Types of ac induction motor rotors.

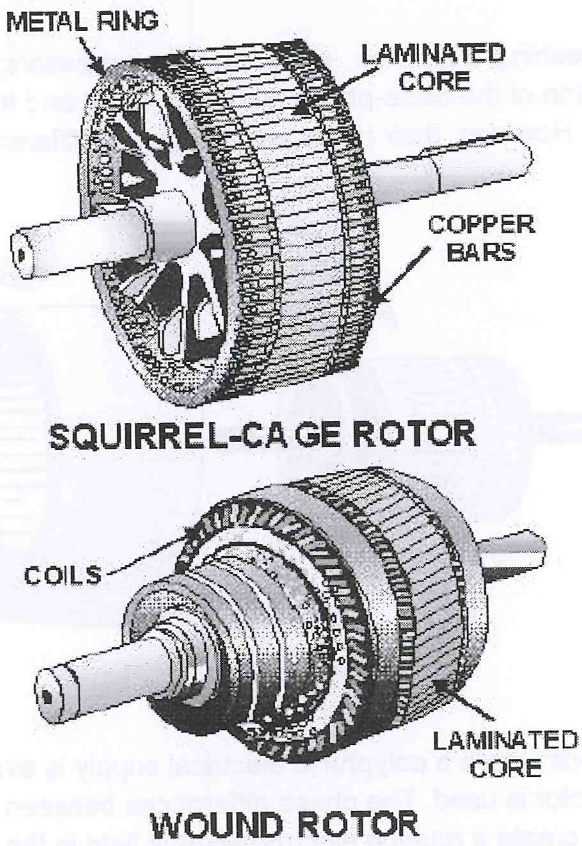
There are two types of rotors used in induction motors. Most use the cage or 'squirrel cage' rotor.

Single cage or double cage Known as Squirrel cage rotors.

The induction rotor is made of a laminated cylinder with slots in its surface. The windings in these slots are one of two types. The most common is the squirrel-cage winding. This entire winding is made up of_heavy copper bars connected together at each end by a metal ring made of copper or brass. No insulation is required between the core and the bars. This is because of the very low voltages generated in the rotor bars.

In the cage rotor, the number of bars is usually a prime number, such as 47.

Figure 8.2



Wound rotor

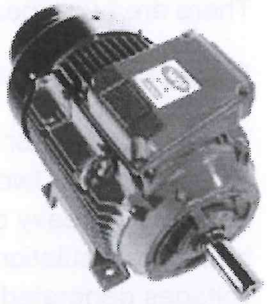
An alternate design, called the wound rotor, is used when variable speed is required. In this case, the rotor has the same number of poles as the stator and the windings are made of wire, connected to slip rings on the shaft. Carbon brushes connect the slip rings to an external controller such as a variable resistor that allows changing the motor's slip rate. In certain high-power variable speed wound-rotor drives, the slip-frequency energy is captured, rectified and returned to the power supply through an inverter.

Compared to squirrel cage rotors, wound rotor motors are expensive and require maintenance of the slip rings and brushes, but they were the standard form for variable speed control before the advent of compact power electronic devices.

Lecture 8 Operation of a polyphase induction motor – Types

Types: single cage, double cage, wound rotor

Introduction - Induction Motors



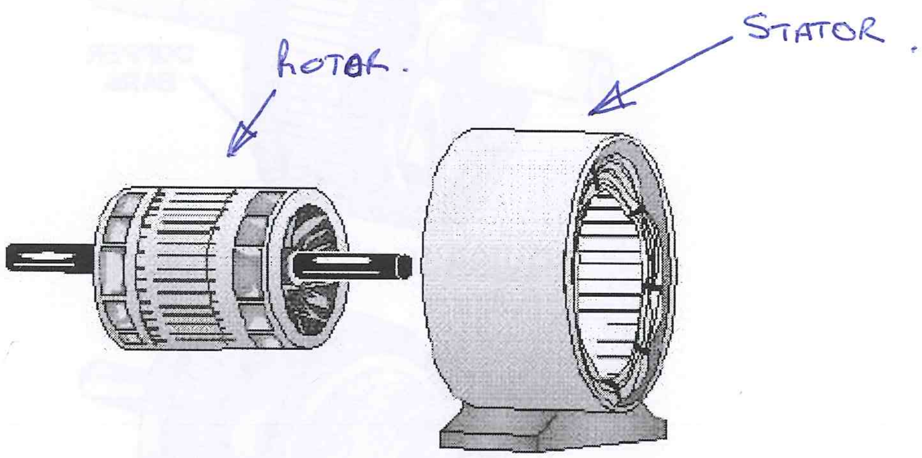
The induction motor is the most commonly used type of ac motor. Its simple, rugged construction costs relatively little to manufacture. The induction motor has a rotor that is not connected to an external source of voltage.

The induction motor derives its name from the fact that ac voltages are induced in the rotor circuit by the rotating magnetic field of the stator. In many ways, induction in this motor is similar to the induction between the primary and secondary windings of a transformer.

Large motors and permanently mounted motors that drive loads at fairly constant speed are often induction motors.

