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# THERMAL ANALYSIS OF BLDC MOTOR USING MOTOR CAD FOR IMPROVED EFFICIENCY

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***Abstract: Thermal analysis of the device plays the key role in the motor design process [5]. The need for motor miniaturisation and the reduction of production materials makes it necessary to conduct a detailed thermal analysis. The BLDC motor requires a complicated commutation scheme, which necessitates a significant amount of computation. The computational and temperature requirements limit the selection of the electrical components.This paper deals with the thermal analysis of two BLDC motor configurations to predict the temperature rise in different parts.The transient thermal analysis is performed to calculate the temperature distribution in different parts with varying time. The analysis involves the thermal motor cad model with the total losses and convection coefficients calculated during static analysis as the inputs.***
***Keywords:BLDC,thermal analysis, motor cad,temperature***

## I. INTRODUCTION

Nowadays, small and medium power Permanent Magnet Brushless Direct Current (PM BLDC) motors are widely applied as a source of drive systems. Many studies cover brushless motor applications for direct driving of vehicles [1][2]. The main advantages of PM BLDC are high efficiency, lack of mechanical commutation, which is replaced by electronic commutation, and high power density. A motor's durability and its lifetime are also dependent on the thermal load and mechanical material properties, especially in high speed PM BLDC motors [3]. The main disadvantage of PM BLDC motors is their high market price [4]. In [6], Reichert et al. indicate that the local thermal situations should be considered, especially for the stator winding, which is one of the main heat sources; an analytical split ratio optimization method for low-speed PM-BLDCM is developed with global and local thermal limitations.

## II. BRUSHLESS DC MOTOR

Brushless DC motors/generators were chosen due to their high efficiency, high torque per amp capabilities, and relatively low maintenance requirements [3]. Because of their control complexity, BDC drives are greatly simplified by using qdo reference frame variables for their control. Using feedback on rotor position and speed, it is then possible to control the performance of the BDC drive by controlling torque or speed, depending on the desired application, in the qdo reference frame and then converting back to the abc reference frame.A brushless direct current (BLDC) motor has high reliability and a long life because it eliminates mechanical friction, and compensates for the defects of a direct-current (DC) motor by removing the brush and commutator. Compared to a DC motor, BLDC motor has the excellent efficiency because there is no voltage drop or friction loss of the brush. However, when the motor is operated for a long time with a high output, the internal motor temperature rises, and the copper-winding temperature increases. The temperature rise of the internal motor affects the resistance of the copper winding and the performance of the permanent magnet.

## III. MOTOR-CAD

Motor-CADSoftware is the unique software for the analytical lumped circuit thermal network analysis of electric motors. Motor-CAD is used by many of the most successful motor manufacturers to optimise the cooling of various motor types and cooling methods. Motor-CAD is unique software dedicated to thermal analysis of electrical motors and generators. It is based on network (lumped circuit) analysis. Nodes are automatically placed at important points on the motor cross-section, such as the stator back iron, tooth, winding hotspot, etc. These are linked with the conduction, convection and radiation thermal resistances

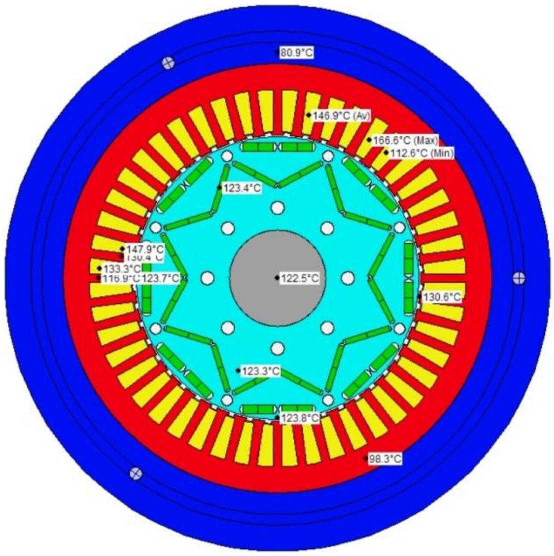


Fig 1. Structure of the BLDC Motor with temperature distribution

In this software On the basis of the input geometry, losses and model settings the Motor-CAD creates a 3D lumped parameter circuit model to characterise the thermal behaviour of the machine.Losses are represented as power sources, and power is dissipated to the ambient node by the cooling systems. By solving this equivalent thermal circuit Motor-CAD can accurately estimate the temperatures in each part of the machine.

