深 圳 大 学 实 验 报 告

课程名称：电磁场与电磁波

实验名称：电磁场电磁波仿真实验 2

学　　院：电子与信息工程学院

专　　业：电子信息工程

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Problem one

Theoretical Calculation

Question: An axial current I is uniformly distributed in an infinitely long hollow cylinder of inner and outer radii a and b. Find the magnetic induction inside and outside the cylinder.

Solution: Use Ampere's law to determine the strength of the magnetic field inside and outside the cylinder B.

$$\oint_l B dl = \mu I$$

① Inside the Cylinder $(r < a)$:

I = 0. So B = 0

② Between a and b $((a \le r \le b))$:

Calculate and get :

$$B = \frac{(r^2 - a^2)\mu_0 I}{(b^2 - a^2)2\pi r}$$

③ Outside the Cylinder $(r > b)$:

Calculate and get :

$$B = \frac{\mu_0 I}{2\pi r}$$

Simulation Model

Simulation: The axis of a hollow cylinder of infinite length is the z-axis and the inner and outer radii are 1mm and 1.5mm respectively, on which an axial current (1+0.3)A is uniformly distributed, find the magnitude of B on the x-axis.

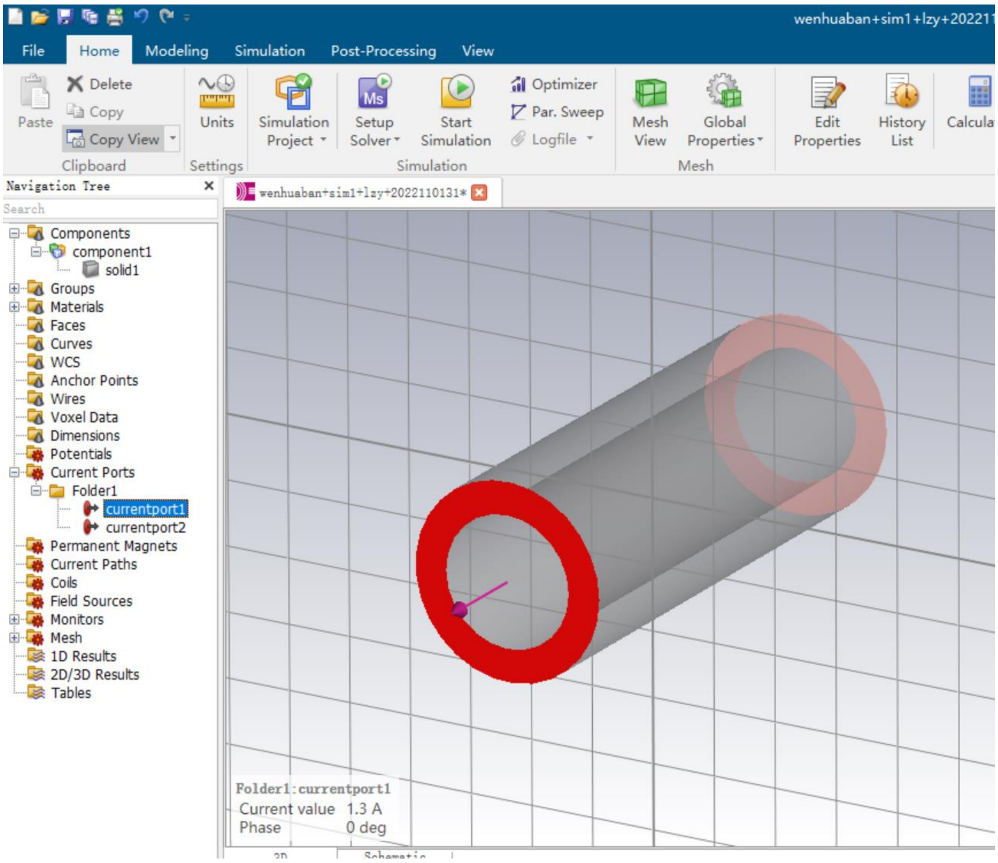

Fig 1.1 Simulation model(1.3 A)

