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Original Research Article

COMPARISON ANALYSIS OF SLOT DESIGN OF BRUSHLESS DC MOTOR

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Abstract*:* Analysis of efficient slot configuration of permanent magnet brushless DC motor for a kind of electric impact used for loading and unloading is an important feature in electrical machine design. The 2D Simulations has been carried for analyzing the effects and performance and the results are discussed and compared with two different slot configuration for same type of input. The corresponding electrical loading, magnetic circuit details and armature winding patterns for both the integral slot and fractional slot configurations are shown in detail.

Keywords- Slot design, poles, efficiency, BLDC motor.

Introduction: Brushless DC (BLDC) motor deliver high efficiency, torque and speed, and are available in dimensions to suit a wide variety of applications..Conventional DC motors use a stationary magnet with a rotating armature combining the commutation segments and brushes to provide automatic commutation. In comparison, the brushless DC motor is a reversed design: the permanent magnet is rotating where as the windings are part of the stator and can be energized without requiring a commutator-and-brush system. Motor torque is the amount of rotational force that a motor generates during operation. The key components involved in producing torque are the magnet, the winding and the flux path. The higher the number of pole pairs in the magnet, the higher the amount of brushless motor torque for the same dissipated power. They have mainly linear motor characteristics, with excellent speed and position control. The number of phases, the number of rotor poles, and the choice of slots configurations depending on them also have great importance when the design process of the brushless motor is examined. The BLDCs have a higher torque density than an asynchronous motor or brush motor for the same size [1].

Power Equation: The power equation for BLDC motor is given by

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$$P_a = i_a e_a + i_b e_b + i_c e_c \quad eq\ (1)$$

The electromagnetic torque produced by a brushless DC motor can be expressed as

$$T_e = \frac{e_a i_a + e_b i_b + e_c i_c}{w_m} \quad eq\ (2)$$

Brushless DC motors (BLDC) have the moment-speed characteristic of brushed DC motors and eliminates the disadvantage of brush and collector mechanism by using electronic commutation [2-3].

Comparison Analysis between 36/24 Slots and 18/16 Poles Configuration: Let us examine the two different slot configuration and the output characteristics for torque and speed and correlate the efficiency for the same.Figure 1 shows the 36 Slots 18 Poles 2d Motor design.

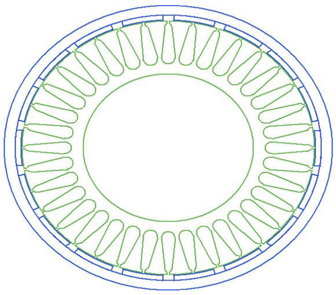

Fig.1: 36 Slots 18 Poles 2d Motor

Below is shown the full load data for 36 Slots 18 Poles

Table 1 : Full load data 36 slots 18 poles

	Name	Value	Units	Description
1	Average Input Current	39331.5	mA	DC current from the source
2	RMS Armature Current	40430.9	mA	AC current through the winding
3	Armature Thermal Load	141.397	A^2/mm^3	
4	Specific Electric Loading	30887	A_per_meter	
5	Armature Current Density	4577890	A_per_m2	
6	Frictional and Windage Loss	10766.3	mW	
7	Iron-Core Loss	41141.1	mW	
8	Armature Copper Loss	130835	mW	
9	Transistor Loss	179449	mW	
10	Diode Loss	25640.6	mW	
11	Total Loss	387832	mW	
12	Output Power	1500080	mW	
13	Input Power	1887910	mW	
14	Efficiency	79.4571	%	
15	Rated Speed	306.951	rpm	
16	Rated Torque	46.6677	NewtonMeter	
17	Locked-Rotor Torque	527.786	NewtonMeter	
18	Locked-Rotor Current	824161	mA	
19	Maximum Output Power	2933410	mW	

Delta connection is not recommended in a brushless PM machine. If there is any third time harmonic in the phase back EMF, then this will induce a circulating zero- order current. This will cause excessive current and copper losses and potential burnout of the winding [4]

