THE DISTRIBUTION OF THE ELECTRICFIELD AND OF THE CURRENT DENSITY IN CASE OF ELECTROCORROSION COUNTERMEASURES USING THE SACRIFICE ANODES TECHNIQUE

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Abstract. An electric field oriented from sea water towards the ship, can develop an extraction work. The corrosion process was thus diminished, by a change in the ship's hull mass, due to a continuous tore of the material from its bulkheads. The issue that arises is an attenuation of the extraction electric forces and a reduction in the process of mass changing. This problem can be solved by using an impressed electric field, opposite to the one developed during the corrosion process, field which can minimize the extraction work generated by this process.

Keywords: electrocorrosion, sacrifice anodes technique

1. INTRODUCTION

Accepting to consider the cathodic protection issue as above mentioned, the practical solutions should be highlighted both by the electric field distributions into sea water – ship system and the current density distribution into the same system. Finding electric field and current density distribution – within the particular case of the issue under discussion – implies solving several problems regarding stationary conduction (electro kinetics). To solve this problem we must first find, using the scalar electric potential „V", the electric field distribution within the particular system analysed and then the usage of electric conductibility rule to determine electric current density distribution.

2. MATHEMATIC MODEL/PATTERN USED FOR STYDYING SHIPS' CATODIC PROTECTION

As a result the mathematical pattern adopted is as follows:

$$(1)\ \Delta\overline{J} = 0\ ;\ \overline{J} = \sigma \cdot \overline{E}$$

where the first equation within system (1) is Laplace equation for conducing mediums (if the dielectric displacement current is neglected) and the second represents electric conduction law.

Electric field distribution is obtained considering that everything derives from a potential. In our case the electric field derives/merges from the scalar electric potential „V", that is:

$$(2)\ \overline{E} = -gradV$$

The field issue being bidimensional, the two components can be determined, only:

$$(3)\ E_x = -\frac{\partial V}{\partial x}\ ;\ E_y = -\frac{\partial V}{\partial y}\ .$$

Using, then, the conducting electric law the two components of current density vector can be determined in plan:

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$$(4)\ J_x = \sigma \cdot E_x;\ J_y = \sigma \cdot E_y$$

Mention must be made that relations (2) and (3) allow the determination of the so-called sinusoidal components of electric field. In our case there is also an impressed electric field, $\overline{E}_i$.

As a result, relation (4) can be written as follows:

$$(5)\ J_{tx} = \sigma \cdot (E_x + E_{ix});\ J_{ty} = \sigma \cdot (E_y + E_{iy}).$$

where E_{ix} and E_{iy} are plan components of the impressed electric field vector; J_{tx} and J_{ty} are global components in plan, of the current density vector.

Initial and border conditions are very important for field issue solving due to the many subsystems included in sea water – ship system. As scalar potential „V" is variable in this case these conditions should be specified for this potential, as follows:

$V_0(x,y) = 0$ - initial value of the scalar potential;

$V(P) = V_1$ - Dirichlet type condition, for those borders where the scalar potential has a value;

$\frac{\partial V}{\partial n}(P) = 0$ - Neumann type condition, for those borders for which derivative of the normal on the surface of the scalar potential is cancelled.

Supplementary, in order the problem be solved absolute values of the interest variables are determined, too:

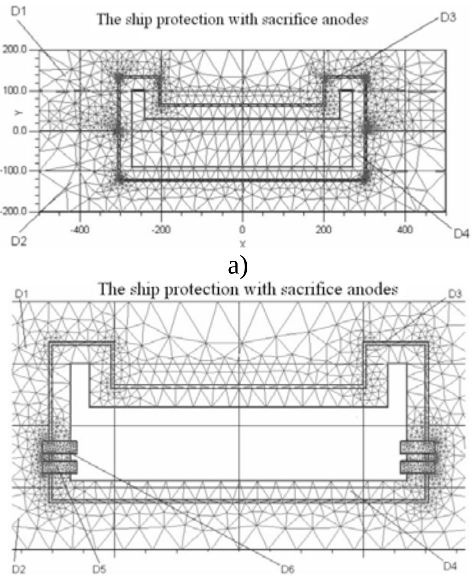
$$(6)\ E = \sqrt{E_x^2 + E_y^2};\ J_t = \sqrt{J_{tx}^2 + J_{ty}^2}$$

3. THE INFLUENCE OF SACRIFICE ANODES

In order to compile such a study a comparative analysis was made between the fields distributions obtained for the ship lacking sacrificial anodes, respectively for the ship equipped with such anodes.

