METHODS OF REDUCING SHIP'S MAGNETIC SIGNATURE

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Key words: naval magnetic signature, numerical modelling, simulation results.

Abstract: A ship's magnetic field is produced mainly by the ferromagnetic materials from the ship [1,2], which are magnetized in Earth's magnetic field. In the Earth's magnetic field, the ship produces a local magnetic disturbance, regardless of its movement. The ship can be modeled in a CAD program and its field can be measured. In this paper we want to point out the great importance of the degaussing coils for reducing ship's magnetic signature, and also to make a comparison between the magnetic field distribution with and without the coils. From the results we extracted a solution for reducing ship's magnetic field, and also we've shown that the existing methods can be improved using computer aided analysis to find new geometrical disposal of the coils on the vessel and values for the currents passed through the coils.

1. INTRODUCTION

The popular misconception is that all marine mines are magnetically attracted to the hull of a vessel. It is true that in the past some mines were detonated by mechanical contact, but most modern mines are more likely to be lying in wait on the seabed. These are triggered by a sensitive device that looks for variations in the ambient magnetic field. Such variations can occur when thousands of tonnes of ship steel pass overhead. The situation would be even more dangerous for those onboard if that steel itself was magnetised.

The study of ship's magnetic signature, based on modelling consists in finding theoretical models that can approximate the ship's behaviour in magnetic field, mathematic formulas of interpretation, theoretical computation of the field for different depths, comparing the results with simulations, determining the demagnetization coils and the variation of the currents passing through them [1,2]. In this paper we have focused on the study of reducing the ship's induced magnetic field, and on finding a configuration of the coils that permit this reduction. We've also presented a description of the degaussing coils currently in use.

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2. METHODS OF REDUCING SHIP'S MAGNETIC SIGNATURE

There are two general ways to camouflage against magnetic detection. Vessels have on-board "degaussing" coils that are supplied with a current to generate their own magnetic fields that oppose the Earth's field at the vessel's location. Modern degaussing systems are very sophisticated but they still rely on the assumption that the permanent magnetisation of a ship or submarine is negligible, or at least well-known [8]. Consequently, in conjunction with degaussing coils, vessels are routinely bulk demagnetised in a process called "deperming". (fig. 1) [3].The demagnetizing process can be made in two ways: component demagnetization or general demagnetization [1,2]. The component demagnetization is made using three coils: a longitudinal coil, for the vertical component of the longitudinal magnetization, a transversal coil, for the vertical component of the transversal magnetization and a vertical coil, for the vertical component of the vertical magnetization.

Fig. 1. Magnetic treatment of ship by a degaussing installation

The compensating coils resemble the demagnetizing coils in position. There are the following types of compensating coils [3]: the Main coil (compensates the induced and permanent vertical components of the ship's magnetic field); the forecastle induced - quarterdeck induced coils compensate for the longitudinal induced component of the ship's magnetic field); the athwartship coil (compensates the athwartship induced and athwartship's permanent components of the ship's magnetic field). These coils have an optimum effect upon the ship's magnetic field when they are used together. The demagnetizing coils are very useful to erase the ship's "magnetic background", and the compensating coils to reduce the inductive effect that a great mass of ferromagnetic material moving through Earth's magnetic field produces. We took one of these compensating coils and simulated its effect upon the ship's magnetic signature.

3. NUMERICAL MODELING OF THE SHIP’S MAGNETIC FIELD

To model the ship’s magnetic signature it is necessary to start from simplified models, with analytical support. The sphere and ellipsoid models can be used to model the ship’s behavior in the Earth’s magnetic field [5].

The surface regions are very useful to model the thickness of the ship’s walls. These regions allow the user to take into account thin regions either magnetic (of sheet type with a high permeability) or non-magnetic (of air gap type) to mesh it [4] (fig. 2). Compared with a description with volume regions, the surface regions ensure a very important saving on the numbers of elements and of unknowns with respect to the volume description, since the thickness is neither geometrically described nor meshed.