Simulation Result(matlab)

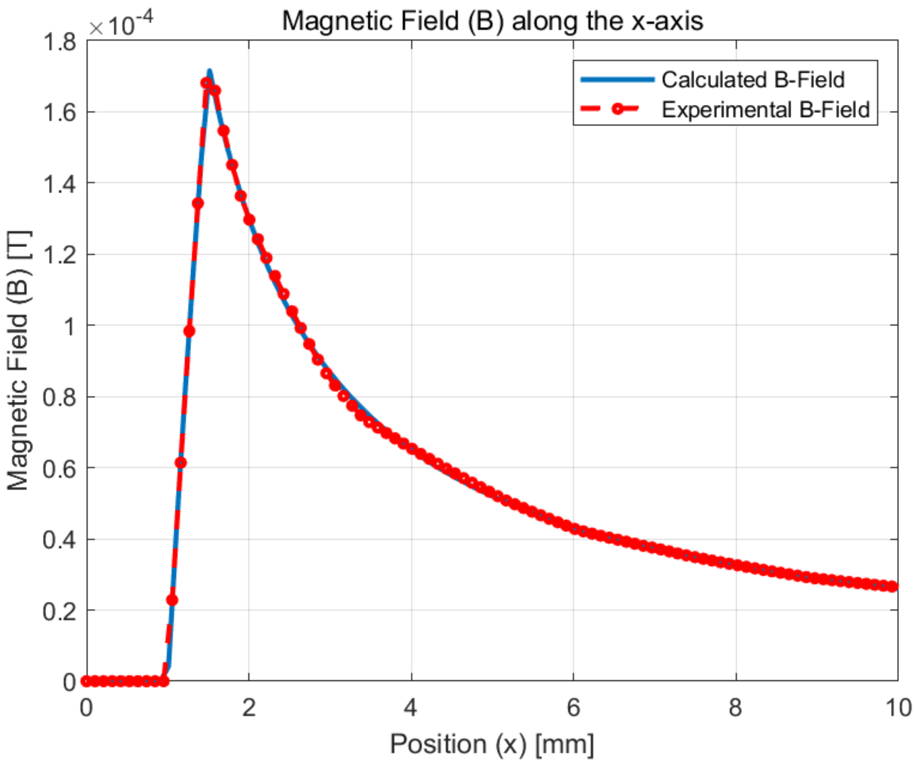

Fig 1.2 Simulation Result(matlab)

Comparison and Analysis:

We first analyze the tendency of the B distribution for calculation and simulation value. From the figure, we observe that the B distribution is symmetrical so we only analyze the B distribution along positive x axis. When 0<=x<1.5mm, the B distribution is equal to 0. When 1.5<=x<2, the B distribution is linear increasing. When x>=2mm, the B distribution decreases by inverse proportional function.

When 0 <= x <= 2mm, the calculation value and simulation value is coincide. When x > 2mm, all the part is coincide.

Problem Two

Theoretical Calculation

Question: Find B at the centre of the circle for a current-carrying circular wire loop.

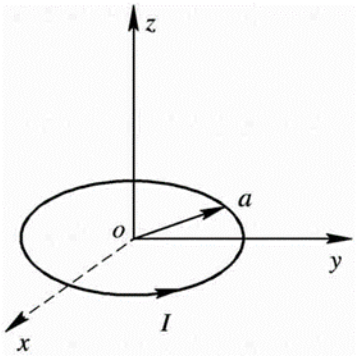

Fig 2.1 Question figure

Solution:

$$\vec{B} = \frac{\mu_0 I}{4\pi} \oint_l \frac{d\vec{l} \times \hat{a}_R}{R^2}$$

$$\vec{R} = z\hat{a}_z - a\hat{a}_r \quad R^2 = (a^2 + z^2)$$

So that

$$\vec{B} = \frac{\mu_0 I a^2}{2(a^2 + z^2)^{\frac{3}{2}}} \hat{a}_z$$

Simulation Model

Simulation: The radius of a current-carrying circular wire is (20 + 0.3) mm, find the magnitude of B at the centre of the circle. The current is given as 1A

