Study on the Minesweeping Magnetic Field of Magnetic Minesweeping Gear

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Abstract. The optimization of minesweeping magnetic field plays an important role in the minesweeping operation which is concerned with magnetic minesweeping gear. In order to analyze the factors which influence the working efficiency of the mine sweeping gear, a magnetic field dipole model is established according to the structure and working mode of the full magnetic field sweeping gear in this paper, then the simulation is taken for different situations. The results show that the mine sweeping effect is related to the number of magnets, the magnetic configuration, the selection of the magnetic field components, and so on.

Introduction

In recent years, accompanying the emergence of new intelligent mine, the magnetic minesweeping gear has been widely used because of its characteristics of "goal setting"[1-3]. The efficiency of minesweeping weapon is directly determined by its magnetic field distribution, and the research on minesweeping magnetic field has become one of the hot spots in the field both at home and abroad [4-7].

Theoretically, the model using a combination of three-ellipsoid and magnetic dipole array can achieve a good simulation results but it is difficult to achieve in engineering. For this reason, combined with the reality, the paper take the magnetic dipole model to describe the minesweeping magnetic field because it needs fewer factors to get a good simulation precision, then base the sensitivity analysis on the practical requirements of high simulation of minesweeping gear, explore magnetic field distribution of magnetic dipole model of single direction, provide important theoretical basis for seeking main factors affecting performance of minesweeping operation.

Model of Magnetic Minesweeping Gear

As shown in Fig. 1, lay a column of N magnetic dipoles to simulate magnetic minesweeping gear with the same distance between the magnetic dipoles. Literature [1-5] show that: The performance will be better if taking variable interval, but the performance improvement is not obvious when the number of dipole exceed 6 while increasing complexity. For this reason, this paper studied the array of equally spaced magnets.

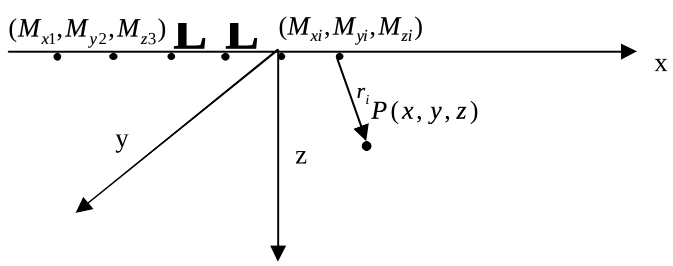

Fig. 1 The line-model of magnetic dipoles

Assume that the coordinate of the ith magnetic dipole is $(x_i, 0, 0)$, and the magnetic momen of it is (M_{xi}, M_{yi}, M_{zi}), then the magnetic field generated by the magnetic dipole at spatial point $P(x, y, z)$ is as follows:

$$\begin{cases} H_{xi} = M_{xi}a_{xi} + M_{yi}a_{yi} + M_{zi}a_{zi} \\ H_{yi} = M_{xi}b_{xi} + M_{yi}b_{yi} + M_{zi}b_{zi} \\ H_{zi} = M_{xi}c_{xi} + M_{yi}c_{yi} + M_{zi}c_{zi} \end{cases} \quad i = 1, 3 \ldots\ldots, N \tag{1}$$

Where:

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

$$a_{zi} = \frac{3(x - x_i)(z - z_i)}{4\pi r_i^5} = c_{xij} \qquad b_{yi} = \frac{1}{4\pi}\left[\frac{3}{r_i^5}(y - y_i)^2 - \frac{1}{r_i^3}\right]$$

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

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

According to the equation (1), the magnetic field generated by all the N magnetic dipoles can be obtained as the following expression:

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

Magnetic Field Distribution

Supposing magnetic moment size is 100000 $A \cdot m^2$ and sampling range in the magnetic field area is (-100m, 100m).Taking into account the actual magnet configuration and representativeness of magnetic field characteristics, we analyze the transverse characteristic curve where $y = -10m$ and longitudinal characteristic curve at equal interval symmetry configuration along the x-axis where $x = 0m$.

Distribution Characteristics of Single Magnet

If the magnet is placed longitudinaly, the transverse characteristic curve where y=-10m and the longitudinal distribution characteristic curve where x=0m can be obtained as shown in Fig. 2.

