Basic Electrical Technology

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Induction Motor

Classification Based On ***<u>Principle Of Operation</u>***:

(a) Synchronous Motors. 1. Plain 2. Super

(b) Asynchronous Motors.

1. ***Induction Motors:*** (a) Squirrel Cage (b) Slip-Ring (external resistance).
2. ***Commutator Motors:*** (a) Series (b) Compensated (c) Shunt (d) Repulsion

(e) Repulsion-start induction

(f) Repulsion induction

Classification ***Based On Type Of Current:*** 1. Single Phase 2. Three Phase

Classification Based On ***Speed Of Operation:***

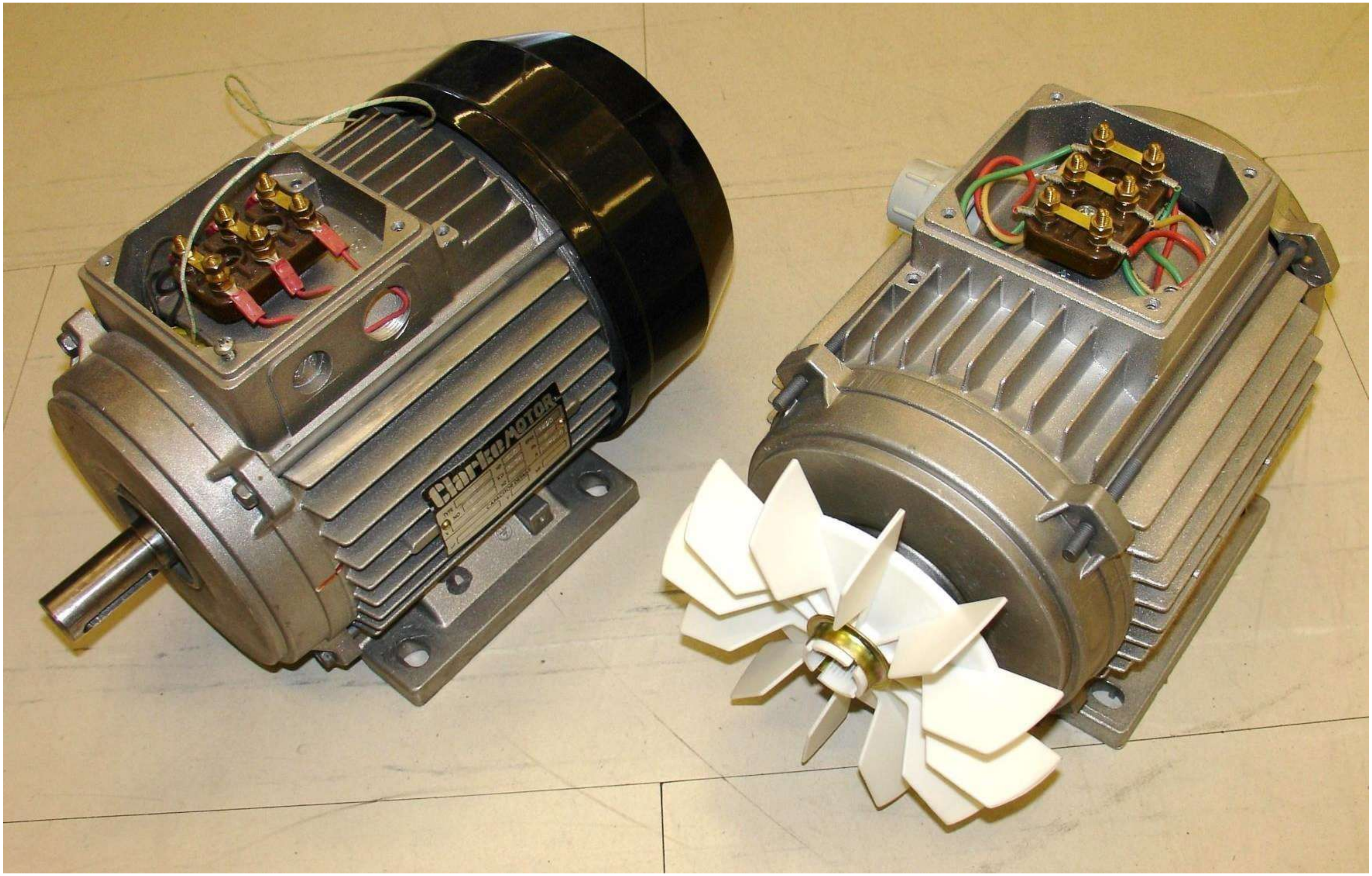
1. Constant Speed.
2. Variable Speed.
3. Adjustable Speed.

