

Study on the infections of magnetic field in LHT-100 thruster

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Abstract: Based on magnetic theorem, Combine with the LHT100 thruster independently developed by Lanzhou Institute of physics, the magnetic field of thruster was simulated by finite element analysis software-Ansoft Maxwell 12. Then the relation was obtained between magnetic field in thruster and the factors including ampere-turn, magnetic pole space and magnetic shield. At last we also discussed the results.

I. Introduction

LHT100 thruster which was independently developed by Lanzhou Institute of physics is a typical SPT type of Hall thruster. The magnetic field is one of the key factors which affect discharge characteristics and performance of the thruster. Then it is very important for performance optimization and degree of design freedom, the magnetic field plays a key role in design of LHT100 thruster.

The magnetic circuit of LHT100 thruster is composed of an inner coil, four outer coils, inner magnetic shield, outer magnetic shield, inner pole piece and out pole piece etc. The configuration of magnetic circuit was designed for C-type structure. The magnetic material were wound by excitation coils, when the excitation coils were energized, the magnetic field could be formed between the two magnetic poles. The direction of the magnetic field in thruster discharge chamber is mainly radial, the typical distribution of magnetic field is increases and reaches a maximum at the exit. The schematic diagram for magnetic circuit in thruster was shown in figure 1.

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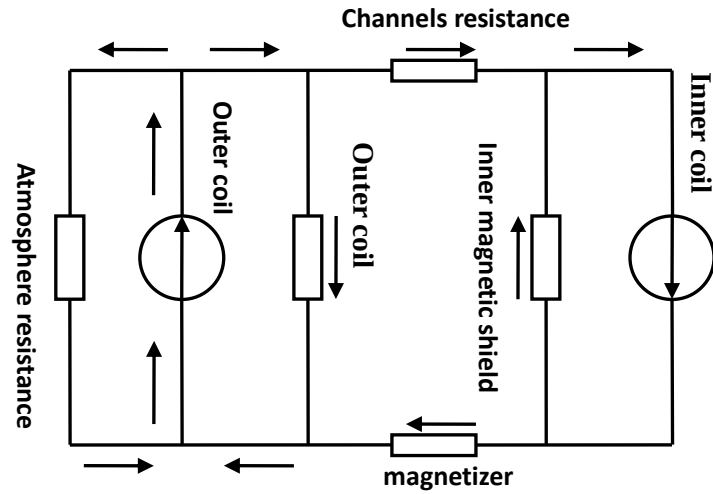


Fig. 1 The schematic of magnetic circuit in LHT100 thruster

The key factors affecting the thruster magnetic circuit mainly include: the ampere-turns of coils, the magnetic pole space and magnetic shield, etc. Based on the magnetic domain, the relationship between the three factors and magnetic field in thruster would be analyzed, and the quantify Interrelation would be calculated by simulation, therefore, the results is as the foundation for magnetic design and performance optimization of thruster.

II. Model of simulation

The magnetic field was simulated by finite element analysis software-Ansoft Maxwell 12 in this paper. The network of thruster was divided before simulated, which divided the network is shown in Figure 2.

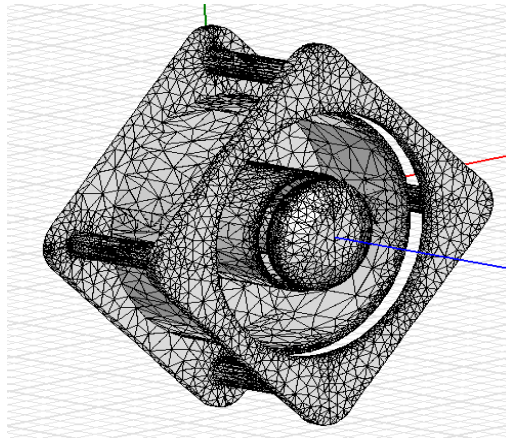


Fig. 2 The network of magnetic circuit in LHT100 thruster

The magnetic material in the magnetic circuit is ferromagnetic material steel-1008, the characteristic curve of magnetic material was showed in Figure 3. The material of excitation coils is the copper.

