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Static Characteristics of Micro disc Magneto Electric Generator--Simulation and Experiment

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Abstract

Maxwell 3D software of finite-element analysis in electromagnetic fields is used to model and simulate the micro disc magneto electric generator. Distribution characteristics of magnetic induction are required and theoretical analysis and calculation is presented. Error between the simulation result and experimental result is about 6% which verify the rationality and accuracy of finite-element simulation. It can be used to guide the structural design and optimization of this type of generator.

Introduction

Compared with traditional electrical excitation generator，permanent magnet generator，especially rare-earth permanent magnet generator has significant advantages such as simple structure, reliable performance, small size, light weight, low loss, high efficiency and flexible and varied in shape and size of generator, etc. It's widely used in various fields as aerospace, defense, industrial and agricultural production and daily life [1]. So to study the performance of the magneto electric generator becomes increasingly important and static performance of magneto electric generator is one of the significant properties. Since magnetic circuit of the magneto electric generator is highly nonlinear, adopting traditional magnetic circuit method, the results are difficult to meet the accuracy requirement. Therefore, it is necessary to use finite element method with higher calculation accuracy to calculate and analyze the static performance of magneto electric generator [2]. What's more, simulation can overcome the shortcomings as expensive tests equipment and long experimental cycle required by experiments. These make computer simulation noticeably significant for product design.

Modeling and simulation

I objectives and contents of simulation

This article adopts model of a six-pole magneto electric generator with diameter of 12mm and height of 8mm. Coil (8 layers) of the generator is the stator and magnet and magnetic yoke are rotor. Stator and rotor are all ring flake. Two magnetic yoke are placed oppositely with a certain interval and stator coil is located in between the two magnetic yoke, shown in Fig. 1. Magnet with opposite direction is positioned adjacent in magnetic yoke to form a static magnetic field. When the rotor magnet rotates, rotating magnetic field cuts the stator coil and alternating voltage is induced. Model of this disc magneto electric generator is built by simulation and the study of its static characteristics is completed. According to the simulation results, its consistency with the experimental results is verified.

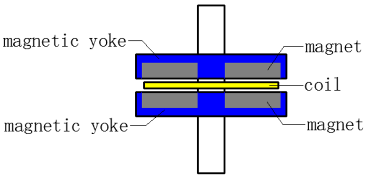

Fig.1 Basic structure of magnet

II simulation method

By Ansoft Maxwell3D, simulation model of disc magneto electric generator is built and magnet and magnetic yoke of the six-pole magneto electric generator are created, shown in Fig. 2.

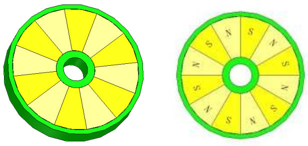

Fig.2 Modeling of six-pole magnet and magnetic yoke

Place the two magnets oppositely, unfold the circumference of circle from side direction, magnets are arranged, shown in Fig. 3.

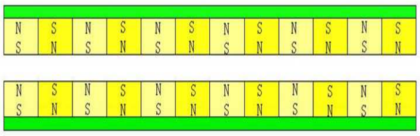

Fig. 3 Side view of unfolded circumference

III simulation results

Simulation is conducted after model built with Ansoft Maxwell. First, Allocate material of each module, define boundaries and operate mesh, shown in Fig. 4.Then, Set solving solution and corresponding post-processing operation. On the basis of simulation results, plot the distribution characteristics of magnetic induction within the 3D model, shown in Fig. 5.

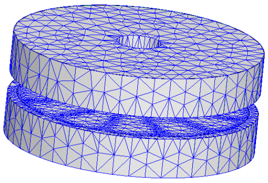

Fig. 4 Mesh operation of model

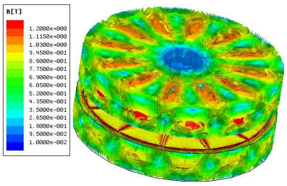

Fig. 5 Distribution characteristics of magnetic induction

Draw a reference plane in the middle of the two opposite magnets and observe its magnetic induction distribution. It's shown that magnetic induction is maximum at the center of the magnet of each pole and smaller at periphery. Here, we use magnetic induction of the center of outer and inner diameter of the magnet to simplify calculation, as shown in the ring of Fig. 6.

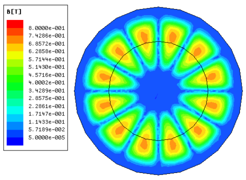

Fig. 6 Distribution characteristics of magnetic induction of reference plane

Draw magnetic induction distribution of the cylindrical surface, shown in Fig. 7, where the ring shown in Fig. 6 locates. Then export the magnetic induction of each point of the cylindrical surface and analyze these data. Though the structure of X axis, Y axis symmetric completely, distribution characteristics of magnetic induction is not strictly symmetrical since there is error existed in iteration of finite element simulation. As what is shown in the magnetic induction exported from the 12 centerline of the cylindrical surface, curve of magnetic induction is roughly the same, but neither of magnetic induction distribution is exactly the same, shown in Fig. 8.