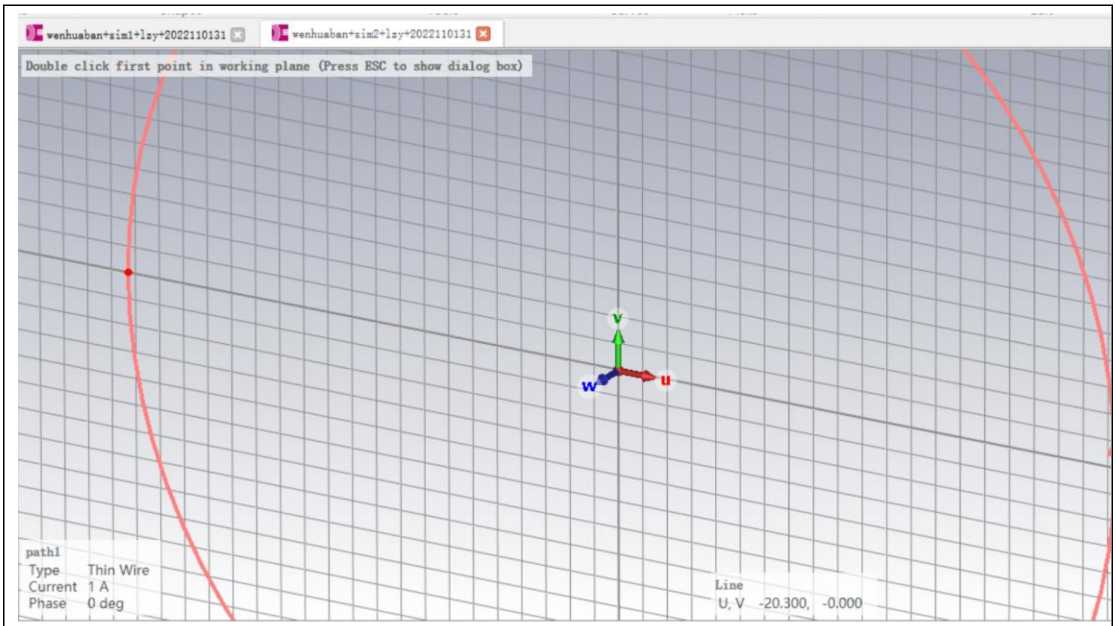

Fig 2.2 Simulation Model(20.3)

Simulation Result(matlab)