Classification Based On ***Structural Features:***

1. Open
2. Enclosed
3. Semi-enclosed
4. Ventilated
5. Pipe-ventilated
6. Riveted frame-eye etc..

Physical image of Induction Motor

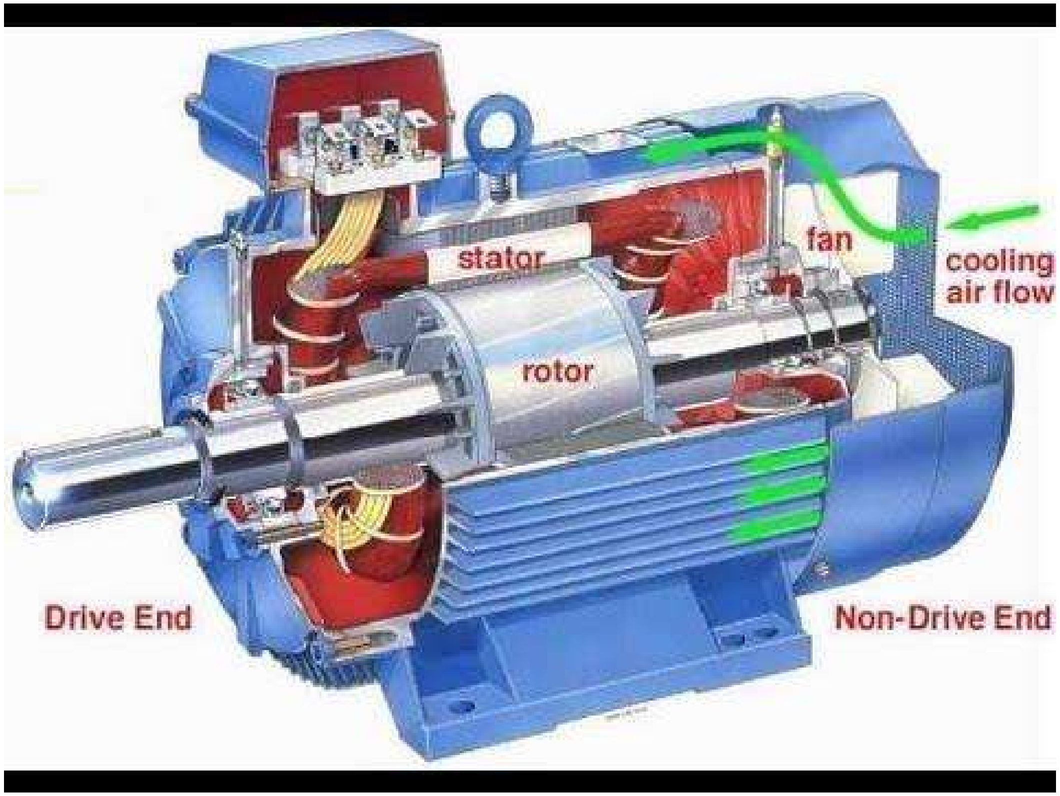
Terminal of Induction Motor

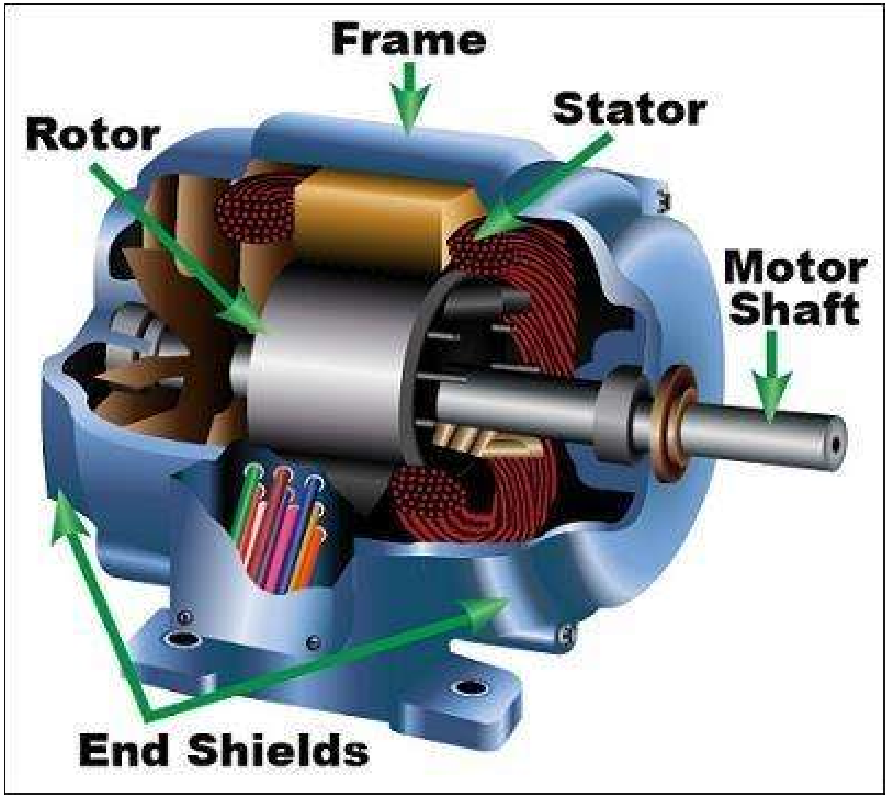