In Fig. 1. a, respectively 1. b, the fields of integration for the two analysed cases are shown. The significance of the sub-domains is as follows:

D1 – represents the air area around the ship;
D2 – represents the sea water area in which the ship is partly submerged (corrosive environment);
D3 – represents the paint coating applied on the exterior of the ship;
D4 – represents the metallic wall of the ship;
D5 – represents the sacrificial anodes;
D6 – represents the anodes insulation related to the metallic wall of the ship.



a) b)

Fig. 1 The integration domain: a) in case there are no sacrificial anodes on the ship; b) when the ship is equipped with aluminium sacrificial anodes

Thus, Fig. 2 presents the distribution of the electric field intensity vector when the ship is not equipped with sacrificial anodes, while Fig. 4 presents the distribution of the current density vector for the same type of ship. Fig. 3 presents instead the variation mode of the electric field intensity absolute value for the ship without sacrificial anodes, a value responsible, in the last instance, for the extent of the electric forces and, implicitly, of the work force (of material 'pulled' out of ship's hull).

It is worth mentioning that the absolute value of the electric field intensity when the ship is not protected through sacrificial anodes is particularly high at the level of that part of the ship which is submerged in sea water. The case analysed in this first stage is the one in which the potential of the sea water is higher than that of the ship's hull (the ship's hull being considered at potential $V = 0$ [V], while the sea water potential was considered $V_{seawater} = 0{,}9$ [V].

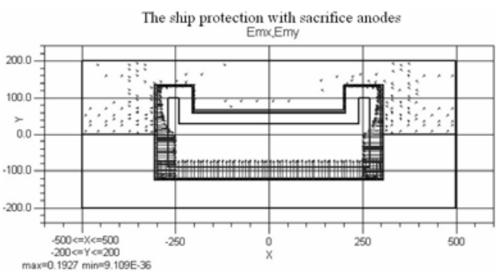


Fig. 2 The distribution of the electric field
$V_{seawater} \rangle V_{ship'hull}$ (without sacrifice anodes)

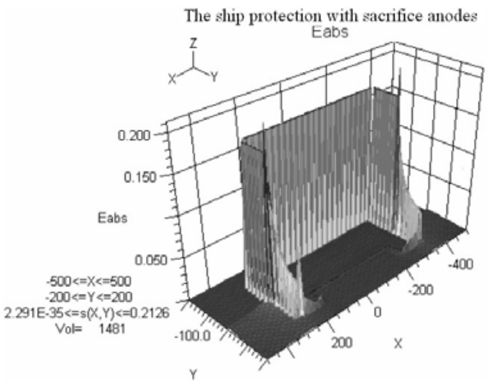


Fig. 3. The variation mode of electric
field absolute value $V_{seawater} \rangle V_{ship'hull}$

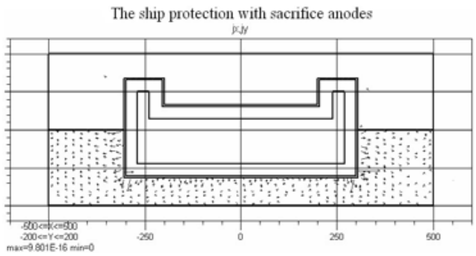


Fig. 4 The distribution of the current density vector
$V_{seawater} \rangle V_{ship'hull}$ (without sacrifice anodes)

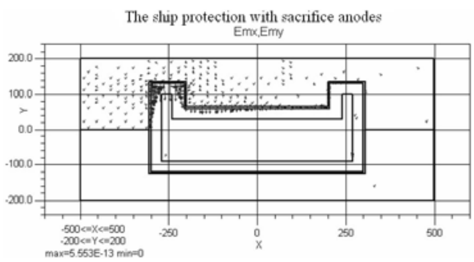


Fig. 5. The distribution of the electric field
$V_{seawater} = V_{ship'hull}$ (without sacrifice anodes)

When the sea water potential equals the one of the ship’s hull, the electric field intensity distribution looks as in Fig. 5. For this particular case, the current density vector distribution is shown in Fig. 7, while the mode of the electric field intensity absolute value variation is emphasized in Fig. 6. A drastic decrease is noticed in the electric field intensity absolute value as well as the reduction (practically to zero) of the ionic current density in the sea water- ship sub-system.

The emphasized aspects suggest the course to be followed, practically, in order to reduce the work force in the sea water – ship sub-system; the reduction of the corrosive effect (and at the same time a destructive one) of the sea water over the ship can be obtained by equalizing the two potentials (anodic and cathodic), but mainly by reversing the potential barrier (respectively, by increasing the ship’s hull potential over the one of the sea water).