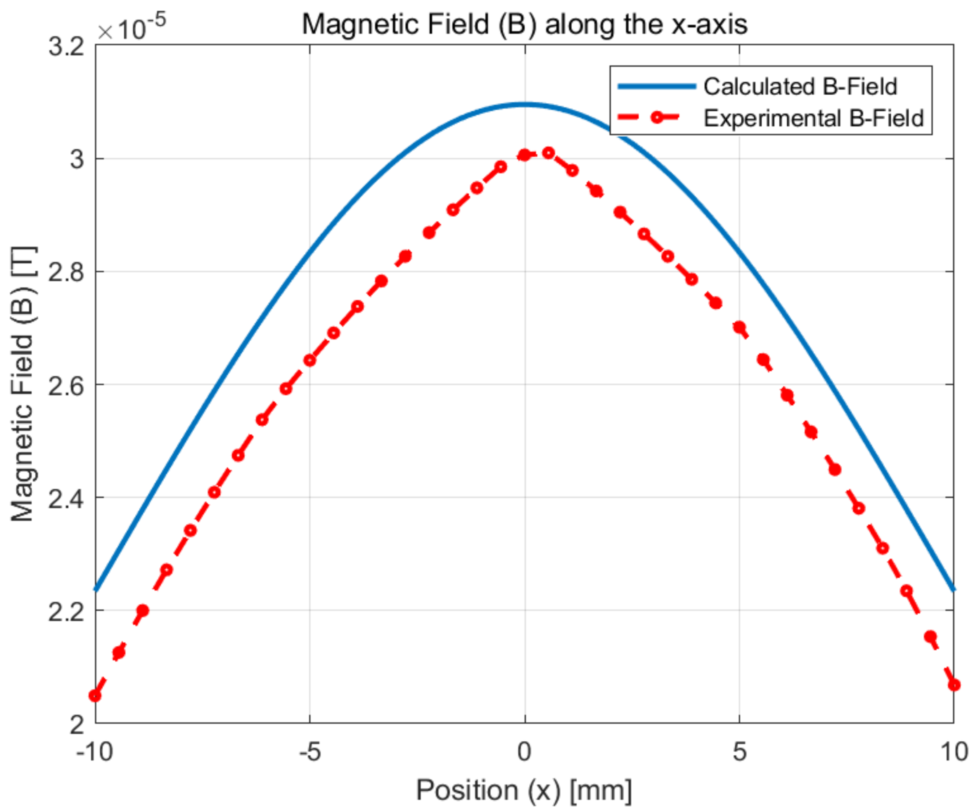

Fig 2.3 Simulation Result(matlab)

Comparison and Analysis

We first analyze the tendency of the B distribution for calculation and simulation value. From the figure, we observe that the B distribution is symmetrical so we only analyze the B distribution along positive x axis. When x = 0mm, the B distribution reaches to the maximum. When x > 0mm, the B distribution decreases by inverse proportional function.

We observe that the calculation value and simulation value have some deviation.

The two difference may causes by the boundary condition or effected by the solver accuracy. In the experiment, I set the boundary condition is equal to 30 which is relatively small compared to the real situation. Although there exists tiny error, it is acceptable since it is impossible to absolutely simulate the real world condition.

Problem Three

Theoretical Calculation

Question: The inner and outer conductors of a coaxial line have radius a. The inner radius of the outer conductor is b, and the outer radius is c, as shown below. Let the inner and outer conductors flow current in opposite phases, and the permeability of the medium between the two conductors is μ,find H and B in each region.

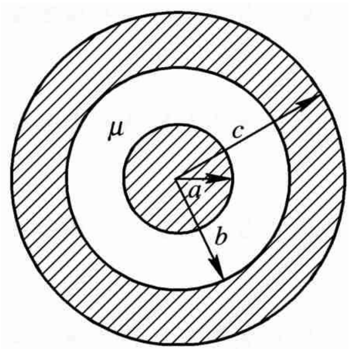

Fig 3.1 Question figure

Solution:

$$\oint Bdl = \mu_0 \frac{\pi r^2}{\pi a^2} I \quad \oint Hdl = \frac{\pi r^2}{\pi a^2} I$$

When r <a:

$$B = \frac{\mu_0 Ir}{2\pi a^2} \quad H = \frac{Ir}{2\pi a^2}$$

When a ≤ r ≤ b:

$$B = \frac{\mu_0 Ir}{2\pi a^2} \quad H = \frac{Ir}{2\pi a^2}$$

When b ≤ r ≤ c:

$$B = \frac{\mu_0 I}{2\pi(C^2 - b^2)} \frac{(C^2 - r^2)}{r} \quad H = \frac{I}{2\pi(C^2 - b^2)} \frac{(C^2 - r^2)}{r}$$

When r > c:

B = 0 H = 0

Simulation Model

Simulation: Coaxial line axis is z-axis, a=0.5mm,b=1mm,c=1.5mm, relative permeability of the medium between the two conductors is (4+0.3), find H and B on the x-axis.(remember the reversed electricity)