Internal View of Induction Motor

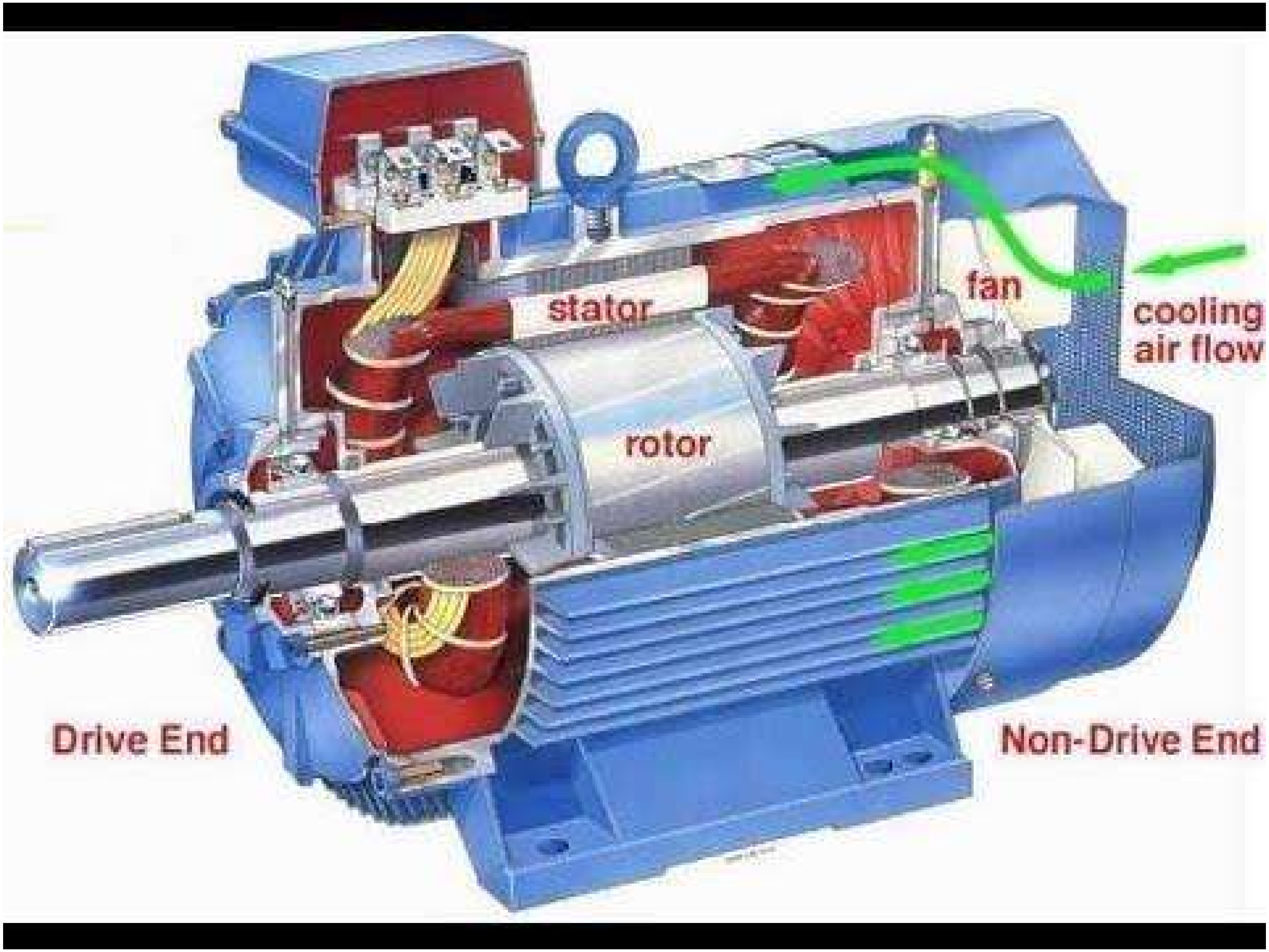
Internal View of Induction Motor

Cut View of an Induction Motor





Main Parts of Induction Motor



Stator (Windings)

- "Stationary" part of the motor sometimes referred to as "the windings".
- Slotted cores made of thin sections of soft