Increasing efficiency of AC induction motor by reducing temperature: A Review

[1]Shrikant Gawas, [2]Rushikesh Gosavi, [3]Aishwarya Asolkar, [4]Kirti Chavan, [5]Nitesh Jadhav

[1]Assistant Professor, [2,3,4,5]UG in Mechanical Engineering
Mechanical Engineering Department,
SSPM COE, Kankavli, Maharashtra, India

***Abstract*: Heat is the common cause for reduction in life and efficiency of the motor. When motor is operated heat generated which causes different type of losses. Increase in operating temperature reduces the insulation resistance of the motor. Insulation resistance of the motor can be increased by adding different insulating material which enhances the properties of the enamel used for coating of stator winding. Different materials for increasing insulating property of enamel are given in this paper. The paper presents different methods to increase the rate of heat dissipation which can be implemented to improve the efficiency of the motor.**

***Index Terms*: Three Phase AC induction motor, insulation resistance, heat generate, temperature.**

I. INTRODUCTION

The three phase ac induction motor is one of the most important motor used in the industry. It is used to convert electrical energy into mechanical energy. Its high performance at low cost in and its reliability make them the most popular alternating current motors used in the industrial and commercial fields. Three phase induction motors consumes more than 40% of industrial electricity of world because of its simple construction as well as easy operation [10].

It was found that, 1% increase in efficiency of all the motors in India will save 500 MW powers which needs the initial generation cost of 2000crores [1]. Therefor it is important to improve the efficiency of induction motor. Efficiency have grate relation with the operating temperature of motor. It is also mainly depend upon property of enamel used for coating of winding of motor. During the operation of motor heat generated which causes some losses such as iron loss, copper loss, core loss etc. which greatly affected on the performance and efficiency of three phase ac induction motor. As heat generated there is increase in the temperature inside motor. All electric motors have their predetermined life span, typically ranging from 30,000 to 40,000 hours. The life of motor decrease with increase in the operating temperature of motor. Every 10 rise in temperature can reduced half of the insulation life which causes decrease in motor life [6]. Increase in a temperature causes several losses in the stator winding and greatly affected on the efficiency and life of the motor, so it is very important to reduce temperature of that type of motor. As temperature reduces insulation resistance increases. This paper give review on the methods of the efficiency increasing in Ac induction motor by reducing temperature of motor. Also in this paper we suggest some insulating material for deep in enamel so that increasing insulation resistance of motor.

II. LITERATURE REVIEW

Improving efficiency of motor which save more energy. Efficiency of induction motor can be increased by improving cooling performance inside and outside of motor as well as improving property of material used for insulation or improving electromagnetic interference.

Kishor S. Deshmukh[2];In this paper they have proposed written pole technology used in three phase induction motor, which has a stator consist of three phase windings inside a core and a squirrel cage rotor with ferrite material coated on its periphery. These improves the power factor and because of ferrite layer the losses are minimized. The efficiency of motor is also improved.

The performance of three phase induction motor is studied with different operating voltages. The three phase induction motor is loaded with Written Pole Technology with Main Winding Voltage 237.9 Volt, Exciter winding voltage 0 Volt. The readings are observed and compared with the readings of three phase induction motor of main winding voltage 239 Volt, Exciter Winding Voltage 7.73 Volt and frequency 648 Hz.

A three phase induction motor with specification 0.75kW, 3-phase, 4-pole, 1440 rpm, and written pole technology is designed, fabricated and tested successfully. When motor is rotated with main winding of 238V supply, the exciter winding is unexcited, thus motor gives less speed range with higher % slip and high line current but when exciter winding is excited with high frequency, motor rotates with wide speed range at lower slip and lower line current. The experimental results illustrate that the efficiency of motor is improved to 84% as well as the power factor is improved to 0.828.

D.Edison Selvaraj [3];In this paper AL2O3 is used as nano filler. Adding nano fillers to the enamel will greatly improve thermal, mechanical and electrical property of enamel. The Ball meal method is used for converting the micro particle of AL2O3 into the nano particles. The winding is dipped in enamel filled with AL2O3 nano filler for coating of the three phase induction motor.

