PERFORMANCE EVALUATION OF THREE PHASE INDUCTION MOTOR USING ROTOR FRAME 0.35 mm AND 0.50 mm OF NON-ORIENTED STEEL SHEETS

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by

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LIST OF ABBREVIATIONS

B	Magnetic Flux Density
H	Magnetic Field Intensity
DC	Direct Current
AC	Alternating Current
HP	Horse Power
IEEE	Institute Electric and Electronic Engineering
IEC	International Electrotechnical Commission
EDM	Electrical Discharge Machining
FEM	Finite Element Method
LF	Load Factor
ASD	Adjustable Speed Drive
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

Penilaian Prestasi Motor Induksi Tiga Fasa Dengan Kerangka Pemutar Kepingan Keluli Tak Berorentasi 0.35 mm Dan 0.50 mm

ABSTRAK

Dalam tesis ini, motor aruhan arus ulang alik tiga fasa telah di kaji dengan teliti dan dianalisa pada aspek parameter, kecekapan, faktor kuasa dan kehilangan kuasa yang berlaku pada motor aruhan ulang alik tiga fasa. Sepanjang projek ini, perbandingan dibuat terhadap prestasi motor aruhan tiga fasa yang di reka bentuk dan dimodelkan dengan menggunakan dua (2) ketebalan kepingan steel yang berbeza, 0.35 mm dan 0.50 mm berasaskan bahan-bahan yang tidak berorientasikan keluli elektrik dengan saiz rotor bar 10 mm. Bahagian pertama perbandingan dilakukan dengan simulasi menggunakan Perisian FEM. Keputusan dari perisian FEM dibandingkan dari segi kehilangan kuasa, ketumpatan fluks magnet, ketumpatan arus pusar, tork vs kelajuan, kehilangan kuasa vs kelajuan, kecekapan vs. Faktor kelajuan dan kuasa vs kelajuan. Bahagian kedua ialah perbandingan antara dua (2) rotor sebenar yang direka dengan saiz daripada kepingan steel dengan ketebalan 0.35 mm dan 0.50 mm masing-masing. Saiz bar pemutar untuk kedua-dua rotor ialah 10 mm. Dalam bahagian ini, kedua-dua pemutar, telah diuji dengan ujian tanpa beban, ujian pemutar disekat, dan kaedah ujian rintangan arus terus (AT) untuk mendapatkan perbezaan kecekapan, kehilangan dan faktor kuasa. Eksperimen keseluruhan iaitu menggunakan perisian FEM dan pemutar yang dibina, keputusan menunjukkan bahawa pemutar dengan ketebalan kepingan steel 0.35 mm meningkatkan kecekapan sebanyak 1.4% dan mengurangkan kerugian sebanyak 13.27 watt berbanding dengan pemutar dengan ketebalan kepingan steel 0.50 mm. Dari aspek ekonomi adalah didapati bilangan tenaga dan wang yang boleh dijimat dengan mengantikan pemutar 0.50 mm dengan pemutar 0.35 mm. Dari segi penjimatan tenaga tahunan (AES) dan penjimatan jumlah kos (TCS), pemutar yang berketebalan 0.35 mm mampu menjimatkan 40.32 kWh untuk setahun dan dengan nilai sebanyak RM 13.54 untuk satu motor setahun. Akhir sekali, satu anggaran kasar dibuat untuk penjimatan 100, 000 biji motor aruhan yang telah digantikan dengan pemutar yang berketabalan 0.35 mm dan menunjukkan sebanyak RM 1.35 juta boleh dijimatkan setahun.

Performance Evaluation of Three Phase Induction Motor Using Rotor Frame 0.35 mm and 0.50 mm of Non-Oriented Steel Sheets

