UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Electrical Technology And Engineering

DESIGN AND EVALUATION OF NEW HOLLOW ROTOR FOR HIGH-VOLUME-LOW-SPEED FAN

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DEDICATION

To my beloved husband and children

Mohd Azam Bin Tumijan (husband)

Khaulah Al-Khansa

Nusaybah Ar-Ramadhani

My beloved parents and family,

Sulaiman Bin Jamaldeen & Gafurah Binti Shadi Khan (parents)

Mohd Feroz Bin Sulaiman

Mohd Faizal Bin Sulaiman

Dr. Fazillah Binti Sulaiman

Mohd Fared Bin Sulaiman

ABSTRACT

This thesis discussed the design and evaluation of a new hollow rotor for High-Volume-Low-Speed (HVLS) fan application. HVLS fan is commonly used in large areas such as factories, barns, and public places. The research focuses on BLDC motor due to its high efficiency, stability, and high performance. Induction motor is frequently used in HVLS fan industry. The main constraint of the HVLS motor is that it's expensive and requires high maintenance. In this research, four types of BLDC motors are designed by using Permeance Analysis Method (PAM) and Finite Element Method (FEM) for HVLS fan applications. Each motor has been developed based on the same stator design and parameter with different rotor types. These are hollow rotor, spoke rotor, embedded rotor, and surface mount rotor. The PAM method is used to model the sizing equation of the HVLS motor reduced computational time. The PAM formulated the sizing equation to calculate the magnetic flux of the air gap. The FEM measured is used to analyse the characteristics of flux linkage, back emf, cogging torque, inductance, stator flux density and electromagnetic torque. The simulation results from PAM and FEM results are validated for the purpose of choosing the best rotor type design for the fabrication process. The percentage difference for each validation part is below 10 % for back emf, 9.1 % for cogging torque and 7 % for static torque. Based on the validation, a hollow rotor is chosen for prototype fabrication. A hollow rotor can maximise the flux density produced by the permanent magnet and coil by reducing flux leakage. It is confirmed that the implementation of hollow rotor design will optimised the magnetic flux and evenly distribute the air gap. The hollow rotor design was further tested for static and cogging torque characteristics. BLDC driver topology is carried out to analyse the performance of the motor connected with the drivers under loaded condition in the torque speed characterisation. In this characterisation, the value of input voltage, input current, input power, torque, output power and efficiency are measured for each type of commutation which is synchronous commutation, basic commutation and THC, in order to confirm the best topology for BLDC motor. From the topology, it can be seen that by using THC, the detailed result of the hollow rotor could be archived and examined compared to other driver topology. This thesis provides guidelines for designing and analysing BLDC motor for HVLS fan.

REKABENTUK DAN PENILAIAN ROTOR BERONGGA BAHARU UNTUK KIPAS BERISIPADU TINGGI BERKELAJUAN RENDAH

ABSTRAK

Tesis ini membincangkan reka bentuk dan penilaian rotor berongga baru untuk aplikasi kipas HVLS. Kipas HVLS biasanya digunakan di kawasan besar seperti kilang, gudang, dan tempat awam. Kajian ini memfokuskan pada motor BLDC kerana kecekapan tinggi, kestabilan, dan prestasi yang tinggi. Motor induksi sering digunakan dalam industri kipas HVLS. Kekangan utama motor HVLS adalah harganya yang mahal dan memerlukan penyelenggaraan yang tinggi. Dalam kajian ini, empat jenis motor BLDC direka menggunakan Kaedah Analisis Permeans (PAM) dan Kaedah Unsur Terhingga (FEM) untuk aplikasi kipas HVLS. Setiap motor telah dibangunkan berdasarkan reka bentuk dan parameter stator yang sama dengan jenis rotor yang berbeza. Ini adalah rotor berongga, rotor berbilah, rotor tertanam, dan rotor dipasang permukaan. Kaedah PAM digunakan untuk memodelkan persamaan saiz motor HVLS yang mengurangkan masa pengiraan. PAM merumuskan persamaan saiz untuk mengira fluks magnet ruang udara. Kaedah FEM digunakan untuk menganalisis ciri-ciri penghubung fluks, emf balik, tork cogging, induktans, ketumpatan fluks stator dan tork elektromagnet. Keputusan simulasi daripada PAM dan FEM disahkan untuk tujuan memilih reka bentuk jenis rotor terbaik untuk proses fabrikasi. Perbezaan peratusan untuk setiap bahagian pengesahan adalah di bawah 10% untuk emf balik, 9.1% untuk tork cogging dan 7% untuk tork statik. Berdasarkan pengesahan tersebut, rotor berongga dipilih untuk fabrikasi prototaip. Rotor berongga dapat memaksimumkan ketumpatan fluks yang dihasilkan oleh magnet kekal dan gegelung dengan mengurangkan kebocoran fluks. Telah disahkan bahawa pelaksanaan reka bentuk rotor berongga akan mengoptimumkan fluks magnet dan mengagihkan ruang udara dengan sekata. Reka bentuk rotor berongga telah diuji lebih lanjut untuk ciri-ciri tork statik dan cogging. Topologi pemacu BLDC dijalankan untuk menganalisis prestasi motor yang disambungkan dengan pemacu di bawah keadaan beban dalam pencirian tork kelajuan. Dalam pencirian ini, nilai voltan input, arus input, kuasa input, tork, kuasa output dan kecekapan diukur untuk setiap jenis komutasi iaitu komutasi sinkron, komutasi asas dan THC untuk mengesahkan topologi terbaik untuk motor BLDC. Dari topologi tersebut, dapat dilihat bahawa dengan menggunakan THC, hasil terperinci rotor berongga dapat dicapai dan diperiksa berbanding dengan topologi pemacu lain. Tesis ini menyediakan garis panduan untuk mereka bentuk dan menganalisis motor BLDC untuk kipas HVLS.

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