of both sides as anode and cathode alternately at certain intervals of time.

In order to satisfy the demand of both the high conductivity and durability, the electro-conductive film layer is constructed from an under layer with a high conductivity and an electrolyzing endurance upper layer as shown in **Fig.2**. Moreover, some metallic foils connected to a power unit are buried in the under layer at certain intervals, and electric current is sent through the metallic foils. Consequently, the path of the electric current in an antifouling system should be as {(Power unit)→(Anodic metallic foil)→(High conductivity under layer)→(Electrolyzing endurance upper layer) in the anodic side. After electrolyzing reaction of seawater caused on the surface of anodic side to form hypochlorous ions (ClO^-), electric current goes back to the power unit through the cathodic electro-conductive film layer.

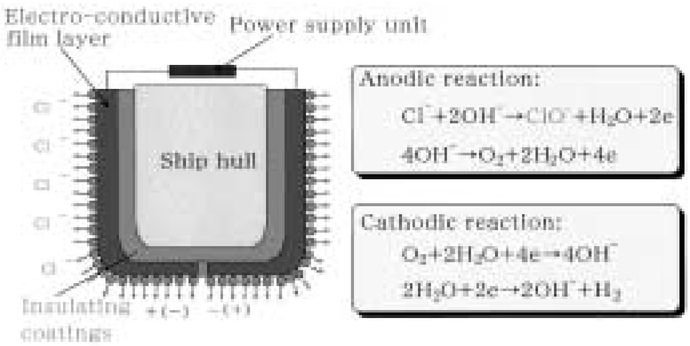

Fig.1 Principle of the antifouling system applied to a ship hull

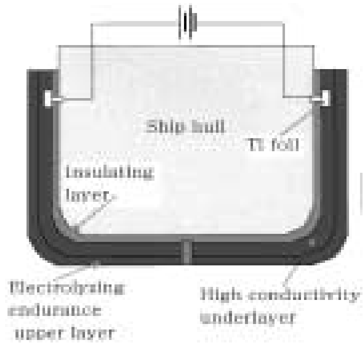

Fig.2 Structure of the antifouling system for a ship hull

Antifouling tests with a small size passenger boat

The antifouling efficiency test was taken with a small size passenger boat as shown in **Photo 1**. The outline of the antifouling system constructed on this boat is shown in **Fig.3**, and the antifouling state on the surface of the boat after thirteen months for testing is shown in **Photo 2**. The antifouling effect is excellent, but the exfoliation of the electro-conductive film layer was observed in the area around current sources.

Photo 1 The small size passenger boat with an antifouling system

Photo 2 The antifouling state after 13 months test

Fig.3 The antifouling system for the passenger boat

Numerical method and numerical results

The numerical model to be analyzed for the potential field formed by an antifouling system of a ship hull is shown in Fig.4. In this model, the specific resistance of the metallic foil and that of the electro-conductive paint are different in the electro-conductive film layer sub-region, and the specific resistance can be considered to be a constant in the seawater sub-region. Therefore, FEM and BEM are applied to the electro-conductive film layer sub-region and the seawater sub-region, respectively.