The performance analysis of three phase induction motor was carried out by no load test, block rotor test and load test. Based on the calculation and result obtained by the test it is observed that the efficiency of induction motor coated with enamel filled with nano filler AL2O3 is increased by 4%, compared to that of induction motor coated with pure enamel.

To determine the total loss of energy disappear as heat, heat run test carried on these motor. It is found that the thermal withstanding capacity of the motor was also improved by 11% by adding AL2O3 Nano filler to the motor.

Subramanian Manoharan[4];The basic losses in an induction motor consist of resistance losses in the stator winding, and rotor cage, iron losses, friction and windage losses, and stray loss. The idea is to replace copper bar in the rotor structure with aluminum bar. The resistivity of copper is less than the aluminum. Hence using copper instead of aluminum results in reduction in resistance loss. High electrical conductivity of copper in the rotor of a squirrel cage induction motor can achieve a reduction in overall energy losses around 11%–19%, Hence increases the energy efficiency.

Due to the labor cost, the fabrication cost is more than die-cast technology. This rotor gives low starting torque and also requires high star up current. Due to higher weight of rotor, rotor inertia increases. Efficiency increase in small motor is higher. A review of the various aspects like implementation of Die-Cast Copper Rotor (DCR) Motor, Efficiency improvement, Energy saving potential, adoption of DCR Technology in India and application of DCR motor in agricultural application has been made in this paper. The DCR motor also reduces the production of greenhouse gases and reduces the total environmental cost of electricity generation.

Banti khan[1];In this paper, the stator and core temperature of three phase induction motor is lowered by means of WCCA method. By the conduction, convection and radiation modes of heat transfer, heat is transferred to the outer casing of motor. Heat is uniformly distributed which results in rise in temperature of surrounding. This method is used to lower down the temperature of the stator winding. So, resistance decreases as result efficiency of motor increases. Most of the losses occur in the stator part of motor. The stator is the major source of heat dissipation. WCCA method increases the thermal withstand capacity and efficiency of motor. A Capillary jacket is used which is placed above the casing of motor. The structure of capillary jacket is a hollow cylindrical structure. Inner layer is made by porous material of Tatties matrix which is used in evaporators for coolers. Materials used to prepare apparatus for this method are easily available and of low cost. WCCA method is highly effective due to high specific heat capacity of water and high heat transfer coefficient.

D. Edison Selvaraj[5]; Enamel filled with SiO2 and TiO2 Nano composite is prepared and it is used as the coating for the induction motor. The efficiency increase of 5% is observed, by addition of Nano composites of SiO2 and TiO2 (1:3) to the enamel of the induction motor used as the coating for the windings of the three phase squirrel cage induction motor.

The total loss of energy dissipated as heat is determined by performing heat run test on electrical machine. Due to addition of Nano composites temperature withstanding capacity of the induction motor is increased. The values of electromagnetic inference produced by normal induction motor and Nano coated induction motor is also compared and analyzed. There was a reduction of 15 to 60% in the values of the electromagnetic interference produced by the normal induction motor, when compared to that of Nano composite filled enamel coated induction motor at various distances.

III. METHODOLOGY

Main causes of electric motor failure:

1. Over-Current, Over-Voltage- Phase voltage unbalance in a three-phase supply can cause electric motor failure due to an excess temperature rise. A 3% voltage unbalance causes an 18% temperature rise in the motor and a current increase of six to ten times the voltage unbalanced.
2. Low Resistance-Low resistance is caused by the degradation of the insulation of the windings due to conditions such as overheating, corrosion, or physical damage. At the starting of motor installation, the resistance of insulation is approximately one thousand mega ohms. After some time, the insulation performance starts to degrade rapidly because the resistance starts to decay gradually.
3. Over heating- **:** Excessive heat in motors can cause a number of performance problems. Overheating of the motor damages the winding insulation. When the power provided to the motor is of low quality then overheating can occur or when an electric motor is operated in a high-temperature environment. It has been concluded that more than 55% of the insulating failures are causes by overheating.
4. Dirt- Dirt is one of the major causes for damage of the electric motors. It can damage the motor by blocking the cooling fan which increases the temperature. It can also reduce the insulating value of the winding insulation if it settles on the motor winding.
5. Moisture-The performance of electric motors is also affected by Moisture. It causes the corrosion of the motor shafts, bearing and rotors. Which lead to insulation failure.

