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# Magnetic Induction Tomography Simulation Analysis Based on Comsol Multiphysics Soft

Jingwen Wang\*, Xu Wang, Dan Yang, Kaiyang Wang and Ye Zhou

School of Information Science & Engineering, Northeastern University, Shenyang 110819, China

\*Corresponding author e-mail: wangjingwenhappy@126.com

**Abstract.** As a new non-invasive imaging technology, Magnetic induction tomography (MIT) is one of the most advanced topics in the noncontract technology. Based on this, aiming at the problem that the valid signal is hard to extract completely, this paper focuses on measurement model establishment and analysis by comsol Multiphysics soft. Firstly, finite element analysis model has been established based on coil-coil model by comsol. Then, the magnetic flux density are obtain by comsol, and the experiment results are analyzed and validated. Verifying the Comsol simulation is effective to the MIT sensor.

## 1. Introduction

Magnetic Induction Tomography (MIT) is a new kind of the electrical characteristics tomography technology. Under the action of adscititious AC excitation magnetic field, the measured object produce eddy current because of the electromagnetic induction effect, when the measured object changes, intensity and distribution of eddy current will change accordingly [1-5]. Then the inductive voltage is picked up through detection coils. Image reconstruction algorithm is used to reconstruct internal structure of the measured object. Magnetic Induction Tomography is safe, non-invasive, non-contact, cheap, etc. So it has a broad application prospect in the field of biomedical research, industrial process control, foreign body monitoring, geological exploration and other fields. MIT is still in the stage of laboratory research, how to apply the MIT to actual production as soon as possible is the objectives of researchers [6-9].

Comsol Multiphysics soft is a most famous general finite element analysis one. A three-dimensional finite element model has been developed for simulating measurements. In a given an excitation source and the conductivity distribution, we research the eddy current distribution and the induced voltage in the sensor. The measured object impacts on sensitive field and inductive voltage, which provided a valid instruction and data sources for the image reconstruction.

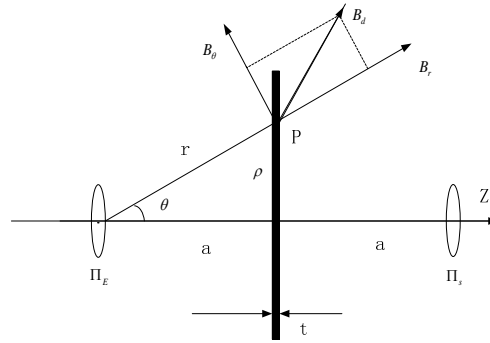
### 1.1. Organization of the Text the Theory of MIT

The magnetic dipole model as shown in figure 1, there are two coils are placed on the z-axis with the distance  $2a$ , the angular frequency  $\omega$  is added to the excitation coil.  $B$  Generated by excitation coil with the conductive medium. The field due to these eddy currents is known as the secondary field. The disk is placed between the two coils. The radius of the disk is  $R$ , the thickness is  $t(t \ll 2a)$  and the conductivity is  $\sigma$ . Suppose that the skin depth is greater than the thickness of the disk:



$$\frac{\Delta B}{B} = (\omega \varepsilon_0 \varepsilon_r - j\sigma) \frac{ta^3 \omega \mu_0}{2} \left\{ \frac{1}{a^2} - \frac{a^2 + 2R^2}{(a^2 + R^2)^2} \right\} \quad (1)$$

Where,  $\varepsilon_0$  is the dielectric constant in the vacuum,  $\mu_0$  is the magnetic permeability. From the equation (1), the change of the disk conductivity mainly affects the imaginary part of  $\Delta B/B$ , the change of the disk permeability mainly affects the real part of  $\Delta B/B$ .



**Fig 1.** Magnetic dipole model

Galerkin method is used to establish the discrete finite element equation, then calculated the finite element solution of the above problems. With the aid of magnetic vector potential (A), the above problem can be formulated in terms of magnetic potential vector A. The solution domain is divided into E small solid element. In one element e, there are:

$$\begin{aligned} A^e &\approx \sum_{k=1}^g N_k^e A_k = \sum_{k=1}^g (N_k^e A_{kx} i + N_k^e A_{ky} j + N_k^e A_{kz} k) \\ &= \sum_{k=1}^g N_{km}^e A_{km} \end{aligned} \quad (2)$$

Where,  $N_k^e$  is primary function at k nodal point, the total number of the element nodal point is g.

$$N_{km}^e = \begin{cases} N_k^e i, & m = x \\ N_k^e j, & m = y \\ N_k^e z, & m = z \end{cases} \quad (3)$$