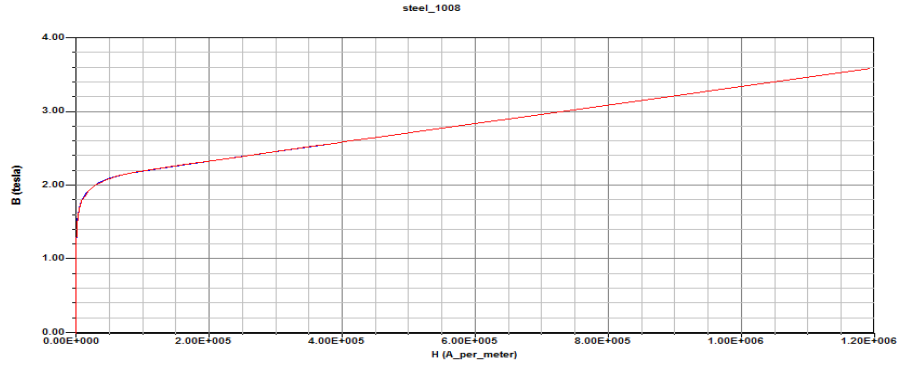


Fig. 3 The characteristic curve of B-H in steel-1008

III. Simulation Result and Discussion

A. Effect of ampere-turn changed in coil

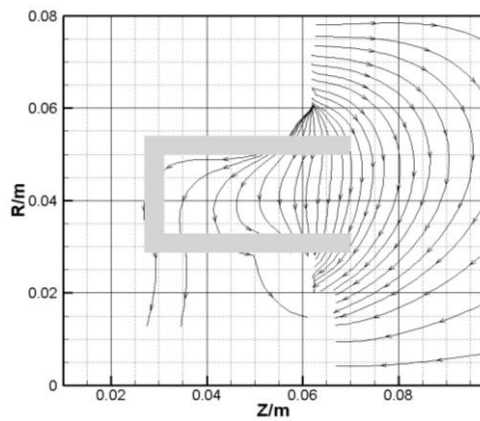
A1 Effect of ampere-turn alone changed in inner coil

In order to study the influence between ampere-turn of inner coil and magnetic field of LHT100 thruster, the ampere-turn of outer coils was assumed in 400A constant. Then four different ampere-turns of inner coil were chosen for parameters to research, they were shown in table 1.

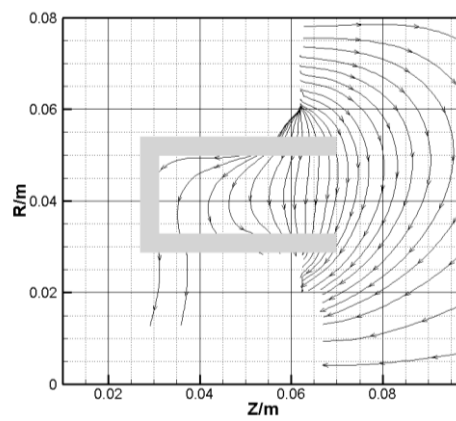
Table 1 Specific parameters were shown (Ampere-turns of inner coils)

Number	1	2	3	4
The ampere-turns of inner coils(A)	600	700	800	900

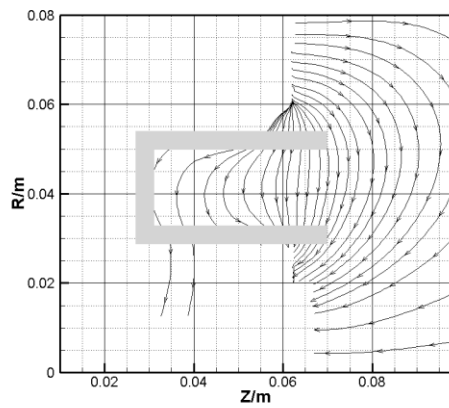
The distribution of magnetic field in thruster was simulated and the magnetic flux density in discharge chamber was calculated under each parameter, the results were respectively showed in Figure 4 and Figure 5.