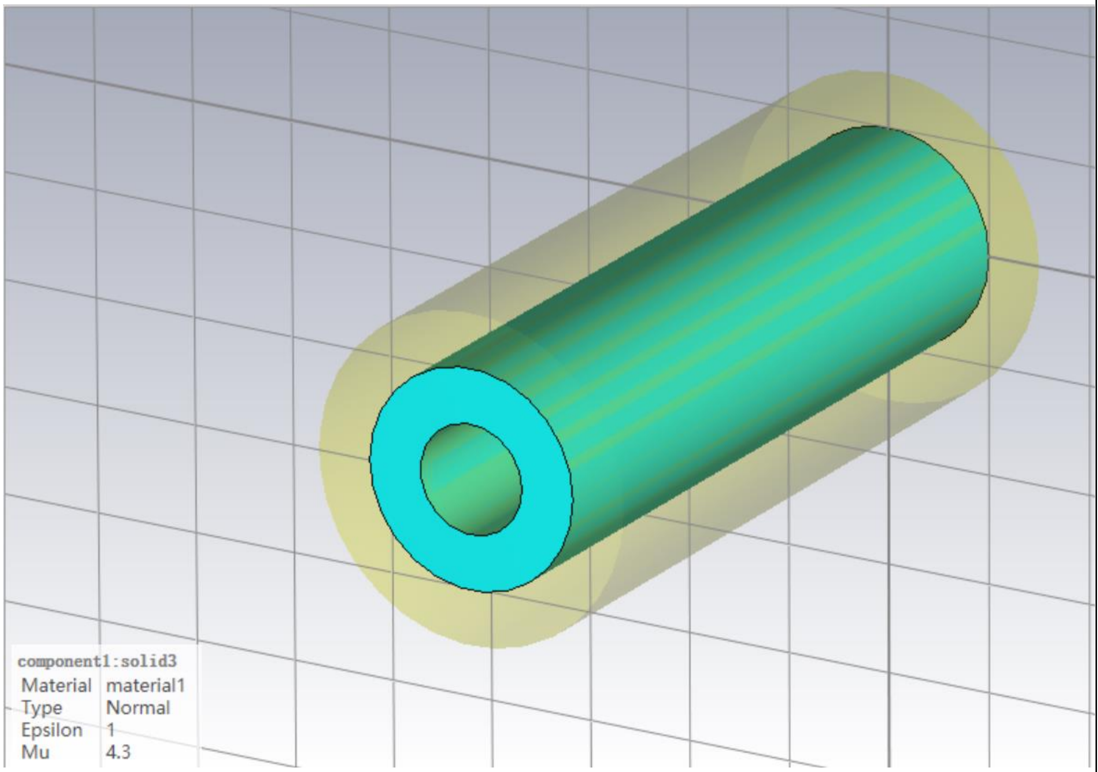

Fig 3.2 Simulation Model(Mu = 4.3)

Simulation Result(matlab)