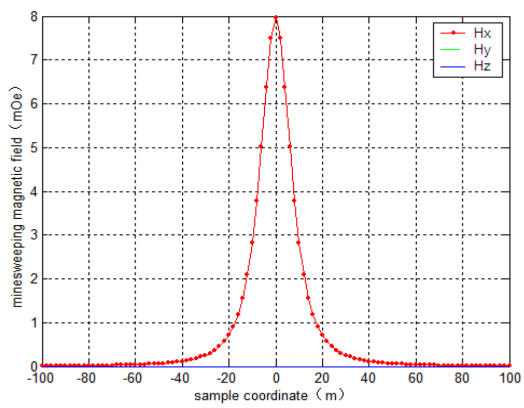

Fig. 2a The transverse characteristic curves of longitudinal single magnet

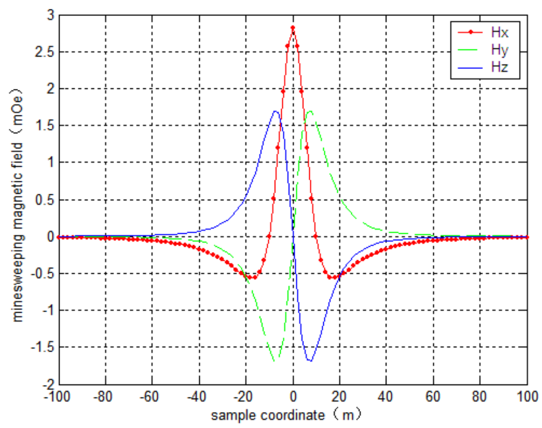

Fig. 2b The longitudinal characteristic curves Of longitudinal single magnet

If the magnet is placed vertically instead, its magnetic field distribution is shown in Fig. 3.

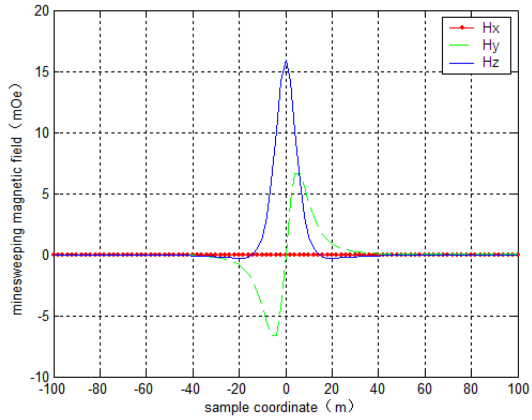

Fig. 3a The transverse characteristic curves of one vertical magnet

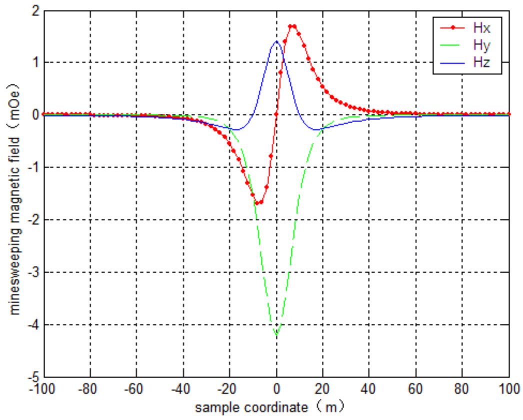

Fig. 3b The longitudinal characteristic curves of one vertical magnet

Distribution Characteristics of Multi Magnet

Suppose there are 4 magnets and the magnetic moment of each magnetic is 100000 $A \cdot m^2$. They are all placed longitudinally, and the distribution characteristic curve can be obtained as shown in Fig. 4.

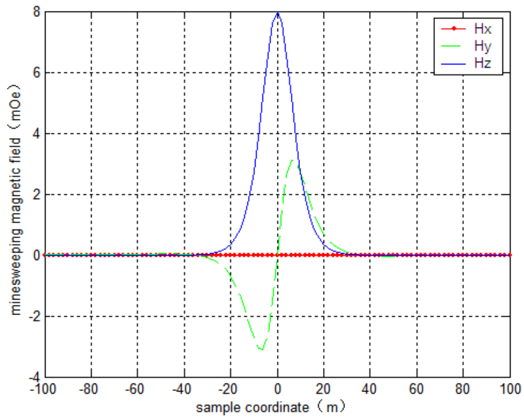

Fig. 4a The transverse characteristic curves of four longitudinal magnets

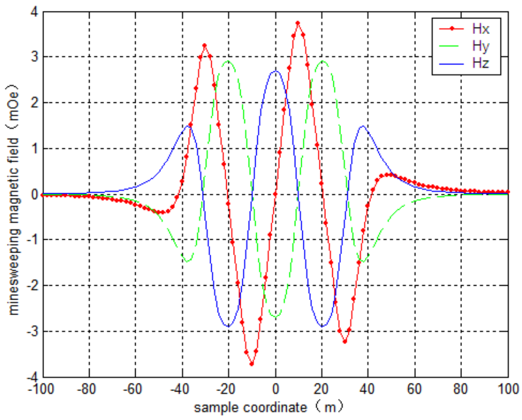

Fig. 4b The longitudinal characteristic curves of four longitudinal magnets

Put above magnets vertically instead, we can obtain the field distribution as shown in Fig. 5.