The number of  $N_{km}^e$  is 3g, then:

$$\begin{aligned} A &= \sum_{k=1}^{NP} (N_k A_{kx} i + N_k A_{ky} j + N_k A_{kz} k) = \sum_{k=1}^{NP} N_{km} A_{km} \\ &= \sum_{k=1}^g N_{km}^e A_{km} \end{aligned} \quad (4)$$

The total number of nodal point in solving regional is NP,  $N_k$  is the whole primary function at then calculate  $\phi$ :

$$\begin{aligned}\phi^e &= \sum_{k=1}^g N_k^e \phi_k \\ \phi &= \sum_{k=1}^{NP} N_k \phi_k\end{aligned}\quad (5)$$

Though the Jacobian matrix which is needed for the inverse problem, the sensitivity of the induced voltage to the conductivity change can be written as:

$$\frac{\partial V_{mn}}{\partial \sigma_x} = -\omega^2 \frac{\int_{\Omega_x} A_m \cdot A_n dv}{I} \quad (6)$$

Where  $I_0$  is the total current in the excitation coil,  $A_m$  and  $A_n$  are respectively forward solvers of excitation coil m excited by  $I_0$  and the sensing coil (n) excited with unit current.  $\sigma_x$  is the conductivity of pixel x and  $\Omega_x$  is the volume of the perturbation.

## 2. Analysis of MIT sensitive properties

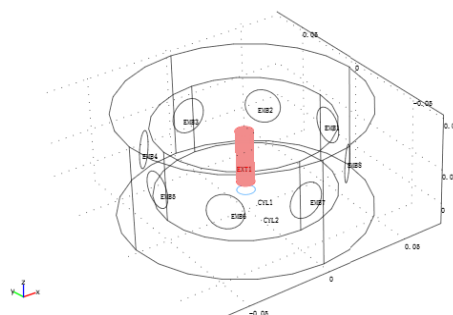
### 2.1. Measurement model of MIT

The three-dimensional section of MIT experimental simulation model based on Comsol Multiphysics simulation software is established, which comprises 8 evenly arranged excitation coil and receiver coil. The object in the measured area is set as the conductivity of the copper. The parameters used in each part of the model are shown in table 1.

The material properties	copper	air
conductivity	6e7	1
relative permittivity	1	1
relative permeability	1	1

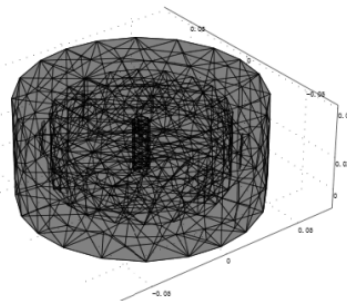
**Tab 1.** parameters used in each part of the model

Using finite element software Comsol, a MIT system of 3-D simulation model is established, which is showed in figure 2.



**Fig 2.** Three dimensional measurement model of MIT

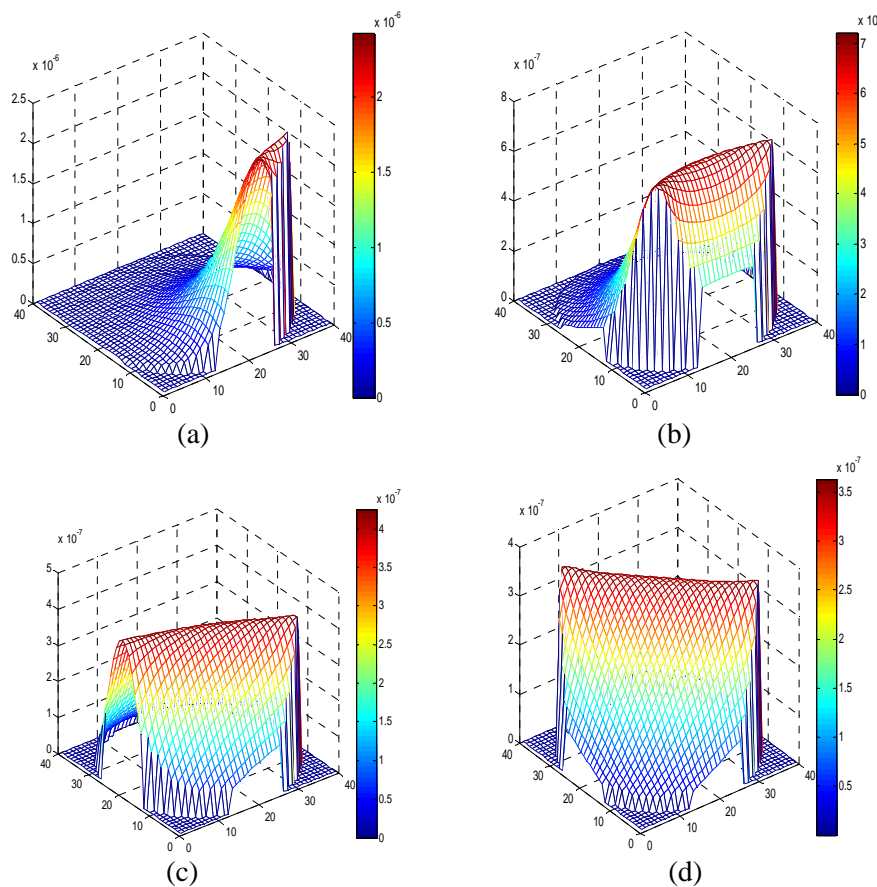
Then the measurement model is divided for calculation. The divided meshes of the conductivity areas are smaller than other areas for calculation accurately, the divided model is showed in figure 3. Finally, the data can be obtained by comsol.