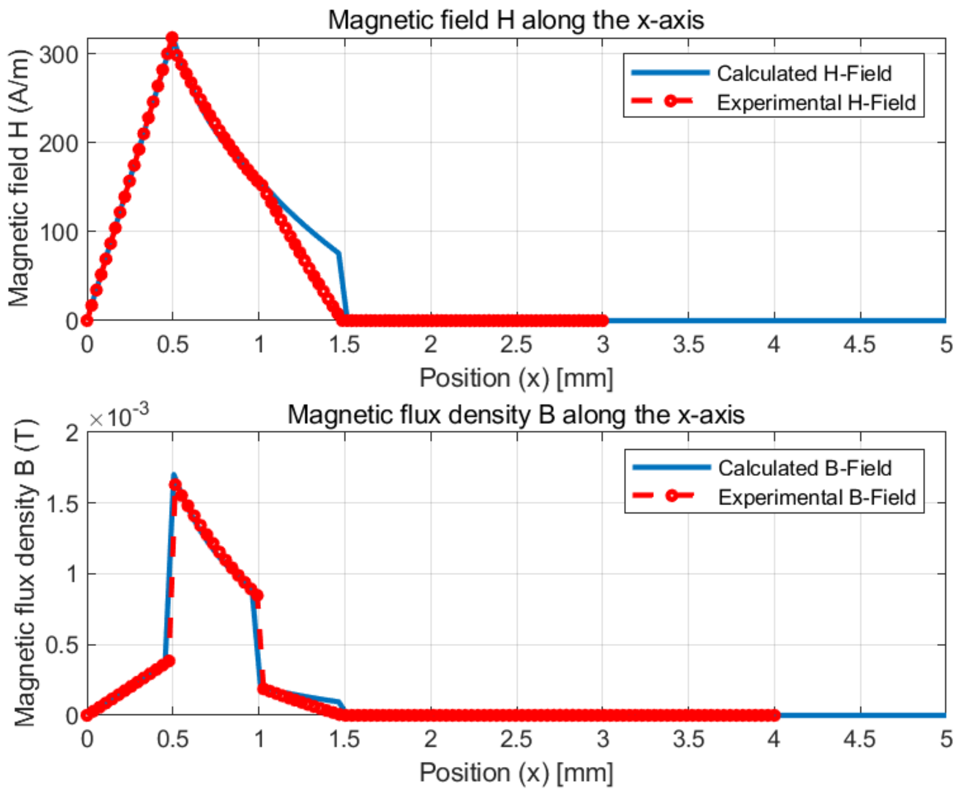

Fig 3.3 Simulation Result(matlab)

Comparison and Analysis

We first analyze the tendency of the B distribution and H distribution for calculation and simulation value. From the figure, we observe that the B distribution and H distribution are symmetrical so we only analyze the B distribution and the H distribution along positive x axis. When x = 0mm, the B distribution is equal to 0. When $0 < x <= 0.5$mm, the B distribution is linear increasing. When x = 0.5mm, the B distribution reaches to the maximum. When $0.5 < x < 1$mm, the B distribution decreases by inverse proportional function. When $1 < x < 1.5$mm, the B distribution is linear decreasing. When x >= 1.5mm, the B distribution is equal to 0. Now we analyze the H distribution. When x = 0mm, the H distribution is equal to 0. When $0 < x < 0.5$mm, the H distribution decreases by inverse proportional function. When $0.5 <= x < 1.5$mm, the H distribution has a tendency to linear decreasing. When x >= 1.5mm, the H distribution is equal to 0.

Comparison of magnetic field strength H: The calculated and experimental results show the same trend in the inner and intermediate radii, but with some deviations at the outer radius. This may be due to the failure of the simplified model to capture the complex boundary conditions and material property variations in the experiments.

Comparison of magnetic flux density B: Similarly, the calculated and experimental results show the same trend in the inner and intermediate radii, but there are some deviations in the values at the outer radius. This may be related to errors in the experimental equipment, material properties or simplification of the model.

Problem Four

Theoretical Calculation

Question: Two cylinders, both of radius a, with axes spaced d, d < 2a, are shown below. Except for the overlapping portion R of the two columns, there is a current of equal magnitude and opposite direction in each of the two columns, with density J. Find B in the region R.

