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Study of Optimization of Squirrel Cage Induction Motor Using DCR Technology

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Abstract: **Induction motors are versatile electric motors suited best for industrial applications as well as low-power application in domestic equipment because of their unique advantage compared to other types such as dc and synchronous motors. Electric motors do not transfer 100% of the input electrical energy into kinetic mechanical energy. A certain percentage of electrical energy is "lost" during the conversion to mechanical energy. These losses, in motor windings, core and rotating mechanical parts reduces the energy efficiency of motors. In today's power crisis condition it is very important to manufacture the motors which are more efficient than the standard motors which are already available. The AC induction motor has been continuously improved by optimising stator and rotor design and electric material properties and quantities. With given exterior motor dimensions, the potential efficiency gain is limited and costly. DCR technology is a new development to reduce losses by using copper instead of aluminium for the conductor bars and end rings in rotors to enhance its efficiency and performance. This paper reviews the historical development in squirrel cage rotor designs, importance of energy efficient motors, efficiency improvement, adoption of DCR technology and the optimization of 3- phase squirrel cage induction motor.**

Keywords: **Induction motor, Squirrel cage rotor, Losses, Energy efficiency, Optimization and DCR technology.**

1. INTRODUCTION

In a three phase induction motor, three phase ac supply is given to the stator winding. The flux from the stator, flowing through the air gap links the rotor circuit. It induces emf in rotor circuit and current in rotor circuit produces torque to rotate the rotor.

This motor is also called asynchronous motor because their operating speed is slightly less than synchronous speed.

Similar to the other rotating electrical machines, a three-phase induction motor also consists Stator, Rotor, Shaft, Bearings, Cooling fans and End plates

Electrical conductivity is a key operating parameter in determining which type of material to use in rotor conductors. Conductors of better conductivity result in more efficient transfer of electrical energy.

Materials has good electrical conductivity are Silver, Copper, Gold & Aluminium. Since silver and copper are precious and costly materials and their property for carrying heavy current and high voltage never allows as a choice of conductor in electrical machines. So the obvious choice is either aluminium or copper.

Since, efficiency being the ratio of the amount of work produced to the amount of energy consumed. The motor losses are the difference between input and output powers, and can be classified into five categories:

1. Iron losses: magnetic losses occur in core laminations.

2. Stator copper losses due to current in stator winding.

3. Rotor copper losses due to current in rotor windings.

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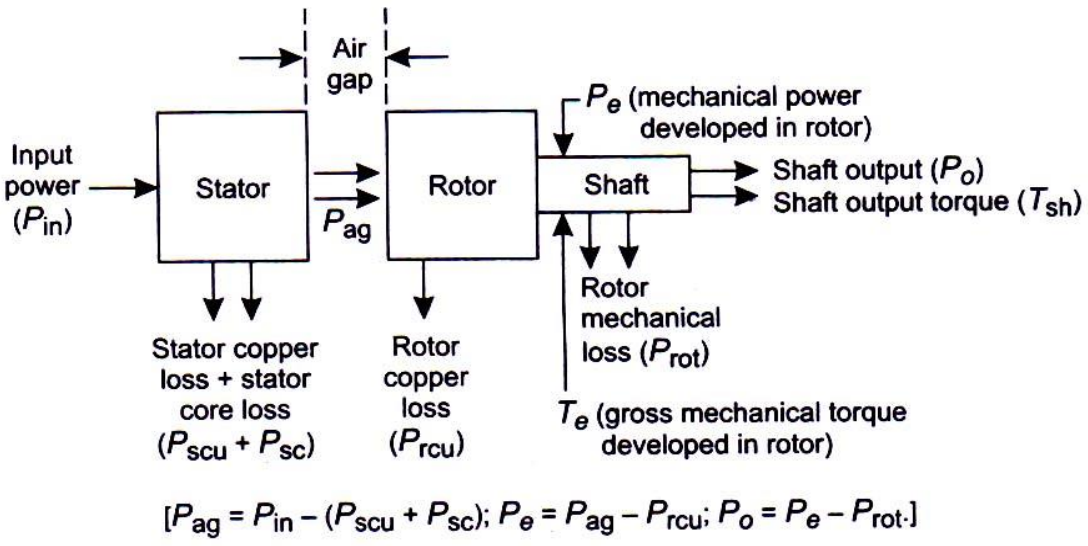
4. Wind age and friction losses due to mechanical drag in bearing and fans.

5. Stray load losses.



2. OPTIMIZATION

The design of electrical machine is both science and an art. A science it follows established and universally accepted physical and mathematical principles which have been verified by experimental methods and an art in that knowledge of these principles is often inefficient to produce correct and economic design. This can only be achieved by correct decisions based upon judgement and intuitions and through understanding of the subject.

The design of electrical machines consist essential solution of many complex and diverse engineering problems and normally these problems are closely interrelated to a greater or a lesser degree.

The aim of optimization in the design of electrical machines is to choose the best solution for a given problem from the multitude of possible solutions. The optimization process, therefore involves the choice of various variables in such a manner that the design in regard to a particular feature is the best, and at the same time satisfied all limitations imposed on its performance.

Hence, optimization is the collective process of finding a set of conditions required to achieve the best from a given situation.

A characteristic feature of optimization in designing of electrical machine is the presence of conflicting or opposing influences.

In modern day the major challenge in designing the rotating machine are:

1. It should be Energy Efficient

2. It should be Economical to design

It is clear that the new challenge in machine design is to optimize the efficiency and manufacturing cost both. The best design will be obtained by the compromise of two main factors i.e. cost and performance, the two exerting opposing influences.