iron are wound with insulated copper wire to form one or more pairs of magnetic poles.

Rotor

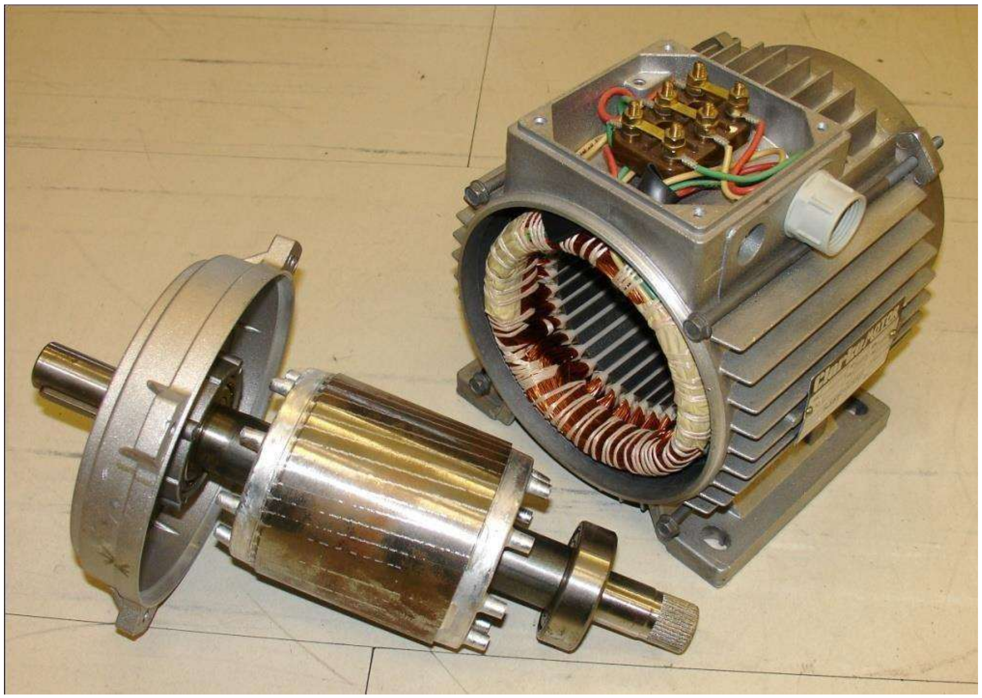
- "Rotating" part of the motor.
- Magnetic field from the stator induces an opposing magnetic field onto the rotor causing the rotor to "push" away from the stator field.

