THE COMPUTATION OF THE ELECTRIC FIELD STRENGTH OF A SEAGOING SHIP

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Abstract. The paper presents an algorithm for the computation of the electric field around a seagoing ship.

1. GENERAL ASPECTS

It is well-known that the study of the electric field is performed taking into account some state variables. They can be scalar, vectorial etc. and they locally describe the state of the considered field.
Therefore, in order to establish the nature, the spatial distribution and the variation in time of such a field, one has to define:

- the flux of the state vector field and the flux density;
- the circulation of the state vector field;
- the spatial variations of some state scalars (for the case of scalar fields);
- the variation in time of the non-steady fields (locally described by the substantial derivates);
- the discontinuity of some fields.

For all these cases, the mathematic models are based on equations with partial derivates of various type, most of these equations being of second order. In order to determine the strength of an electric field on three spatial directions, we first introduce a mathematical model and then, an algorithm is developed.

2. THEORETICAL BACKROUND

The intensity of the electric field in a point can be computed by means of the gradient of the electric potential function on that point. This assume that by measurements and computation, the electric potential values are known on all the points concerned. What we do not know is the potential variation law.
To find the potential law, we consider a rectangular section of area S = a x b, uniformly loaded with electric charge, and surface density ρ_S. (fig.1)

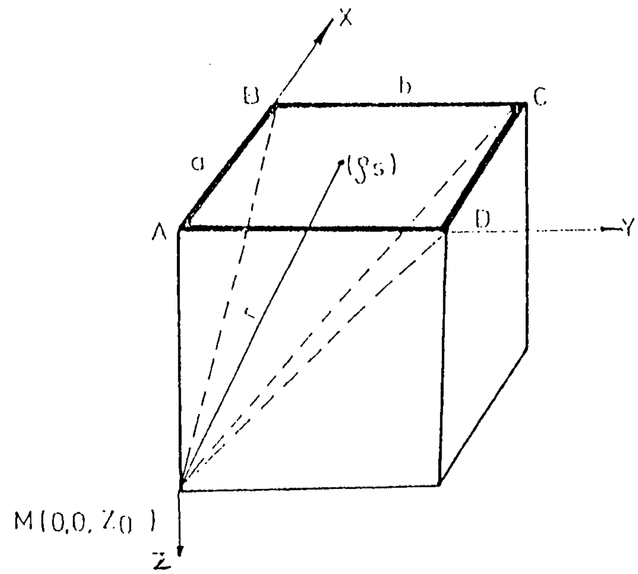

Fig. 1 The rectangular section uniformly loaded with electric charge

The potential in point M (0,0, z_0) is:

$$V_M = \rho_S / 4 \pi \varepsilon \int_S dS / r = \rho_S / 4 \pi \varepsilon \int d y \int d x / (x^2 + y^2 + z_0^2)^{1/2} \qquad (1)$$

By solving (1), with respect to x, one has:

$$V_M = \rho_S / 4 \pi \varepsilon \int \{\ln [a + (a^2 + y^2 + z_0^2)^{1/2}] - \ln (y^2 + z_0^2)^{1/2}\} d y \qquad (2)$$

By integration with respect to y [7], the arcsin is expressed in function of arctg and a constant is added, namely arctg (z_0 / a). Thus:

$$I_1 = \int \ln [a + (a^2 + y^2 + z_0^2)^{1/2}]d y = y \ln [a + (a^2 + y^2 + z_0^2)^{1/2}] + a \ln [\ln [y + (a^2 + y^2 + z_0^2)^{1/2}] - y + z_0 \operatorname{arctg} y / z_0 + z_0 \operatorname{arctg} a z_0 / [y_2 + z_0^2 + y (a^2 + y^2 + z_0^2)^{1/2}] \qquad (3)$$

Then:

$$V_M = \rho_S / 4 \pi \varepsilon [a \ln (b + \overline{MC}) / \overline{MB} + b \ln (a + \overline{MC}) / \overline{MD} - z_0 \operatorname{arctg} a \cdot b / z_0 \cdot \overline{MC}] \qquad (4)$$

From (4), if V_M is known, ρ_S can be determined and then, from (1) it follows:

$$\rho_S = 4 \pi \varepsilon V_M / [a \ln (b + \overline{MC}) / \overline{MB} + b \ln (a + \overline{MC}) / \overline{MD} - z_0 \cdot \operatorname{arctg} a \cdot b / z_0 \cdot \overline{MC}] \qquad (5)$$

The electric field vector in M is given by:

$$E_M = -\text{grad } V_M = i\cdot E_x + j\cdot E_y + k\cdot E_z \tag{6}$$

The strength of the electric field in M is:

$$E_M = \sqrt{E_x^{\,2} + E_y^{\,2} + E_z^{\,2}} \tag{7}$$

3. THE ALGORITHM

The discrete grid we use for the computation of the electric field is shown in fig.2 (a part of the immersed bull of the ship).