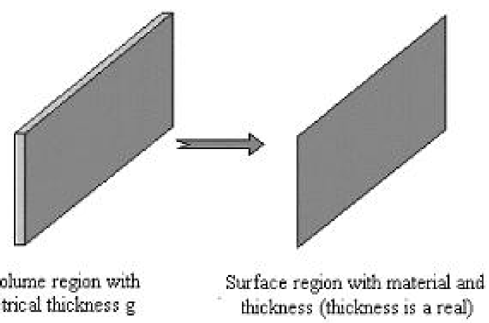

Fig. 2 Principle of taking into account thin regions by means of surface region [4]

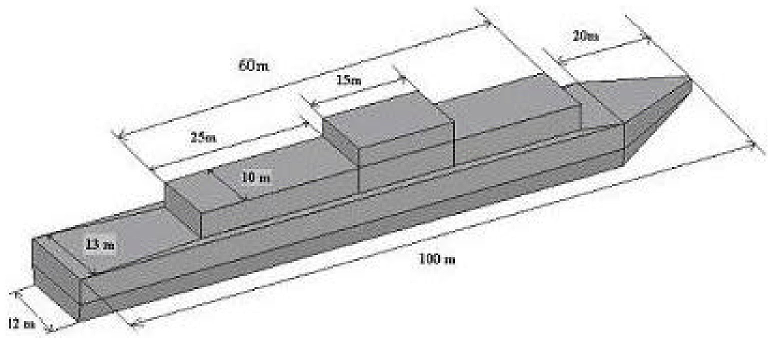

Fig. 3 Geometry of the ship

The permanent magnetization of the ship can be modeled using a permanent magnet for the ship’s material. The field’s sources on the vessel can be modeled using permanent magnets of different strengths and in different positions on the ship, according to the real sources. The Earth's magnetic field can be generated with homogenous Dirichlet conditions on the boundaries [6,7]. Because of the ship's complex structure, we have used a simplified model. We took the dimensions of a frigate and approximated it with parallelepipeds (fig. 4).

We have focused on the following cases: the ship in earth's magnetic field (case 1), and the ship in earth's magnetic field with the main coil on (case 2).

Case 1: The ship was placed in an air box (600 x 600 x 600 m^3). The Earth's magnetic field was obtained using homogenous Dirichlet condition (magnetic potential) on the opposite faces of the air box (V_{m1}=1000A, and V_{m2}=0A). The ship was placed in the air ($s_{air}=10^{-10}$ S/m, $\mu_{r\_air}=1$). We have considered the volume of the ship filled with air, and on the faces we have defined surface regions, of 10 cm thick. We have used MS3RED formulation, in reduced scalar potential, for the air inside and outside the ship and also for the surface regions. This formulation can be used for non-conductive materials and takes into account non-meshed coils as field sources. The mesh has 74650 1st order elements. To be able to compare the two studied cases, we have used the same formulation for the regions in both cases.

Case 2: The data from the first case was preserved and we have placed non-meshed coils (fig.4) around the ship through which the following currents were passed: I_1 = 4.5 A, N = 9 sp., I_2 = 1.9 A, N = 4 sp.,I_3 = 2 A, N = 5 sp., I_4 = 0.9 A, N = 2 sp., I_5 = 0.9 A, N = 7 sp., I_6 = 2.5A, N = 4 sp., I_7 = 1 A, N = 3 sp.

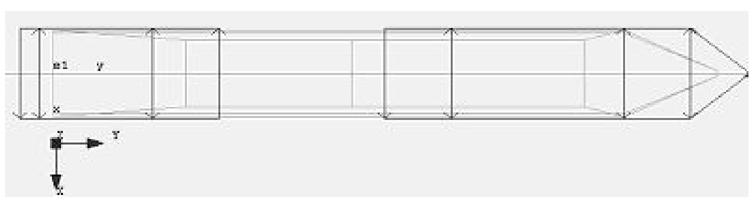

Fig. 4 Geometrical position of the degaussing coils

The results are presented below.

Case 1: We have studied only the effect of the compensating coil on the vertical component of the magnetization. This component represent the main contribution to the ship's magnetic field at our country's latitude.The goal of these simulations was to find a configuration of the coils that assures a reduction of the ship's magnetic field in a horizontal plane below the ship.

