Studies on magnetic shielding effectiveness by finite element method

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Abstract. Maxwell 2D software is introduced in this paper to calculate the magnetic shielding effectiveness (MSE) properties of iron plate. The three-dimensional magnetic shield is thought isotropic and simplified as two-dimensional model to study its MSE properties by the finite element method. In this method, a uniform magnetic field is generated by two huge magnets and the MSE properties of iron plate, which is in the centre of the uniform magnetic field, is then calculated by the ratio of magnetic field intensity after and before magnetic shielding. All the results indicate that shape of shield materials affects the MSE properties much and the MSE properties of shield with square and circular shape with 3mm in depth are 39.3 and 53.5 dB, respectively. That means the shield shape with fewer bending is favorable to the conductivity of magnetic energy. It also shows that the MSE value decreased linearly with the distance between the magnetic shield and the centre of the magnetic field. That is, the increase of side length of magnetic shield will lead to the decrease of MSE properties of iron plate, which is agreement with the theoretical prediction of Lu H.M. model. Furthermore, the MSE properties of double layers shielding (iron plate with 2mm in depth and 3mm iron plate with 81% porosity) are also studied in this paper. The effect of places of iron plate with 2mm in depth is presented to play important role in double layers shielding and the MSE value increases with the distance between the two magnetic shields. Compared to that of shield with circular shape, the MSE properties are similar to each other when the distance of the two shields is 8mm. In addition, it also indicates that the MSE value is higher when the iron plate with 2mm in depth is inside of the other than that when it is outside.

Introduction

Nowadays, finite element method is in common use in material simulation on structural, thermal and electrical analysis and would be paid more attention in other complicated conditions to give more intuitive explanation of the mechanisms [1-4]. For example, studies on the use of finite element method on mechanical behavior of the aluminum foams have resulted in a significantly profound understanding of the foams performance [5-6].

As for the magnetic materials, it is necessary to study the design of materials properties, material shape and other aspects before its application for their thermal and vibration sensitivity. However, it is in fact difficult to emulate the magnetic or electromagnetic field, and few attentions have been
paid on the simulation of finite element method on magnetic shielding. In this paper, the Maxwell 2D software is introduced to study the magnetic shielding effectiveness (MSE) of iron plate, meanwhile, factors that influencing the MSE of iron plate is also investigated in order to provide another reference for magnetic shielding simulation.

Establish of model

The Maxwell software, developed by Ansoft company, are widely used in the thermal and electromagnetic analysis in the electric motors, electrical sources, DC/AC drive and other power systems [7]. This software is based on the Maxwell equations and usually presented as second other equations in the practical calculation. In this software, the Neumann boundary condition is used and then the solution of these equations is obtained by the finite element method. Generally, the more the number of unit subdivision in the finite element method, the more accurate the solution is. In this method, the nonhomogeneous scalar wave equation of equation solver for two dimensional magnetic fields can be expressed as [7]:

\[ \nabla \times \frac{1}{\mu} \nabla \times A_2 = J_z. \]  

Where, \( A_z \) and \( J_z \) are the magnetic vector potential and current in Z direction, respectively.

In the Maxwell 2D simulation, the uniform magnetic field is generated by two huge magnets and the MSE properties of iron plate, which is in the centre of the uniform magnetic field, is then calculated by the ratio of magnetic field intensity after and before magnetic shielding (Eq. 2). The model of magnetic shielding and the uniform magnetic field are also shown in Fig. 1.

\[ SE = 20 \log\frac{H_0}{H_1}. \]  

Where, the shielding effectiveness (SE) is commonly expressed in dB, \( H_0 \) and \( H_1 \) are the magnetic field intensity before and after magnetic shielding, respectively.

![Fig.1 Model of Maxwell 2D on magnetic shielding (left) and the uniform magnetic field where materials located (right)](image)

Results and discussion

The simulated magnetic shielding effectiveness of shield with square and circular shape with 3mm depth is listed in Table 1. It shows that shape of shield materials affects the MSE properties much and the MSE properties of shield with square and circular shape with 3mm in depth are 39.3 and 53.5 dB, respectively. The simulated MSE value of shield with square shape is compared to the prediction of iron in Wang’s study, which confirms that this method can be practical applied to the
It can be seen that the MSE of shield with circular shape is higher than that of square shape, which means shield shape with fewer bending may be favorable to the conductivity of magnetic energy. In Wang’s view, besides the materials of magnetic field, the MSE is also related to the structure of the shield.

Table 1 The magnetic shielding effectiveness of material with different shape

<table>
<thead>
<tr>
<th>Magnetic intensity [×10^{-2} wb/m]</th>
<th>Shape of materials</th>
<th>Before shielding</th>
<th>After shielding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnetic shielding effectiveness [dB]</td>
<td>square</td>
<td>61.4</td>
<td>0.67</td>
</tr>
<tr>
<td></td>
<td>circle</td>
<td>0.13</td>
<td>53.5</td>
</tr>
</tbody>
</table>

Fig. 2 shows the MSE dependence of iron plate with side length of magnetic shield. It indicates the MSE value decreased linearly with the distance between the magnetic shield and the centre of the magnetic field. That is, the increase of side length of magnetic shield will lead to the decrease of MSE properties of iron plate. This can be explained by the theoretical prediction of Lu H.M. model, in his view, the MSE can be calculated [9]:

\[ SE \approx 20 \log (1 + \frac{\mu_r t}{2R}) \]  

(3)

Where, \( \mu_r \) is magnetic permeability, \( t \) and \( R \) are the depth and radius of shield, respectively. In Eq. 3, the MSE is influenced by the radius of magnetic shield and would decrease with the increase of it. In our simulation, increase of side length will lead to the difficulty increase of the magnetic lines conductivity.

As for double layers magnetic shields, the distance dependence of the two shield and the effect of places of iron plate are also studied in this paper, as shown in Fig. 3. The effect of places of iron plate with 2mm in depth is presented to play important role in double layers shielding and the MSE value increases with the distance between the two magnetic shields. Compared to that of shield with circular shape, the MSE properties are similar to each other when the distance of the two shields is 8mm. In addition, it also indicates in Fig. 3 that the MSE value is higher when the iron plate with 2mm in depth is inside of the other than that when it is outside. Actually, the iron plate with 2mm in depth is inside of the porous one, its side length is smaller than that when it is outside the porous iron plate. This is similar to the results of that the MSE properties of iron plate...
decrease with the increase of the side length of material shield, as we have already pointed out in Fig. 2.

![Fig. 3 The magnetic shielding effectiveness of two layers shielding](image)

### Summary

The magnetic shielding effectiveness of iron plate is simulated in this paper by the finite element method. All the results indicate the magnetic shield shape with fewer bending is favorable to the conductivity of magnetic energy. It also shows that the MSE value increased with decrease of the side length of magnetic shield and the distance between two magnetic shields. In addition, it also indicates that the MSE value is higher when the iron plate with 2mm in depth is inside of the porous one than that when it is outside.

### References


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