It is observed that every ten centigrade rise in temperature reduces the insulation life to half. The above failure causes the temperature rise which in turn reduces the insulation life as well as the motor's overall life span. So it is very important to maintain the temperature inside the motor.

IV. TEMPERATURE INSIDE THE MOTOR

Temperature rises in the motor windings as the AC motor is started. Every time the machine over-heats, the insulation deteriorate. Service life of motor will be reduced if the motor is operated at temperature greater than designed temperature. Coil temperatures variation affects much on the efficiency of motor [8].It is found that the hottest element in the induction motor is the stator end winding and the rotor bars [7].Following table 1 shows insulation classes for different operating temperature motor [6].The recommended temperature according to standards IEC 60085, IEC 60034-1.The classification of insulating materials is based on their maximum continuous working temperature, established for 20 years of working life.

Table 1 Insulating classes according to diferent operating temperature inside the motor

Temperature class	Hot spot allowance tenperature in
A	105
B	130
F	155
H	180

The main factor that shorted the motor life is heat. As current increases in the motor there is heat generation which causes increase in the temperature. Due to increase in temperature insulation resistance of the motor decreases which lead to damage the induction motor. The operating temperature and life of the motor have a great relation with each other which
is shown by the following graph in fig.1 [6].

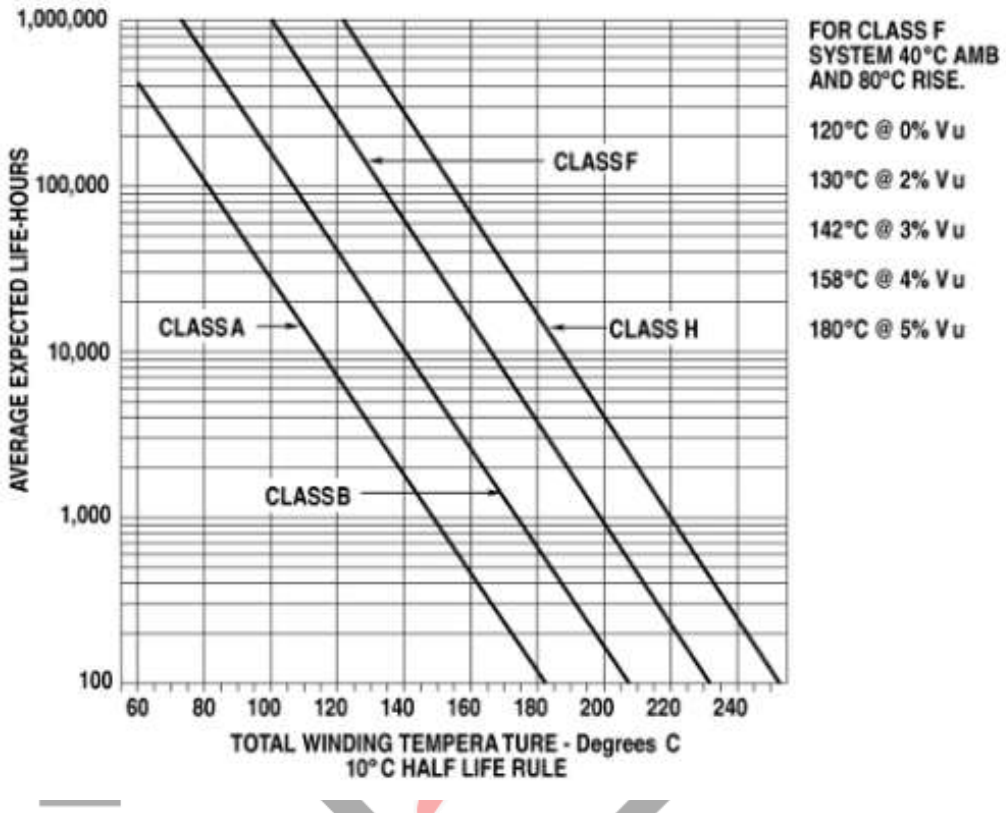

Figure 1Relation between temperatture aand life of motor

V. PROPERTY OF DIFFERENT INSULATING MATERIAL

Efficiency of the motor can be improve by adding good property of insulating material in the enamel. During operation these materials may be subject to electrical, thermal and mechanical stresses. Exceeding the temperature limit results in acceleration of the oxidation process in insulation materials which leads to induction motor damage [9].These are the materials which can be added for improving property of the enamel which result in increasing efficiency and improving thermal withstand capacity.

The material and their mechanical, electrical and thermal property given below [10].

