THERMAL ANALYSIS OF AN ELECTRIC MOTOR

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DECLARATION

I declare that this thesis entitled “THERMAL ANALYSIS OF AN ELECTRIC MOTOR is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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APPROVAL

I hereby declare that I have checked this report entitled “title of the project” and in my opinion, this thesis it complies the partial fulfillment for awarding the award of the degree of Bachelor of Mechatronics Engineering with Honours

Signature : ....

Supervisor Name : ....

Date : ....

DEDICATIONS

To my beloved mother and father

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ABSTRACT

A thermal management of an electric motor is one of the important factor to ensure optimum performance and efficiency of the motor. The thermal behaviour of the motor depends on the motor geometry and the heat sources. The performance of electric motor is influenced by its temperature due to the heat dissipated from the motor. During the operation of the electric motor, more heat will dissipated from the motor which cause the temperature of the motor rised. An excessive heat that generated from the motor will affect the motor performance and may cause a failure. Understanding the importance of the thermal management had motivated the aim of this study is in creating thermal model of motor and letting the capability of the motor performance. The Permanent Magnet Synchronous Motor (PMSM) is selected to its highest performance and necessary to avoid demagnetized due to excessive heat. The model of the motor simulated using Finite Element which is 2D Flux Altair software. The expected result for this study is to predict the thermal capability of the motor performance before it reaches the failure level and known as Mean Time Before Failure (MTBF). The simulated result showed that the heat generated in the motor is directly proportional with the increased torque of the motor..

ABSTRAK

Pengurusan termal motor elektrik adalah salah satu faktor penting untuk memastikan prestasi dan kecekapan motor yang optimum. Sifat haba motor bergantung kepada geometri motor dan sumber haba. Tindak balas motor elektrik dipengaruhi oleh suhu dan kadar haba yang dihasilkan dari motor. Semasa motor elektrik beroperasi, lebih banyak haba telah terhasil dari motor yang menyebabkan suhu motor meningkat. Haba yang berlebihan yang dihasilkan dari motor akan memberi kesan kepada prestasi motor dan boleh menyebabkan kegagalan. Dalam memahami kepentingan pengurusan haba, matlamat kajian ini adalah untuk mencipta model termal motor dan mampu menganalisa keupayaan prestasi motor. "Permanent Magnet Synchronous Motor (PMSM)" dipilih kerana mempunyai prestasi tertinggi dan perlu untuk mengelakkan dari nyah magnet disebabkan oleh haba berlebihan. Model motor telah dijalankan menggunakan perisian"Finite Element", iaitu "2D Flux Altair. Hasil yang dijangkakan untuk kajian ini adalah untuk meramalkan keupayaan prestasi motor sebelum mencapai tahap kegagalan dan dikenali sebagai "Mean Time Before Failure (MTBF)". Hasil simulasi menunjukkan haba yang dijana di dalam motor adalah berkadar terus dengan peningkatan tork motor.

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LIST OF SYMBOLS AND ABBREVIATIONS

PMSM	-	Permanent Magnet Synchronous Motor
T	-	Temperature
G	-	Thermal conductances
λ	-	Thermal conductivity
A	-	Cross sectional area
R	-	Thermal resistance
α	-	Heat transfer coefficient
f	-	Frequency

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CHAPTER 1

INTRODUCTION

1.1 Overview

In this chapter, the research background, problem statement, objective and scope of the project will be explained briefly for the understanding towards the project purpose.

1.2 Research Background

In globalization era, the technologies development used a lot of electric application such as electric vehicles (EV) in order to minimize the pollution. An electric motor that has high power density high of efficiency and wide constant power operating region as well a low cost of manufacturing is required foe EV to use in order to continue to be competitive with conventional vehicles. Permanent Magnet Synchronous Motor (PMSM) are appropriate for electric vehicle because PMSM contain the necessary advantages such as has high torque, has no windings at its rotor and has no contact sliding which simple in rotor construction with good dynamic performance that help to optimizing of cost, mass and electric vehicles performances. The size of Permanent Magnet Synchronous Motor (PMSM), the torque of the motor will increase although the range of speed is large [1]. Permanent Magnet Synchronous Motor also one of the type of motor that reaches the higher efficiency levels [2] [3].