Examples are found in washing machines, refrigerator compressors, bench grinders, and table saws. The stator construction of the three-phase induction motor and the three-phase synchronous motor are almost identical. However, their rotors are completely different.

Figure 8.1



For higher-power applications where a polyphase electrical supply is available, the three phase (or polyphase) AC induction motor is used. The phase differences between the three phases of the polyphase electrical supply create a rotating electromagnetic field in the motor.

Through electromagnetic induction, the rotating magnetic field induces a current in the conductors in the rotor, which in turn sets up a counterbalancing magnetic field that causes the rotor to turn in the direction the field is rotating. The rotor must always rotate slower than the rotating magnetic field produced by the polyphase electrical supply; otherwise, no counterbalancing field will be produced in the rotor.

Induction motors are the workhorses of industry and motors up to about 500 kW in output are produced in highly standardized frame sizes, making them nearly completely interchangeable between manufacturers (although European and North American standard dimensions are of course different).

Electronic inverters with variable frequency drive can now be used for speed control and wound rotor motors are becoming less common. Electronic inverter drives also allow the more-efficient three-phase motors to be used when only single-phase mains current is available.

Regardless of the type of rotor used, the basic principle is the same. The rotating magnetic field generated in the stator induces a magnetic field in the rotor. The two fields interact and cause the rotor to turn. To obtain maximum interaction between the fields, the air gap between the rotor and stator is very small.

PRINCIPLE OF 3 PHASE INDUCTION MOTOR

1, A 3 Phase Supply to the Stator produces a rotating magnetic field, this speed is called the 'Synchronous Speed'

N_s rev. per. min

$N_s = \frac{60 f}{p}$ f = frequency in Hertz

p = Number of pairs of poles.

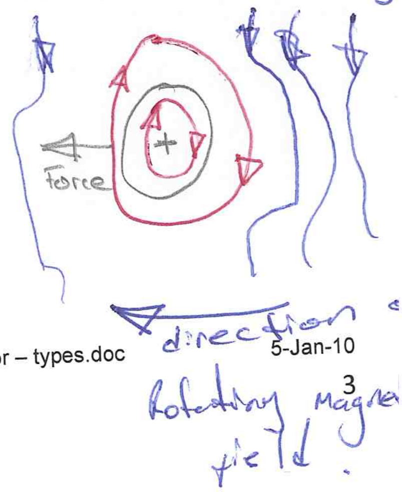
eg. A 4 pole, 3 phase 50 Hz induction Motor, has a synchronous speed of $N_s = \frac{60f}{p} = \frac{60 \times 50}{2} = 1500$ rpm

2, The rotating magnetic field sweeps past the rotor and induces an EMF into the rotor conductors (which have a low resistan[ce]) resulting in a large induced current.

3, This induced current produces a magnetic field which combines with the rotating magnetic field, resulting in a torque being exerted.

4, The rotor will turn in the same direction as the rotating field.

Rotor speed = N_R rpm.



5, Synchronous speed - Rotor Speed = Slip Speed

Per Unit Slip $= \frac{N_S - N_R}{N_S}$

or

$$S = \frac{N_S - N_R}{N_S}$$

Given, $N_S = 1500$ rpm

Slip, $S = 0.06$

Calculate the rotor speed.

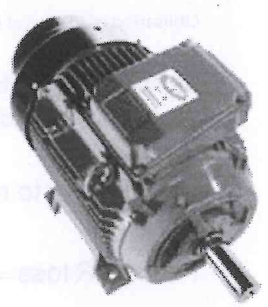
$$0.06 = \frac{1500 - N_R}{1500}$$

$$\therefore N_R = 1500 - 0.06 \times 1500$$

$$= 1500 - 90$$

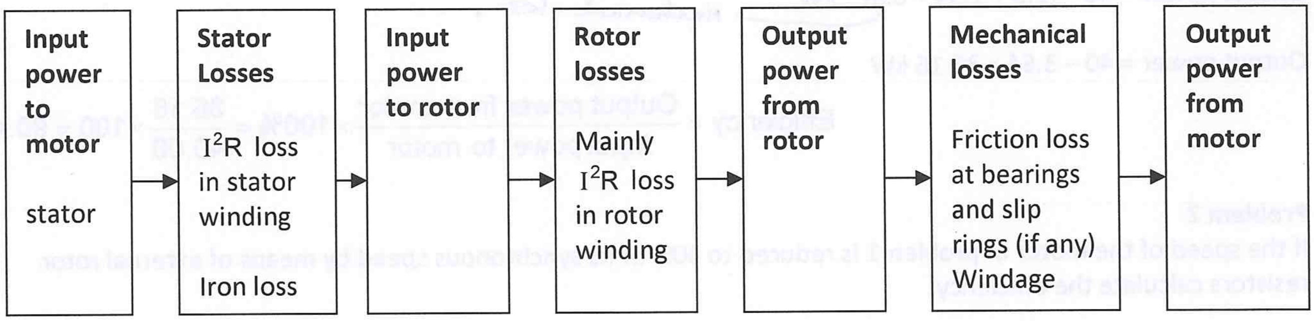
$$N_R = 1410 \text{ rpm}$$

ROTOR SPEED = MOTOR SPEED.



