DESIGN OF 0.5 HP INDUCTION MOTOR ROTOR BARS WITH 0.35 MM AND 0.50 MM THICKNESS OF STEEL SHEETS FOR ROTOR FABRICATION

by

YANAWATI BINTI YAHYA

(1340911079)

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THESIS DECLARATION

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Author's full name	:	YANAWATI BINTI YAHYA
Date of birth	:	8 JULY 1979
Title	:	Design of 0.5 Hp Induction Motor Rotor Bars with 0.35 mm and 0.50 mm Thickness of Steel Sheets for Rotor Fabrication.
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Yanawati Binti Yahya	Dr. Ir. Dina Maizana
IC. NO: 790708-13-5090	
Date:	Date:

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LIST ABBREVIATIONS

AC	Alternating Current
IM	Induction Motor
mm	millimeter
MMF	Magneto Motive Force
N	Number of Winding Turns
NEMA	National Electrical Manufacturers Association
RPM	Revolution per Minute
HP	Horse Power
IEEE	Institute Electric and Electronic Engineering
FEM	Finite Element Method
NEMA	National Electrical Manufacturers Association
TNB	Tenaga Nasional Berhad
SESCO	Sarawak Electricity Supply Corporation
SESB	Sabah Electricity Supply Sendirian Berhad
SEU	Energy Consumed per unit physical product
AES	Annual Energy Saving
TCS	Total Cost Saving

LIST OF SYMBOLS

Φ	Magnetic Flux
Ω	Ohm
°C	Celsius
μ	Magnetic Permeability
A	Ampere
A	Cross Sectional on the Surface of Yoke
B	Magnetic Flux Density
emf	Electromotive Force
f	Frequency
H	Magnetic Field Strength
s	Slip
T	Tesla
t	Thickness of Yoke Lamination
V	Volt
Vs	Voltage Supply
W	Watt
w	Width of Yoke Lamination
B	Magnetic Flux Density
H	Magnetic Field Intensity

Reka Bentuk pada 0.5 Kuasa Kuda Bar Pemutar Motor Aruhan dengan Ketebalan 0.35 mm dan 0.50 mm pada Lembaran Steel untuk Pembikinan Pemutar

ABSTRAK

Dalam projek ini, 0.5 kuasa kuda tiga fasa motor aruhan telah dikaji dengan teliti dan dianalisis pada aspek parameter, tork, kecekapan, faktor kuasa, pengurangan kerugian, mekanisme pemindahan dan aspek ekonomi. Sepanjang projek ini, prestasi dan pembangunan motor aruhan tiga fasa apabila di reka bentuk dan dimodelkan dengan menggunakan 0.35 mm dan 0.50 mm ketebalan kepingan keluli telah dibuat dan dibandingkan. Fasa pertama adalah dengan melakukan analisis matematik (pengiraan teori) motor aruhan arus ulang alik dilakukan untuk mengira semua kerugian dan parameter litar setara bagi 0.5 kuasa kuda tiga fasa motor aruhan. Ini adalah untuk menunjukkan kecekapan dan jumlah tenaga yang digunakan dalam motor aruhan. Fasa kedua, kajian ini melibatkan bentuk dan simulasi 0.5 kuasa kuda 3 fasa motor aruhan menggunakan perisian MotorSolve IM, perisian AutoCAD, perisian Opera 2D dan perisian MATLAB. Dari simulasi, analisis seperti kehilangan kuasa, ketumpatan fluks magnet, ketumpatan arus pusar, tork terhadap kelajuan, kehilangan kuasa terhadap kelajuan, kecekapan terhadap kelajuan, dan faktor kuasa terhadap kelajuan telah siap dijalankan. Satu kajian perbandingan juga dilakukan antara kegunaan 0.35 mm dan 0.50 mm ketebalan bahan dalam pemutar motor aruhan. Fasa ketiga melibatkan pembikinan dan kajian dengan teliti ke atas bahagian pemutar dengan ketebalan lembaran steel yang berbeza pada motor aruhan pada aspek peningkatan kecekapan, peningkatan faktor kuasa, pengedaran fluks dan pengurangan kehilangannya. Fasa keempat melibatkan prosedur eksperimen yang dijalankan ke atas 0.5 kuasa kuda 3 fasa motor aruhan jenis sangkar tupai boleh dibahagikan dua eksperimen yang utama antaranya ujian ke atas bahan (seperti nominal, inplane dan thermister untuk kaedah carian gegelung), dan prestasi ujian pada penghasilan pembikinan pemutar motor aruhan (seperti No-Load Test, DC rintangan ujian dan Blok Rotor Test) yang dilakukan untuk membuktikan data kecekapan yang diperolehi daripada simulasi. Ini telah siap dilakukan bagi menentukan kerugian, mekanisme pengagihan dan untuk menyiasat kecekapan 0.5 kuasa kuda 3 fasa motor aruhan dengan 0.35 mm dan 0.50 mm tebal kepingan keluli. Berdasarkan pada keseluruhan eksperimen, keputusan hasil uji kaji menunjukkan bahawa pemutar dengan ketebalan 0.35 mm mampu menaikkan kecekapan motor sebanyak 4%, faktor kuasa sebanyak 5.5% dan tork sebanyak 1.6% dan dapat mengurangkan kehilangkan arus pusar sebanyak 50.1%, kehilangan tembaga pemegun sebanyak 8.98%, kehilangan teras sebanyak 25.25%, dan kehilangan tembaga pemutar sebanyak 12.37% berbanding dengan penggunaan 0.50 mm pemutar. Satu perhitungan ekonomi telah disediakan dan dibentangkan untuk menunjukkan bahawa kos penjimatan dengan menggantikan motor aruhan yang sedia ada dengan motor aruhan baru dengan ketebalan 0.35 mm yang telah direka bentuk boleh mengurangkan bil utiliti dengan RM 2.46 juta (89%) berbanding dengan motor aruhan yang sedia ada.