Table 2 Mechanical property

Mechanical	Unit	ZnO	Al2O3	SiO2	TiO2	ZrO2
Density	g/cm3 (lb/ft3)	5.606	3.69	2.16/2.65	4.23	5/6.15
Porosity	%	0	0	0	0	0
Elastic Modulus	GPa (lb/in2x106)	73	300	45	230	115/ 711
Shear Modulus	GPa (lb/in2x106)	31	124	27.9/32.3	90/112.5	53.4/86.4
Refractive Index		1.46	1.17	1.46	2.67/2.55	2.13

Poisson's Ratio		0.17	0.21/0.33	0.15/0.19	0.27/0.29	0.22/0.33
Compressive Strength	MPa (lb/in2x103)	1108	2100	1100/1600	660/3675	1200/5200
Micro Hardness	Kg/mm2	600	1175	870/980	880	-
Fracture Toughness	MPa*m1/2	-	3.5	0.62/0.67	2.4/3.3	1/8
Maximum temperature (no load)	°C	1100	1700	879/1397	1840/1910	1248/2522

Table 3 Thermal property

Thermal property	**Unit**	**ZnO**	**Al2o3**	**SiO2**	**TiO2**	**ZrO2**
Thermal Conductivity	W/m*°K (BTU*in/ft2*hr*F)	1.38	18	1.3/1.5	4.8/11.8	1.7/2.7
Thermal Expansion Coefficient	10–6/°C or 10–6/°F	0.55	8.1	0.55/0.75	8.4/11.8	2.3/12.2
Specific Heat	J/Kg*°K (Btu/lb*°F)	740	830	680/730	683/697	420/540

Table 4 Electrical property

Electrical property	**Unit**	**ZnO**	**Al2O3**	**SiO2**	**TiO2**	**ZrO2**
Dielectric Strength	ac-Kv/mm (volts/mil)	30	16.7	25/40	4	1/12.5
Dielectric Constant	@ 1 MHz	3.82	9.1	3.6/4.2	10/85	10/23
Dissipation Factor	@ 1 kHz	0.00002	0.0007	0.001	0.5	0.02/0.03
Volume Resistivity	Ohm*cm	10^{12}-10^{14}	$>10^{14}$	10^{12}/ $>10^{18}$	$>10^{14}$	$>10^{12}$

VI. Conclusion

The temperature increase inside the motor reduces the life of the insulation used for winding, thus it affects the life of the motor. The efficiency of the motor can be increased by reducing the temperature rise inside as well as outside of the motor. Heat dissipation can be increased by adding good property insulating materials in the enamel. This paper has demonstrated the materials to increase the insulation properties of an enamel used for coating of stator winding of motor also different properties of the materials are demonstrated. The different methods to increase insulation properties as well as efficiency of the motor are studied.
Further studies are to be conducted in order to find out other methods to increase insulation resistance and life of motor by reducing temperature.

References

[1] Banti khan, Ashita Goyal, "Efficiency Improvement of Three Phase Induction Motor Using WCCA Method," International Journal for Research in Applied Science & Engineering Technology (IJRASET), Volume 3 Issue I, January 2015.