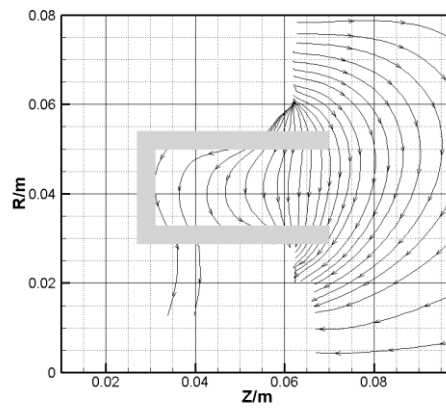
ampere-turns of inner coil: 600A



ampere-turns of inner coil: 700A

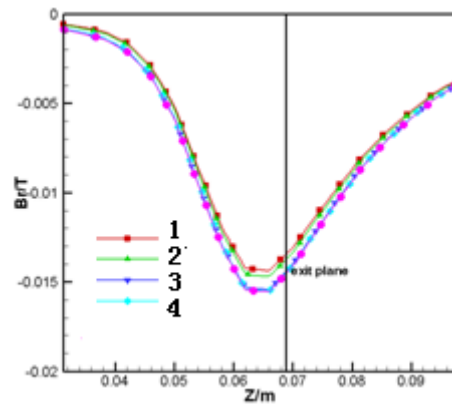


ampere-turns of inner coil: 800A

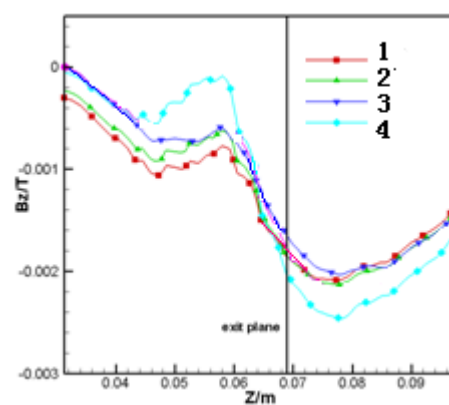


ampere-turns of inner coil: 900A

Fig. 4 The distribution of magnetic field in LHT100 thruster under different ampere-turns of inner coil



magnetic flux density in radial direction(B_r)



magnetic flux density in axes direction(B_z)

Fig. 5 magnetic flux density in center axes of LHT100 thruster under different ampere-turns of inner coil

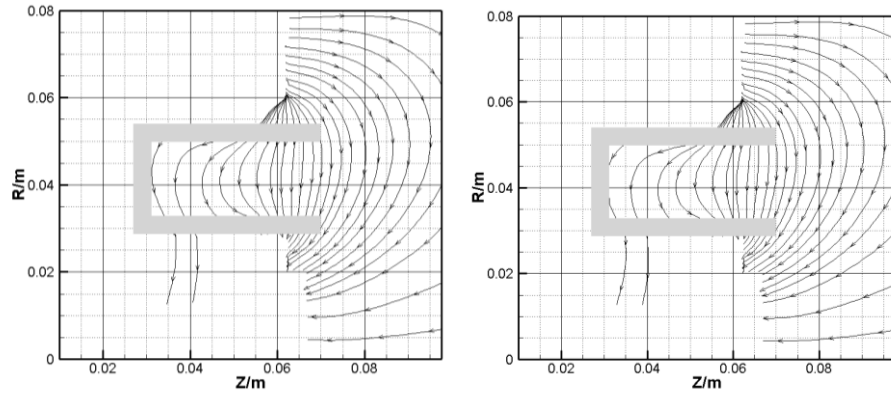
A2 Effect of ampere-turn alone changed in outer coils

In order to study the influence between ampere-turns of outer coils and magnetic field of LHT100 thruster, the ampere-turns of inner coil was assumed in 800A constant. Then four different ampere-turns of outer coils were chosen for parameters to research, they were shown in table 2.