Design of 0.5 Hp Induction Motor Rotor Bars with 0.35 mm and 0.50 mm Thickness of Steel Sheets for Rotor Fabrication

ABSTRACT

In this project, the 0.5 Hp three phase induction motor have been thoroughly investigated and analyzed in terms of the induction motor parameter, torque, efficiency, power factor, losses reduction, transfer mechanism and economic aspects. Throughout this project, the performance and the development of the three phase induction motor when it design and modelling by using 0.35 mm and 0.50 mm thickness of steel sheets was fabricated and compared it. First, the mathematical analysis of alternating current (AC) induction motor is done to calculate all the loss and equivalent circuit parameters for 0.5 Hp 3 phase induction motor. This is to show the efficiency and the amount of energy that is consumed in an induction motor. Second, the research involves designing and simulating the 0.5 Hp 3 phase induction motor using MotorSolve IM software, AutoCAD software, Opera 2D software and MATLAB software. From the simulation, analysis such as power loss, magnetic flux density, eddy current density, torque vs. speed, power loss vs. speed, efficiency vs. speed, and power factor vs. speed is done. A comparative study is done between the uses of 0.35 mm and 0.50 mm thickness of material in the rotor of induction motor. Third, the rotor part of an induction motor for different thicknesses are fabricated and investigated in terms of its efficiency increment, power factor improvement, flux distribution and loss reduction capabilities. Fourthly, experimental procedures are performed on the 0.5 Hp 3 phase induction motor can divide by two main focuses such as test on material (like nominal, in plane and thermister for search coil method), and test performance on rotor fabrication of induction motor (like No-Load Test, DC Resistance Test and Block Rotor Test) are performed in order to prove the efficiency data obtained from simulation. This is done, in order to determine the losses, transfer mechanism and to investigate the efficiency of 0.5 Hp 3 phase induction motor with 0.35 mm and 0.50 mm thickness of steel sheet. From the overall experiment of software and hardware, the results show that the 0.35 mm thickness has an increment 4% of the efficiency, 5.5% of the power factor, and 1.6% of torque and has an decrement 50.1% of eddy current loss, 8.98% of stator copper loss, 25.25% of core loss, and 12.37% of the rotor copper loss compared to 0.50 mm. An economical aspect was presented to shows that the saving cost by replacing the existing of induction motor with the new design of induction motor can reduce the utility billing by RM 2.46 million (89%) compared to existing of induction motor.