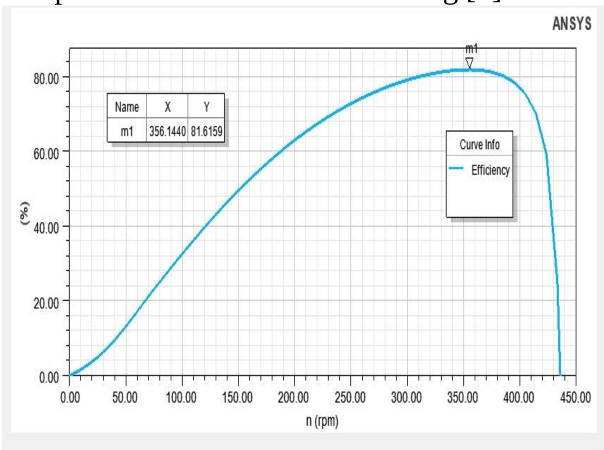

Fig 2: Efficiency vs speed

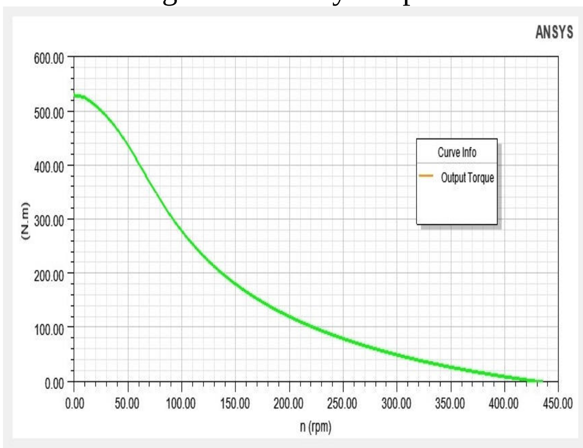

Fig 3: Output Torque vs speed

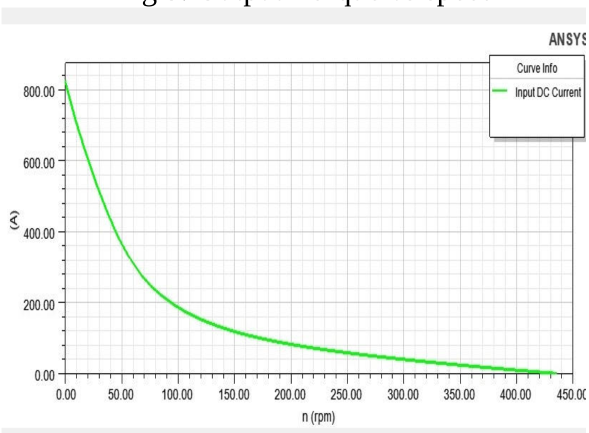

Fig 4 : Input DC current vs speed

The detailed electromagnetic analysis of the selected slot/pole type, i.e. 24/16 is conducted in this phase of study by using Maxwell analysis software. Figure 5 shows the 2 d model of BLDC motor for 24 slots 16 poles and the overall data is given in table no 2.

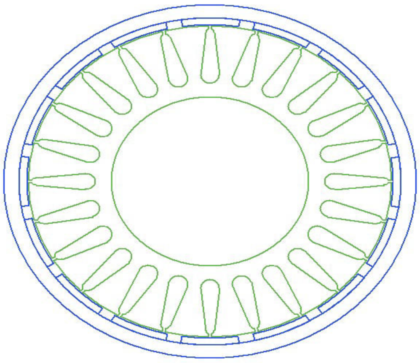

Fig 5 :24 slots 16 poles 2d cross section

The 2d cross sectional view of 24 slots 16 poles bldc motor is shown in figure 5 showing the slot configuration along with poles. The full load data of this configuration is shown in table 2 for an input power of 1810780 mW .the rated speed was found at around 411.287 rpm as shown in fig 7 with an output power of 1500030 m W. The characteristics curve between dc input current with respect speed is also shown in figure 6.

