AC Electrical Machines

1-1 Introduction:

3-phase induction motors are simple, rugged, low cost, and easy to maintain. They run at essentially constant speed from zero-to-full load. Therefore, they are the motors most frequently encountered in industry

AC machines can be classified into two types:

Synchronous machines: - Alternators –Motor

A) Salient-Pole B) Cylindrical Rotors

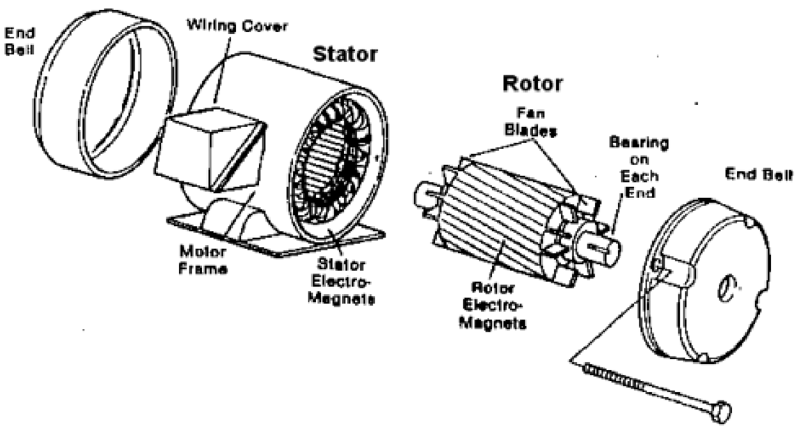
Asynchronous (induction) machines:- induction motors – induction generator

A) Squirrel –Cage B) Slip-Ring

1-2 Constructional Parts: -

An AC induction motor has two main parts:

1. Stator: consisting of a steel frame that supports a hollow, cylindrical core of stacked laminations. Slots on the internal circumference of the stator house the stator winding.
2. Rotor: also composed of punched laminations, with rotor slots for the rotor winding.
3. Shaft.
4. Bearing.
5. Yoke.



1-3 Materials: -

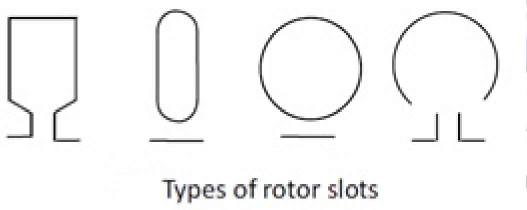
A) Electrical –Conductors (Winding)

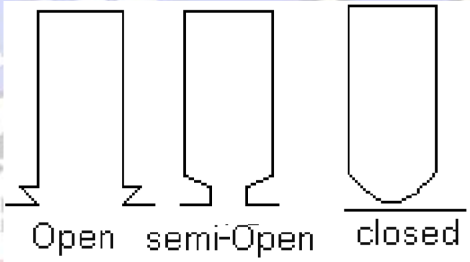
B) Magnetic – Stator and Rotor Cores (M. Circuit)

Note: - The air-gap between stator and rotor of a 3phase induction motor ranges from 0.4-4mm

1-4 Types of Motor Slots:

Open, Closed, Semi Open, Semi Closed



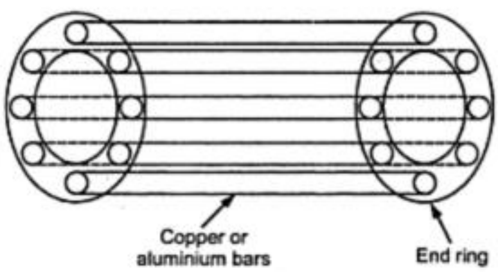


1-5 Types of Rotor Winding:

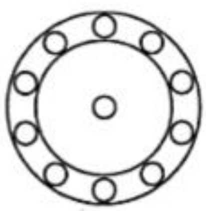
There are two-types of rotor windings:

1- **Squirrel-cage windings**, which produce a squirrel-*cage induction motor (most common)*