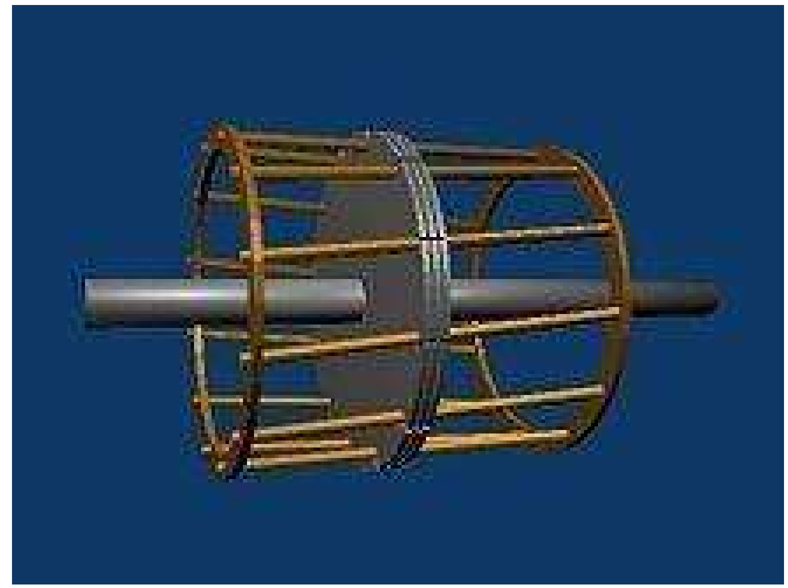
- Frame
- Stator
- Stator Winding
- Rotor
- Rotor Winding
- Cooling Fan
- Bearings

Principle of Operation

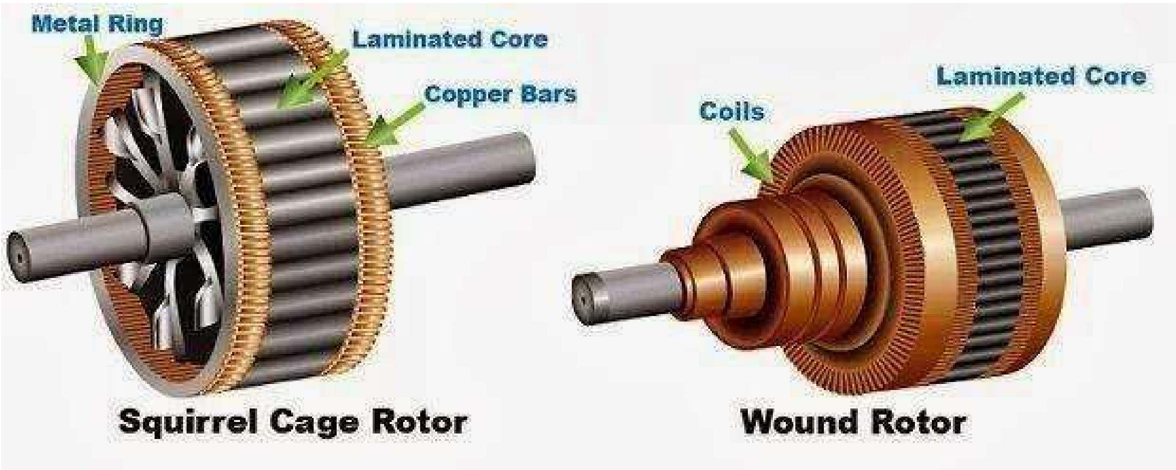
- A Rotating Magnetic field (RMF) is set up in the stator when a 3- Phase supply is given.
- The stationary rotor cut the revolving field and due to electromagnetic induction an e.m.f. is induced in the rotor conductor.
- As the rotor conductor is short circuited current flows through them.
- It becomes a current carrying conductor in magnetic field and start rotating.

