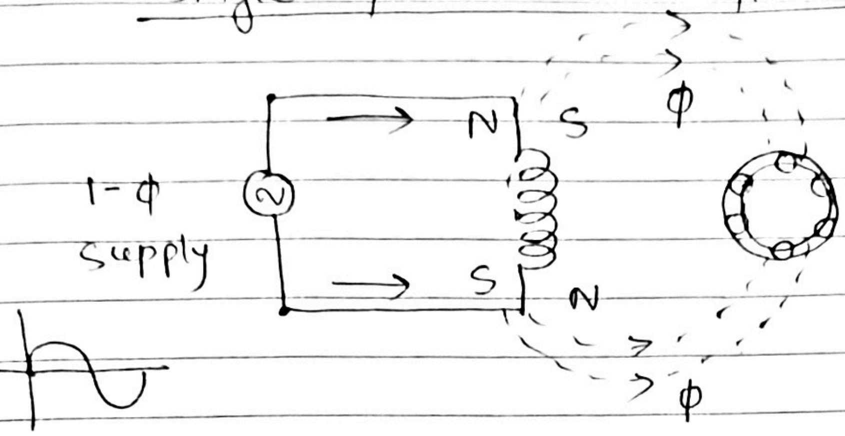
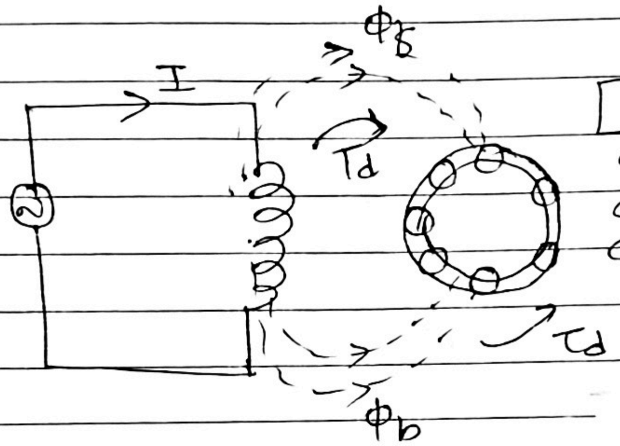
Single phase Induction motor



current polarity change → φ direction also change.



[flux cuts rotor conductor and emf will be induced and as it is short circuit current will also be induced] ← developed torque

Voltage same → developed torque is same in both direction

T_d in forward direction $=$ T_d in backward direction

So resultant torque $= 0$

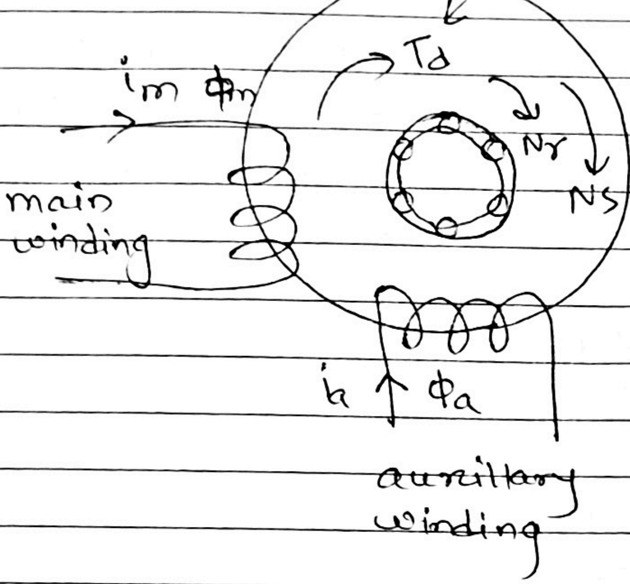
⇒ single phase induction motor is an ac motor which always run on ac.

