Research on the Efficiency of Minesweeping Operation for Multi-Magnetic Minesweeping Gear

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***Abstract*—The multi-magnet minesweeping gear can eliminate new smart mines because the magnetic field of it can simulate the characteristic of target ship more closely. But at the same time, the magnetic field of different regions will strengthen or weaken due to the superposition of the magnetic field in the adjacent regions, and it brings great difficulties for analyzing minesweeping efficiency and obtaining effective minesweeping width . In order to solve the above problems, the main work in this paper is to build a line magnetic dipole model accoring to the actual situation of magnetic minesweeping gear. First, the isomagnetic lines are drawn aimed at different multi-magnet configurations. Then, the optimum sweeping width is obtained by the characteristics of isomagnetic lines. The study shows that the performance of mine-sweeping arms system is related to different magnet configurations, the choice of different components, and so.**

Keywords—multi-magnet minesweeping gear, isomagnetic line, minesweeping width

I. INTRODUCTION

With the emergence of new intelligent mine, the intelligent mines and traditional mines are generally laid in the same region in order to improve the operational efficiency. The new intelligent mine has the characteristics of intelligent target recognition and selective attack while the traditional mine′ fuse is triggered only when the magnetic field strength must exceed its threshold. For minesweeping weapons, on the one hand their magnetic field distribution should simulate the target features more closely, on the other hand they must have a certain magnetic field strength to ensure larger minesweeping width. The multi-magnet minesweeping gear can achieve these goals through reasonable magnet configurations and parameters selections.

The final magnetic field of multi-magnet minesweeping weapon may be enhanced or weakened because of the interactions with the parts of magnetic field, and it will result in a corresponding change in the minesweeping width which is a important indicator to measure the efficiency of minesweeping operations. In the light of the foregoing, in this paper an array dipole model is established for multi-magnetic minesweeping gear and the impacts of isomagnetic lines on minesweeping width are analyzed according to different possible arrangements of magnets: longitudinal, transverse, vertical.

II. THE MAGNETIC FIELD DISTRIBUTION MODELS

For the modeling of multi-magnet minesweeping gear, we can use the following models: ellipsoid array model, dipole model, mixed distribution model, etc. Literatures [1-5] show that: the model based on a large number of dipoles with equal interval between each other can get better simulation results of ship magnetic field, and easy to be implemented. The performance improvement is not obvious if the number of dipole exceed 6 while increasing complexity. For this reason, as shown in Fig. 1, we use lay a column of N magnetic dipoles to simulate multi-magnet minesweeping gear.

If the coordinate of the ith magnetic dipole is $(x_i, 0, 0)$, and its magnetic moment is, then the magnetic field at spatial point $P(x, y, z)$ can be obtained as follows:

$$\begin{cases} H_{xi} = M_{xi}a_{xi} + M_{yi}a_{yi} + M_{zi}a_{zi} \\ H_{yi} = M_{xi}b_{xi} + M_{yi}b_{yi} + M_{zi}b_{zi} \\ H_{zi} = M_{xi}c_{xi} + M_{yi}c_{yi} + M_{zi}c_{zi} \end{cases} \quad i = 1, 3 \cdots\cdots, N \qquad (1)$$

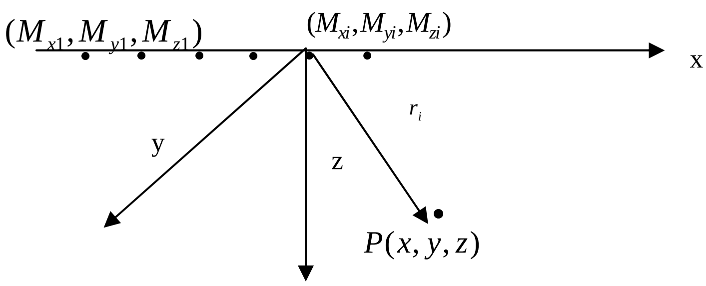

Fig. 1 The line-model of magnetic dipoles

Where:

$$a_{xi} = \frac{1}{4\pi}[\frac{3}{r_i^5}(x - x_i)^2 - \frac{1}{r_i^3}]$$

$$a_{yi} = \frac{3(x - x_i)(y - y_i)}{4\pi r_i^5} = b_{xij}$$

$$a_{zi} = \frac{3(x - x_i)(z - z_i)}{4\pi r_i^5} = c_{xij}$$

$$b_{yi} = \frac{1}{4\pi}\left[\frac{3}{r_i^5}(y - y_i)^2 - \frac{1}{r_i^3}\right]$$

$$b_{zi} = \frac{3(y - y_i)(z - z_i)}{4\pi r_i^5} = c_{yij}$$

$$c_{zi} = \frac{1}{4\pi}\left[\frac{3}{r_i^5}(z - z_i)^2 - \frac{1}{r_i^3}\right]$$

$$r_i = \sqrt{(x - x_i)^2 + (y - y_i)^2 + (z - z_i)^2}$$

According to the equation (1), the magnetic field of all the N magnetic dipoles can be obtained:

$$\begin{cases} H_x = \sum_{i=1}^{N} M_{xi}a_{xi} + M_{yi}a_{yi} + M_{zi}a_{zi} \\ H_y = \sum_{i=1}^{N} M_{xi}b_{xi} + M_{yi}b_{yi} + M_{zi}b_{zi} \quad i = 1, 2, 3\cdots\cdots, N \\ H_z = \sum_{i=1}^{N} M_{xi}c_{xi} + M_{yi}c_{yi} + M_{zi}c_{zi} \end{cases} \qquad (2)$$

