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Analysis of ship's magnetic field with consideration of inner ferromagnetic devices

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***Abstract*—This paper presents computer simulations of ship's magnetic signatures. The influence of ship's inner ferromagnetic devices on the signature was presented. The magnetic fields of the ship's model were calculated in Opera 3D 18R2. The model was built from thin plates. The new, thin plate boundary condition [1] was introduced on all ship's surfaces.**

***Keywords*—magnetic field, ship, degaussing.**

I. Introduction

The ship built from materials with ferromagnetic properties disturbs Earth's magnetic field in its surrounding. This disturbance is defined as ship magnetic signature. The ferromagnetic ship contains constant and induced magnetization [2]. The constant magnetization does not depends on the ship's course. On the other hand, the induced magnetization of a ship depends on course and is the biggest for the north-south course. Magnetic signature is a complicated function of the shape, size, magnetic properties of materials of a ship and its direction. In the case of warships, the magnetic signature should be less than the values contained in the defensive standards. Magnetic signature can be determined using numerical modeling or the measurement method [2]. The numerical modeling of the ship's magnetic field with commercial software has limited capability, because the thickness of ship's metal sheets is very small in comparison with its size. This makes it necessary to use a dense grid of a huge number of finite elements. This disadvantage can be overcome when the "thin plate" method is used [1]. The described ship model was built from thin plates. In this paper the authors analyzed the influence of ferromagnetic devices inside a ship on the magnetic signature. The results of a degaussing of ship was also presented in this paper. Computer simulations of ship's magnetic signatures were carried out in Opera 3D 18R2.

II. The Ship Magnetic Signature

A. The ship model

The superstructure, decks, hull and bulkheads of a ship were modelled to determine the vessel's magnetic signature in the presence of the Earth's magnetic field. The three dimensional volume structure can be recreated with a two dimensional surface. The corvette type ship model (length 70 m, beam 10 m, draft 4 m) was built from plates. The thin plate boundary condition [1] was introduced on all ship's surfaces. The 2D surface is labelled with a boundary condition in Opera 3D. During assembly of the matrix of finite element equations, additional triangular prism or hexagonal elements (Fig.1) of the plate thickness are created [1]. The models of an engine, shaft and two other ferromagnetic devices were placed inside the ship's model (Fig.2).

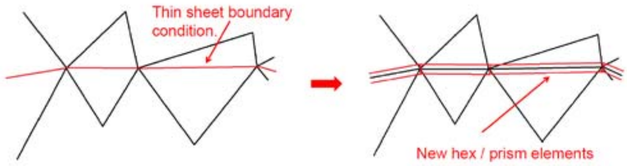

Fig. 1. The idea of the thin plate boundary condition [1].

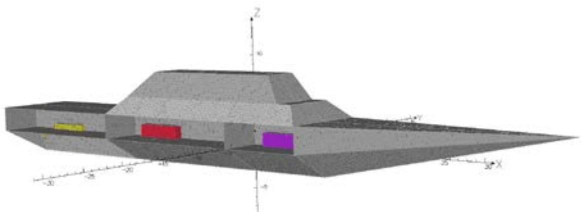

Fig. 2. The ship's model with inner devices

B. The results f computer simulations

Computer simulations were carried out in NS and WE directions of ship in Earth's magnetic flux density 50 μT (the magnetic inclination 70 deg). An external field was introduced in order to simulate the Earth's magnetic field.

The ship's magnetic signature for NS direction and relative magnetic permeability equal to 250 with and without inner devices is shown in Fig.3 (10 m below the level of water along the ship under the keel).

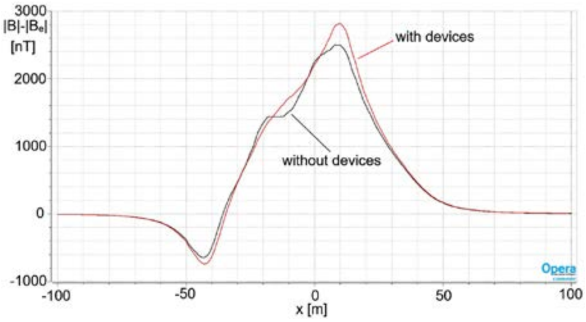

Fig. 3 The magnetic signature for NS direction and $\mu_r = 250$ for the ship with and without inner devices.