**Fig 3.** Subdivision model

### 2.2. The influence of excitation current on sensitive field.

The sensitivity matrix is important for MIT, which implies the voltage on the sensing coil caused by the small change in the conductivity of the measured area. In this paper, sensitivity matrix is calculated by using the electromagnetic software COMSOL. In this paper, Fig. 2 shows four sensitivity maps. From figure4(a)-(d), we can draw some conclusions: ① The position of the excitation coil and the detection coil determines the distribution of the sensitivity, which is the different "projection" direction; ② The sensitivity field value is high near the excitation coil and the detection coil, while the sensitivity field is small in the part that is far away from the excitation coil and the detection coil; ③ The numerical value of the sensitivity field is relatively small in the central area of the pipe, regardless of the coil in the "projection" direction. These common points reflect that the electromagnetic field is a "soft field".



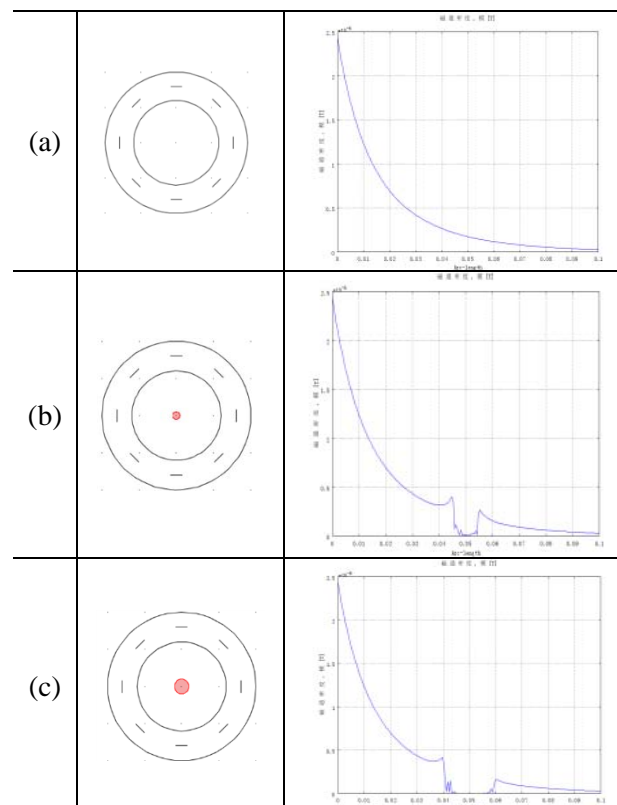
**Fig. 4** sensitivity distribution

### 2.3. The influence of disturbed object the sensitive field

In order to investigate the influence of the conductor area on the induced voltage, only the conductor area is changed when the other simulation conditions are unchanged. Table 2 (a), (b) and (c) are the profiles of the magnetic flux intensity along the excitation direction for the open, conductor radius of 0.5cm and conductor radius of 1cm separately. The horizontal axis is the diameter length of the pipe, and its longitudinal axis is the size of the magnetic flux density.

It can be concluded that the flux density near the excitation coil is large, and the flux density decreases with the increase of the excitation coil distance. The existence of conductive material has a great influence on the excitation magnetic field, and the magnetic flux density in the conductive object is very small, which shows that the conductive object has repulsion to the magnetic field. By comparison between (b) and (c), it can be concluded that the magnetic flux density will decline when the conductor area increases. The larger the conductor area, the greater the secondary magnetic field, and the reduction of the original magnetic field generated by the excitation coil is also greater, so the flux density is smaller.

**Tab.2** Model and Magnetic flux density distribution of MIT



### 3. Conclusion

In this work, the simulations were realized assuming a motionless model by Comsol Multiphysics simulation software, which is a most famous general finite element analysis software. A three-dimensional finite element model of eight-channel MIT system has been developed for simulating measurements. The results of simulation analysis are consistent with the results of theoretical calculation. The simulation experiment shows that magnetic field can change by different excitation current and different conductivity. This experiment is contribution to designing the measurement model and subsequent reconstruction problems.

### Acknowledgments

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