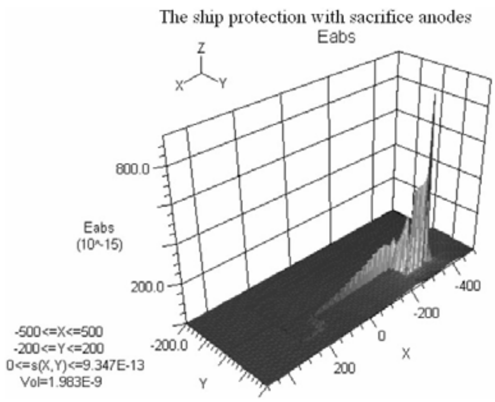


Fig. 6 The variation mode of electric field absolute value $V_{seawater} = V_{ship'hull}$

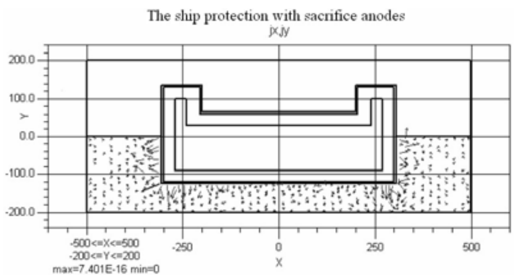


Fig. 7 The distribution of the current density vector
$V_{seawater} = V_{ship'hull}$ (without sacrifice anodes)

The solution contemplated above can be applied by means of the sacrificial anodes technique. The electric field and current density vector distributions, respectively the electric field intensity absolute value variation, in case the equalization of the sea water potential with that of the sacrificial anode placed on the ship would succeed, are shown in figures 8-10.

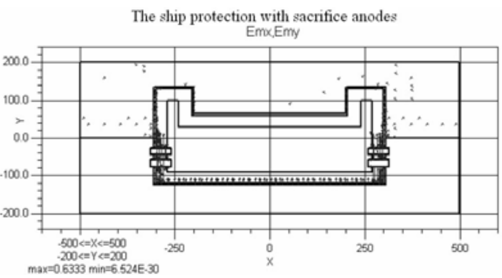


Fig. 8 The distribution of the electric field
$V_{seawater} = V_{sacrificeanode}$

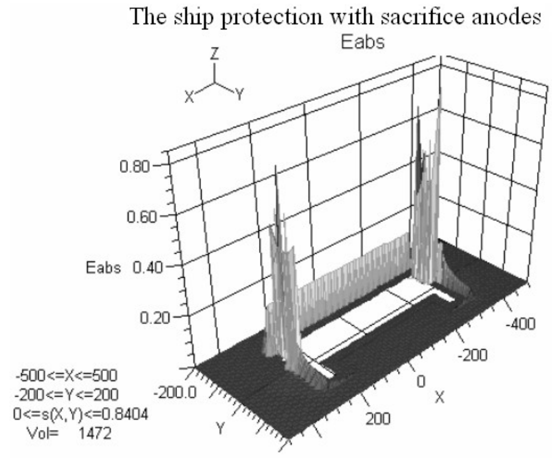


Fig. 9 The variation mode of electric field absolute value $V_{seawater} = V_{sacrificeanode}$

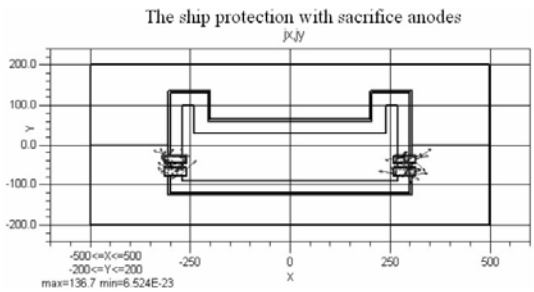


Fig. 10 The distribution of the current density vector $V_{seawater} = V_{sacrificeanode}$

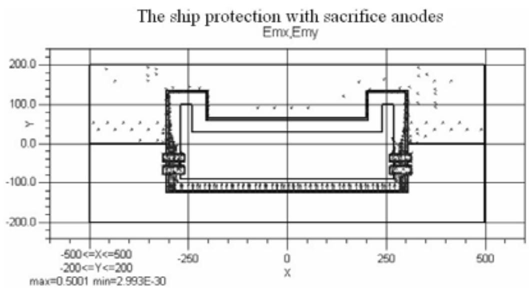


Fig. 11 The distribution of the electric field $V_{seawater} \rangle V_{sacrificeanode}$

If, nevertheless, the sea water potential remains superior to that of the sacrificial anodes, a current injection will appear through the insulated anodes from the ship’s hull, without any means to shut off this current. Thus there is a justification (as emphasized by the distributions in Figures 11-13) for the need of some reference anodes on the vessel to which the potential of the sacrificial anodes could be related.