The measurement depth is given by these formulas:for surface vessels with compensating coils: h_n = (0.6…0.8) B_{max}, where B is the maximum beam of the ship (here 13.6m); for surface vessels without compensating coils h_n = (0.8…1.5) B_{max}; for submarine: h_n= (1.3…2.0) B_{max}. We have used an average (12m) from the first two cases because our vessel had only one compensating coil on. In fig. 5 we have presented the distribution of the field's vertical component in the measurement plane.

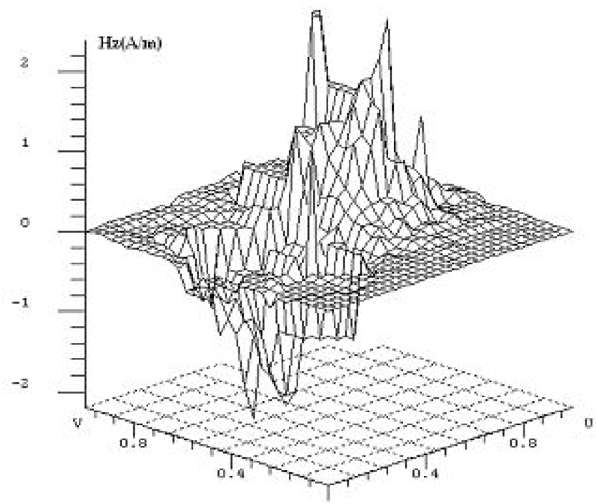

Fig. 5 Distribution of the Z component of the field in the measurement plane (case1)

Case 2: In the second case we have presented the same distribution as in the first case (fig. 6).

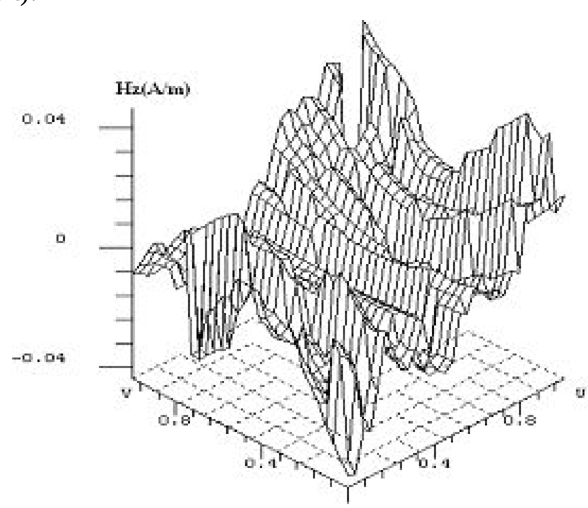

Fig. 6 Distribution of the Z component of the field in the measurement plane (case2)

In fig. 7 we've made a comparison between the vertical components of the field obtained in the measurement plane before and after placing the compensating coil.

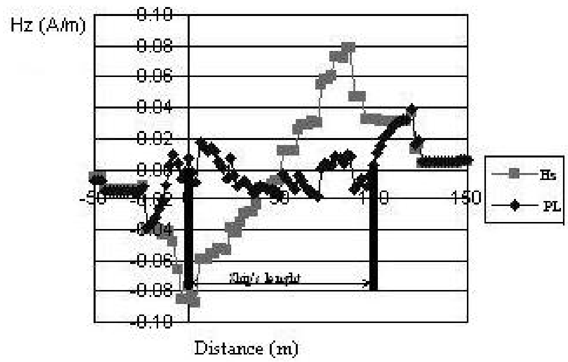

Fig. 7 The compared characteristics of the field's Z component

CONCLUSIONS

A ship is made from a great number of metallic elements with distinct magnetization, which in the moment of the launch to the sea give the ship's magnetic signature. The study of the ship's magnetic signature is made at a certain measurement depth. This depth is different for each class of vessels and depends on the latitude of the navigation area and also of the ship's geometry. From the simulation resulted that the main coil is very useful for reducing the values of the field's strength. The currents through the aft and bow coils are higher than the ones through the middle coils. From the simulations we can see that is not sufficient the magnetic treatment of the ship. It is necessary to combine all proceedings for the local and global compensation and demagnetization of the ship.

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