Table 2 Specific parameters were shown (Ampere-turns of outer coils)

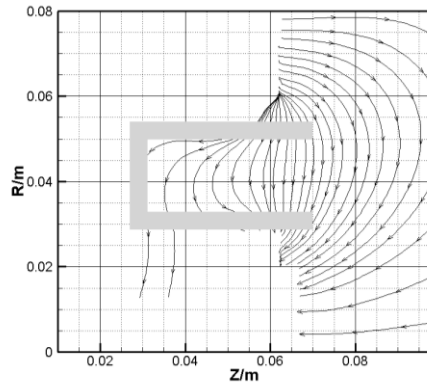
Number	1	2	3	4
The ampere-turns of outer coils(A)	300	350	400	450

The distribution of magnetic field in thruster was simulated and the magnetic flux density in discharge chamber was calculated under each parameter, the results were respectively showed in Figure 6 and Figure 7.

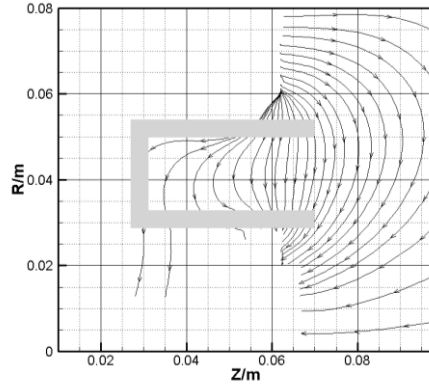


ampere-turns of outer coils:300A

ampere-turns of outer coils:350A

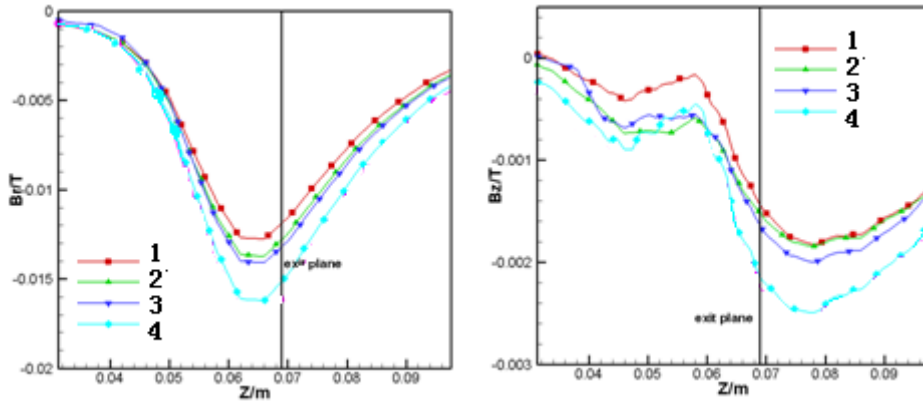


ampere-turns of outer coils:400A



ampere-turns of outer coils:450A

Fig. 6 The distribution of magnetic field in LHT100 thruster under different ampere-turns of outer coils



magnetic flux density in radial direction(B_r)

magnetic flux density in axes direction(B_z)

Fig. 7 magnetic flux density in center axes of LHT100 thruster under different ampere-turns of outer coils

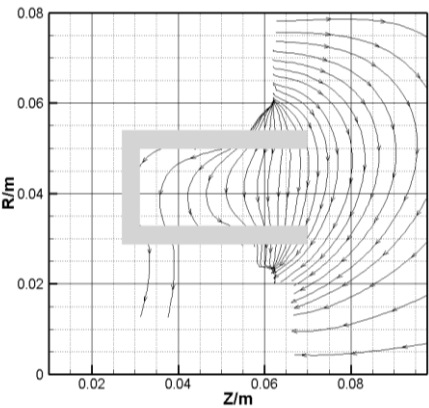
A3 Effect of ampere-turn proportion changed in inner coil and outer coils

The ampere-turns of coil were adjust always at the same time for inner coil and outer coils and it was changed in proportion, in order to study the infection between the ampere-turns of coils and magnetic field in thruster, four different of parameters have been chosen to research, the specific parameters were shown in Table 3.