⇒ 1-φ induction motor is not self starting motor

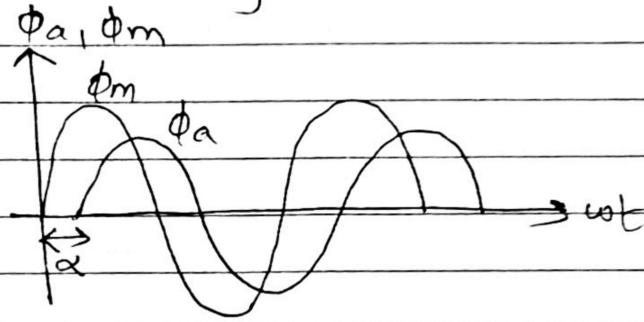
⇒ when we apply 1-φ ac in single winding then it will produce flux (field) in alternating nature due to this flux cuts rotor conductor also in forward and reverse (backward) both side hence it produce equal and opposite magnitude of torque on rotor hence its resultant torque is zero thus 1-φ induction motor is not self starting.

depend on phase angle α

$$\boxed{T_d \propto \phi_a \phi_m \sin\alpha}$$



RMF (rotating magnetic field)



Developed torque

$$\boxed{T_d \propto \phi_a \phi_m \sin\alpha}$$

For T_{max}, $\alpha = 90°$

$$T_d \propto i_m i_a \sin\alpha$$

α = angle between ϕ_a and ϕ_m

$\alpha \langle^{i_a}_{i_m}$ or $\alpha \langle^{\phi_a}_{\phi_m}$

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=> As we have seen, Single phase induction motor is not self starting motor, so we always use one addition winding to start this motor, which is called auxillary winding.

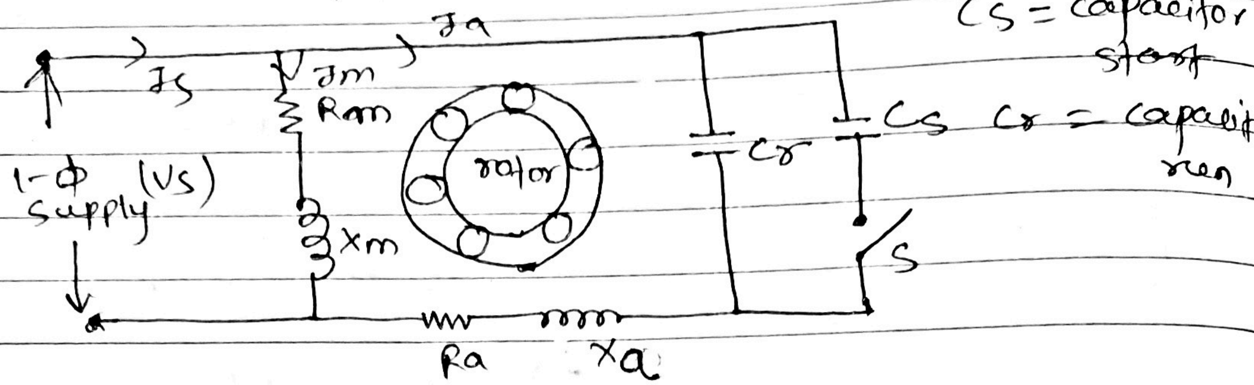
=> Thus to make 1-ϕ I.M self starting we use two winding, so some time it is also called two phase motor.

=> Now by their connection, 1-ϕ Induction motor starts in different connection and additional components, called starting methods.

Type of 1-ϕ Induction motor
or starting method

1) Split phase Induction motor
2) Capacitor start motor
3) Capacitor start capacitor run motor
4) Shaded pole Inductor motor.
5) Reluctance start motor.

3) Capacitor start capacitor run motor –
(two capacitor motor)



⇒ fig shows the schematic diagram of a two value capacitor motor. It has a cage rotor and its stator has two windings namely the main winding and the auxillary winding (starting winding). The two windings are placed at 90° in space.

⇒ The motor uses two capacitors C_S and C_R. The two capacitor are connected in parallel at starting.

⇒ In order to obtain a high starting torque, a large current is required. for this capacitive reactance X in the starting winding should be low.

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⇒ Since $X_A = \frac{1}{2\pi f C_A}$, the value of C_S should be large.

The capacitor C_S is short-time rated and is almost always electrolytic.

⇒ During normal operation, the rated line current is smaller than the starting current. Hence the capacitive reactance should be large. Since $X_R = \frac{1}{2\pi f C_R}$ the value of C_R should be small.

⇒ As the motor approaches synchronous speed, the capacitor C_S is disconnected by a centrifugal switch Sc.

⇒ The capacitor C_R is permanently connected in the circuit and is called run capacitor. It is long time rated for continous running so it is usually of oil-filled paper construction.

⇒ Since one capacitor C_S is used only at starting and the other C_R for continous running, this motor is called capacitor start capacitor run motor.

