A Design of Disk Permanent Magnet Brushless DC Motor

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Abstract

The two-dimensional finite element method was used for analysis of magnetic field inside the motor of disc permanent magnet brushless dc motor (DPMBLDC), the impact of the motor parameter change on the magnetic flux leakage, power, efficiency, and torque of motor has been analysed , a kind of light weight, low noise, small moment of inertia disc motor is designed on the basis of test results.

Keywords

Disk brushless dc motor,the finite element analysis, the test of motor.

1. Introduction

Compared with other types of motor with the same power, brushless DC motor has the advantages of small volume, light weight, low price, high efficiency, without brush and slip ring parts, simple structure, reliable performance and better environmental adaptability. At the same peak voltage and peak current, the torque produced by the interaction of square wave current and square wave magnetic field is larger, so the permanent magnet brushless motor can output larger electromagnetic torque, so it is applied widely. A new kind of disk brushless DC motor is designed in this paper.

2. Distribution of Magnetic Density in the Air Gap of a Disk Brushless DC Motor

The electromagnetic field in the motor can be calculated in two dimensional finite element method. Combined with the boundary conditions, the distribution of magnetic flux density at each point of the air gap and stator windings can be calculated by computer program.

The following conclusions can be obtained by the results of the calculation.

(1) The power per unit volume of a disk permanent magnet brushless DC motor is proportional to the average diameter of the armature, and inversely proportional to the total axial length.

(2) If the outer diameter and the maximum electric load are certain, the maximum output power of the armature diameter of the disk permanent magnet brushless DC motor can be obtained when the armature length is $\sqrt{3}$ times diameter of the motor.

(3) Disk permanent magnet motor, although magnetic flux leakage is very large, but in order to have higher efficiency, it still uses more poles. From the point of view of optimal design, the optimal arc coefficient is about 0.8.

3. Design Scheme of Disk Brushless DC Motor

3.1 Requirements of Motor Design

The design requirements of the disk brushless DC motor are shown in Table 1.

Tab.1 Design requirement of DPMBLDC

parameter	parameter values
Rated voltage (V)	48
Rated power (kW)	2.0
Rated speed (r/min)	3500
Rated efficiency (%)	76

3.2 Design Parameters of Disk Brushless DC Motor

The design parameters of the disk brushless DC motor are shown in Table 2. The stator size is shown in Figure 1. The stator slot is shown in Figure 2, and figure 3 is the structure and size of the permanent magnet.

Tab.2 Design parameters of DPMBLDC

parameter	numerical value	parameter	numerical value
Stator Lam Dia(mm)	147	Rotor diameter(mm)	129
Stator inner diameter (mm)	83	Inner diameter of the rotor (mm)	30
Axial length of stator (mm)	50	Rotor thickness (mm)	8.3
Number of stator slots	24	Number of permanent magnets	8
Air gap length (mm)	3	Permanent magnet thickness (mm)	4.3
Permanent magnet Br (T)	1.29	Permanent magnet Hc (kA/m)	-978
Winding line diameter (mm)	1.5	And around the number of roots	4
Number of parallel branches	2	Number of conductors per slot	10
Number of turns per phase		Per phase measurement resistance (omega)	0.01