In electric vehicle, the thermal management of the motor is very important because the efficiency of the motor effected by its temperature. Motor is the most important part in energy conversion system. The failure of the motor may cause the failure of the whole system [4]. The motor must operate and deliver the power at a specific temperature without any risks of stator windings failure and demagnetization of the magnet [5]. During its operation, the temperature should not reach the levels that could destroy the sensitive parts such as winding insulation and the permanent magnet. In avoiding the winding from overheating during operation, heat generated should be monitored and stop the operation reaching up maximum temperature [6]. Because of this, thermal modelling and analysis is important to analyse the performance of the motor for the motor's thermal model to make sure the motor can operate for longer life span [7].

1.3 Problem Statement

The limitation of thermal cause the restraint of the motor. If the motor exceed the thermal limit, this will decrease the life time of the motor. Heat sources and motor geometry is important in order to reduce the thermal stress because thermal behaviour is important for the lifetime of motor, the limit of temperature insulation and the motor efficiency. Heat stress may cause the damage of the motor.

Electric motors have the problem with regards to the temperature that dissipited during the motor operation. Electric motors also have problem about the maximum temperature that the windings and permanent magnet of the motor can stand. During the operation of the electric motor, the temperature of the motor will rise and more heat will dissipated from the electric motor. The excessive heat that produce from the electric motor will effect the performance of the electric motor and may cause the failure of the motor [8].

1.4 Objective

The objectives of this project are:

i) To understand the thermal behaviour in electric motor.

ii) To model and simulate the thermal generated in electric motor.

iii) To analyse and predict the motor thermal capability before reaching Mean Time Before Failure (MTBF).

1.5 Scope of Project

The main scopes of project are:

a) The thermal behaviour is investigated by heat sources and the motor geometry.

b) The type of electric motor used for this project is Permanent Magnet Synchronous Motor (PMSM).

c) The analytical lumped circuit used as the design technique for the thermal analysis.

d) The capability of the thermal motor is analysed using the finite element simulated model.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

This chapter is about the studied that related to the subject of the project. The background theory that related to the project is also included in this chapter to make sure the project is properly understand.

2.2 Thermal Behaviour in Electric Motor

In electric motor thermal analysis is very important because the temperature of the motor will effect the efficiency of the motor. The thermal behaviour of the motor depends on the heat sources and the motor geometry [4].

2.2.1 Heat Sources in motor

The heat sources in a motor are generated due to copper losses and iron losses in the electric motor. The copper losses is from ohmic resistances and eddy current. Ohmic resistance losses depend on the current of the coils, while eddy current copper losses depend on the speed of motor. Iron losses from eddy currents and hysteresis depend on the motor speed. The mechanical losses which from motor bearing friction also depend on the speed of motor [4] [9].

Copper losses

The copper losses is come from ohmic resistance and eddy current. Ohmic resistances losses depend on the current in the coils while eddy current copper losses depend on motor speed. In synchronous permanent magnet motor, the copper losses are function by phase current and phase resistance. The copper losses are given by the following expression [9]:

$$\boldsymbol{P_j = 3R_{ph}I_{eff}^2 = 3R_{ph}\left(\frac{i_{max}}{\sqrt{2}}\right)^2} \quad (1)$$

R_{ph} is the phase resistance given by the following expression:

$$\boldsymbol{P_j = 3R_{ph}I_{eff}^2 = 3R_{ph}\left(\frac{i_{max}}{\sqrt{2}}\right)^2} \quad (2)$$

Iron losses

The iron losses are described as losses in the stator yoke and teeth [9] [10]. The iron losses in the teeth are given by:

$$\boldsymbol{P_{f\_d} = q\left(\frac{f}{50}\right)^{1.5}\left[M_{ds}B_d^2\right]} \quad (3)$$

Where q is quality coefficient of the meta sheets, f is frequency supply of the motor, B_d is the value of peak flux density in the teeth and M_{ds} is the teeth mass. The iron losses in the stator yoke are given by following:

$$\boldsymbol{P_{f\_c} = q\left(\frac{f}{50}\right)^{1.5}\left[M_{cs}B_{cs}^2\right]} \quad (4)$$

Where B_{cs} is the value of peak flux density in the stator yoke and M_{cs} is the stator yoke mass.