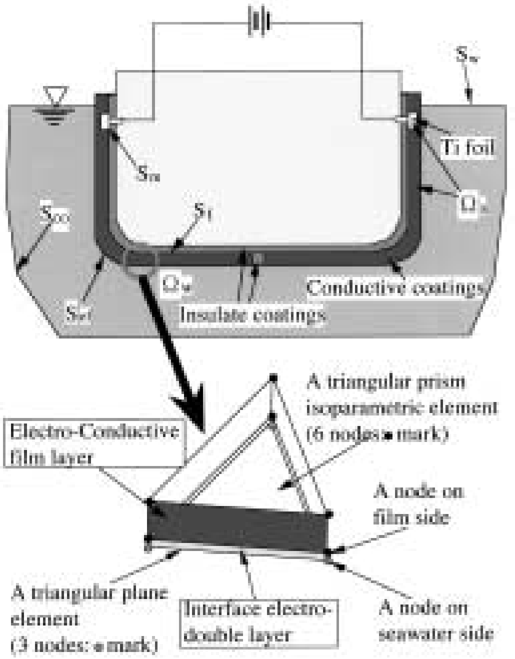

Fig.4 The calculating model for the antifouling system

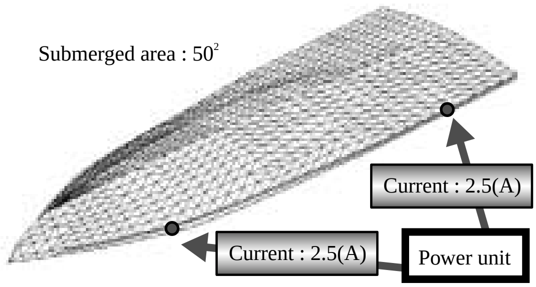

Fig.5 The FEM and BEM coupled model

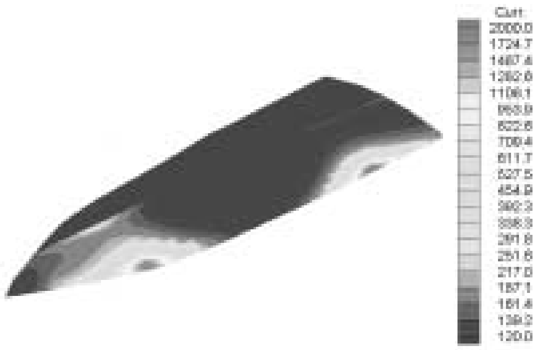

Fig.6 Current density (mA/m^2) distribution on ship hull surface

In the model shown in **Fig.4**, when electric current is sent from the power unit, the Interface Electro-Double Layer is formed on the interface between seawater and the electro-conductive film layer. In this case, the potential difference between the positive charge layer and the negative charge layer stands for the polarizing potential, and the relationship between the polarizing potential and the current density can be taken as the polarization characteristics of the electrolyzing endurance upper layer in seawater. That means, the difference between the potential of the electro-conductive film layer side and that of seawater side on the interface is same as the potential measured with a reference electrode.

In the numerical simulation method for such a model as shown in Fig.4, the FEM equations[2)] for the electro-conductive film layer sub-region and the BEM equations for the seawater sub-region are coupled with the polarization characteristics on the interface (*Sef*) between two sub-regions[3)].

The FEM and BEM coupled model for the antifouling system as shown in Fig.3 is shown in **Fig.5**

For the antifouling test case that 0.2A/m^2 of the average current density was supplied from the power unit to the submerged surface, the calculated current density distributions is shown in **Fig.6**, and the calculated potential values and the measured ones are compared in **Fig.7**.

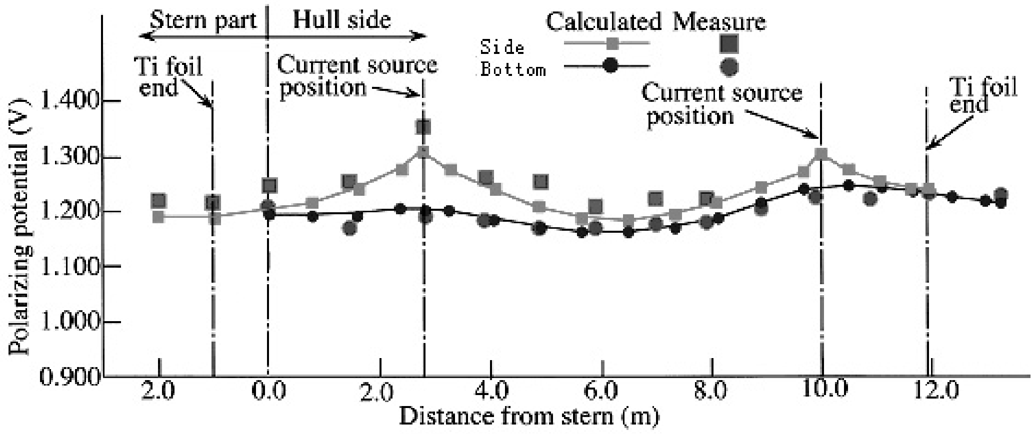

Fig.7 Comparison between calculated and measured potential values on ship hull surface

Consideration

It is clear according to Fig.7 that the calculated potential values correspond to the measured ones in a good agreement. Consequently, the developed numerical simulation method is applicable to the antifouling system by using the electro-conductive film.

The antifouling test using a small-size passenger boat within an open seawater domain demonstrated an excellent antifouling efficiency of the antifouling system. On the other hand, exfoliation of the electro-conductive paint was observed in the area around current sources, and the current density in this area is very high as shown in Fig.6. Therefore, the current density around the current sources in an antifouling system should be made as lower as possible so as to extend the life of the whole antifouling system.

Conclusions

The excellent antifouling efficiency of the antifouling system by using the electro-conductive film was demonstrated from a long term antifouling test with a small-size passenger boat. In order to evaluate the state of the potential field formed by an antifouling system, a numerical simulation method using

FEM and BEM jointly was developed, and the validity of this method was verified by its applications to the antifouling system of a small-size passenger boat. The current density around the current sources should be made as lower as possible so as to extend the life of the whole antifouling system. Namely, it is expected to make the current density distribution on the overall submerged surface of a ship hull as even as possible, and it is possible to realize an optimum design of an antifouling system with the aid of the developed numerical simulation method.

References

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2) Y. Huang, M. Usami, M. Iwata and K. Ueda: "A Study on CAD of Antifouling System by Seawater Electrolysis (Report 1 Development of the Analysis Method for the Potential Field)", Journal of the Society of Naval Architects of Japan, Vol.178, pp.601-608, 1995.
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