Acta Technica 62 (2017), No. 5A, 703–708

Imitation the vessels Magnetic Field by A certain amount of Magnets

Hao Chen[1], Chunsheng Lin[1], Wendou Jia[1]

Abstract. The paper presents an overview make use of a certain amount of magnets of magnets to produce variable magnetic moment. So it can produce a magnetic field of vessel. The single magnetic comprise three coils which are orthogonal. When the coils switched on the current respectively, the magnetic can produce three magnetic fields which are irrelevant and orthogonal. The magnetic field which is produced by magnets is simulated by MATLAB simply. The simulation shows the method is valuable.

Key words. Magnetic, magnets, imitation.

1. Introduction

Being magnetized in the magnetic dipole, a steel vessel or UUV generates a magnetic field, causing noticeable distortion of the earth's magnetic field at this point. Some vessels may be equipped with degaussing function, but they can only weaken the magnetic field and are unable to eliminate the magnetic field entirely. Therefore, the magnetic field may inevitably become the trigger signal to torpedoes. For irregular external shape and uneven internal structure, a vessel or UUV's magnetic field is also featured by irregular distribution [1]. Generally speaking, among a vessel's pass features, each of three components H_x, H_y and H_z has two or more positive and negative half-waves, and three components have different laws of change, e.g. phase characteristic, frequency characteristics and gradient characteristics.

2. Problem formulation

At present, we often electrify multiple coils of single axis to generate the component of magnetic field of three axes, which is controlled only by single current. Thus, this component of three axes varies with the single current, so errors are inevitable when it is used to simulate the magnetic field of vessel and UUV. In order to

[1] Workshop 1 - Naval University of Engineering, 717 Jiefang Road, Wuhan 430033, China

effectively protect against highly intelligent torpedo, it is necessary to realize good fitting between magnetic field of electromagnetic sweep gear and magnetic field of vessel. In other words, it is necessary to eliminate or reduce the difference between such two fields. In order to solve this problem, we can make use of magnet of three axes to simulate the magnetic field of vessel.

3. Design of magnet

The author designs a magnet of three axes. This magnet consists of three iron cores and coil assembly that are orthogonal to each other. It makes use of the magnetic field generated by electrified magnetizing coils to magnetize iron cores and generate the appropriate intensity of three-axis orthogonal magnetic field around coil assembly, so as to simulate the magnetic fields of vessels. Electromagnetic coil assembly is made according to the principle of solenoid electromagnet Electromagnetic coil assembly has the length of 4m, the diameter of 0.8m and the total weight of about 2.2T. Coil 1 is the main body of the whole sweep magnet, while Coil 2 and Coil 3 are orthogonal to each other and fixed in Coil 1. The gap between coils is filled with polyurethane for securing, protection, damping and floating.

In the design calculation, electromagnet 1 has the coil of 500 turns, electromagnet 2 has the coil of 100 turns and electromagnet 3 has the coil of 150 turns. All coils are made through vacuuming under high temperature and filling with epoxy resin. Each coil is provided two joints and wrapped onto each iron core. These isolated coils are filled with polyurethane to form a whole.

4. Modeling of magnetic field for magnet

Under normal circumstances, when calculation distance is larger than the size of magnet, the calculation of magnet's magnetic field [5] can be simplified into magnetic field of magnetic dipole for calculation. Let spatial magnetic dipole M be at the origin of rectangular coordinate system, the component of magnetic field intensity generated by the magnetic dipole at any point p *(x,y,z)* in the space is as follows:

$$\bar{v} = \sqrt{8RT/\pi M} \tag{1}$$

In which, $M=iM_x+jM_y+kM_z$.

As Coil 1 moves only horizontally, there is $M_z=0$. M shall be horizontal dipole and its dipole moment M can be obtained by simply being equivalent to the magnetic field generated by current-carrying circle on the axis. See equivalent magnetic field in Fig. 3.