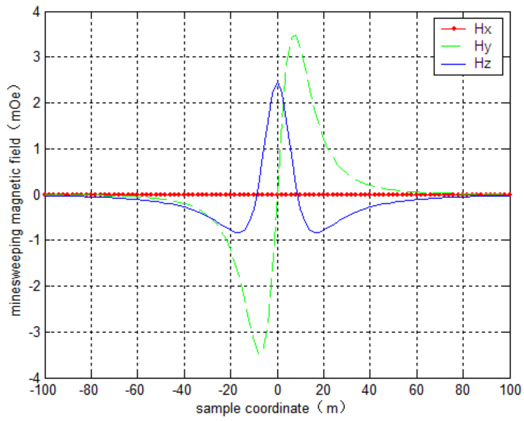

Fig. 5a The transverse characteristic curves of four vertical magnets

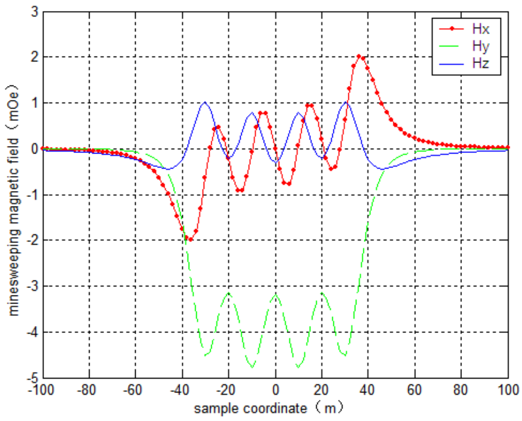

Fig. 5b The longitudinal characteristic curves of four vertical magnets

Let above magnets be cross-conFig.d, and the distribution characteristic curve is obtained as shown in Fig. 6.

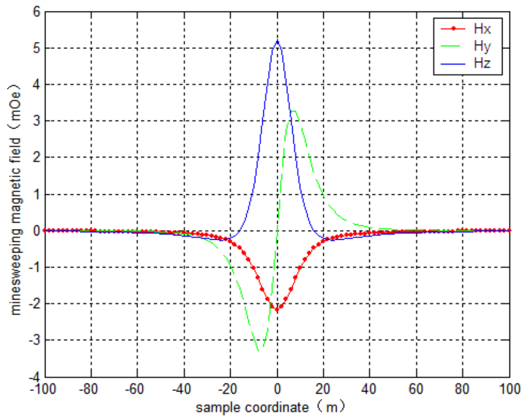

Fig. 6a The transverse characteristic curves of four cross-configured magnets

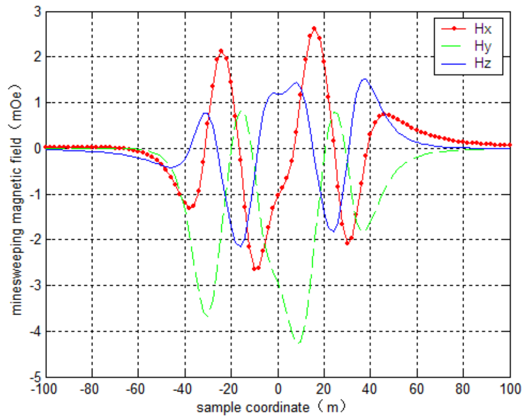

Fig. 6b The longitudinal characteristic curves of four cross-configured magnets

Discussions and Conclusions

Comparing Fig. 2 and Fig. 3, we found that the magnetic field distribution of longitudinal magnet is better than that of vertical one for a single magnet, and the component H_x has better reliability of minesweeping than H_y and Z_x without any dead zone.

By analyzing Fig. 4, Fig. 5 and Fig. 6, we found that the magnetic field of cross- configured magnets is better than that of longitudinal and vertical magnets. For cross-configured magnets, folded magnetic field will be strengthened because the adjacent magnets are the same polarit1y. But for the latter, the magnetic field of some regions is reduced due to the magnetic field superposition with opposite polarity, there may even be dead zone in these regions. In addition, when sweeping modern mines in minesweeping operations we must also take into account traditional mines, that can be perfectly achieved by use of cross- configured magnets. On the one hand the minesweeping width can increase through the adoption of an appropriate number of longitudinal magnets, on the other hand the simulation result of the protected ship magnetic field can be improved because of a certain quantity of vertical magnet.

It must be taken into account comprehensively to choose what kind configuration mode of magnet. The longitudinal configuration mode is simple and feasible, and can guarantee a certain minesweeping speed, but minesweeping width of it is not optimal. For example, there will be a larger minesweeping width when using transverse magnet, but it is difficult to realize in engineering, and what's worse, the minesweeping speed is likely to be seriously affected.

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