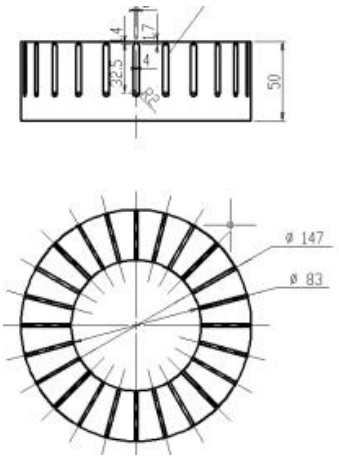

Fig.1 Structure diagram of the DPMBLDC

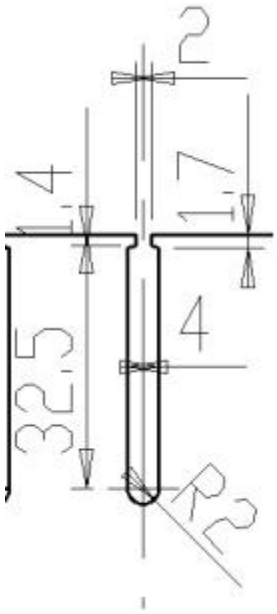

Fig.2 Structure diagram of stator slot

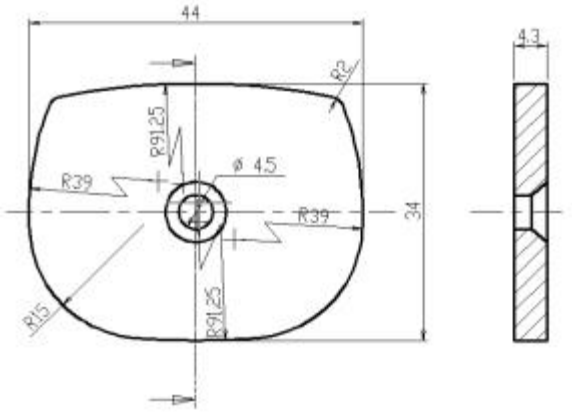

Fig.3 Structure diagram of permanent magnet

3.3 Prototype Development

According to the design requirements and parameters, a prototype of a disk brushless DC motor is developed in this paper. The stator and the rotor are shown in Figure 4 and figure 5, respectively.

Fig.4 Stator of DPMBLDC

Fig.5 Rotor of DPMBLDC

4. Test Method and Test Result of Disk Brushless DC Motor

4.1 Test Method

The motor is placed on a 4kW hysteresis dynamometer, powered by a 100v/100A DC power supply, and a brushless DC motor controller with throttle control is used to control the motor rotation. The torque, speed, current, power, efficiency and other data of the motor are measured by a dynamometer. The specific test steps are as follows:

(1) The DC power supply voltage is adjusted to 48V, and the current knob is placed to the maximum.

(2) Open the power supply, the throttle, the speed to close to 4000rpm (Due to the speed limit of the dynamometer, the throttle can not be completely released. That is to say, the maximum no-load speed of the motor is higher than 4000rpm).

(3) The automatic loading of the dynamometer is controlled and the data is automatically collected until the upper limit of the current of the controller.

(4) Restart the motor and control the dynamometer to add a little load to the motor, so that the speed of the motor is still below 4000rpm when the throttle is rotated to the maximum, which is about 3900rpm.

(5) The automatic loading of the dynamometer is controlled and the data is automatically collected until the upper limit of the current of the controller.

4.2 Test Result

4.2.1 No-load Test

The no-load test data of the prototype is shown in Table 3, the variety of voltage, current, torque, speed, output power and efficiency with time is shown in Figure 6. As can be seen from Figure 6, the efficiency of the motor is more than 76% in conformity with the design requirements. The rated voltage, Un=48V, rated speed n=3500r/min, rated power Pn=2.0Kw, meet the design requirements.

4.2.2 Load Test

The load test data of the prototype is shown in Table 6.Figure 7 is the load test voltage, current, torque, speed, output power, efficiency with time - varying curve. From Figure 7, when the motor is loaded, the motor efficiency is 78.6%, more than 76%.This is in line with the design requirements. Rated Speed n=3500r/min, rated power Pn=2.5kW, more than 2.0kW, it is in line with the design requirements.

Tab.3 No load test data of DPMBLDC

	Voltage	current	Input power	torque	speed	output power	efficiency	time
Serial number	V	A	W	N.m	rpm	W	%	S
1	46.63	43.40	2024	3.60	3900	1468	72.5	0.000
2	46.34	52.12	2415	5.74	3868	2326	96.3	2.609
3	46.24	55.35	2559	4.99	3733	1951	76.2	4.219
4	46.18	57.04	2634	5.18	3707	2010	76.3	5.828
5	46.13	58.64	2705	5.48	3663	2101	77.7	7.437
6	46.06	60.80	2800	5.70	3636	2171	77.6	9.047
7	46.00	62.50	2874	5.94	3611	2246	78.1	10.66
8	45.92	64.52	2963	6.24	3588	2345	79.1	12.27
9	45.85	66.75	3061	6.49	3559	2420	79.1	13.88
10	45.77	68.78	3148	6.70	3520	2469	78.4	15.48
11	45.68	71.03	3245	6.96	3490	2542	78.3	17.09
12	45.60	73.31	3343	7.25	3464	2629	78.7	18.70
13	45.50	75.24	3424	7.56	3438	2720	79.4	20.31
14	45.39	77.78	3530	7.84	3407	2796	79.2	21.92
15	45.28	80.11	3627	8.05	3380	2850	78.6	23.53
16	45.27	83.07	3761	8.36	3351	2932	78.0	25.14
17	45.26	85.73	3880	8.54	3325	2973	76.6	26.75
18	45.23	86.06	3893	8.79	3263	3004	77.1	28.36
19	45.24	86.28	3904	8.89	3225	3003	76.9	29.97
20	45.24	85.92	3887	9.03	3194	3018	77.7	31.58

