Design and development of high power to weight ratio PMDC motor for short duty cycle

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Abstract - *there are various types of prime mover used to drive various machines such as IC engines, turbines, motors etc. these are the mandatory parts required for functionality of any machine. Motor is most widely used prime mover considering its size and input power requirements. In this paper we will discuss on design and optimization of PMDC motor for high power to weight ratio for short duty cycle. By lowering the net resistance of armature and maximizing the net magnetic flux density we can increase the power output of motor.*

Key Words: PMDC motor, Generator, Motor, Neodymium, Motor Armature, EV's. Electrical Vehicles, etc

1. INTRODUCTION

An electric motor is an electrical machine that converts electrical energy into mechanical energy. Electric motors are used to produce linear or rotary force (torque). The reverse of this is the conversion of mechanical energy into electrical energy and is done by an electric generator, which has much in common with a motor. The largest of electric motors are used for ship propulsion, pipeline compression and pumped-storage applications with ratings reaching 100 megawatts. Electric motors may be classified by electric power source type, internal construction, application, type of motion output, and so on. Most electric motors operate through the interaction between an electric motor's magnetic field and winding currents to generate force. In certain applications, such as in regenerative braking with traction motors in the transportation industry, electric motors can also be used in reverse as generators to convert mechanical energy into electric power. A PMDC motor does not have a field winding on the stator; instead it has permanent magnets to provide the magnetic field against which the rotor field interacts to produce torque. Compensating windings in series with the armature may be used on large motors to improve commutation under load. Because this field is fixed, it cannot be adjusted for speed control. Permanent Magnetic fields (stators) are convenient in miniature motors to eliminate the power consumption of the field winding. Permanent Magnets could not be made to retain high flux if they were disassembled; field windings were more practical to obtain the needed amount of flux. However, large Permanent Magnets are costly, as well as dangerous and difficult to assemble. To minimize overall weight and size, miniature PM motors may use high energy magnets made with neodymium or other strategic elements; most such are neodymium-iron-boron alloy. With their higher flux density, electric machines with high-energy Permanent Magnets are at least competitive with all optimally designed singly-fed synchronous and induction electric machines. Miniature motors resemble the structure in the illustration, except that they have at least three rotor poles (to ensure starting, regardless of rotor position) and their outer housing is a steel tube that magnetically links the exteriors of the curved field magnets. In upcoming days electrical motors are going to play an important role in the in automobile industry. Due to continuous decreasing fossil fuels levels like petrol diesel and increasing their rates people have started liking electrical vehicle (EV'S) as an option. Companies like FIAT and TESLA have started developing electrical vehicles looking at its future scope. The main problem in front of electric vehicle is optimisation of batteries and motor. This paper can help understanding ways to optimise electrical PMDC motor for various applications.

2. OBJECTIVES

The objective of "Design and development of high power to weight ratio PMDC motor for short duty cycle" are as follows:

- To increase the net power output by optimizing the electrical and magnetic design consideration
- To decrease the size and total weight of the motor
- To reduce the net thermal losses

3. PROBLEM STATEMENT

The PMDC motors use permanent magnets to generate magnetic flux. As the magnet has constant magnetic flux density (Neodymium: 1-1.4 W/m2 Ferrite: 0.05W/m2) it is difficult to achieve more power output in PMDC motor. Hence it is necessary to improve electrical properties in order to improve the net power output. In this article we will optimize electrical properties by reducing net resistance of armature windings, by increasing number of poles and hence the net result will reflect as improvement in motor power output at same magnetic configuration. In this paper we designed a motor which has low weight up to 5kg having power output up to 8HP power.

4. DESIGN CONSIDERATION

- Designed layout of the motor

First we design CAD model of motor on FUSION 360 Software as shown in figure below. This figure is exact replica of motor.

Figure: CAD model of motor

- Motor Armature

The motor we designed is four pole parallel winding motor with skewed armature to reduce cogging effect.

Figure: Motor Armature

- Commutator

The armature wires are soldered to commutator in the motor. The soldering is done to withstand higher centrifugal force due to high RPM.

- Stator

Mild steel cylinder is used to manufacturing stator as it has good magnetic permeability. The stator cylinder is designed more thick in order to dissipate heat energy generated during the working of the motor.

- Magnets

Neodymium magnets (NdFeB n35sh 175) are used due to their higher magnetic flux density. The magnets are stacked in four sets as the motor is four pole. Spacers are provided to fix the motors rigidly at their position.

- Shaft

The shaft of the motor is designed to withstand higher power and torque output. En-24 (AISI 4340) material is used for shaft, and it is hardened to 30 HRC.

Figure: Shaft used in motor

- Brushes

Copper Graphite brushes are used for maximum current conduction at minimum wear and tear.

5. OPTIMISATION

The Initial specifications of motor resulted in high power and torque. But due to more current consumption the heat generated in motor was high which lead us to melting of soldered joints at commutator. Hence by further increasing net resistance of commutator winding we reduced current consumption. Also soldered joints are replaced by welded joints to withstand against higher temperatures.

6. RESULT TABLE

The final motor assembly weighs 4.8KG. The motor is designed for 48V DC at 6140 RPM. The variation in current consumption with respect to Voltage is given in observation table below

Sr. No.	Voltage input	Current Consumption at No load	Motor RPM	Stall Current
01	12	2 A	1625	118 A
02	24	4 A	3160	242 A
03	48	7 A	6140	450 A

Hence the Final Specifications achieved are as follows,

Motor Weight: 4.8 Kg

Working Voltage: 48V

Current Consumption: 7A (No Load)

Stall Torque: 45N-m

Rpm at 48V: 6140rpm

Figure: final manufactured motor

7. CONCLUSION

In this motor we optimized electrical specifications which lead us to manufacturing of high power permenent magnet dc motor at minimum weight possible. As the power to weight ratio is high the duty cycle of the motor is less because thermal mass available for heat dissipation is not sufficient .external cooling can help to increase the duty cycle of the motor

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