Determination of the Wire size of a Three phase Squirrel Cage Induction Motor with a Missing Nameplate

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Abstract

An empty stator of a squirrel cage induction motor rated at 220/380V, 50Hz with a missing nameplate and without winding has been lying down in a factory for so long and now the factory wants to use it for production purposes. This is a motor whose class protection degree is IP44, IP54 or IP55. This paper presents a method of determining the wire size (diameter) required to rewind the motor to its full rating power capacity. With motor nameplate and using National Electrical Code (NEC) and National Manufacturers Association (NEMA) specifications, the diameter of the wire can be determined. In the absence of the nameplate and the windings, the motor is difficult to rewind in order to obtain its desired characteristics. This can be achieved by the measurement of main dimensions of motor stator, using standard rating specifications, standard performance curves and analytical method.

Keywords: Squirrel cage induction motor stator, nameplate, winding, number of poles, slots.

Introduction

The stator of squirrel cage induction motor of class protection degree IP44, IP54 or IP55 is made of stator of laminated core and pressed into a frame made of cast iron. The windings are housed inside the slots (Sen, 1997) and their arrangement depends on the number of poles of the motor. The type of motor protection degree can easily be identified by physical observation of the cooling means of that motor. Three phase squirrel cage induction motor of class protection degree IP44, IP54 or IP55 has one or two fans attached to its shaft at the sides of rotor to cool the circuit. Motor with IP23 have perforated holes for ventilation on the coupling side of the shaft. For a motor with a missing nameplate and without winding, its rewinding is difficult but as its operational voltage and the frequency from the power source to where the motor was previously installed are known, the size of the wire can be achieved by the following methods. The main dimensions of the motor stator (Deshpande, 2010) are first taken by measuring the inside and outside diameter of the stator by vernier caliper (Aggarwal, 2000). The height from the centre of the shaft to the base of the motor, which is known as the rotation height axis, h in mm is measured. Then using the rating standard according to National Electrical Manufacturers Association (NEMA) and National Electric Code (NEC) specifications, data from previous measurements and Standard performance curves and the use of analytical method, the size of the wire can be determined.

Materials and methods

The main dimensions of the empty motor stator without coils are compared with the National Electrical Manufacturer Association (NEMA) and National Electrical Code (NEC) specifications. International standardization of physical dimensions and frame sizes means that motors from most manufacturers are physically interchangeable and they have similar performance characteristics.

Dins = Inside diameter of stator bore in meters (m)

Dout = Outside diameter of stator bore in metres (m)

Lg = Stator core length or length of the air gap in metres (m)

h = Rotation axis height, in mm

Figure 1 shows the main dimensions of the motor stator.

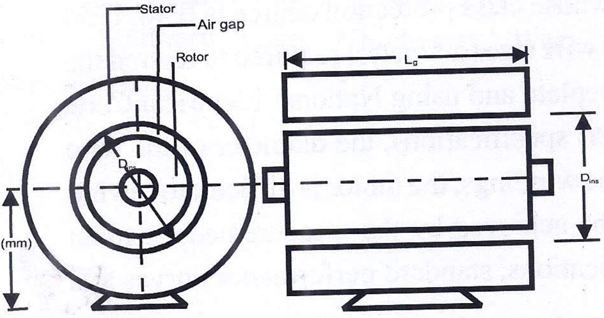


Fig. 1. Main dimensions of stator core

The outside diameters measured in metres (M) and their corresponding rotation height axes, h in mm, are simulated as shown in Figure 2.

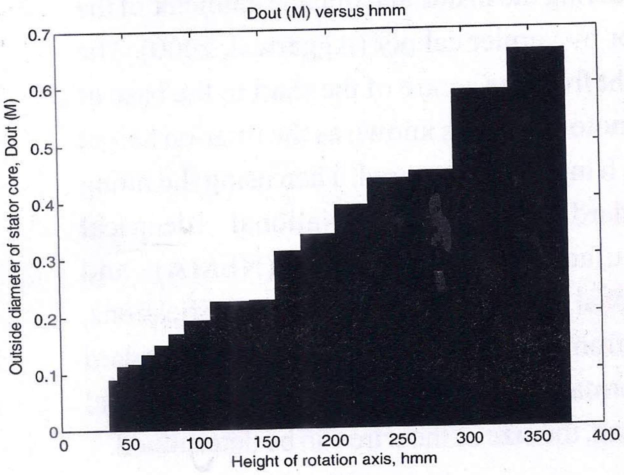


Fig. 2. Outside diameter of motor stator versus rotation height axis

Choice of the Number of Poles

The ratio of inside diameter of the motor stator to the outside diameter of the motor stator s given by $K_D = \frac{D_{ins}}{D_{out}}$ (1)

The value obtained in this relationship must correspond to the number of poles in the histogram shown in Figure 3.