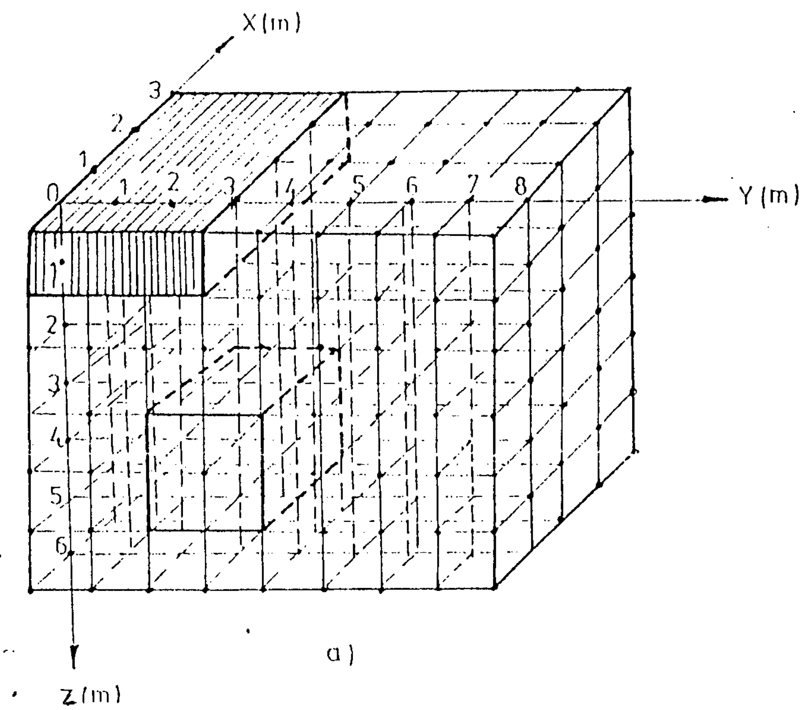

Fig.2 The cubic network for the computation of the electric field

The resolution of the grid on ox, oy and oz directions is of 1 meter. The domain to be considered in the sequel (for $x = -1 \div 3$ and $y = 3 \div 8$ - the area $(xoy)_{z=0}$, $x = -1 \div 3$ and $y = 0 \div 3$ - area $(xoy)_{z=1}$ respectively) is thus divided in squares ($h = 1$ m). Each square has virtually a uniform charge distribution which can be determined with (5) for $a = b = h$. The electric field strength can be computed on oz direction for each square (fig.1), at k h distance, for k = (1 ...6) m. Thus:

$$z = k\cdot h\,, \quad k = 1 \ldots 6 \tag{8}$$

Since direct computation is tedious, we simplify it as follows: taking into account that the potential gradient in a point is determined by the difference of the potentials of two points in its neighbourhood (M(x, y, z) and M(x + Δ x, y, z); M(x, y, z) and M(x, y + Δ y , z) or M(x, y, z) and M(x, y, z +Δ z), with Δ x = Δ y = Δ z = h = 1 m - fig.3).

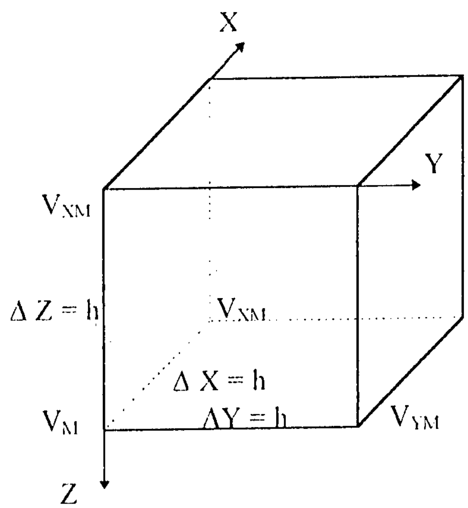

Fig.3 The potentials distribution on the three axis nearby $M(V_M)$

$\Delta V(x) = V_M - V_{xM}$ (9a)
$\Delta V(y) = V_M - V_{yM}$ (9b)
$\Delta V(z) = V_M - V_{zM}$ (9c)
which can be approximated by:

$\Delta V(x) = (\partial V / \partial x)\,\Delta x = E_{xM} \cdot \Delta x$ (10a)
$\Delta V(y) = (\partial V / \partial y)\,\Delta y = E_{yM} \cdot \Delta y$ (10b)
$\Delta V(z) = (\partial V / \partial z)\,\Delta z = E_{zM} \cdot \Delta z$ (10c)

The components on point M of the electric field on the three directions are:

$E_{xM} = \Delta V(x) / \Delta x = (V_M - V_{xM}) / \Delta x = (V_M - V_{xM}) / h$ (11a)
$E_{yM} = \Delta V(y) / \Delta y = (V_M - V_{yM}) / \Delta y = (V_M - V_{yM}) / h$ (11b)
$E_{zM} = \Delta V(z) / \Delta z = (V_M - V_{zM}) / \Delta z = (V_M - V_{zM}) / h$ (11c)

From 11 (a, b, c) it appears that the three components of the electric field on point M depend only of the potential difference in M and the points at h = 1 m in its neighbourhood, on the three directions.
The electric field strength on M is:

$$E_M = \sqrt{E_{xM}^{\;2} + E_{yM}^{\;2} + E_{zM}^{\;2}} \qquad (12)$$

As above, the electric field strength on all the points of the cubic network can be determined.

4. CONCLUSIONS

The strength of the electric field generated by a ship (trade or naval) at a certain depth or a certain distance from the ship, is of considerable importance (e.g. for active anticorrosive protection of the ship).

The strength of the electric field is of great importance in the case of a military conflict; if the marine unconnecting mines'explosion are known, the appropriate measures in order to minimise the electric field of the ship can be taken.

A model for the computation of the electric field has been presented. The derived algorithm is simply enough to be implemented on an IBM PC computer.

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