III. Analysis of Isomagnetic Line

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Given the following parameters: speed $v = 12kn$, sea depth $h = 10m$, mine sensitivity $H_s = 3mOe$. Supsoe the shortest time required for mine fuze reliable action is 2s, introducing 3 single longitudinal magnets whose magnetic moments are $99 \times 10^3 A.m^2$ as the subjects, we can obtain the distribution of isomagnetic line as shown in Fig. 2a and minesweeping width : 60/1m, 60/0m, 38/1m.

If the distance between the magnets is close while the other parameters are not changed, then the magnetic field will be subject to the influence of adjacent magnetic field. The component H_x is improved, and the other two components of the magnetic field are relatively weakened. The isomagnetic line of component (H_x , H_y and H_z) can be obtained as shown in Fig. 2b. The corresponding minesweeping width is 58/1m 、 68/0m, 40/1m.

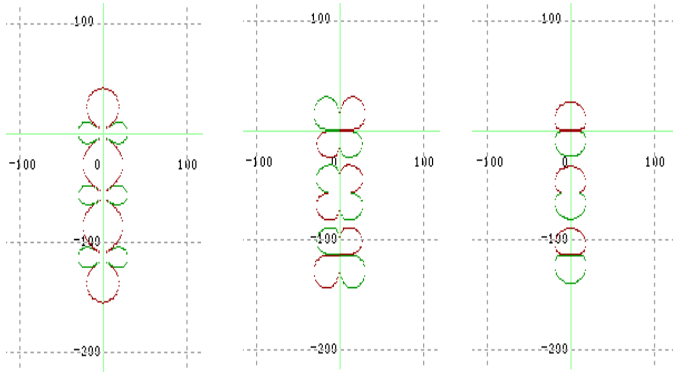

Fig. 2a The isomagnetic line of H_x , H_y and H_z for 3 longitudinal magnets

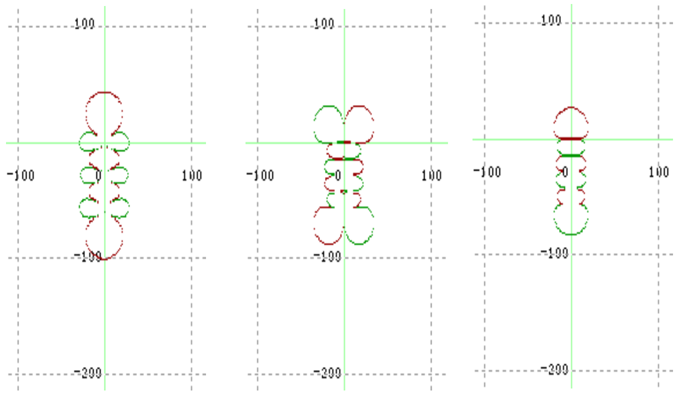

Fig. 2b The isomagnetic line of H_x , H_y and H_z for 3 longitudinal magnets

For the above magnets, if the second one is energized reversed, namely, contrary to other magnet magnetic moment, the isomagnetic line can be obtained as shown in Fig. 2c. Its minesweeping width of each component is: 68/0m, 70/5m, 44/1m.

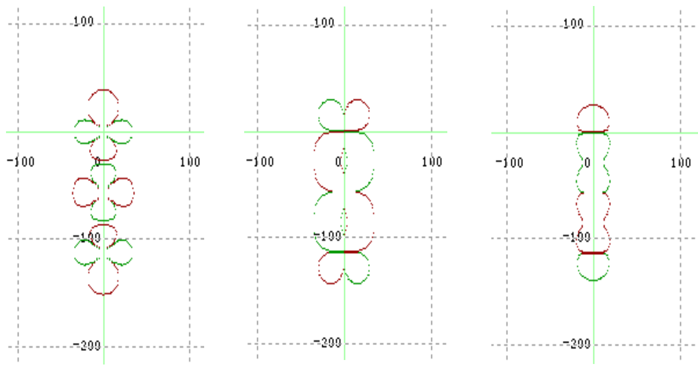

Fig. 2c The isomagnetic line of H_x , H_y and H_z for 3 longitudinal magnets

Introducing 3 single transverse magnets whose magnetic moments are $99 \times 10^3 A.m^2$ to replace the above magnets as the subjects, we can obtain the distribution of isomagnetic line as shown in Fig. 3a and minesweeping width : 68/0m, 96/1m, 56/2m.