CHAPTER 1

INTRODUCTION

1.1 Background of Rotating Electrical Machine

The design of a rotating electric machine can be started with the basic features of a particular such as internal operation, external construction, and controlling performance of machine. Type of machine, construction, rated power, rated rotational speed, number of pole pairs, rated frequency and rated voltage of the machine are important parameters to be considered in machine design. Other important parameters are number of phases, intended duty cycle, standard applied in the machine design, economic boundary conditions, manufacturability, enclosure class and structure of the machine. Besides that, in machine design there is a considerable number of free parameter such as slot width, slot teeth, air gap, rotor bar slot, stack length, inner diameter and outer diameter. When aiming for an optimal solution, the task becomes extremely complicated unless the number of these free parameters is limited. Therefore, many free parameters vary only slightly, and the task will be simplified hence can be assumed constant (Juha Pyrhonen, 2008).

The induction motor is a significant category in electric machines. It is widely applied as a motor in industry as well as working independently in some domestic applications. Today, more than 85% of industrial motor is using induction motors. It is substantially a constant speed motor with an internal characteristic; a few per cent speed drop from no-load to full-load. It is a singly-fed motor (stator-fed), unlike the synchronous motor which requires alternating current (AC) supply on the stator side and direct current (DC) excitation on the rotor. The torque developed in the motor has its origin in the induction rotor current can only be done at the speed of asynchronous machines. On the other hand, torque in asynchronous machine is developed only at asynchronous speed when the "locking" of the two fields takes place. Therefore, the induction motor is not plagued by the stability problem inherent in the asynchronous motor (Kothari, D. P., & Nagrath, 2010).

Selecting the best induction motor for a specific application requires consideration of many factors and often presents a complex problem that requires sound judgment and considerable experiences. To optimum the performance of driven machine, the motor must be selected to match as closely as possible to the operating characteristic of the load. In order to assist the purchaser in selecting and obtaining the proper motor for the particular application, the National Electrical Manufacturer Association (NEMA) has developed the product standards. The motor standard includes the frame dimensions, voltage and frequency, power ratings, service factors, temperature rises, and performance characteristics. The benefits derived from these standards are greater availability of motors, a sounder basis for accurate comparison of machines, prompter repair service, and shorter delivery time. The NEMA data stamped on motor nameplates provide a wealth of information on motor operation, characteristics, and applications (Hubert, 2002).

The stator of an induction motor consists of a frame with a magnetically active, annular cylindrical structure as known as stator lamination stack punched from non-grain oriented electrical steel sheet and has a three phase winding set embedded in evenly spaced inside internal slots. The individual coils of this electrical winding are random-wound for smaller motors and form-wound for larger motors. The rotor of an induction motor is made up of a shaft-mounted in term of magnetically active and cylindrical structure as known as rotor lamination stack also constructed from non-grain oriented electrical steel sheet punching with evenly spaced slots located around the outer periphery to accept the conductors of the rotor winding. The rotor part can be divided by two types which are squirrel cage and wound rotor (Cathey, 2001).

The lamination thickness of steel sheet is a vital property of electrical steels. The reducing lamination thickness of steel sheet will restrain eddy current loss, but decreasing of lamination thickness of steel sheet will cause the price more expensive and will be tended to deteriorate of the iron space. The power loss of lamination steel sheet is assessed at specified peak operation inductions, e.g. 1.5 Tesla, therefore the quantity at the active cross-sectional area of metal is required. Width and length of lamination steel sheet is comparatively easy to measure. Loss is unit of watts/kg and the mass is available from the multiplication of width, length, density and thickness. Generally, loss is the unit of watts/kg hence the mass is determined directly from a weighting machine. Then, the lamination thickness of steel sheet was calculated by using a conventional method of density. On other occasions, the lamination thickness of steel sheet may be determined and the mass of lamination steel sheet will be calculated from width, length and conventional method of density. However, the entrench of