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) Cage type structure

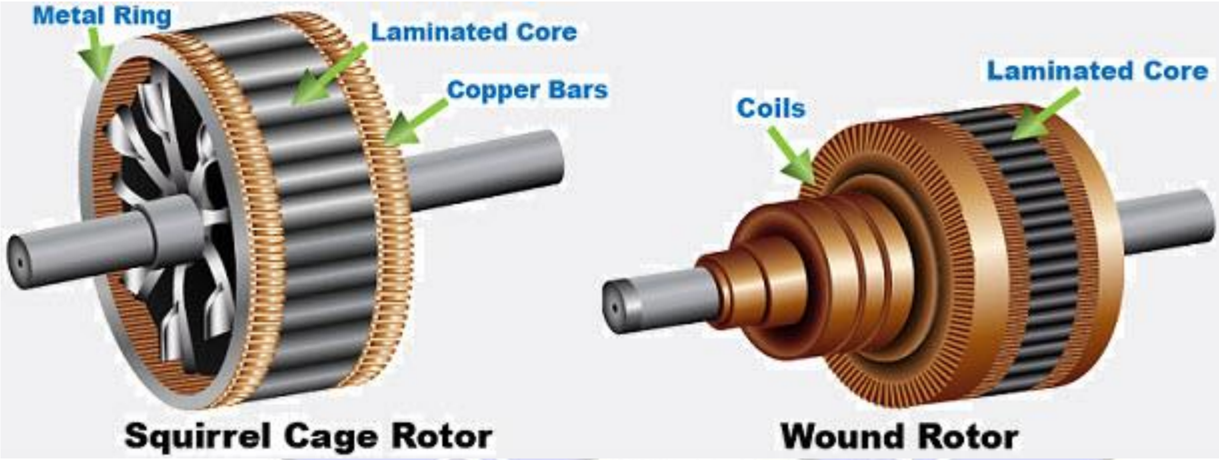


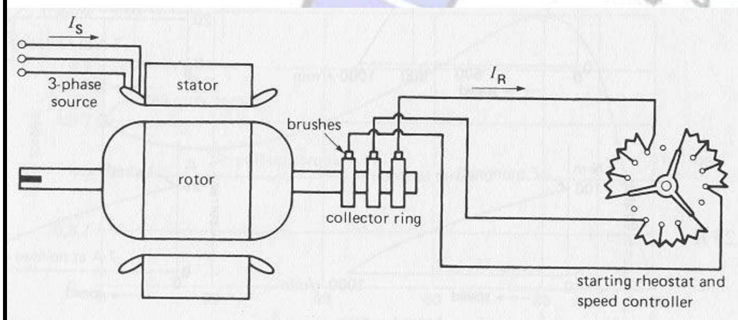
(b) Symbolic representation

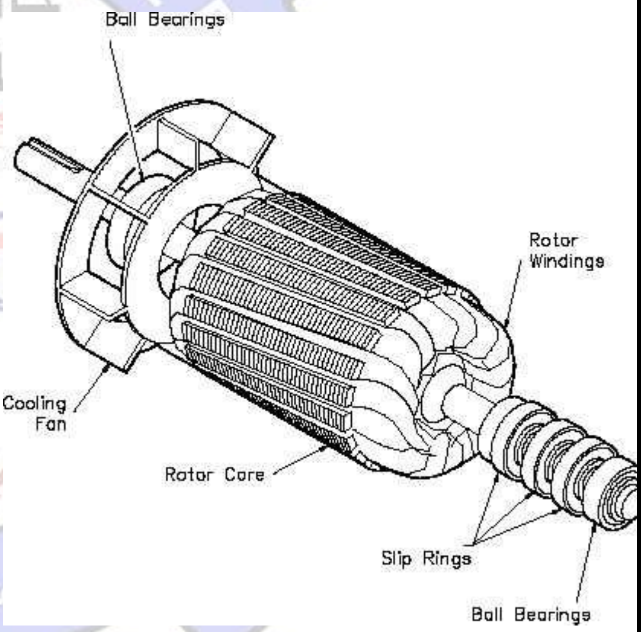
2- Conventional 3-phase windings made of insulated wire, which produce a ***Wound-Rotor Induction Motor or Slip Ring Induction Motor (special characteristics)***

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.