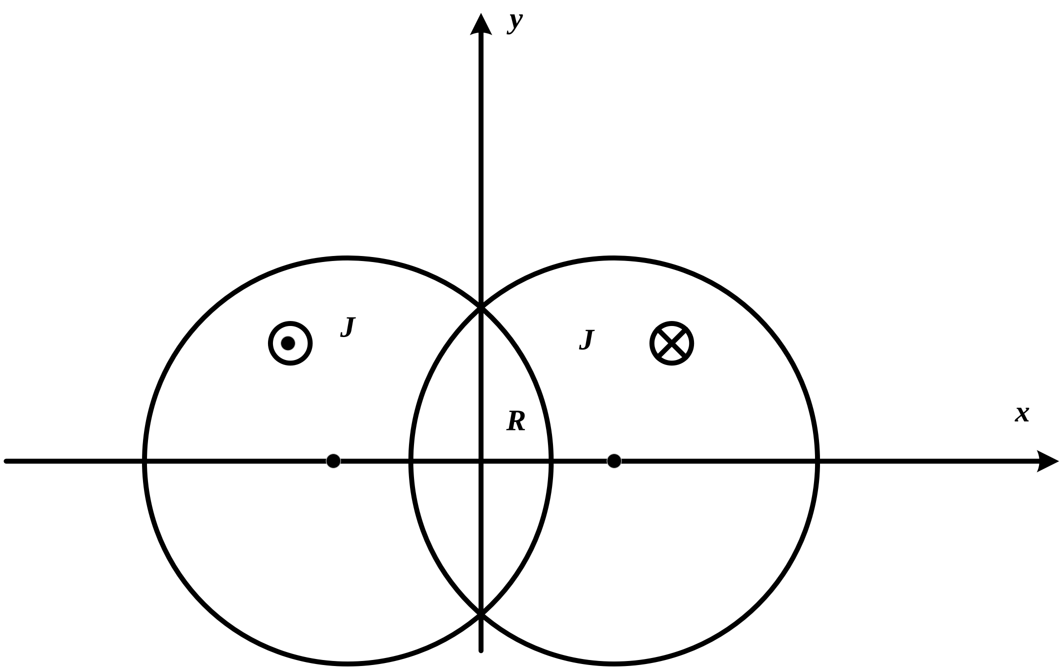

Fig 4.1 Question figure

Solution: we use the fact that each cylinder carries equal and opposite currents with current density J. At a point $(x, 0,0)$ in the overlapping region, the magnetic field contributions from each cylinder add up. Using Ampère's law

The magnetic induction generated by the current along the positive direction (left cylinder) in the overlapping region is B_1.

$$\oint B_1 \cdot \mathrm{d}l = 2\pi r_1 B_1 = \mu_0 \pi r_1^2 J B_1 = \frac{\mu_0 r_1 J}{2}$$

The magnetic induction generated in the overlapping region by the current along the negative direction (right cylinder) is B2:

$$B_2 = -\frac{\mu_0 r_2 J}{2}$$

$$B\& = B_1 + B_2 = \frac{\mu_0 J}{2} \mathrm{d}e_y$$

Simulation Model

Simulation: As shown in the figure below, the radius of two cylinders is 1mm, the axis is parallel to the z-axis, and the axes are located at x=0.5mm and x=-0.5mm, respectively. In addition to the overlapping part of the two columns, R, each of the two columns has a current of equal magnitude and in opposite direction, 1A, and find the magnitude of the x-axis in the range of [-0.4mm,0.4mm].