Efficiency of a three phase induction motor

Rotor = Rotating Magnetic Field produces an induced current into the rotor conductors resulting in a torque. NR



$$\text{Efficiency} = \frac{\text{Output power from motor}}{\text{Input power to motor}} \times 100\%$$

Input power to motor $P = \sqrt{3}\, V I \cos\phi$ (watts)

Output power = input power – losses

Output power = input power – (stator losses + rotor losses + mechanical losses)

Rotor I^2R loss = per unit slip × input power to rotor = s(input power to rotor)

Problem 1

The power supplied to a three phase induction motor is 40 kW and the corresponding stator losses are 1.5 kW and the friction and windage losses are 0.8 kW

(Assignment 5.1)

Calculate the efficiency of the motor when the slip is 0.04 per unit.

Solution 1 $\text{Efficiency} = \frac{\text{Output power from motor}}{\text{Input power to motor}} \times 100\%$

Output power = input power – (stator losses + rotor losses + mechanical losses)

Input power = 40 kW

Stator losses = 1.5 kW

SLIP × INPUT POWER TO ROTOR.

Rotor losses = Rotor I^2R loss = s(input power to rotor) = 0.04 (input power to rotor)

Mechanical losses = 0.8 kW

Output power = 40 – (1.5 + rotor losses + 0.8) kW

S = SLIP SPEED.

LOSSES = LOSSES IN STATOR + ROTOR LOSSES + MECHANICAL LOSSES

Calculate the rotor losses

input power to rotor = input power to the motor − stator losses

input power to rotor = 40 − 1.5 = 38.5 kW

Rotor I^2R loss = 0.04 (input power to rotor) = 0.04 × 38.5 = 1.54 kW

slip Rotor loss

Output power = 40 – (1.5 + 1.54 + 0.8) kW

input power stator loss Rotor loss Mechanical loss

Output power = 40 – 3.84 = 36.16 kW

$$\text{Efficiency} = \frac{\text{Output power from motor}}{\text{Input power to motor}} \times 100\% = \frac{36.16}{40.00} \times 100 = 90.4\%$$

Problem 2

If the speed of the motor of problem1 is reduced to 40% of its synchronous speed by means of external rotor resistors calculate the efficiency.

Solution 2 $\text{Efficiency} = \frac{\text{Output power from motor}}{\text{Input power to motor}} \times 100\%$

Output power = 40 – (1.5 + rotor losses + 0.8) kW

Calculate the **rotor losses**

input power to rotor = input power to the motor − stator losses

input power to rotor = 40 − 1.5 = 38.5 kW

Rotor I^2R loss = s × 38.5

Calculate the **slip** From $s = \frac{N_s - N_r}{N_s}$

The speed of the motor N_r is reduced to 40% of N_s $\Rightarrow N_r = \frac{40}{100} \times N_s = 0.4\,N_s$

per unit slip $s = \frac{N_s - N_r}{N_s} = \frac{N_s - 0.4N_s}{N_s} = \frac{N_s(1-0.4)}{N_s} = 0.6$

Now calculate the rotor I^2R loss

Rotor I^2R loss = s × 38.5 = 0.6 × 38.5 = 23.1 kW

Output power = 40 – (1.5 + 23.1 + 0.8) kW

Output power = 40 – 25.4 = 14.6 kW

$$\text{Efficiency} = \frac{\text{Output power from motor}}{\text{Input power to motor}} \times 100\% = \frac{14.6}{40} \times 100 = 36.5\%$$

Problem 3

The power supplied to a three phase induction motor is 50 kW and the corresponding stator losses are 1.6 kW and the friction and windage losses are 0.85 kW

Calculate the efficiency of the motor when the slip is 0.05 per unit.

[90.26%]

Input Power = 50 − 1.6 = 48.4 kW

Rotor Loss = 0.05 × 48.4 = 2.42 kW

Output Power = 50 − (1.6 + 2.42 + 0.85) = 45.13

$$\text{Efficiency} = \frac{\text{Output Power from Motor}}{\text{Input Power to motor}} \times 100\%$$

$$= \frac{45.13}{50} \times 100 = 90.26\%$$

Problem 4

A 25 kW, three-phase, 50 Hz, six-pole induction motor has a full load slip of 0.04 per unit. The mechanical loss is 300 W.

Calculate the rotor speed and the rotor I^2R loss.

[960 rpm ; 1.05 kW]

$$N_s = \frac{60f}{\text{Pairs of Poles}} = \frac{60 \times 50}{3} = 1000 \text{ rpm}$$

Synchronous Speed − Rotor Speed = Slip Speed.

Slip = 0.04.

$$S = \frac{N_s - N_R}{N_s} \quad \therefore \quad N_R = N_s - S \times N_s$$

$$= 1000 - (0.04 \times 1000)$$

$$N_R = 960 \text{ rpm.}$$

Rotor loss