1-6 Winding: -

Choice of winding

1- Type of Coil: Concentric, Lap, Wave

2- Overhang: - diamond, multi plane ,mash

3-Layers: - single-layer, double –layer

4-Slots: - open-closed, semi closed

5-Connections: Star, Delta

6-Phase Spread: - 60̊, 120̊

7-Slotting: - Integral, Fractional

8-Coil-Span:- Full-Pitch, Chorded

9-Circuits: - Series, Parallel

10- Coils: - Single-Turn, Multi Turn

1-7 Symbols:

S-total no. of slots in the stator

C-total no. of coils

P- no. of pole pairs

$\propto -slot\ pitch(elec.radious)$

$\boldsymbol{Q} - no.of\ slots/polepair$

q -*no .of slots/pole/phase*

$б - spread\ of\ phase - group$

a - *no. of parallel circuits/phase wending*

m - *no.of phase,* ***y*** - *coil span*

1-8 main equation

Q=S/P

q= Q /2m= S/2pm

$$\boldsymbol{\alpha = \frac{2\pi p}{s} = \frac{2\pi}{Q}}$$

$$\boldsymbol{\sigma = q\alpha = \frac{\pi}{m}}$$

$$\boldsymbol{\mathcal{T} = \frac{s}{2p} = \frac{Q}{2} = qm \quad pole - pitch}$$

If y=$\mathcal{T}$→ full pitch

Ns=conductors/slot

Z=total conductors in machine

Ts=total turns connected in series/phase

Tc=turns/coil

Tc=1 single-turn coil

Tc>1 multi-turn coil

Ns=Z/S ,Z=S Ns ,c=Z/2Tc

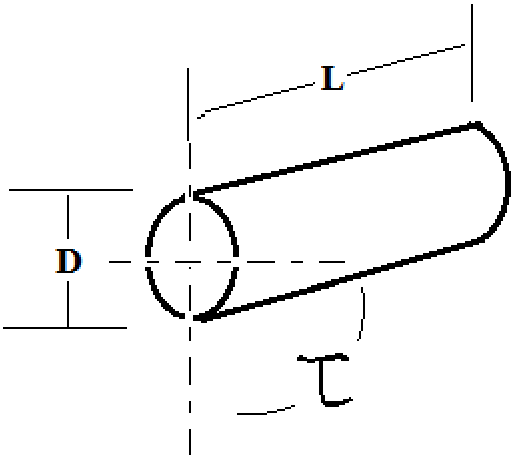
Ts=Z/2m= SNs/2m

1-9 Induced EMF

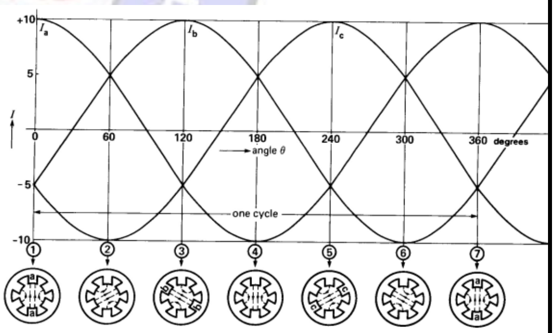
F=P.n (R/S) =P.n/60 (R/M)

n =NO. of Turns per min.

e $=E_m \sin(wt)$, E_m=maximum E.M.F



$E_m = B\,L\,\mathcal{V}$ $\mathcal{V}$= peripheral speed



$$v = (\pi D)n = (2p\tau)n = 2f\tau \ ,$$

$$D = dimeter$$

$$Bav = \frac{\emptyset}{\tau L} = \frac{2P\emptyset}{\pi \mathrm{DL}}$$

$$Em = \frac{2P\emptyset}{\pi D\ L} \times L \times \pi D n = 2P\emptyset n$$

$$Erms = Kf\ Em$$

$$kf = form\ factor = 1.11 = \frac{\pi}{2\sqrt{2}}$$

$$Erms = 2.22\ P\ \emptyset \frac{F}{P} = 2.22\emptyset\ F$$