Design of Induction Motor using Magnet Software and Analysis using Finite Element Analysis

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***Abstract*—Induction motor is one of the most commonly preferred motors used in the industry due to its long life & rugged construction. Faults occurring in an induction motor can significantly affect the performance of the motor and the drive which is running it. This paper aims to design and an induction motor .To implement analysis first the machine is modeled using MAGNET software. The motor is studied under healthy conditions. In the model of induction rotor bars are studied mostly based on magnetic field analysis of the motor under healthy conditions.**

MAGNET Soltware, Finite Element Analysis, Magnetic Field Intensity (key words)

1. INTRODUCTION

Motors convert electrical energy to mechanical energy by the interaction of magnetic fields set up by in the stator & rotor windings. All the four motors have the same operating components: stator (stationary parts), rotor (rotating parts), bearings & enclosure. The name induction motor arises from the nature of the developed torque. Torque is developed when voltage is applied to the stator and current begins to flow in the stator windings.

The stator winding currents produce a magnetic field that rotates in a counterclockwise direction. The changing magnetic field of the stator induces electromotive force in the rotor cage winding. The induced emf causes current to flow and magneto motive force in the rotor windings. In turn the rotor mmfs produce a magnetic flux pattern which also rotates in the air gap at the same speed as the stator winding field. Induction motors are the most commonly used prime movers in industrial applications. They are best suited for constant speed applications. Speed control can also be done with the help of power converter circuits. The 3-phase squirrel cage induction motor is the workforce of the industry as it is rugged & reliable.

The interaction between the primary field and secondary currents produces torque from zero rotor speed onwards. The rotor speed at which the rotor currents are zero is called ideal no-load or synchronous speed. The rotor windings may be multiphase (wound motors) or made of bars short-circuited by end rings (cage rotors). All primary and secondary windings are placed in the uniform slots stamped into thin silicon steel sheets called laminations. The induction machine has a rather uniform air gap of 0.2 to 3mm.The secondary windings may be short circuited or connected to an external impedance or to a power source of variable voltage and frequency.

Induction motors are the most commonly used prime movers in industrial applications. They are best suited for constant speed applications. Speed control can also be done with the help of power converter circuits. The 3-phase squirrel cage induction motor is the workforce of the industry as it is rugged & reliable. Electrical related faults are frequently occurring faults in three-phase induction machine which will produce more heat on both stator and rotor winding. This leads to the reduction the life time of induction machine.

Stator winding fault in Induction Motors can be detected using Unknown Input Observer (UIO) & Extended Kalman Filter methods. They are used for speed estimation and fault detection methods respectively[1].Using analysis of permeance and MMF harmonics, frequency of air gap flux density harmonics which occur due to irregularities are calculated. It helps in detecting faulty ball bearing conditions [2]. A procedure for electromagnetic design of three phase Induction Motor is discussed. This procedure is based on self-consistent equations. The electrical and magnetic properties are imposed by the user but the geometric dimensions are automatically calculated [3].The choice between Copper rotor bar s and fabricated Aluminum rotor bars is discussed and debated. The fundamentals of rotor construction and basic information on how the Induction Motor works are discussed [10]. The new IEC standard which defines the stator winding insulation requirement when the Induction Motor operates with Adjustable frequency drives (AFDs) is discussed. The magnetic noise that may be generated if higher frequency voltage harmonics are present in the AFD is minimized.

2. DESIGNING THE THREE PHASE INDUCTION MOTOR USING MAGNET SOFTWARE

Designing the induction motor consists of designing the stator, rotor, ball bearings, end rings & shaft. The stator consists of the stator core & winding. Stator core is made up of laminated sheet steel of thickness of 0.5mm. The stator core internal diameter & length are the main dimensions of the induction motor. All the values of the diameter & length have been by measuring them from a real induction motor. Hence the respective values for diameters of different parts are:

1. Stator frame-600mm
2. Stator Bore-460mm
3. Rotor-324mm
4. Shaft-1mm
5. Ball bearings-2.2mm
6. End Rings-3mm

The length of the motor has been assumed to be 40.5mm. Air gap can be calculated from the following formulae:

$Lg=0.2+2[(DL)^{1/2}]$ in mm where Lg-air gap, D=Diameter of the stator bore & L= Length of the motor.
$Lg=0.2+D$ in mm where D is the diameter of the stator.

Rotor core is made up of laminated sheet steel of thickness 0.5mm.The Copper bars & end rings are directly casted over the rotor core. The current rating assigned=7.5Amperes & Number of conductors=100. When Copper is employed, the rotor bars are inserted on the slots from the end of the rotor & end-rings are joined to them by bracing. Cold Rolled Stainless Steel is used as design material for stator, rotor, and ball bearing. Aluminium is used for the construction of end ring. The bars used in the rotor are made up of Copper & are skewed. The conductors used are also made up of copper.

