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COMPARISON ANALYSIS FOR SLOT DESIGN OF BRUSHLESS DC MOTOR

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Abstract: This paper presents a comparison analysis for the design of the slot configuration of permanent magnet brushless dc motor (pmbldc motor) for a kind of electric impact used for loading and unloading. Simulations are carried out using the 2d and 3d modeling for analyzing the effects and performance and the results are discussed and compared for 24 slots 8 poles and 48 slots 16 poles configuration. . The corresponding electrical loading, magnetic circuit details and armature winding patterns for both the integral slot and fractional slot configurations are shown in detail. The slot configuration for the efficiency for these two configurations is also studied.

Keywords:Slot design, bldc, efficiency

I. INTRODUCTION

The bldc motor is widely used in applications including appliances, automotive consumer, automated industrial equipment medical, instrumentation and aerospace. The bldc motor is electrically commutated by power switches instead of brushes. Compared with a brushed dc motor or an induction motor, the bldc motor has many advantages:[1]

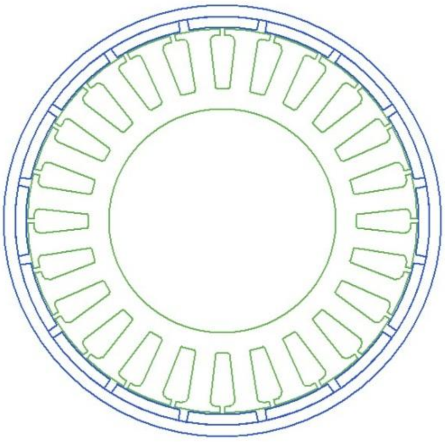


Figure:1 basic 2d model of bldc motor

1.1. Brushed dc motor: a brushed dc motor consists of a commutator and brushes that convert a dc current in an armature coil to an ac current. As current flows through the commutator through the armature windings, the electromagnetic field repels the nearby magnets with the same polarity, and causes the winging to turn to the attracting magnets of opposite polarity. As the armature turns, the commutator reverses the current in the armature coil to repel the nearby magnets, thus causing the motor to continuously turn. The fact that this motor can be driven by dc voltages and currents makes it very attractive for low cost applications. However, the arcing produced by the armature coils on the brush-commutator surface generates heat, wear, and EMI, and is a major drawback.

1.2 Brushless dc (bldc) motor: Abldc motor accomplishes commutation electronically using rotor position feedback to determine when to switch the current. The 2d model is shown in fig 1. The stator windings work in conjunction with permanent magnets on the rotor to generate a nearly uniform flux density in the air gap. This permits the stator coils to be driven by a constant dc voltage which simply switches from one stator coil to the next to generate an ac voltage waveform with a trapezoidal shape.

Slot configuration: the basic slot configuration of brushless dc motor is shown in the fig: 2 shown below. This design gives the slot sizing of a single slot showing the height and the width.

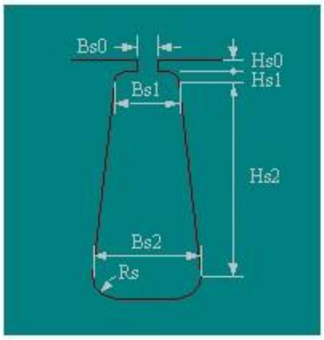


Figure.2 slot sizing

II. THE 24 SLOTS 8 POLES CONFIGURATION

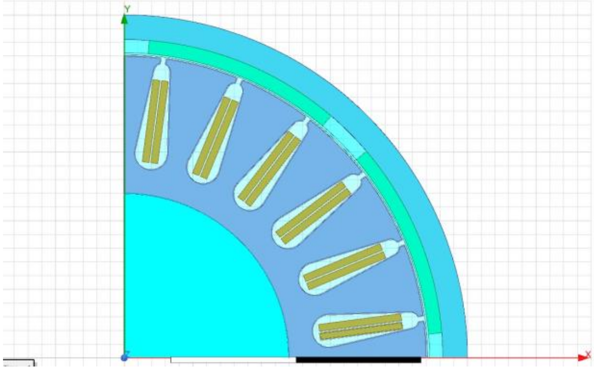
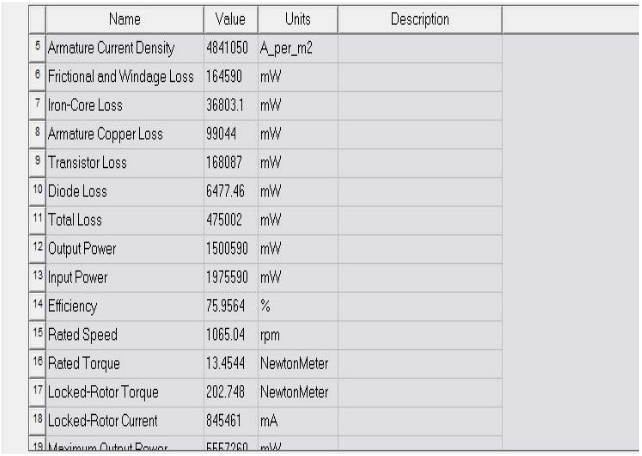