The signature was calculated as a difference between the modulus of the total magnetic flux density and the modulus of the Earth's magnetic field (disturbed field). One can observe that the signature of the ship's model with inner devices is greater by 10% than the signature of an empty ship. The next example for the same conditions, but for $\mu_r = 25$ is shown in Fig.4.

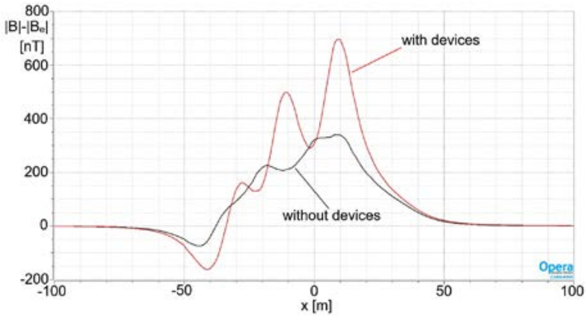

Fig. 4 The magnetic signature for NS direction and $\mu_r = 25$ for the ship with and without inner devices.

The magnetic field for the ship with devices is greater by 100% in this case. The comparison of magnetic fields for NS direction and for the ship with inner devices for $\mu_r = 25$ and $\mu_r = 1$ are shown in Fig.5.

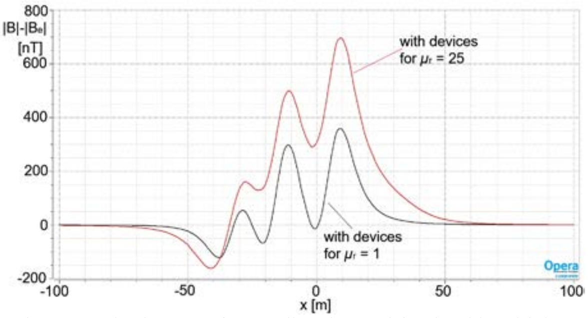

Fig. 5 The magnetic signature for NS direction and for the ship with inner devices for $\mu_r = 25$ and $\mu_r = 1$.

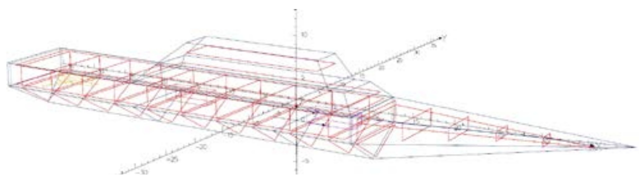

Fig. 6 The coils of degaussing system.

The Opera 3D 18R2 allows to calculate of the magnetic ship signature with a system of coils inside the ship model in relatively simple way. It is possible also to optimize the coils current for minimization of a ship signature [3]. The example of the coils of degaussing system is shown in Fig.6. The result of calculations of ship signatures with and without degaussing system is shown in Fig.7.

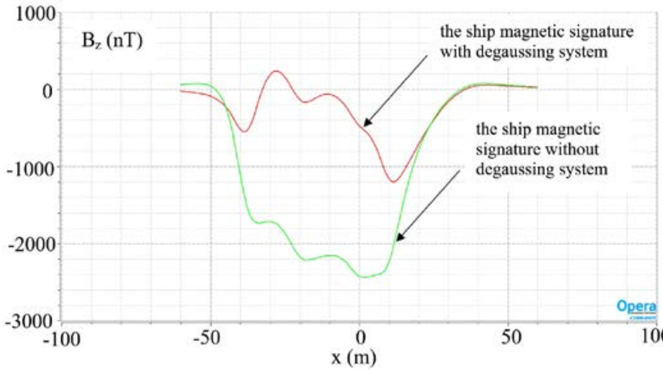

Fig. 7 The ship magnetic signatures with and without degaussing system.

III. Conclusions

The computer simulations have shown that for relative magnetic permeability of a few hundred range the influence of inner ferromagnetic devices on the ship's magnetic signature is negligible. In the case of minehunter class ships it is necessary to use degaussing systems for inner ferromagnetic devices. The thin plate boundary condition is the good method for calculating of magnetic ship signatures. The FEM net has good shapes and the calculation time is more less compared to the ship model with layers of steel. The Opera 3D 18R2 program allows to calculate the ship magnetic signature with degaussing system and optimize currents of coils.

References

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[2] K. Jakubiuk, P. Zimny, M. Woloszyn: Multidipoles model of ship's magnetic field. International Journal of Applied Electromagnetics and Mechanics, pp.183-188, vol.39, no 1-4, 2012.

[3] Opera 3D, User Guide.