Chapter Seven

Induction Motors

General Principle

As a general rule, conversion of electrical power into mechanical power takes place in the ***rotating*** part of an electric motor. In d.c. motors, the electric power is ***conducted*** directly to the armature (*i.e*. rotating part) through brushes and commutator. Hence, in this sense, a d.c. motor can be called a ***conduction*** motor. However, in a.c. motors, the rotor does not receive electric power by conduction but by ***induction*** in exactly the same way as the secondary of a transformer receives its power from the primary. That is why such motors are known as ***induction*** motors. In fact, an induction motor can be treated as a ***rotating transformer*** *i.e*. one in which primary winding is stationary but the secondary is free to rotate.

Of all the a.c. motors, the polyphase induction motor is the one which is extensively used for various kinds of industrial drives. It has the following main advantages and also some dis-advantages:

Advantages:

1. It has very simple and extremely rugged, almost unbreakable construction.

2. Its cost is low and it is very reliable.

3. It has sufficiently high efficiency. In normal running condition, no brushes are needed, hence frictional losses are reduced.

4. It requires minimum of maintenance.

Disadvantages:

1. Its speed cannot be varied without sacrificing some of its efficiency.

2. Its speed decreases with increase in load.

Construction

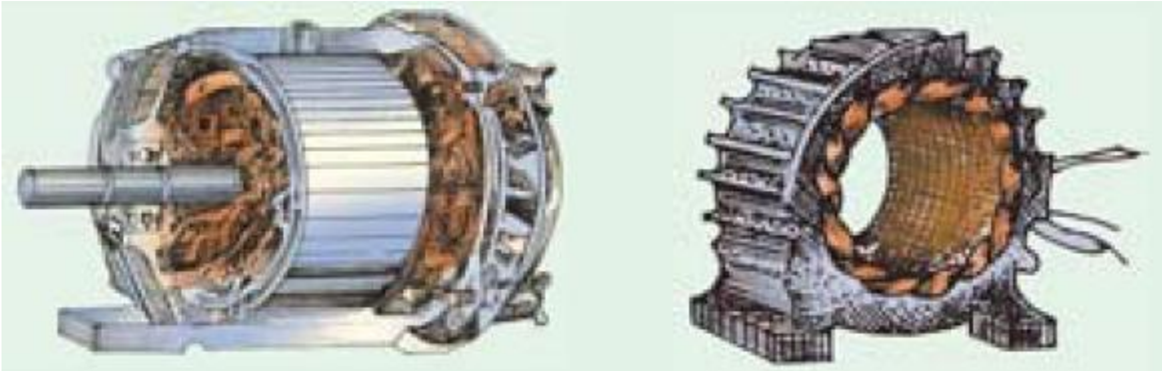
An induction motor consists essentially of two main parts :

(a) a stator and

(b) a rotor.

(*a*) Stator

The stator of an induction motor is, in principle, made up of a number of slots to receive the windings [Fig.7.1 (*a*)]. The stator carries a 3-phase winding [Fig.7.1 (*b*)] and is fed from a 3-phase supply. It is wound for a definite number of poles, the exact number of poles being determined by the requirements of speed. Greater the number of poles, lesser the speed and ***vice versa***. The stator windings, produce a magnetic flux, which is of constant magnitude but which revolves (or rotates) at synchronous speed (given by $Ns = 120\ f/P$). This revolving magnetic flux induces an e.m.f. in the rotor by mutual induction.



(a) (b)

Fig.7.1.induction motor.

(*c*) Rotor

Three-phase induction motors are classified into two types: squirrel-cage and wound-rotor motors. Both motors have the same stator construction, but differ in rotor construction

(*i*) *Squirrel-cage rotor* : Motors employing this type of rotor are known as squirrel-cage induction motors.

(*ii*) *wound rotor* : Motors employing this type of rotor are variously known as 'wound' motors or as 'slip-ring' motors.

Squirrel-cage Rotor

Almost 90 per cent of induction motors are squirrel-cage type, because this type of rotor has the simplest and most rugged construction imaginable and is almost indestructible. The rotor consists of a cylindrical laminated core with parallel slots for carrying the rotor conductors. One bar is placed in each slot. The rotor bars are electrically welded to two heavy short-circuiting end-rings, thus giving us, what is so picturesquely called, a squirrel-cage construction (Fig. 7.2).

The rotor slots are usually not quite parallel to the shaft but are purposely given a slight skew (Fig. 7.2).

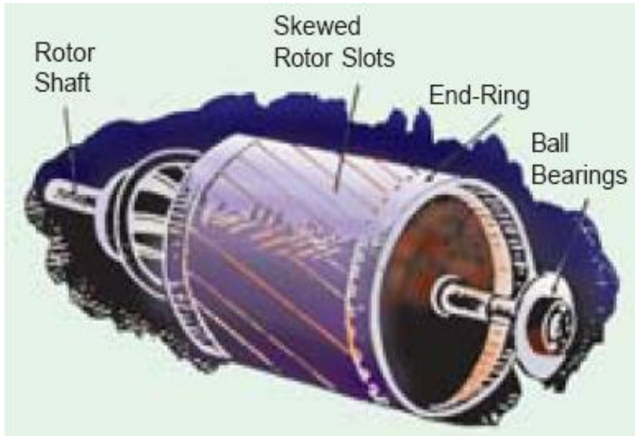


Fig. 7.2.

Speed and Slip

The speed of the rotating magnetic field is called the synchronous speed of the motor.

$$n = \frac{120f}{p}$$

where n = speed of rotating magnetic field, rpm

f = frequency of rotor current, Hz

p = total number of poles

The difference between rotor speed and synchronous speed is called slip and is expressed as a percent of synchronous speed.

$$\text{Percent } S = \frac{N_S - N_R}{N_S} 100$$

where S = slip

N_S = synchronous speed, rpm

N_R = rotor speed, rpm

Example: A four-pole 60-Hz squirrel-cage motor has a full-load speed of 1754 rpm. What is the percent slip at full load?

Solution:

$$\text{Synchronous speed } N_S = \frac{120f}{p}$$

$$= \frac{120(60)}{4} = 1800 \text{ rpm}$$

$$\text{Slip} = N_S - N_R = 1800 - 1754 = 46 \text{ rpm}$$

$$\text{Percent } S = \frac{N_S - N_R}{N_S} 100$$

$$= \frac{46}{1800} 100 = 2.6\%$$

Rotor Frequency

For any value of slip, the rotor frequency is equal to the stator frequency times the percent slip,

$$f_R = Sf_S$$

where f_R = rotor frequency, Hz
S = percent slip
f_S = stator frequency, Hz