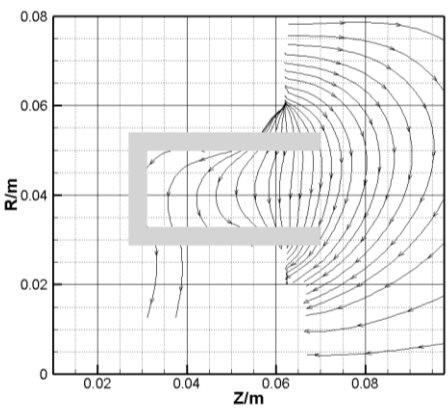
Table 3 Specific parameters were shown (Ampere-turns of inner and outer coils)

Number	Ampere-turns of inner coils	Ampere-turns of outer coils
1	600	300
2	700	350
3	800	400
4	900	450

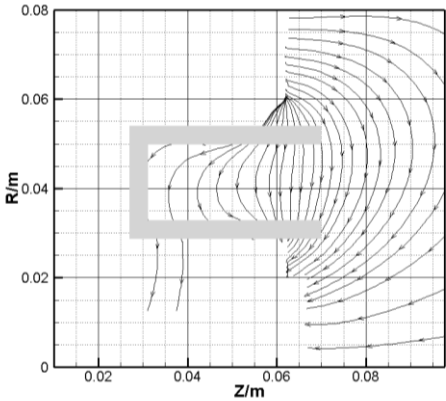
The distribution of magnetic field in thruster was simulated and the magnetic flux density in discharge chamber was calculated under each parameter, the results were respectively showed in Figure 8 and Figure 9.



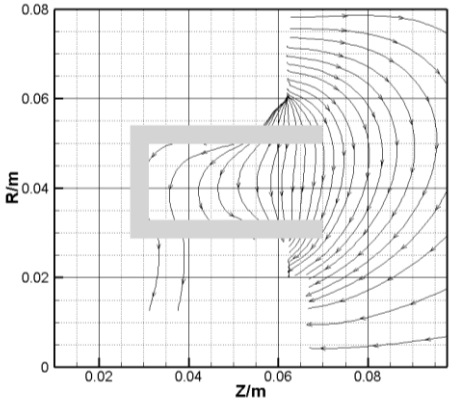
Ampere-turn of inner coil:600A
Ampere-turn of outer coils:300A



Ampere-turn of inner coil:700A
Ampere-turn of outer coils:350A

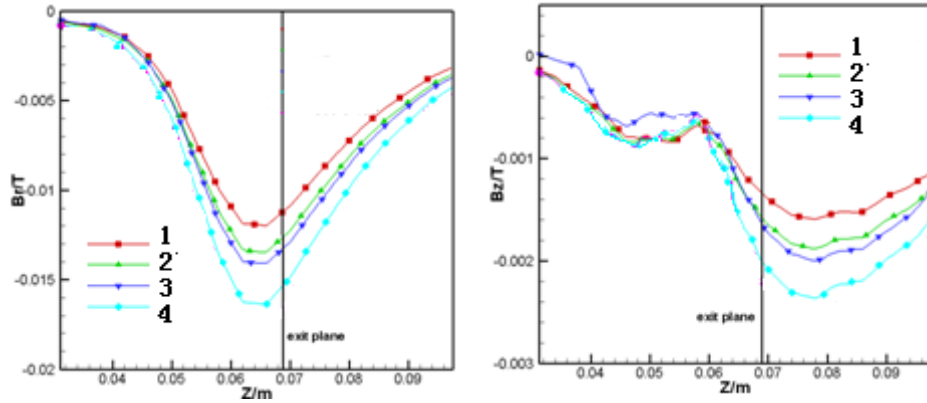


Ampere-turn of inner coil:800A
Ampere-turn of outer coils:400A



Ampere-turn of inner coil:900A
Ampere-turn of outer coils:450A

Fig. 8 The distribution of magnetic field in LHT100 thruster under changed in ampere-turns of inner coil and outer coils