Figure 3: 24 slots 8 poles configuration 2d model

Figure 3 shows the 24 slots 8 poles configuration for the stator core lamination and magnet rotor assembly. The permanent magnet brushless dc motor has three phase star connected winding. The quadruplex winding redundancy requires four three phase windings in four quadrants of the motor. The rotor assembly should have minimum of two poles per quadrant and hence 8 poles and 16 poles are the possible options for the proposed motor. 12 poles rotor configuration is not suitable for this requirement and hence 8 poles configuration is selected initially for the preliminary design. From the volume apportionment of stator 48 assembly and rotor assembly the integral slot configuration of six slots per quadrant, total of 24 slots for four quadrants is selected such that slots per pole per phase is one.

2.1 Solution data:

The important output parameters and plots are described below.



	Name	Value	Units	Description
5	Armature Current Density	4841050	A_per_m2	
6	Frictional and Windage Loss	164590	mW	
7	Iron-Core Loss	36803.1	mW	
8	Armature Copper Loss	99044	mW	
9	Transistor Loss	168087	mW	
10	Diode Loss	6477.46	mW	
11	Total Loss	475002	mW	
12	Output Power	1500590	mW	
13	Input Power	1975590	mW	
14	Efficiency	75.9564	%	
15	Rated Speed	1065.04	rpm	
16	Rated Torque	13.4544	NewtonMeter	
17	Locked-Rotor Torque	202.748	NewtonMeter	
18	Locked-Rotor Current	845461	mA	
19	Maximum Output Power	5557260	mW	

Table 1: solution data of full load 24 slots 8 poles

2.2 Speed vs efficiency

The magnetic circuit calculations are worked out for preliminary design configuration. The tooth width, back iron thickness and slot opening are calculated based on the magnetic flux density value and validated with the finite element analysis.