ABSTRACT

In this project, the three phase AC induction motor have been thoroughly investigated and analyzed in terms of the induction motor parameter, efficiency, power factor and loss segregation. Throughout this project, the performance of the three phase induction motor when it design and modeling by using two (2) different thickness, 0.35 mm and 0.50 mm, of non grain oriented electrical steel sheets with 10 mm rotor bar size. The first part of comparison is done with simulation using FEM Software. The results from FEM Software were compared in terms of power loss, magnetic flux density, eddy current density, torque vs. speed, power loss vs. speed, efficiency vs. speed and power factor vs. speed. The second part is the hardware comparison between two (2) fabricated rotors with sizes of lamination thicknesses 0.35 mm and 0.50 mm respectively. The size of rotor bars for both rotors is 10 mm. In this part, the two (2) different thicknesses for rotor frame were tested with no load test, blocked rotor test, and direct current (DC) resistance test methods to obtain the difference of efficiency, losses and power factor improvement. From the overall experiment of software and hardware, results shows that 0.35 mm thickness rotor does increase the efficiency by 1.4% and reduce losses by 13.27 watts compared to 0.50 mm rotor. An economical aspect is presented to show the amount of energy and billing that can be saved from replacing the 0.50 mm with the 0.35 mm rotor lamination steel. As for the annual energy saving (AES) and total cost saving (TCS), the 0.35 mm lamination thickness rotor manage to save 40.32 kWh per year and utility billing by RM 13.54 per year per motor. Finally a rough estimation of 100,000 pieces induction motor that have been replaced with the 0.35 mm thickness for rotor frame is assumed and shows that it will save approximately RM 1.35 million per year.

CHAPTER 1

AIM OF THE INVESTIGATION

An induction motor is sometimes called a rotating transformer because the stator is essentially the primary side of the transformer and the rotor is the secondary side. Induction motors are widely used, especially poly-phase induction motors, which are frequently used in industrial arena (Theraja, B.L. & Theraja, A.K., 1998).

The induction motor machine is an important class of electric machines which finds wide applications. More than 85% of industrial motors in use today are in fact induction motors. Induction motors are complex electromechanical devices utilized in most industrial applications for the conversion of power from electrical to mechanical form. Three phase induction motor are used because it is simple, rugged, low price, and easy to maintain. They run at essentially constant speed from zero to full-load (Theodore, W., 2006).

Induction machines represent a class of rotating apparatus that includes induction motors, induction generators, induction frequency converters, induction phase converters, and electromagnet slip couplings. Induction motors can be used effectively in all motor applications, except where very high torque or very fine adjustable speed controller is required. Induction motors can range in size from fractional horsepower to more than 100 000 horsepower. They are more rugged, simplest, require less maintenance, and are less expensive than direct-current motors of equal power and speed ratings (Charles I. Hubert P.E, 2002)

The aim and objective of this research is to investigate the performance of AC induction motor using different thickness of steel sheets which are 0.35 mm and 0.50 mm based on losses and efficiency. The investigation involved a study to assess the effect of an induction motor's efficiency (3 phase/4 pole/10 rotor bar slots). The first stage of the research involves designing and simulating the 0.5 HP three phase AC induction motor using FEM 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 were done. A comparative study then carried out to know how the usages of different thicknesses of material influenced the performance of induction motor. The second stage is to construct a rotor frame for both thicknesses of the 0.5 HP induction motor. Laboratory tests, such as no load test, DC resistance test and block rotor test, are done to investigate in terms of its efficiency increment, power factor improvement and loss reduction capabilities. This is done, in order to determine the losses of the Induction Motor and to investigate the efficiency of three-phase induction motor of both thicknesses which are 0.35 mm and 0.50 mm.

CHAPTER 2

INTRODUCTION OF ROTATING MACHINE

2.1 Introduction of Rotating Machine

Francois Arago (1824) has developed the idea of rotating magnetic field and first implemented by Walter Baily. Nikola Tesla of United States conceived the principle of rotating magnetic field in 1882 which lead him to create the first brushless AC motor or induction motor in 1883. The induction motor was then understood and developed by Galileo Ferrari, in Italy in year 1885. In 1888, Ferraris published research in the paper Royal Academy of Sciences in Turin in which he detailed theoretical basis to understand how the motor operates. Separately, in the same year, Tesla raised U.S. Patent 381,968. Induction motor with a cage created by Mikhail Dolivo-Dobrovolsky about a year later (Chapman, S. J. (Ed.). (2005)).

Induction machines are rotating classes of apparatus including induction motor, induction generator, induction frequency converter, converters and electromagnetic induction phase slip coupling. Induction motor can be used effectively in all motor applications, except where the torque is very high or very finely adjustable speed control is required. They are more rugged, require less maintenance, and less expensive than direct current motors of the same power and speed ratings (Chapman, S. J. (Ed.). (2005)).