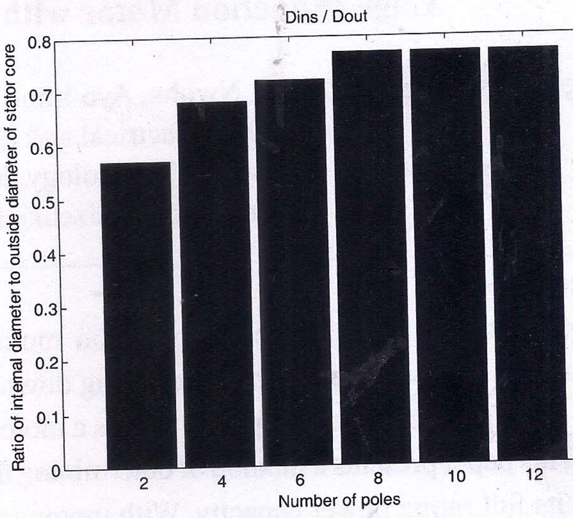


Fig. 3. Dins/Dout versus number of poles

Pole Pitch

The pole pitch is calculated as $\tau = \frac{\pi D_{ins}}{2P}$ (2)

Motor Speed

In (Pooler W.J.R.H, 2011), the synchronous speed of the motor in revolutions per minute, $n(s)\text{rpm} = \frac{60f}{P}$,

where P is the number of pair of poles and f is the frequency in hertz.

Horse power Rating

Having known the rotational height axis, h in mm, the number and the corresponding number of poles, the output power rating (□) in kilowatts of the motor is taken from a standard Table according to National Electrical Manufacturers Association (NEMA) specifications.

Power Factor And Efficiency

The apparent power is expressed as KVA=

$$\frac{h.p \times 0.746}{\eta \times Cos\theta} = \frac{KW}{\eta \times Cos\theta} \qquad (3)$$

Full load power factor usually varies between

0.82 and 0.92. High power factor is generally obtained with high speed motors. The full load efficiency, η usually varies between 0.82 and 0.93.

Angular Velocity

The angular velocity is given as $\Omega = \frac{2\pi n_{rpm}}{60} (rad/sec).$ (4)

Coefficient Form of Pole

The coefficient form of pole is $KB = \frac{\pi}{2\sqrt{2}} = 1.11$ (5)

Number of slots per pole and number of slots per pole per phase

The number of slots per pole is given by $\varsigma = \frac{Z}{2P}$ (6)

where Z is the number of slots

According to (Bakshi, 2009), the number of slots pole per phase is $q = \frac{Z}{2Pm}$ (7)

where m is the number of phase

Phase Current $\frac{P}{m \times U_{ph} \times Cos\theta \times \eta} (A)$ (8)

Air Gap Length (L_g)

The size of the air gap between the stator and rotor ranges from 1.25 mm, in small motors to 2.5 mm in large motors.

First, find the calculated value of power, $\frac{K_E}{\eta \times Cos\theta}$ (9) where p is power in kw and KE is the ratio of the stator winding e.m.f to its voltage rating.

The air gap length is given by:

$$L = \frac{P'}{K_B \times D_{INS} \times \Omega \times K_W \times ac \times B_g} (M) \quad (10)$$

The value of specific magnetic loading (Bg) is taken from Figure 4. The specific electric loading (ac) ranges from between 5,000 and 45,000 ampere-conductors per meter depending on the capacity of the motor.

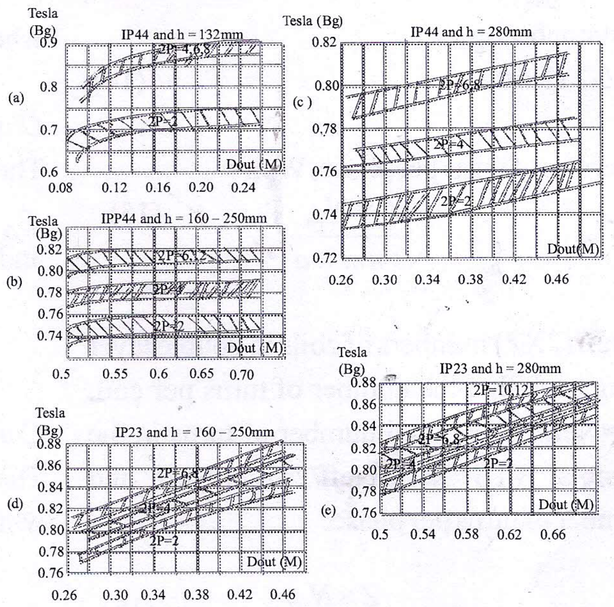


Fig.4: Bg versus Dout

Ratio, $\lambda = \frac{L_g}{\tau}.$ (11)

The value of λ should be within the permissible limit (Aggarwal, 2000).