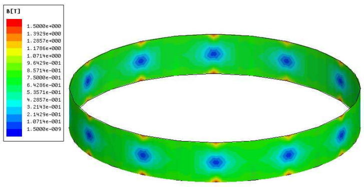

Fig. 7 Distribution characteristics of magnetic induction of the cylindrical surface

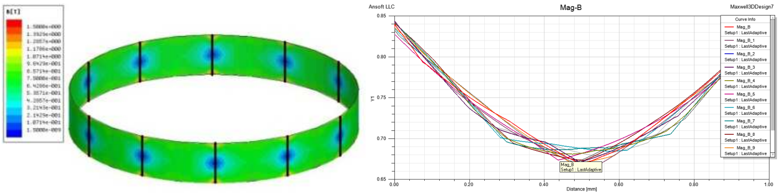

Fig. 8 Magnetic induction of each centerline

IV analysis of simulation results

1 Magnetic induction and voltage amplitude

When rotor magnet rotates at angular velocity Ω, magnetic induction below rotor changes approximately to sine law [3]. Changes of magnetic induction $B_\delta(t)$ at the coin can be expressed as,

$$B_\delta(t) = B_\delta \sin(p\Omega t) \tag{1}$$

In Eq. 1, Ω represents angular velocity of rotor magnet, p represents number of pole pairs, B_δ represents magnetic induction at the interval (coil) in static magnetic field, it also means the maximum magnetic induction at the interval (coil) when the rotor rotates.

surrounding area of a single layer of coil is known is S_Z, changes of magnetic flux within a single layer can be expressed as,

$$\Phi_c\,(t) = Sz \bullet B_\delta(t) = S_Z \bullet B_\delta \sin(p\Omega t) \tag{2}$$

According to Faraday's law of electromagnetic induction, output voltage U'(t) of single layer can be expressed as,

$$U'(t) = -\frac{d\Phi_c\,(t)}{dt} = -S_Z\frac{dB_\delta(t)}{dt} = -p\Omega S_Z B_\delta \cos(p\Omega t) \tag{3}$$

Total output voltage Us of 8 layers can be expressed as,

$$U_S(t) = 8p \times U'(t) = -8p\Omega S_Z B_\delta \cos(p\Omega t) \tag{4}$$

and $S_Z = 184.6272\text{mm}^2$

When generator speed v=29.79kr/min, angular velocity $\Omega = 993\pi\text{rad/s}$

2 Magnetic induction B_δ

Magnetic induction of each point of magnetic field is obtained from above. Though the structure of X axis, Y axis symmetric completely, distribution characteristics of magnetic induction is not strictly symmetrical since there is error existed in iteration of finite element simulation. So we get magnetic induction of sampling points from 12 columns of the cylindrical surface and add up magnetic induction of each layer of coil then take average. Calculation result is shown in Table 1.

Table 1 Calculation result of magnetic induction

Sampling No.	1	2	3	4	5	6	7	8
Sampling position	0.281	0.344	0.406	0.469	0.531	0.594	0.656	0.719
Average magnetic induction of sampling points	0.7153	0.6999	0.6886	0.6788	0.6782	0.6875	0.7013	0.7184

Average magnetic induction of 8 layer coin

$$\begin{aligned} B_\delta &= (B_1+B_2+B_3+B_4+B_5+B_6+B_7+B_8)/8 \\ &= (0.7153+0.6999+0.6886+0.6788+0.6782+0.6875+0.7013+0.7184)/8 \\ &= 0.696\mathrm{T} \end{aligned}$$

3 Voltage amplitude of simulation

Substitute S_Z and B_δ to Eq. 4 and get the voltage amplitude of simulation

Experimental verification

Output characteristic of generator structure described above is tested. Output voltage of generator under different speed is compared to calculation results of simulation. Table 2 shows the result of experiment and comparison with simulation.

Table 2 Output voltage of generator and comparison with simulation results

Experiment No.	generator speed [kr/min]	Output voltage amplitude[V]	Calculation voltage amplitude of simulation[V]	Error[%]
1	29.79	18.75	19.24	2.6
2	27.76	16.9	17.93	6.1
3	26.04	16.1	16.82	4.4
4	22.63	14.55	14.62	0.5

From the experimental results, error between the simulation result and experimental result is about 6% which verify the rationality and accuracy of finite-element simulation.

Conclusion

Existed references of simulation are most related to excitation generator, few of disc magneto electric generators can be for reference. This article verifies the feasibility and effectiveness of finite element simulation through the theoretical analysis and experimental verification of magnetic induction distribution characteristics. It can be used to guide structural design and integrative optimization of this type of generator and has significant practical value for further application in engineering practice and teaching research.

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