magnetic flux density in radial direction(B_r)

magnetic flux density in axes direction(B_z)

Fig. 9 the magnetic flux density in center axes of LHT100 thruster under different ampere-turns of inner coil and outer coils

The results show that: the magnetic field of LHT100 thruster type into the "magnetic lens" morphology. Maximum magnetic flux density is in the region near the exit and magnetic flux density in the region closer to the anode is almost zero gauss. With the ampere-turns of inner coil increased from 600A to 900A, the maximum magnetic flux density at the exit in the thruster increased from 145 gauss to 155 gauss; when the ampere-turns of outer coils increased from 600A to 900A, the maximum magnetic flux density in the thruster increased from 130 gauss to 175 gauss; while proportionally increasing the coil ampere-turns of inner coil and outer coils, maximum magnetic flux density in the thruster increased from 130 gauss to 180 gauss.

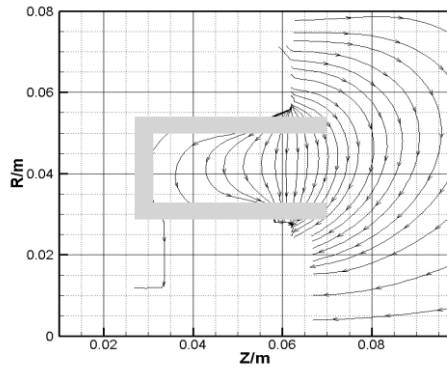
B. Effect of magnetic pole space

In order to study the influence between magnetic pole space and the magnetic field in LHT100 thrusters, the ampere-turns inner coil and outer coils were supposed to constant wherein ampere-turns of the inner coil was 800A and the ampere-turns of outer coils was 400A. four different of parameters have been chosen to research, the specific parameters were shown in Table 4.

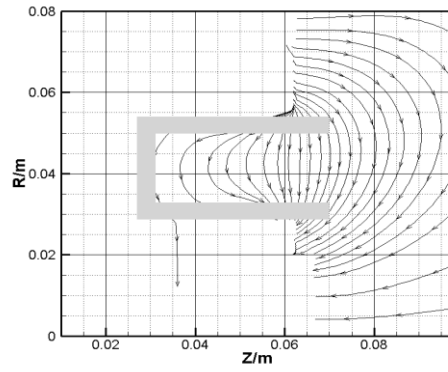
Table 4 Specific parameters were shown (The magnetic pole space)

Number	1	2	3	4
The magnetic pole space(mm)	20	25	30	35

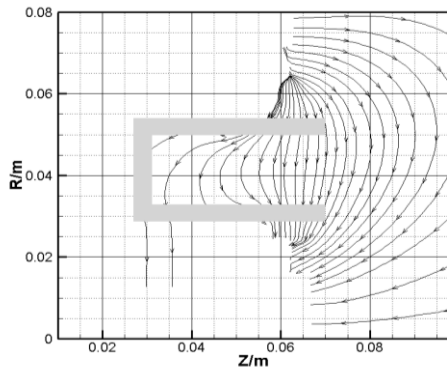
The distribution of magnetic field in thruster was simulated and the magnetic flux density in discharge chamber was calculated under each parameter, the results were respectively showed in Figure 10 and Figure 11.