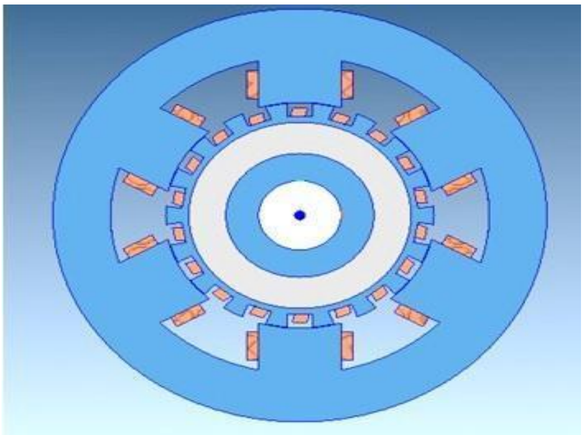

Fig 1: Designed Model of Three Phase Induction Motor Using MAGNET

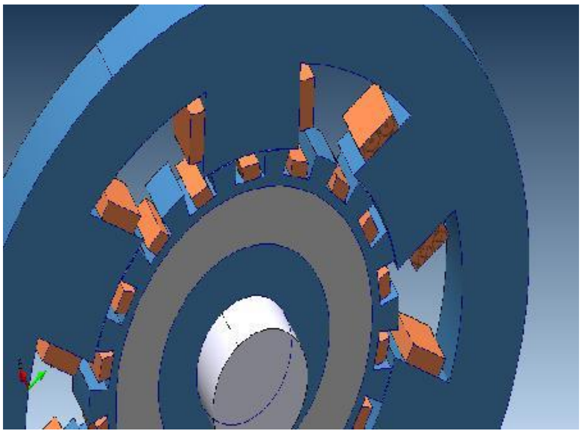

Fig.2.Close View of the Induction Motor

Fig.2. shows a close view of the induction motor modelled using MAGNET software. Shaft is denoted by the white coloured cylindrical structure protruding outside

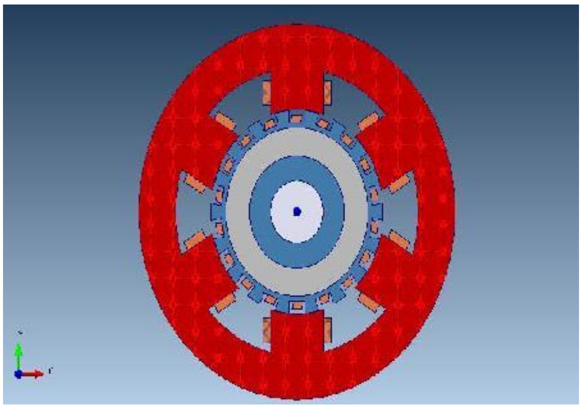

Fig. 3. Checking leakage of modelled induction motor

In MAGNET software an area depicted by the deep-red colour shown above is a proof that the component doesn't have any holes or leakage. In the above figure it means the stator component is perfectly designed and it doesn't have any leakages or air gap. Similarly the accuracy of the design of all the components was verified by implementing the features of the MAGNET software to all other parts

Fig.4. depicts the arrow plot of the magnetic field lines. The red colored lines show heavy magnetization while the blue color arrows show relatively weak magnetization. The direction of the magnetic field is in accordance with the polarity of the excitation. The left-hand side pole windings are given positive excitation & the right-hand side pole windings have been given negative polarity. Hence one can clearly see the magnetic flux lines rotating in an anticlockwise direction. The magnetic field is the strongest n ear the stator poles and then on the rotor slots. This observation is in accordance with the working principles of an induction motor

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The application of the finite element method in the design of electrical machines is proficient in the determination of important design parameters, such as flux linkages, induced voltages, core losses, winding inductances and electromagnetic torque developed, with a very high accuracy.

3.FLUX PLOTS

Prediction of flux distribution is very useful for the design process. It gives the status of magnetic saturation throughout the machine as well as the ratio of leakage to useful flux in various parts of the magnetic circuit. Once the value of the vector potential has been determined at each node, the flux distribution is plotted.

4. CALCULATION OF FLUX LINKAGES

Consider one pole of the motor carrying a concentrated winding. The flux that is linked by a representative turn of a coil can be expressed in terms of the flux density B and the area enclosed by the coil. At this point, non-linear continuum problem, will be reduced to a set of non-linear algebraic equations. The most common solution method is the Newton - Raphson (N-R) algorithm and the resulting set of equations is solved by Gaussian elimination. The N-R algorithm starts from an assumed value for the reluctivity ν and proceeds by means of iterations. In each iteration, ν is updated with respect to the B-H characteristics of the material.

5. ANALYSIS OF THREE PHASE INDUCTION MOTOR

After the three phase motor was designed, it was simulated in 2D. The resultant magnetic field intensity plot was obtained and analyzed. The resultant field circle graph shows the magnetic field intensity at a radius of 160mm from the centre at various points around the circle. From point 0 to 0.05, H is highest as this part of the rotor comes directly under the stator and is the slot area of the rotor. Just as it reaches the edge of the rotor pole, it becomes 0. It remains 0 from 0.05 to 0.1 as some of the part of this region falls in the air gap and most of the field lines pass through this region due to low reluctance

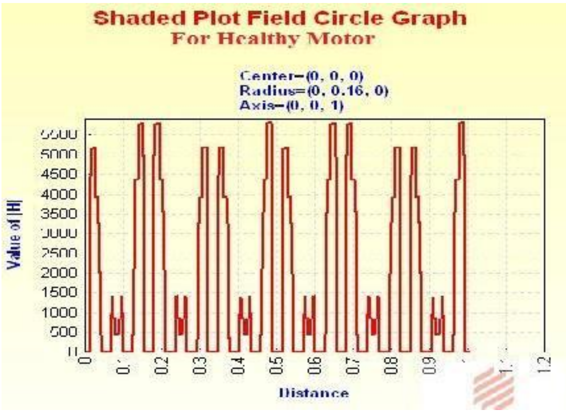

Fig. 5. Variation of Magnetic Field Intensity with Radii for Healthy Motor

The breaks in the peaks arise due to the positioning of the rotor copper bars with respect to the stator poles. When they are perfectly aligned, the field intensity is less compared to when they are just moving out of the influence of 1 stator pole & entering the influence of the second. The torque value was calculated to be 15.92 Nm under healthy conditions

6. CONCLUSION

A three phase induction motor was designed using MAGNET software. Its magnetic field intensity was analyzed near the rotor bars. Flux distribution and magnetic saturation are plotted and analysed for this three phase induction motor by using MAGNET software.

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