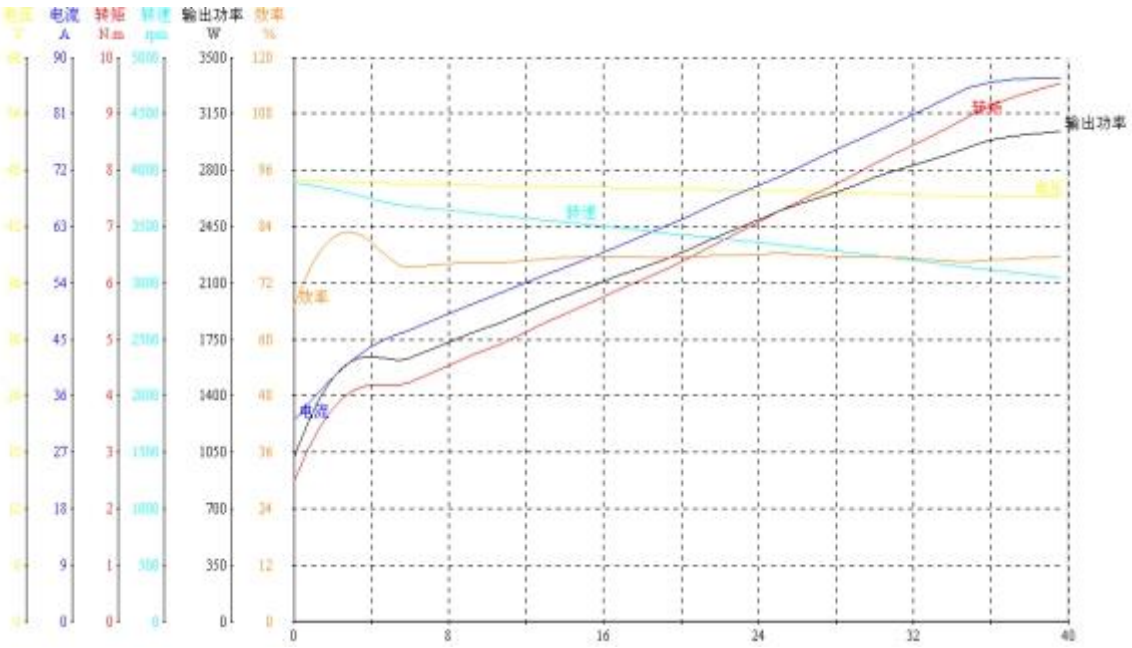

Fig.6 No load curves of voltage, current, torque, speed, power and efficiency

Tab.4 Load test data of DPMBLDC

	Voltage	current	Input power	torque	speed	output power	efficiency	time
Serial number	V	A	W	N.m	rpm	W	%	S
1	46.63	43.40	2024	3.60	3900	1468	72.5	0.000
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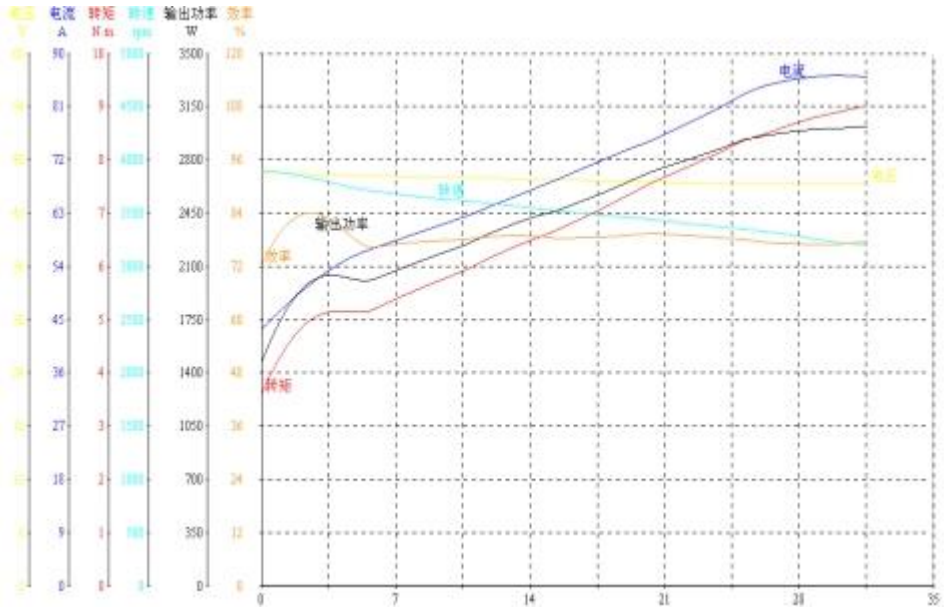

Fig.7 Load curves of voltage, current, torque, speed, power and efficiency

5. Conclusion

The disk brushless DC motor designed by this scheme has the characteristics of high power, high efficiency, large torque and relatively small size, and has a certain popularization value.

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