There are two types of rotor winding
(a) Squirrel Cage (b) Slip-Ring

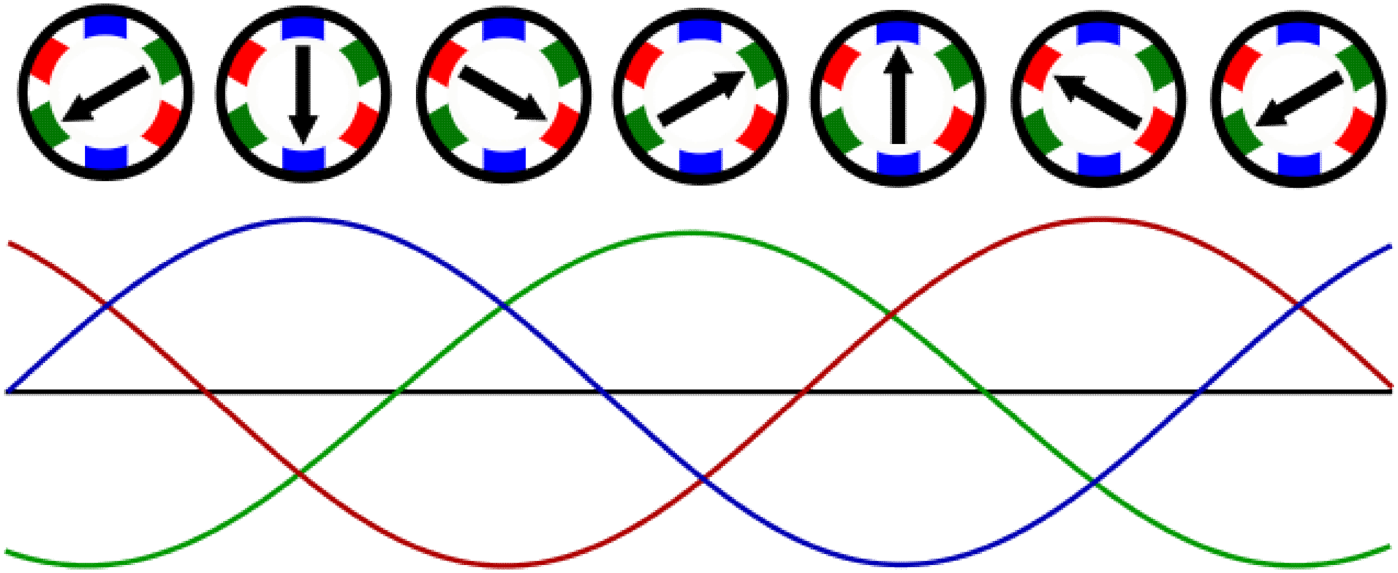


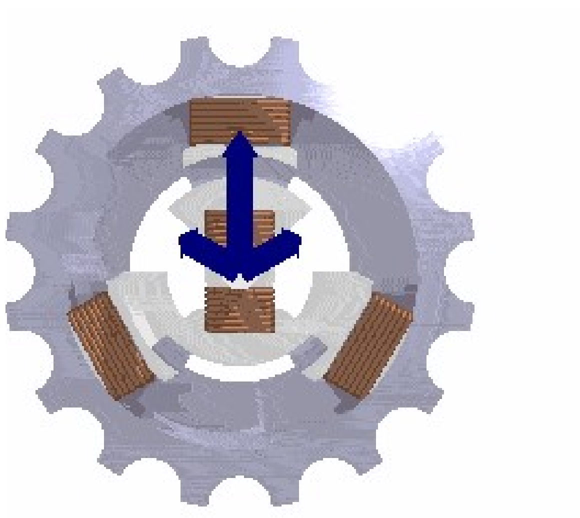


Squirrel cage rotor consists of copper bars, slightly longer than the rotor, which are pushed into the slots. The ends are welded to copper end rings, so that all the bars are short circuited. In small motors, the bars and end-rings are die cast in aluminum to form an integral block



A wound rotor has a 3-phase winding, similar to the stator winding.
The rotor winding terminals are connected to three slip rings which turn with the rotor.
The slip rings/brushes allow external resistors to be connected in series with the winding.
The external resistors are mainly used during start-up – under normal running conditions the windings short circuited externally.





