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Abstract

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The Design of Magnetic Particle Imaging Gradient Magnetic Field Generator using Finite Element Method  
  
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**Introduction** Magnetic particle imaging (MPI) has been more and more attractive because of its potential to achieve real-time, nonionizing radiation and high spatial resolution 3-D imaging [1]. Under gradient and dynamic magnetic fields, MPI utilizes the nonlinear magnetization response to map the concentration spatial distribution of the magnetic particles *in vitro* and *in vivo* [1-3]. Gradient magnetic field generator (GMFG) is one of the most important components in MPI system making its design is of great significance. For given magnetic nanoparticles, the spatial resolution of MPI is mainly determined by the GMFG. The increase of magnetic field gradient improves the spatial resolution but meanwhile increases the power consumption and heating of GMFG. Two kinds of structural GMFGs (see Fig. 1) were analyzed through finite element method in this paper. The number of turns, power consumption and magnetic field gradient of the GMFGs were compared to each other.

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**Figure 1:** The geometrical structure of MPI systems.

**Material and Methods** The red components in Fig. 1 represent the magnetic coils whereas the blue components represent the iron cores and yoke steel, which are made of high permeability materials. The magnetic gradients of MPI systems mentioned above were analyzed by finite element method using ANSYS. To compare the magnetic gradients generated by the GMFGs, the same parameters (such as the number of turns (1550 turns), current (10 A) and geometrical dimensions) of the coils were used in the simulation. A phantom with two delta samples (radius of 2 mm and a distance of 7 mm) filled with magnetic nanoparticles (SHP-25, Ocean NanoTech, LLC) was employed in the MPI system with similar structure in Fig.1 B. The FOV of the MPI system is 30 × 28 mm2 with magnetic gradients of about 1.8 and 5.5 T/m in *x* and *z* directions. Meanwhile, the exciting current of the GMFG was 8 A.

**Results** The dashed lines and solid lines in Fig. 2 represent the absolute value of the magnetic field generated by GMFG with structure A and B, respectively. The magnetic gradients of structure A are about 1 and 3.5 T/m in *x* and *z* directions whereas those of structure B are about 2 and 6.6 T/m. The magnetic gradient of structure B is about twice as large as that of structure A. To generate the same magnetic gradient, double the power consumption and number of turns are demanded in the MPI system with structure A. Fig. 3 shows the measurement of a phantom with two delta samples with 7 mm distance.

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**Figure 2:** The absolute value of magnetic field in x and z directions.

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**Figure 3:** The measurement of a phantom with two delta samples.

**Conclusion** From the simulation results, we found that the yoke steel providing a high permeability magnetic circuit makes the GMFG easy to generate high gradient magnetic field and as well as to reduce power consumption. Although the image of the phantom has been reconstructed, our present MPI system needs to be improved in spatial resolution and SNR.

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**References**

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