Temperature effects on different parts of motor:
All metal conductors have a positive temperature coefficient

  

of resistance. This means as temperature increases, the resistance of the material also increases as a function of the type of conductor used.Motor winding resistance (Rmt) is the main cause of heat generation within the motor. In order for any electric motor to generate torque, current needs to be forced through the motor windings.Depending on the physics of the magnet material used, overall flux density will change at a given percentage with an increase in magnet temperature. As the material temperature increases, atomic vibrations cause once-aligned magnetic moments to "randomize" resulting in a decrease in magnetic flux density.Here as shown in the data table the bldc motor has been simulated at different operating points for temperature and then the best configuration of stator and rotor slots has been taken on the basis of temperature distribution.

Steady-State Calculation

Here in the motor cad software Under the the Steady State Calculation is performed to Solve Thermal Model .When solving is complete Motor-CAD will automatically show the results. Under theTemperatures calculation results the Radial and Temperatures after solving the motor cad will show in the Axial tabs the final machine temperatures on the radial/axial cross-section drawings. Throughout the thermal module the colours used to represent components in the model match those used in the cross-section drawings.The Output Data sheets provide detailed results from the thermal simulation, including temperatures, heat transfer coefficients, and thermal resistances. The details of the current and voltage and mechanical losses with results so obtained are shown in table 1 and 2.

| Variable | Value | Units | Variable | Value | Units |
|---|---|---|---|---|---|
| Shaft Speed | 6000 | rpm | Total Loss | 2645 | Watts |
| Shaft Torque | 160 | Nm | Stator Copper Loss | 1981 | Watts |
| Shaft Power | 1.0058E005 | Watts | --- | | |
| Efficiency | 97.44 | | Iron Loss | 659.5 | Watts |
| --- | | | Magnet Loss | 4.254 | Watts |
| Stator Phase Current (peak) | 330.6 | Amps | Mechanical Loss | 0 | Watts |
| Stator Line Current (peak) | 330.6 | Amps | --- | | |
| DC Terminal Current | 275.1 | Amps | Electromagnetic Power | 1.0126E005 | Watts |
| Phase Voltage (peak) | 216.5 | Volts | Electromagnetic Torque | 161.1 | Nm |
| Line Voltage (peak) | 375 | Volts | Magnet Torque | 78.27 | Nm |
| Phase Advance | 60.53 | EDeg | Reluctance Torque | 82.78 | Nm |
| --- | | | Terminal Power | 1.0326E005 | Watts |
| Flux Linkage D | 19.15 | mVs | Power Factor | 0.961 | |
| Flux Linkage Q | 82.41 | mVs | | | |
| Magnet Flux Linkage | 80.21 | mVs | | | |
| D axis Inductance | 0.212 | mH | | | |
| Q axis Inductance | 0.5067 | mH | | | |

Table 2:Duty cycle data of bldc motor

Duty Cycle Data

| | Value |
|---|---|
| Average Efficiency (Energy Use) (%) | 94.92 |
| Average Efficiency (Point by Point) (%) | 92.06 |
| Electrical Input Energy (Wh) | 1815.32 |
| Shaft Motoring Energy (Wh) | 1734.61 |
| Electrical Output (Recovered) Energy (Wh) | 674.73 |
| Shaft Generating Energy (Wh) | 723.07 |
| Total Loss (Wh) | 129.04 |
| Copper Loss (Wh) | 97.47 |
| Iron Loss (Wh) | 31.54 |
| Magnet Loss (Wh) | 0.03 |
| Mechanical Loss (Wh) | 0.00 |
| Motoring Operation (%) | 71.64 |
| Generating Operation (%) | 28.36 |

The shaft generating energy ,copper loss iron loss and other losses such as magnetic loss and mechanical losses in the motor is depicted in table 1.The results in terms of output power and efficiency show comparison between the average efficiency in use and point to point average efficiency .