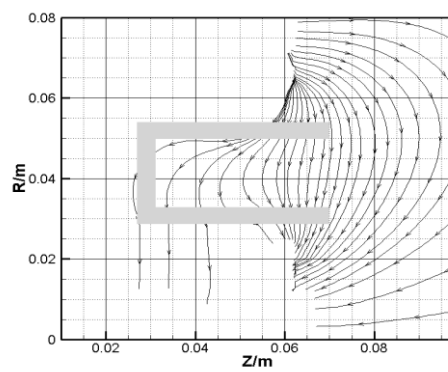
magnetic pole space:20mm



magnetic pole space: 25mm

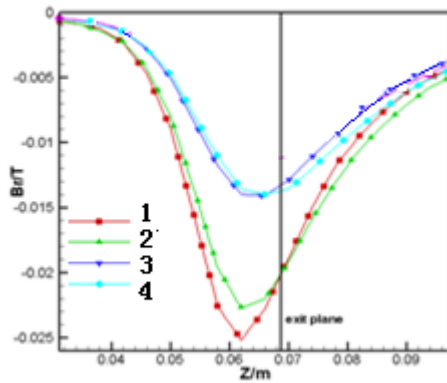


magnetic pole space: 30mm

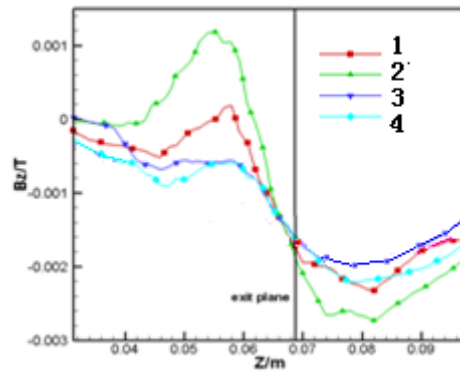


magnetic pole space: 35mm

Fig. 10 The distribution of magnetic field in LHT100 thruster under different magnetic pole space



magnetic flux density in radial direction(B_r)



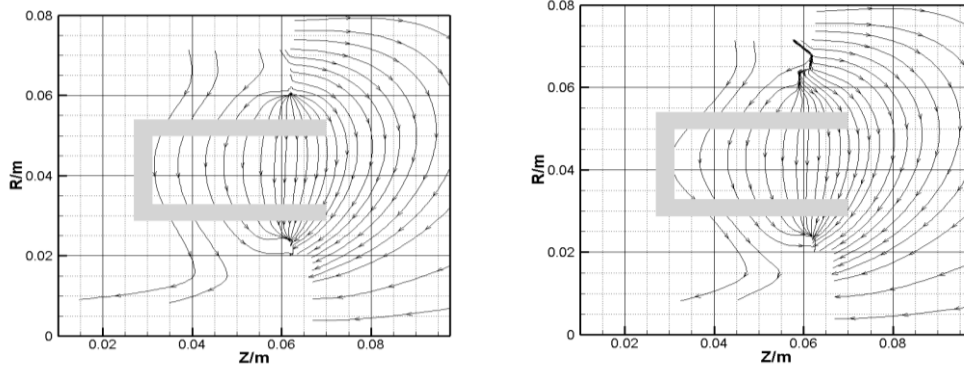
magnetic flux density in axes direction(B_z)

Fig. 11 The magnetic flux density in center axes of LHT100 thruster under different magnetic pole space

The results show that the magnetic field in the chamber exit perpendicular to the axis of thruster when the magnetic poles space was 25mm, and the corresponding magnetic field type is the most ideal for thruster design. With the magnetic poles space reduced from 35mm to 20mm, the maximum magnetic flux density in the thruster increased from 115 gauss to 250 gauss. Based on magnetic theory, the magnetic flux density become smaller with the magnetic resistance becoming the greater, when the magnetic conductance and section were constant, the magnetic resistance is proportional to the magnetic poles space.