This solution is used in practice, as we pointed out in several chapters of our paper. It is worth stating that an equalization of the two potentials (that of the sea water, respectively that of the ship’s hull) and even an increase of the ship’s hull potential over that of the sea water can also be obtained in case the second protection method is used, respectively the one of the impressed currents.

In such a case it is ascertained that on board the ship would practically exist an impressed electric field of an opposite direction to the one determined by the high potential of the sea water.

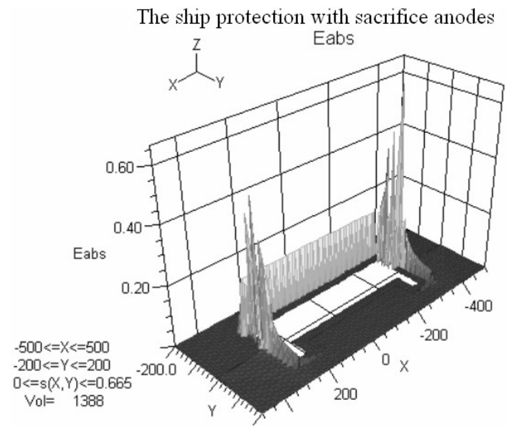


Fig. 12 The variation mode of electric field absolute value $V_{seawater} \rangle V_{sacrificeanode}$

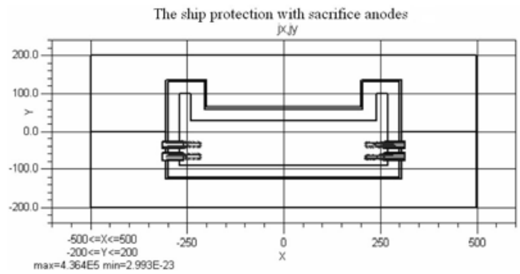


Fig. 13 The distribution of the current density vector $V_{seawater} \rangle V_{sacrificeanode}$ (need for reference anode)

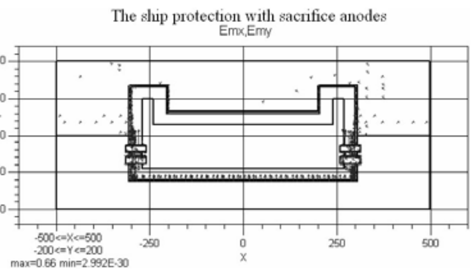


Fig. 14. The distribution of the electric field $V_{seawater} \langle V_{sacrificeanode} (V_{referenceanode} \cong V_{ship'shull})$

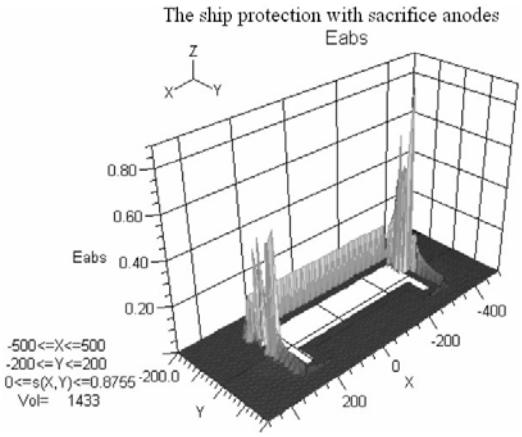


Fig. 15 The variation mode of electric field absolute value $V_{seawater} \langle V_{sacrificeanode}$

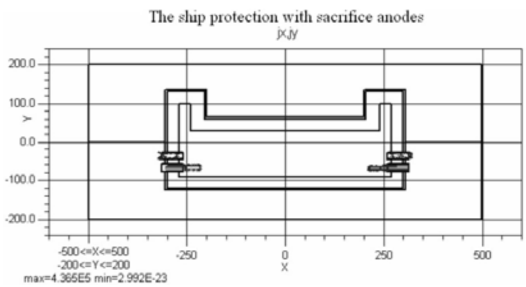


Fig. 16 The distribution of the current density vector $V_{seawater} \langle V_{sacrificeanode} (V_{referenceanode} \cong V_{ship's hull})$

In Figures 14–16, the electric field intensity vector distribution, the electric field intensity absolute value variation, respectively the current density vector distribution are shown, when the anodes from the ship's lower area become reference anodes and are connected to a potential close to that of the ship's hull.

4. CONCLUSION

- The real sacrificial anodes (the ones on the higher part) are at a slightly higher potential(by 16,6%) than that of the sea water; they become, strictly speaking, sacrificial anodes, because the ionic-like current which is materialized in their area gradually leads – through the work force developed by the electric forces - to their destruction.
- By using this technique, the ship's hull is protected.

5. REFERENCES

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