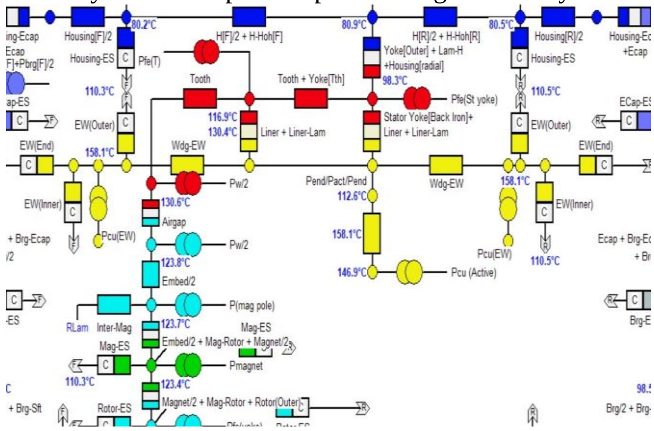


Fig 2 Lumped Model of motor

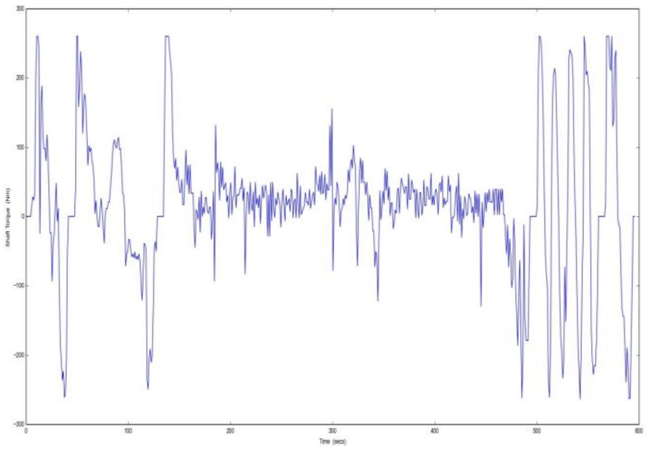

Fig 3:Torque vs time characteristics

Torque - Speed Characteristics:

There are two torque parameters used to define a BLDC motor, peak torque and rated torque. During continuous operations, the motor can be loaded up to rated torque. This requirement comes for brief period, especially when the motor starts from stand still and during acceleration. During this period, extra torque is required to overcome the inertia of load and the rotor itself. The motor can deliver a higher torque up to maximum peak torque, as long as it follows the speed torque curve. Figure 4 and 5 showstorque vs speed and Shaft power vs speed characteristics of a BLDC motor analysed using motor cad software.As the speed increases to a maximum value of torque of the motor, continuous torque zone is maintained up to the rated speed after exceeding the rated speed the torque of the motor decreases. The stall torque represents the point on the graph at which the torque is maximum , but the shaft is not rotating. If the phase resistance is small, as it should be in an efficient design, then the characteristic is similar to that of a shunt DC motor. Figure 4 shows the Torque vs Speed Characteristics of BLDC Motor.

  

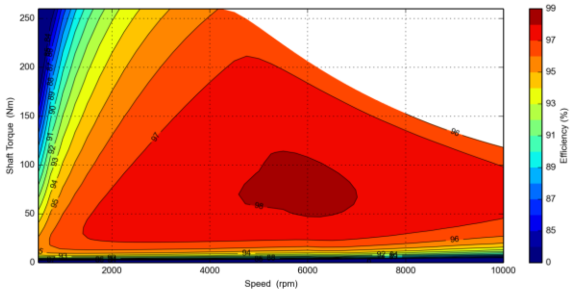

Figure 4 Torque vs Speed Characteristics of BLDC Motor.

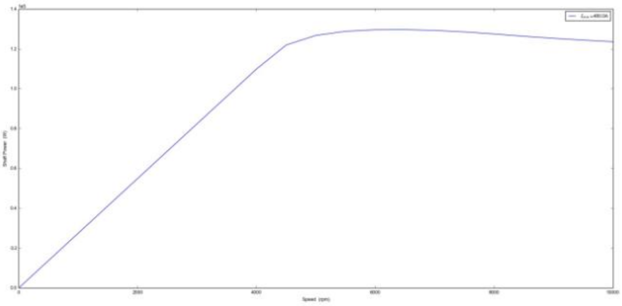

Fig 5 Shaft power vs speed

## IV. CONCLUSION

The speed is essentially controlled by the voltage, and may be varied by varying the supply voltage. The motor then draws just enough current to drive the torque at this speed. As the load torque is increased, the speed drops, and the drop is directly proportional to the phase resistance and the torque.It has been observed that the suggested model for bldc motor suited good and presents efficiency as shown in the figure 4.It justify that within the range of 4800 to 7000 rpm the motor represents the best efficiency ie 99 % which is for a very short duration of time and quite impractical due to frictional losses however the same represents an efficiency of about 97.5 over a range of 1800 to 10000 rpm which is the expected performance.

Future scope

In a traditional BLDC control scheme, rotor position is directly sensed via Hall effects sensors, and the next phase step can be applied at the optimal timing for the greatest efficiency. However, the lack of Hall effects sensors necessitates a complex control algorithm in order to electronically control both the speed and torque of the motor. By introducing air flow for cooling the optimal air flow rate to the internal motor can be improved.

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