Similarly, for the above transverse magnets, if the second one is energized reversed, the isomagnetic line can be obtained as shown in Fig. 3b. Its minesweeping width of each component is: 68/0m, 74/1m, 49/0m.

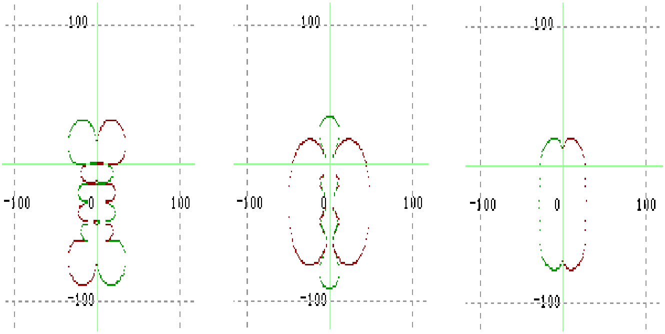

Fig. 3a The isomagnetic line of H_x, H_y and H_z for 3 transverse magnets

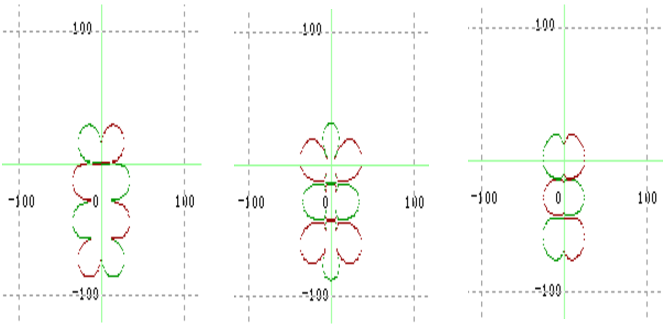

Fig. 3b The isomagnetic line of H_x, H_y and H_z for 3 transverse magnets

For the above transverse magnets, if they are replaced by vertical magnets while the other parameters are not changed, we can obtain the distribution of isomagnetic line as shown in Fig. 4a and minesweeping width: 40/1m, 56/2m, 80/1m.

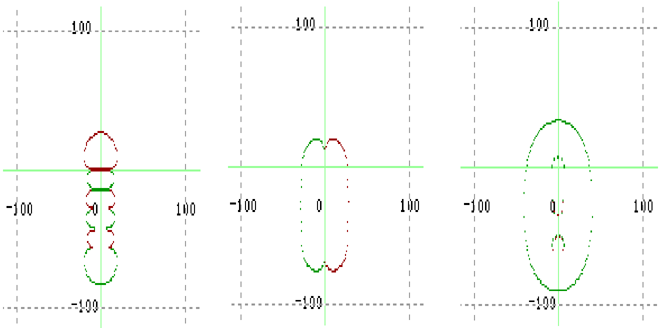

Fig. 4a The d isomagnetic line of H_x, H_y and H_z for 3 vertical magnets

If we reverse the second magnet electricity, and keep the other parameters unchanged, then the distribution of isomagnetic line can be obtained as shown in Fig. 4b. The minesweeping width each component is: 44/1m, 50/0m, 56/1m.

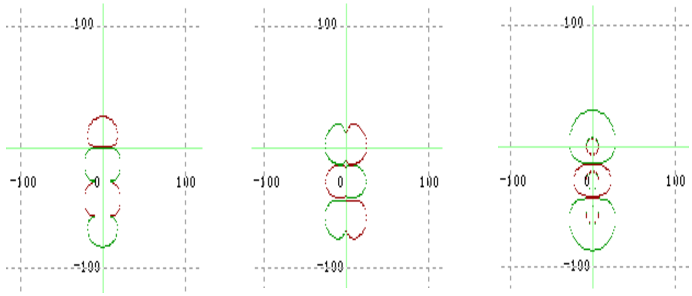

Fig. 4b The isomagnetic line of H_x, H_y and H_z for 3 vertical magnets

IV. Discussions and Conclusions

For single magnet minesweeping gear, the minesweeping reliability of transverse magnet is the best, followed by that of longitudinal magnet and lastly by that of vertical magnet [4-7]. However, for multi-magnet minesweeping gear, the magnetic field of each part may be enhanced or weakened due to the superposition of adjacent magnetic fields, resulting in the corresponding changes in the minesweeping width.

If H_x is use as the effective minesweeping component, for longitudinal magnets, the lager minesweeping width can be obtained, because its magnetic field will be enhanced due to the superposition of adjacent magnetic fields whose polarity is opposite. In order to obtain larger minesweeping width, for H_y, it requires a transverse magnet arrangement with the same polarity to adjacent one, and for H_z it requires a longitudinal arrangement of the magnet with the same polarity to adjacent one.

Taking into account various factors, this paper considers that the cross cross-arrangement of vertical and vertical magnets is more practical than the others. The good simulation effects of the target ship's magnetic field and big minesweeping width can be achieved by way of suitable distribution interval and direction of the magnetic field (same direction or reverse). In order to get a good minesweeping effect, we can shorten or increase the distance between the magnets according to their polarities (same or opposite).

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