Performance optimization means motor is high efficient, has low losses and low temperature rise during the operation. Where, the cost optimization means the overall manufacturing cost of the motor should be minimised.

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3. ENERGY EFFICIENT MOTORS

An 'Energy Efficient' Motor produces the same shaft output (H.P.), but absorbs less input power (KW) than a standard motor of same rating.

Efficiency = Output power / Input power

= (Input power – losses) / Input power

= 1 – (losses / Input power)

Energy – efficient motors, also called premium or high efficiency motors. Motors qualify as 'energy efficient' if they meet or exceed the efficiency level standards. In conventional design, the cost of motor increases while attempting to reduce the losses.

In simplest terms, energy-efficient electric motors are high-quality versions of standard motor products. They pack more of 'active' electric materials (steel laminations and copper) into essentially the same physical package.

4. SQUIRREL CAGE ROTOR DESIGNS

The Squirrel cage rotors are manufactured by two ways:

1. Fabrication techniques **2.** Die Cast technique

A fabricated rotor is one in which the rotor bars are individually inserted and then shorted together on each end rings. The rotor bars may be aluminium, copper or the alloys of aluminium or copper. The end rings are usually the same material as the bars.

Die casting is a process involving injecting molten metal at a high pressure into a mold or cavity (called a "die") in order to manufacture a part quickly and repeatedly. Die casting is commonly used in high production volume applications to manufacture small or medium size parts.

Hence, die casting is a cheaper manufacturing technique comparing to fabrication technique because fabrication is a time consuming, costs high labour and doesn't fit for industrial volume production requirements.

Based on the choice of conducting material for rotor winding and the after development of manufacturing techniques, following types of rotors design exist for a squirrel cage induction motor:

1. Fabricated Copper Bar Rotor (CuBar)

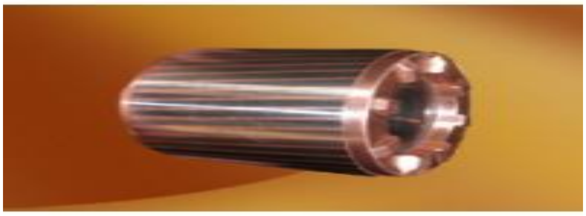
2. Fabricated Aluminium Bar Rotor (AlBar)

3. Aluminium Die Cast Rotor (DAR)

4. Copper Die Cast Rotor (DCR)

5. COPPER DIE CAST ROTOR (DCR) TECHNOLOGY

For the three phase low voltage Induction motor, the used material for the cage rotors is aluminium because of lower price when compared to copper, which was convenient for the existing technological solutions.
As it is known, the copper's resistivity is lower than that of aluminium, and therefore the copper cage rotor losses decrease with the ratio of resistivity of copper to resistivity of aluminium.



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Hence for the same current requirement, the substitution of copper for aluminium results in (16.06 – 10.37) / 16.06 = 35.04 % reduction in copper losses. It helps in significant improvement in efficiency and reduction in temperature rise during the operation of motor which is loaded continuously for hours.

Die casting is a process involving injecting molten metal at a high pressure (1500 – 25000 psi) into a mold or cavity in order to manufacture a part quickly and repeatedly. Typically, die casting is done with low melting temperature metals, given their typically lower cost of processing. Occasionally, higher melting temperature metals such as ferrous alloys are also used in die casting, but this is rare given the higher processing costs.

DCR technology or DCR rotors are those in which conducting material is copper in place of aluminium and rotor is manufactured by Die casting method. The molten material is the copper and its alloys in place of traditional light weighted aluminium rotor.

The previous challenges of die casting copper, which are higher temperatures and pressures compared with die casting aluminium, have been solved with the development of a die casting process using nickel base alloy die inserts operated at elevated temperature.

6. BENEFITS OF DCR ROTOR

Die cast copper rotors can provide advantages in three ways:

1. Improvement in motor energy efficiency in operation

2. Reduction in overall manufacturing cost

3. Reduction in motor weight

If motor re-design efforts are solely to improving efficiency, it is estimated that the new design with DCR could achieve 92.5% efficiency. This DCR motor creates a super-premium efficiency motor with an efficiency level higher than currently available motors.

The superior conductivity of copper over aluminium, ensures reduction of motor losses by 14 – 23 % and rotor I^2R losses by 29 – 41%, leading to improvement of the overall efficiency of the motor by at least 2% - 5 %, for the same slot design.

Copper die cast rotors operate at 10 – 12^0 C less, than aluminium die cast rotors, resulting in doubling the life of insulation, thus increasing the service life of the motor. Copper rotors reduce operating temperatures due to their lower I^2R losses. Elevated temperatures accelerate degradation of the insulation on motor’s winding, eventually leading to failure.

Although the cost of die-casting a copper rotor is higher than that of die-casting an aluminium rotor, the overall cost of the motor utilizing the copper rotor can be lower. Due to the higher efficiency of the copper rotor, the overall length of the rotor (and motor) can be decreased, while still matching the performance of a motor utilizing an aluminium rotor.

7. CONCLUSION

From the above discussion it can be concluded that:

By keeping the main dimension and other design parameters constant, replacing copper in place of aluminium in die-cast rotors, the rotor winding resistance losses get decreased because of the higher conductivity of the copper and its alloy. It sure helps in improving the efficiency level and reduces the temperature rise of the motor during its operation. It is certainly the performance optimization of a standard efficient induction motor.

On the other hand when the performance parameters (i.e. losses, efficiency, temperature rise, output power etc.) remains constant and aluminium is replaced by copper in die cast rotor , the main dimensions (Overall length D and stator bore diameter L) can be decreased. It reduces the overall manufacturing cost and over all weight of the motor. It is certainly the cost optimization of the motor.

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