C. Effect of magnetic shield

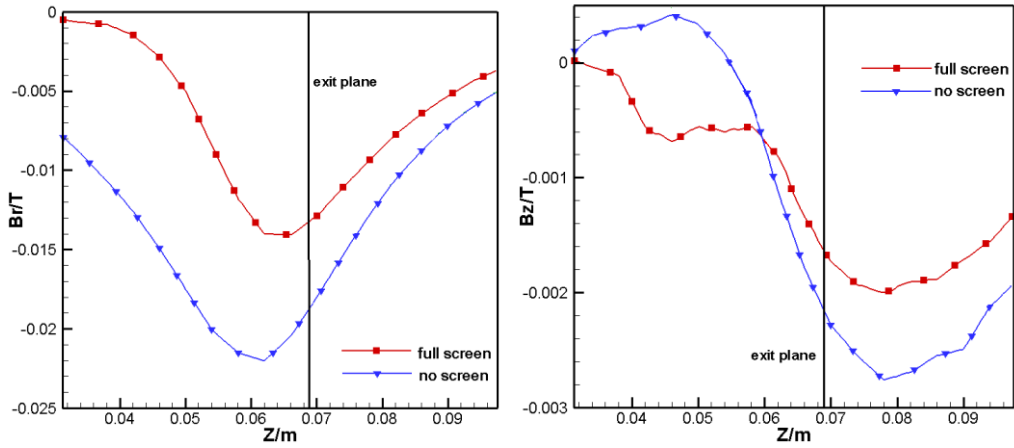
In order to study the influence between magnetic shield and the magnetic field in LHT100 thrusters, the ampere-turns inner coil and outer coils were assumed to constant wherein ampere-turns of the inner coil was 800A and the ampere-turns of outer coils were 400A. Under with or without magnetic shield conditions, the magnetic field of thruster have been researched, the result were shown in Figure 12 and figure 13.



Without magnetic shield

With magnetic shield

Fig. 12 The distribution of magnetic field in LHT100 thruster under different magnetic shield



magnetic flux density in radial direction(B_r)

magnetic flux density in axes direction(B_z)

Fig. 13 the magnetic flux density in center axes of LHT100 thruster under different magnetic shield

The results show that: 1)The distributions of magnetic field were similarity under the conditions with or without magnetic shield.2)under the condition of with magnetic shield, the maximum of magnetic flux density at the exit in the thruster was about 140 Gauss and the magnetic flux density near the anode was almost zero gauss. While without magnetic shield, the maximum of magnetic flux density at the exit in the thruster was 122 Gauss and the magnetic flux density near the anode was about 80 gauss.

IV. Conclusion

The magnetic field of LHT100 thruster was studied under the different conditions by the finite element method, including that the distribution of magnetic field was simulation and the magnetic flux density was calculated. According to the results, the ampere-turns of the coils, the

magnetic pole space and with or without magnetic shield were discussed as the key factors of LHT100 thruster magnetic circuit. Some conclusions were gained as following:

1) The distributions of magnetic field is irrelevance with ampere-turns of coils. The magnetic flux density is sensitivity with ampere-turns of outer coils alone changed and the ampere-turns of inner coil and outer coils proportion changed at the same time.

2) The distributions of magnetic field was relevance with magnetic pole space, the ideal distribution of magnetic field was corresponding to the right magnetic pole space; With the magnetic pole space reducing, the magnetic flux density was increased. It is a monotonically increasing trend.

3) The effect of magnetic shield is limited for the distribution of magnetic field but it is great for the magnetic flux density. The ideal distribution of magnetic field in LHT100 thruster is that the magnetic flux density near anode was almost zero gauss and it was “positive gradient” along the axial direction in the chamber. The configuration of magnetic field in thruster is just to achieved by increasing the magnetic shield structure.

Acknowledgments

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References

- [1]Bassner H., Killinger R., Leiter H., et al. Development Steps of the RF-Ion Thrusters RIT[R]. IEPC01-105
- [2]Goebel D M, Katz I, Fundamentals of electric propulsion: Ion and Hall thrusters[M], 2008