From the approach of current, the axial component of magnetic field generated only at the point P is as follows:

$$\begin{cases} D_t\left(\frac{\partial^2 C}{\partial r^2}+\frac{1}{r}\frac{\partial C}{\partial r}+\frac{\partial^2 C}{\partial z^2}\right)=\frac{\partial C}{\partial t} \\ C\left(r,z,0\right)=C_0; C\left(\pm R_0,\pm h_0,t\right)=C_1 \\ \frac{\partial C}{\partial r}\Big|_{r=0}=0;\ \frac{\partial C}{\partial z}\Big|_{z=0}=0 \end{cases} \tag{2}$$

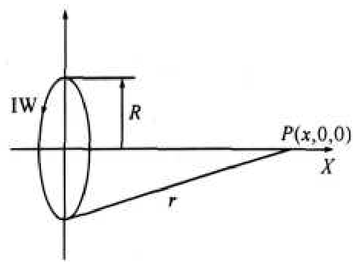

Fig. 1. Equivalent magnetic field

When $r>>R$, there is rx;

$$\begin{cases} \left(\frac{\partial^2 C_N}{\partial r^2}+\frac{1}{r}\frac{\partial C_N}{\partial r}+\frac{\partial^2 C_N}{\partial z^2}\right)=\frac{\partial C_N}{\partial f} \\ C_N\left(r,z,0\right)=C_0-C_1 \\ \frac{\partial C_N}{\partial r}\Big|_{r=0}=0;\ \frac{\partial C_N}{\partial z}\Big|_{z=0}=0 \end{cases} \tag{3}$$

From the approach of magnetic moment, the axial component of magnetic field generated by the corresponding horizontal dipole M is as follows:

$$\frac{1}{S}\frac{\partial^2 S}{\partial r^2}+\frac{1}{Sr}\frac{\partial S}{\partial r}+\frac{1}{H}\frac{\partial^2 H}{\partial z^2}=\frac{1}{L}\frac{\partial L}{\partial f} \tag{4}$$

When they are equivalent, there will be:

$$L\left(f\right)=A_2 e^{-\varepsilon^2 f} \tag{5}$$

Then

$$\frac{1}{H}\frac{\partial^2 H}{\partial z^2}=-\varepsilon^2-\frac{1}{Sr}\frac{\partial S}{\partial r}-\frac{1}{S}\frac{\partial^2 S}{\partial r^2}=-\mu^2 \tag{6}$$

Thus, we can learn that in this magnet, Coil 1 has only magnetic moment M_x in direction x, Coil 2 has only magnetic moment M_y in direction y, and Coil 3 has only magnetic moment M_z in direction z. To Coil 2 and Coil 3, since $r>>R$, it can be regarded as circular coil.

Let the overall coordinate of magnet be as presented in Fig. 1. It is assumed that Coil 1, Coil 2 and Coil 3 are supplied with currents I_1, I_2 and I_3 respectively.

The magnetic elements of three components are calculated on this basis as follows:

$$H=B_1\cos\left(\mu z\right)+B_2\sin\left(\mu z\right) \tag{7}$$

5. Calculation simulation analysis

In order to analyze and determine its effect, the magnetic field is simply simulated according to the requirements of design calculation. Based on the above calculation formula for magnetic moment of three components, Equation (1) is used to calculate Hx, Hy and Hz.

For simplification, we select several special states to explore the relationship of Hx, Hy and Hz.

1) When I1=30; I2=0; I3=0, within the range of -200<x<200; -200<y<200; z=100, MATLAB simulation is conducted as follows:

As shown in the figures, only when Coil 1 is supplied with positive current, equivalent to magnet of single axis, Hx has a positive wave within the narrow area in the positive and negative direction of x, and has negative waves in other directions. Hy has positive waves in quadrant 1 and quadrant 3 of the coordinate and has negative waves in quadrant 2 and quadrant 4. Hz has negative waves in quadrants 2 and 3 of the coordinate and has positive waves in quadrants 1 and 4. At the origin of the coordinate, Hx and Hy are both 0

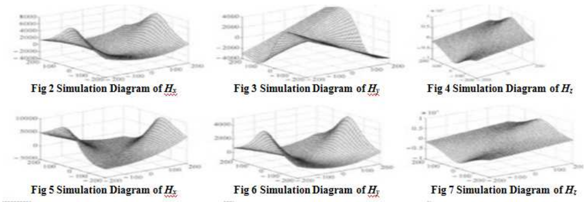

Fig. 2

2) When I_1=30; I_2=-30; I_3=0, within the range of -200< x <200; -200< y <200; z =100, MATLAB simulation is conducted as follows:

Compared with the case of supplying positive current only to Coil 1, it is noticed that the supply of positive current to Coil 2 changes the distribution of the whole magnetic field; As shown in the comparison of Fig. 2 and Fig. 5, the negative wave of H_x rotates leftward by a certain angle, while the distribution of positive wave remains unchanged. As shown in the comparison of Fig. 3 and Fig. 6, it has the highest influence on H_y and basically redistributes H_y. As shown in the comparison of Fig. 4 and Fig. 7, it has the lowest influence on H_y, whose distribution remains unchanged.

3) When I_1=30; I_2=I_3=-30, for clearly identifying the distribution of magnetic field, within the range of $-1000<x<1000$; $-1000<y<1000$; z=100, MATLAB simulation is conducted as follows:

As shown in these figures, when current is supplied to three coils simultaneously, equivalent to magnet of three axes, as shown in the comparison of Fig. 5, Fig. 6 and Fig. 7, we notice some change in the distribution of magnetic field due to electrification of Coil 3. Among them, the distributions of H_x and H_y remain unchanged, while H_z is basically redistributed.

4) When I_1=30; I_2=I_3=-15, for clearly identifying the distribution of magnetic field, within the range of $-1000<x<1000$; $-1000<y<1000$; z=100, MATLAB simula-

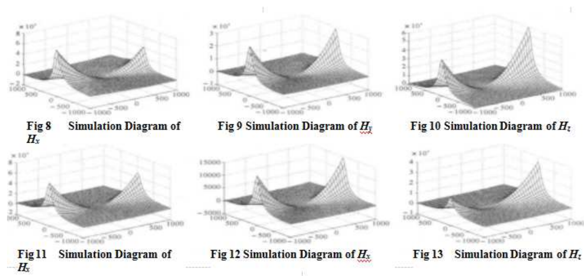

Fig. 3

tion is conducted as follows:

As shown in the figures, when the current supplied to coils is adjusted, the distributions of H_x, H_y and H_z basically remain unchanged, but only the intensity of magnetic field changes in three directions.

6. Conclusion

As revealed in the above MATLAB simulation analysis, any change of current supplied to three coils and their polarity can cause the change of distribution of magnetic field generated by magnet. When coils 1, 2 and 3 radiate magnetic fields respectively, each coil plays a decisive role in only the component and distribution of its corresponding H_x, H_y and H_z, and will only adjust the component magnetic field in other two directions. It is therefore deduced that if three coils are supplied with different currents, polarities and frequencies, etc. at the same time, the size, direction and frequency, etc. of generated magnetic fields H_x, H_y and H_z will be different as well. This can effectively reduce the relevance of magnet to the three components of magnetic field generated during operation, and make it more effective to simulate the magnetic field of UUV, so as to improve the degree of fitting and fulfill the goal of enhancing work efficiency.

References

[1] I. Cnossen: *The Impact of Century-Scale Changes in the Core Magnetic Field on External Magnetic Field Contributions.* Space Science Reviews *206* (2016), 1–22.

[2] K. Masanori, H. Kazuya, S. Michio: *Study of spurious solutions of finite method in the three magnetic field formulation for dielectric waveguide problems.* Electronics & Communications in Japan *68* (2010), No. 8, 114–119.

[3] D. Wu, Y. Ji: *Dynamic Estimation of Forest Volume Based on Multi-Source Data and Neural Network Model.* Journal of Agricultural Science *7* (2015), No. 3, 171–180.

[4] W. M. Wynn, C. P. Frahm, R. H. Carroll: *Advanced superconducting gradiometer/magnetometer arrays and a novel signal processing technique.* IEEE Trans. On Magnetics *11* (1975), No. 2, 701–707.

[5] Z. Y. Zhong, T. S. Sheng: *Calculation of magnetic field of current coils in arbitrary shape.* Journal of Naval University of Engineering *21* (2009), No. 3, 71–74.

[6] B. Sajjadi: *Solid-liquid mixing analysis in stirred vessels: Reviews in Chemical Engineering*. Reviews in Chemical Engineering *31* (2015) 119–147.

Received November 16, 2017