Advantages of Induction Motor

1. Induction motors are simple and rugged in construction. Advantage of induction motors are that they are robust and can operate in any environmental condition
2. Induction motors are cheaper in cost due to the absence of brushes, commutators, and slip rings
3. They are maintenance free motors unlike dc motors and synchronous motors due to the absence of brushes, commutators and slip rings.
4. Induction motors can be operated in polluted and explosive environments as they do not have brushes which can cause sparks
5. 3 phase induction motors will have self starting torque unlike synchronous motors, hence no starting methods are employed unlike synchronous motor. However, single-phase induction motors does not have self starting torque, and are made to rotate using some auxiliaries.

These advantages in induction motors make them more prominent in industrial and domestic applications

Disadvantages of Induction Motor

1. **3 phase induction motors have poor starting torque and high have in rush currents. Therefore these motors are not widely used for applications which require high starting torques like traction systems.**

2. **Induction motors always operate under lagging power factor and during light load conditions they operate at very worst power factor (0.2 to 0.4 lagging). Some of the disadvantages of poor power are increase in I^2R losses in the system, reduction in the efficiency of the system.**

3. **One of the main disadvantages of induction motors is that speed control of induction motors are difficult. Hence for fine speed control applications dc motors are used in place of induction motors.**

Applications of Induction Motor

Squirrel cage induction motor

Squirrel cage induction motors are simple and rugged in construction, are relatively cheap and require little maintenance. Hence, squirrel cage induction motors are preferred in most of the industrial applications such as in

Lathes
Drilling machines
Agricultural and industrial pumps
Industrial drives.

Slip ring induction motors

Slip ring induction motors when compared to squirrel cage motors have high starting torque, smooth acceleration under heavy loads, adjustable speed and good running characteristics.

Lifts
Cranes
Conveyors , etc.,

Induction motor speed

- At what speed will the IM run?
  - Can the IM run at the synchronous speed, why?
  - If rotor runs at the synchronous speed, which is the same speed of the rotating magnetic field, then the rotor will appear stationary to the rotating magnetic field and the rotating magnetic field will not cut the rotor. So, no induced current will flow in the rotor and no rotor magnetic flux will be produced so no torque is generated and the rotor speed will fall below the synchronous speed
  - When the speed falls, the rotating magnetic field will cut the rotor windings and a torque is produced

Induction motor speed

- So, the IM will always run at a speed lower than the synchronous speed
- The difference between the motor speed and the synchronous speed is called the *Slip*

$$n_{slip} = n_{sync} - n_m$$

Where n_{slip}= slip speed

n_{sync}= speed of the magnetic field

n_m = mechanical shaft speed of the motor

The Slip

$$s = \frac{n_{sync} - n_m}{n_{sync}}$$

Where *s* is the *slip*

Notice that : if the rotor runs at synchronous speed

$s = 0$

if the rotor is stationary

$s = 1$

Slip may be expressed as a percentage by multiplying the above eq. by 100, notice that the slip is a ratio and doesn't have units

Frequency of rotor current

- The frequency of the voltage induced in the rotor is given by

$$f_r = \frac{P \times n}{120}$$

Where f_r = the rotor frequency (Hz)

P = number of stator poles

n = slip speed (rpm)

$$f_r = \frac{P \times (n_s - n_m)}{120}$$

$$= \frac{P \times sn_s}{120} = sf_e$$

Frequency

- What would be the frequency of the rotor's induced voltage at any speed n_m?

$$f_r = s\, f_e$$

- When the rotor is blocked (s=1) , the frequency of the induced voltage is equal to the supply frequency
- On the other hand, if the rotor runs at synchronous speed (s = 0), the frequency will be zero