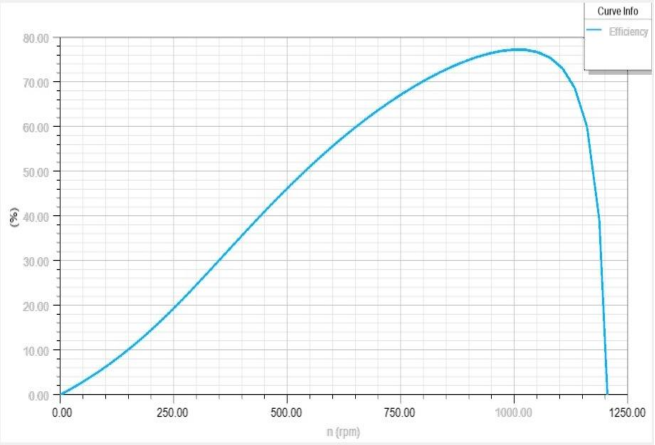


Figure 4: efficiency vs speed curve for 24 slots 8 poles configuration 2d model

III. THE 48 SLOTS 16 POLES CONFIGURATION

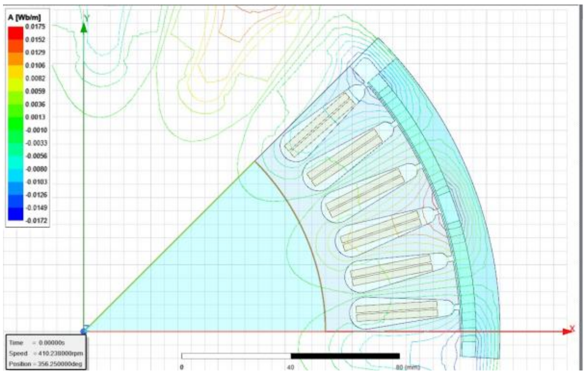
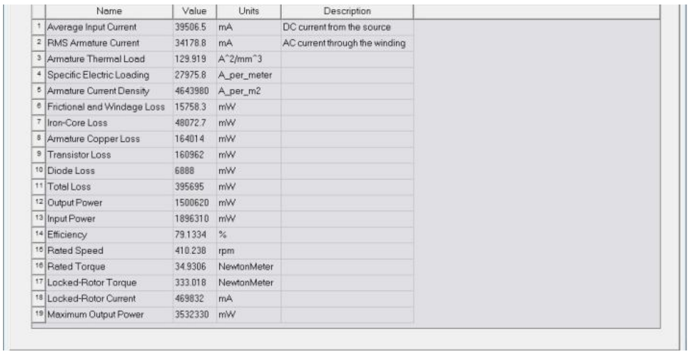


Figure 5: 48 slots 16 poles configuration 2d model

In order to limit the overhang thickness with in the required dimension the number of conductors per slot should be reduced. This is achieved by distributing the conductors in the armature by increasing the number of poles to 16 and number of slots to 48. To reduce the line to line resistance value the total number of turns per phase is reduced. To get the required torque with the reduced turns the magnetic loading is increased. The distribution of the armature conductors is also studied for the 60 slots 16 poles motor (fractional slot) configuration possible for this quadruplex redundancy magnetic circuit.

3.1 Solution data:

The important output parameters and plots are described below.



	Name	Value	Units	Description
1	Average Input Current	39506.5	mA	DC current from the source
2	RMS Armature Current	34178.8	mA	AC current through the winding
3	Armature Thermal Load	129.919	A^2/mm^3	
4	Specific Electric Loading	27975.8	A_per_meter	
5	Armature Current Density	4643980	A_per_m2	
6	Frictional and Windage Loss	15758.3	mW	
7	Iron-Core Loss	48072.7	mW	
8	Armature Copper Loss	164014	mW	
9	Transistor Loss	160962	mW	
10	Diode Loss	6888	mW	
11	Total Loss	395695	mW	
12	Output Power	1500620	mW	
13	Input Power	1896310	mW	
14	Efficiency	79.1334	%	
15	Rated Speed	410.238	rpm	
16	Rated Torque	34.9306	NewtonMeter	
17	Locked-Rotor Torque	333.018	NewtonMeter	
18	Locked-Rotor Current	469832	mA	
19	Maximum Output Power	3532330	mW	

Table 2: solution data of full load 48 slots 16 poles

The permanent magnet rotor assembly is kept common for both the motors. In order to reduce the cogging torque, the proposed skew for 48 slots stator is one slot pitch since it is an integral slot configuration and half slot pitch skew for 60 slots configuration.

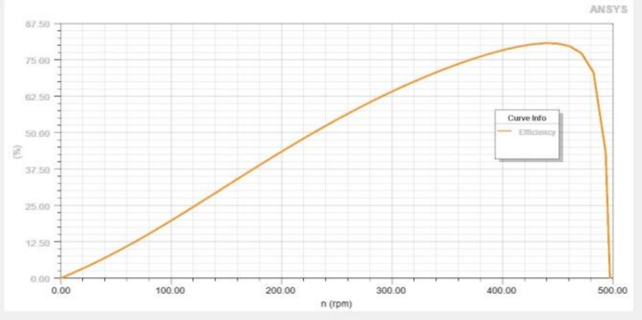


Figure 6: efficiency vs speed curve for 48 slots 16 poles configuration

IV. DISCUSSION AND COMPARISON

Between slots configuration: rom the above two configuration it has been clear from the efficiency vs speed curve from the full load data that for an input power of 1896310 mw the efficiency is 79.1334 % for 16 pole 48 slots giving an output power of 1500620 mw having a rated speed of 410.238 rpm whereas in case of 24 slots 8 pole efficiency is 75.9564% giving an output power 1500590 mw for an input of 1975590 mw having a rated speed of 1065.04 rpm. Thus it can be concluded that 48 slots 16 pole configuration is better as compared to 24 slot 8 pole.

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