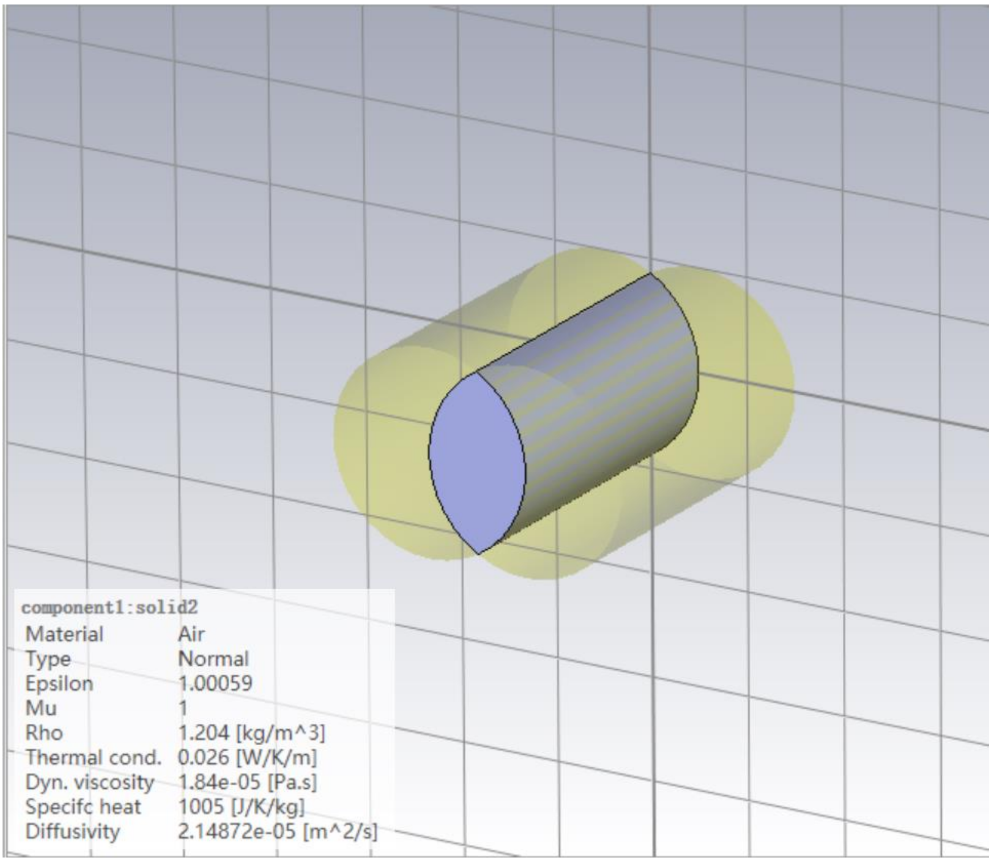

Fig 4.2 Simulation Model

Simulation Result(matlab)

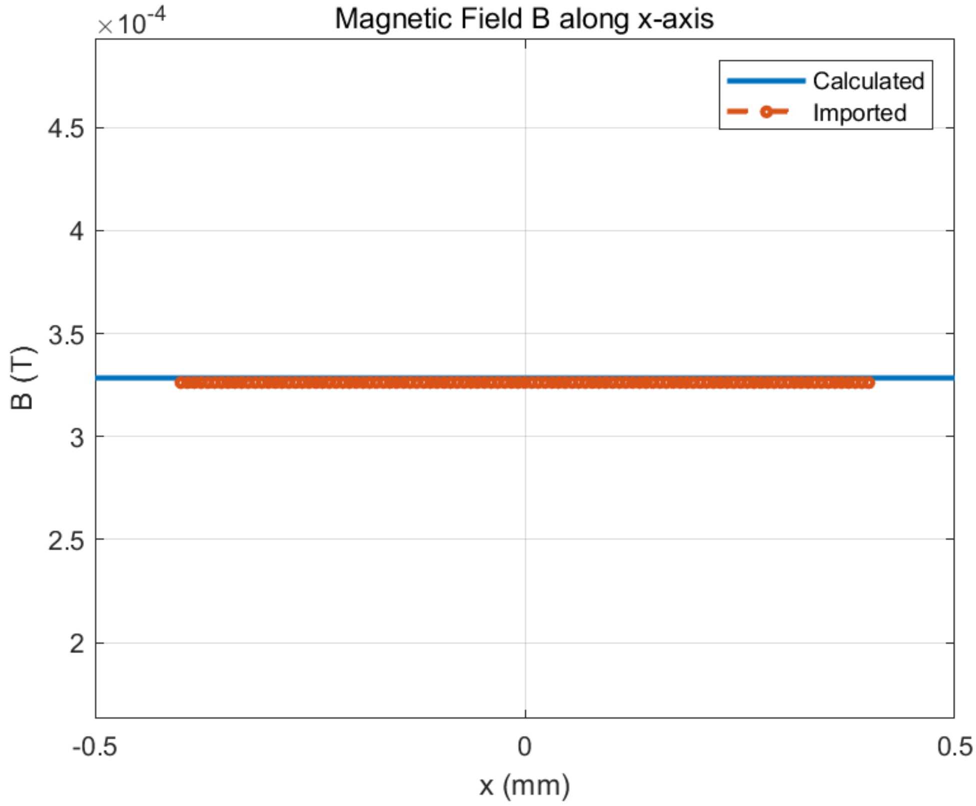

Fig 4.3Simulation Result(matlab)

Comparison and Analysis

We first analyze the tendency of the B distribution for calculation and simulation value. In the range of [-0.4,0.4]mm, the B distribution is a constant that means the B distribution is the same value along these range.

From the figure, we observe that the calculation value and the simulation value is basically coincide which indicates that the setting of our experiment is reasonable.

五、指导教师批阅意见：

成绩评定：

指导老师签名：

年　月　日