[2] Kishor S. Deshmukh, Dr. Prof. Kamal Bansal ,Dr. Atul Killedar, "Design and Development of Three Phase Induction Motor Using Written Pole Technology,"IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE) e-ISSN: 2278-1676,p-ISSN: 2320-3331, Volume 11, Issue 5 Ver. III (Sep - Oct 2016), PP 49-56 ,www.iosrjournals.org

[3] D .Edison Selvaraj,C.RubanKartik,R.Arun," Energy Efficient Three Phase Squirrel Cage Induction Motor fed AC Drives," International Journal of Science and Engineering Applications Volume 3 Issue 2, 2014, ISSN-2319-7560 (Online).

[4] Subramanian Manoharan, Nanjundappan Devarajan, Subbarayan M.Deivasahayam, Gopalakrishnan Ranganathan, "Review on efficiency improvement in squirrel cage induction motor by using DCR technology," Journal of ELECTRICAL ENGINEERING, VOL. 60, NO. 4, 2009, 227–236.

[5] D. Edison Selvaraj, Dr. C. Pugazhendhi Sugumaran, B. Guru Prakash, R. Vishnu Prakash, E. Muthupandi, R. Balakumar, "Analysis of Efficiency, Thermal Withstanding Capacity and Electromagnetic Interference of Three Phase Squirrel Cage Induction Motor Coated with SiO2 & TiO2 Nano Composite Filled Enamel," International Journal of Science and Engineering Applications (IJSEA) Volume 1 Issue 1, 2012.

[6] Bruno Baptista, André Mendes, Sérgio Cruz, António Cardoso, "Temperature Distribution Inside a Three-Phase Induction Motor Running with Eccentric Airgap," PRZEGLĄD ELEKTROTECHNICZNY (Electrical Review), ISSN 0033-2097, R. 88 NR 1a/2012.
[7] Omar Badran, Hussain Sarhan, Bilal Alomour, "Thermal performance analysis of induction motor".
[8] M. K. Yoon, C. S. Jeon, and S. Ken Kauh, "Efficiency Increase of an Induction Motor by Improving Cooling Performance," IEEE transactions on energy conversion, vol. 17, no. 1, march 2002.
[9] Aleksejs Gedzurs, Andris Sniders, "Induction motor stator winding thermal process research and modelling under locked rotor mode,"engineering for rural development, Jelgava, 29.-30.05.2014.
[10] Wan Akmal Izzati, Yanuar Z. Arief, Zuraimy Adzis,and Mohd Shafanizam, "Partial Discharge Characteristics of Polymer Nano composite Materials in Electrical Insulation: A Review of Sample Preparation Techniques, Analysis Methods, Potential Applications, and Future Trends," Hindawi Publishing Corporation e Scientific World Journal Volume 2014, Article ID 735070, 14 pages http://dx.doi.org/10.1155/2014/735070.
[11] S. Jeyadevi, C. Pugazhendhi Sugumaran, D.Edison Selvaraj, J.Ganesan, R. Anandharaj, K. Sathiyamoorthi, M. Raja, "An Innovative and Effective Efficiency Improvement of Single Phase Induction Motor by Using Nano Technology," ISSN(Online): 2349-9338, ISSN(Print): 2349-932X Volume -2, Issue -1, 2015.
[12] B.Guruprakash, R.vishnuprakash, E.Muthupandi, R.Balakumar, N.Vanaja, D.Edision selvaraj, "Improvement of Efficiency and Thermal Withstanding Capacity of Single Phase Induction Motor using organic Nano Filler Mixed Enamel," International Journal of Scientific & Engineering Research, Volume 4, Issue 4, April-2013.
[13] D. Edison Selvaraj, Dr. C. Pugazhendhi Sugumaran, D. Krishnamoorthi, M. Raj Kumar, J. Ganesan, S. Geethadevi, K. Rajaram, S. Dinesh Kumar, "Improvement of Efficiency and Thermal Withstanding Capacity of Single Phase Induction Motor," European Journal of Academic Essays 1(5): 10-15, 2014 ISSN: 2183-1904 www.euroessays.org.