2.2.2 Heat Transfer Mechanism

During the heat transfer process, the heat energy from the coil of the motor will transfer into the motor's body. Then, the heat generated from the motor will transfer out from the motor's body due to the losses of heat [11]. According to second law of thermodynamics, in the real processes the net entropy is always increase. Entropy is the measure of disorder in a system, it also describe as the energy quality in a system. Low quality means a high level of disorder, and the highest possible entropy would be having the energy evenly distributed in space. The second law of thermodynamic also can be explained that an isolated system always strives for thermal equilibrium which heat flow from hot place to cooler places. There are three process of heat transfer can occur which are conduction, convection and radiation. Conduction is the energy transmission between molecules in medium. It is the only mechanism takes place in solid but it is not exclusive and it also take place in solid as well [9] [12].

This process is linear and described by:

$$\boldsymbol{P} = \boldsymbol{G}(\boldsymbol{T_i} - \boldsymbol{T_j}) \tag{5}$$

Where P is the power flow, G is the thermal conductance while T_i and T_j are the temperature in two adjacent nodes.

The convection phenomena can be found in fluids and gases. In non-solid medium the molecules move freely. Transportation of the molecules improved the heat transfer ability of the medium. The molecule will contact to each other and cause the intermixing molecule of different energy level and increasing the rate. The mechanism is linear for the pure conduction and can be described by (5).

Another process of heat transfer is radiation, it is describes as the mechanism of energy carrying by body photons emitting. The amount of body emit radiation depends on the emissivity of object, the surface area and the most strongly depends to temperature. The net energy transfer can described by (6)

$$P = G(T_i^4 - T_j^4) \tag{6}$$

Figure 2-1 below shows the cross-section of the Permanent Magnet Synchronous Motor (PMSM). From this, the value of thermal resistance and capacitances can be calculated based on the dimension of motor geometry. In this motor, there will be heat transfer form one element of the motor to another element of the motor [5].

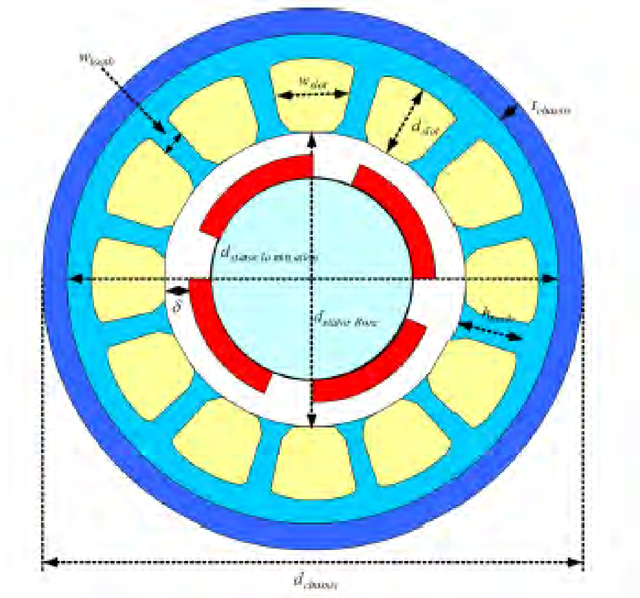

Figure 2-1 The Cross-section of Permanent Magnet Synchronous Motor (PMSM)

Figure 2-2 below shows the diagram of heat transfer in PMSM, the arrow in red colour is represent as the conduction hear transfer. The arrow with purple colour is show the radiation heat transfer while the arrow with green colour is represent as convection heat transfer. All three type of heat transfer occur in the electric motor [5].