Table 2 : Full load data 24 slots 16 poles

	Name	Value	Units	Description
1	Average Input Current	37724.6	mA	DC current from the source
2	RMS Armature Current	34088.7	mA	AC current through the winding
3	Armature Thermal Load	68.5336	A^2/mm^3	
4	Specific Electric Loading	17755.8	A_per_meter	
5	Armature Current Density	3859780	A_per_m2	
6	Frictional and Windage Loss	19357.3	mW	
7	Iron-Core Loss	57856.9	mW	
8	Armature Copper Loss	64015.2	mW	
9	Transistor Loss	157817	mW	
10	Diode Loss	11704.6	mW	
11	Total Loss	310751	mW	
12	Output Power	1500030	mW	
13	Input Power	1810780	mW	
14	Efficiency	82.8388	%	
15	Rated Speed	411.287	rpm	
16	Rated Torque	34.8278	NewtonMeter	
17	Locked-Rotor Torque	597.573	NewtonMeter	
18	Locked-Rotor Current	1197420	mA	
19	Maximum Output Power	4797120	mW	

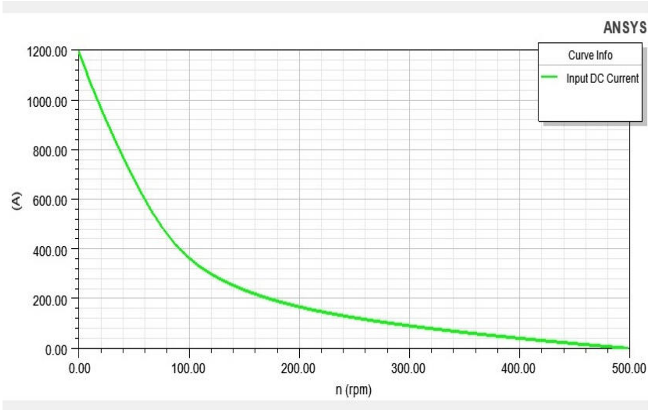

Fig 6: Input DC current vs speed

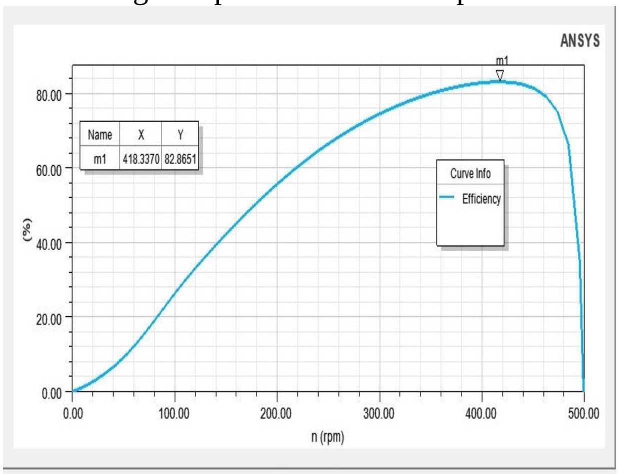

Fig 7: Efficiency vs speed

Result Analysis: The 2d modelling of BLDC motor was done in ANSYS software and various waveforms have been analysed for 2 different slot configuration. It was observed that 24 Slot and 36 Slot Machines the moving torque for 2D models were shown in figure above. The average torque for the 36 Slot machine was abnormally high as compared to the 24 Slot machine with high ripple content. The winding currents for the 36 Slot machine were abnormally high in order of 300 A, which consequently resulted in high stranded loses in orders of few kW. The flux linkages for all machines were in agreement with each other. The 24 Slot Machines have favorable performance characteristic due to its nominal magnetic field density, lower losses and proximity to rated operating parameters along with accordance to available machines in the market. The torque pulsations and wave form distortion were prominent for the 36 Slot machines as compared to others. The efficiency in configuration 82.8388 % in 24 slots 16 poles configuration as compared to 36 slots 18 poles 79.4571 % which is comparatively low.

Conclusion and future scope:

This paper deals with the analysis of two different configuration of slots and poles to analyse which configuration is comparatively better that another in terms of efficiency and output power and speed at rated through the use of Ansys software which is mostly used for design purpose in electrical machines. Further with the use of power electronic converter and expert system this configuration can be studied more for better efficiency.

Nomenclature

i_a ,i_b , i_c = Currents of phases a, b, and c

e_a, e_b,e_c = Induced back-electromotive force

T_{e}= electromagnetic torque

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