Induction motor requires transfer of energy from a stationary to a rotating member through electromagnetic induction. Rotating magnetic field which is generated by a stationary winding induces alternating emf and current in the rotor. The resultant rotor current-induced interaction with the rotating field winding produces a stationary motor torque (Akbaba, M., Taleb, M., & Rumeli, A. (1995)).

Induction motor has the same physical stator as a machine with different rotor construction. There are two different types of rotor induction motor can be placed in the stator. One is called the induction motor rotor cage, while the other is called the wound rotor. Cage induction motor rotor consists of a series of exercise bars set into the slot carved in the face of the rotor and shorted at the end of either the large bypass ring. This design is called a cage rotor induction motor as a conductor in which if examined, would seem like an exercise wheel for hamsters. Wound rotor induction motors are more expensive than a cage induction motor because it requires more maintenance due to wear associated with their brushes and slip rings. Due to this reason wound-rotor induction motors are seldom used (Bottauscio, O., Chiampi, M., Concari, C., Tassoni, C., & Zucca, M. (2008)).

According to Stranges, N. RDF (1994) when the machine rotates, the pattern of flux in the core can be very complex. Some sections of the core flux face rotation, especially at the back of the stator teeth and slots. The degree of polarization of the various flux densities may be encountered. Empirical scaling factor is often required in order to do damage predicted a loss normally found in a rotating machine (Stranges, N. RDF (1994)). An iron loss in the motor occurs due to the alternating, high frequency, and flux rotation (Findlay, RD. et al, 1994).

2.2 Background of Three Phase (3ϕ) Induction Motor

The most common type of three phase electric load is three phase electric motors. Three-phase motors are more compact and less expensive than single-phase motors of the same voltage class and rating. Three-phase induction motor has a simple design, is high starting torque, and efficiency. The motor that is used in industry are the three phase pumps, fans, blowers, compressors, delivery drivers, and other types of three-phase motor equipment. There are many benefits of using a three-phase electric motor rather than single phase electric motor. (Retrieved from: http://www.3phasepower.org/3phasemotors.htm).

When single-phase electricity is needed, it can be found between any two phases of three-phase system, or in some systems, between one phase and ground. By using three-conductor, three-phase system can provide 173% power for more than two conductors per phase system. Three-phase power allows heavy duty industrial equipment to operate more smoothly and efficiently. Three-phase power can be transmitted over long distances with smaller conductor size (Retrieved from http://www.3phasepower.org/3phasemotors.htm).

2.3 Rotor Fabrication with Manufacturing Aspect

Challenges faced during the used of different rotor material are during the starting, this is due to the motor is subjected to extreme operating conditions. During this period, the rotor cage will reach its thermal limit before the stator winding. It is during this operation that requires a high conductivity material such as copper which can offer greater range of higher resistivity and higher thermal margin. Copper also provides a lower coefficient of expansion, higher tensile strength and ideal conductivity. Copper rotor construction can provide greater reliability, efficiency, and versatility. Among things to be considered are as follows:

- Rotor core should consist of solid stack of thin high-grade (low loss) fully processed silicon-coated steel laminations.
- The core is pressed and held together with two heavy rotor endplates and studs.
- Shaft is shrunk with a heavy interference fit to prevent core movement under all operating conditions.
- Copper or copper alloy bars (depending on the design requirements) are used to achieve specified torque and high efficiency.
- Bar mounted tightly in the slot and remain locked in the slot with the swaging* process, to prevent vibration and broken bar.
- Bars are brazed to resistance rings at each end of the rotor.
- Bar connection between the ring core and the resistance of glass with tape stripe (which is saturated with resin) and oven cured "rock hard" consistently to prevent any vibrations of laminated teeth that occur.
- The rotor is turned to the right size to achieve the required air gap.
- Cooling fans are mounted at each end of the rotor, some cooling fan rotor resistance fused ring disposed.
- The rotor is dynamically balanced in two places to the very low level of residual imbalance; weight approximately remains welded in place.
- The rotor is coated with red epoxy insulating protective coating of varnish or other (according to customer specifications) to prevent corrosion.