Peripheral Velocity $v = \pi \times D_{ins} \times n_{rps}$ (12)

The value obtained must be less than the permissible limit of 30m/s or else the value of Dins should be measured again.

Effective Conductors (Neff)

The number of effective conductors (Neff') per slot when the number of parallel connections in a phase winding, 'a'=1 is given by Neff' =

$$\frac{\pi \times D_{ins} \times ac}{I_{phase} \times Z} \quad (13)$$

where ac is the specific electric loading and it varies from 5,000-45000A/M depending upon the capacity of the motor. If 'a' is more than one, the number of effective conductors per slot, Neff=Neff' x a.

Number of Turns (W)

There are Z/2 number of coils in single layer winding such that the total number of turns in the stator becomes,

WT=Z/2 xNeff. (14)

The number of turns per phase, Wph =

$$\frac{Z \times N_{eff}}{2 \times m \times a} \qquad (15)$$

There are (2XZ) numbers of coils in double layer winding such that the number of turns per coil, Wpc = Neff/2. The total number of turns in the stator slots, WTS=2Z X Neff/2=Z X Neff and the number of turns per phase:

$$W_{ph} = \frac{Z \times N_{eff}}{m \times a} \qquad (16)$$

Verification of specific electric loading, 'ac'

The value of 'ac' chosen in equation 13 must be equal to specific electric loading given by:

$$\text{'ac'} = \frac{2 \times I_{phase} \times W_{ph} \times m}{\pi \times D_{ins}} (A/M) \qquad (17)$$

Winding Factor (Kw)

Short-pitched coils cannot be used in single layer winding and its winding factor is 0.95 while short-pitched coils can be used in double layer winding. In double layer winding, the winding factor is the product of the span factor, the distribution factor and the skew factor (Barasubramanian etal, 2011).

Kw=Kpx Kd Kskew (18)

Magnetic Flux

The magnetic flux is given by, ϕ =

$$\frac{K_E \times U_{phase}}{4 \times K_B \times W_{ph} \times K_W \times f} (Wb). \qquad (19)$$

Verification of Specific Magnetic Loading

The value of 'Bg' chosen from Figure 4 must be equal to specific magnetic loading given by:

$$B_g = \frac{P \times \phi}{D_{ins} \times L_g} (Tesla) \qquad (20)$$

where P in this equation is the pair of poles.

Output Equation of an Induction Motor

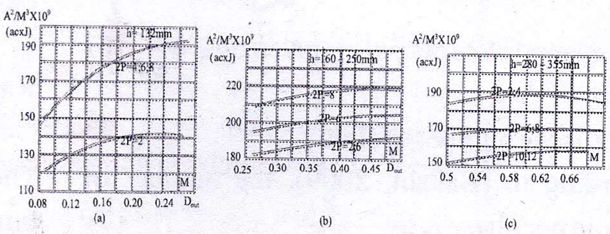
The output coefficient of an induction motor, $C_O = 1.11 \times \pi^2 \times K_W \times B_g \times ac \times 10^{-3}$ and the output equation is given by

$$KVA = C_O \times D^2_{ins} \times L_g \times n_{rps} \qquad (21)$$

Current Density of Stator Winding

The value of(acxJ) is taken from Figure 5 below while the current density of the coil is given by:

$$J = \frac{(ac \times J)}{ac} (A/M^2) \qquad (22)$$



An average value of (ac X J) for asynchronous motor with IP44

Fig.5 : (acxJ) versus Dout

The value obtained in equation (22) must correspond to that obtained below in equation (23)

The current density, J= $\frac{I_{phase}}{a \times S_{eff} \times n_{elem}} (A/MM^2).$ (23)

Area Of Effective Conductor

The cross-sectional area of an effective conductor, S'eff= $\frac{I_{phase}}{a \times J} (mm^2)$

The number of elementary conductor, nelem can be used. In such a case, the cross-sectional area of each wire or conductor, Snelem=(Seff/nelem) and the diameter of each of the elementary conductor, $dn_{elem} = \sqrt{\frac{4 \times Sn_{elem}}{\pi}} (mm).$

Results and Discussions

Two squirrel cage induction motor stators were tested through analytical method, using standard specifications of the empty motor stators of squirrel cage induction motors without nameplates and the windings and the results obtained are shown in Table 1.

Table 1. Results of tested empty stator motors

KW	η %	p.f	ac ^{3} A/M	Bav T	h mm	Z	a	2P	Dout (M)	Standard wire size in mm	Wire size obtained in mm
11	88	0.87	29	0.9	160	36	2	4	0.254	1.12	1.121
15	89	0.88	33.5	0.75	132	48	2	4	0.225	1.80	1.83

Conclusion

The results obtained are close to the desired results and some of the parameters of the nameplate data like the number of poles, synchronous speed, ns in revolutions per minute (rpm), power rating in kilowatts, phase current in Ampere, power factor, and efficiency were obtained.

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