⇒ fig (1) and fig (2) show the phasor diagrams of a 2-value capacitor motor. At starting both the capacitors are in the circuit and $\phi > 90°$ shown in fig (1). When the capacitor C_S is disconnected ϕ becomes 90° (electrical) as shown in fig (2)

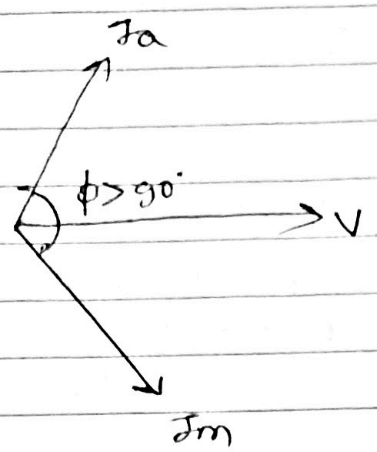


fig ①

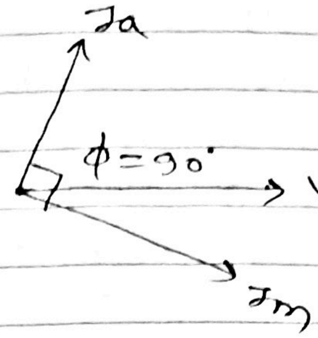


fig ②

⇒ Two value capacitor motors are quiet and smooth running. They have have higher efficiency than motors that run on the main windings alone.

Applications

Two value capacitors are used for loads of higher inertia requiring frequent starts where the maximum pull out torque and efficiency required are higher. They are used in pumping equipment, refrigeration, air compressors etc.

4) Shaded pole motors -

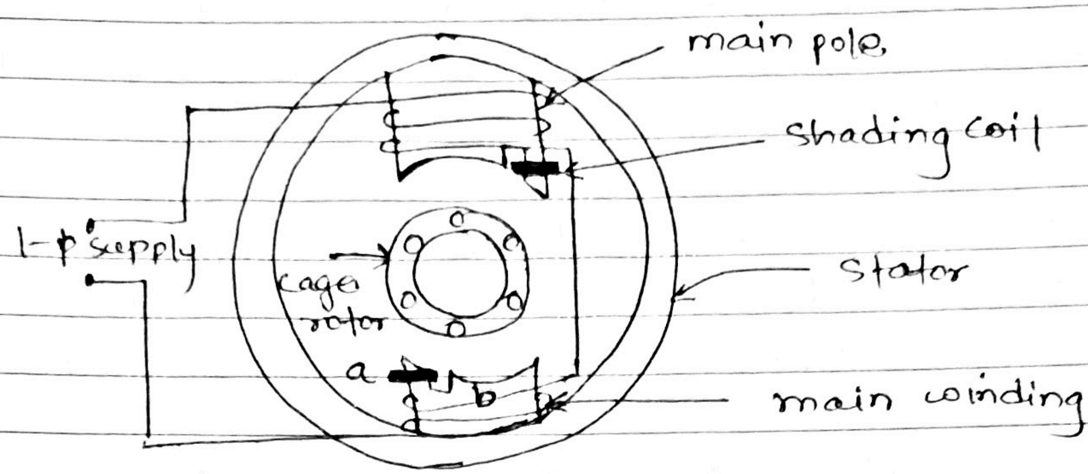


Fig. shaded - pole motor with two starter poles

=> A shaded - pole motor is a simple type of self-starting phase induction motor. It consists of a stator and a cage - type rotor. The stator is made up of sailent poles.

=> Each pole is slotted on side and a copper ring is fitted on the smaller part a as shown in fig above. This part is called the shaded pole. The ring is usually a single turn coil and is known as shading coil.

=> when alternating current flows in the field winding, an alternating flux is produced in the field core. A portion of this flux links with the shaded coil, which behaves as short-circuited secondary of a transformer.

A voltage is induced in the shading coil, and this voltage circulates a current in it. The induced current produces a flux called induced flux which opposes the main flux (core flux).

⇒ The shading coil, flux, causes the flux in the shaded portion a to lag behind the flux in the unshaded portion b of the pole.

⇒ At the same time, the main flux and the shaded pole flux are displaced in space. This space displacement is less than 90°. Since there is time and space displacement between the two fluxes, the conditions for setting up rotating magnetic field are produced.

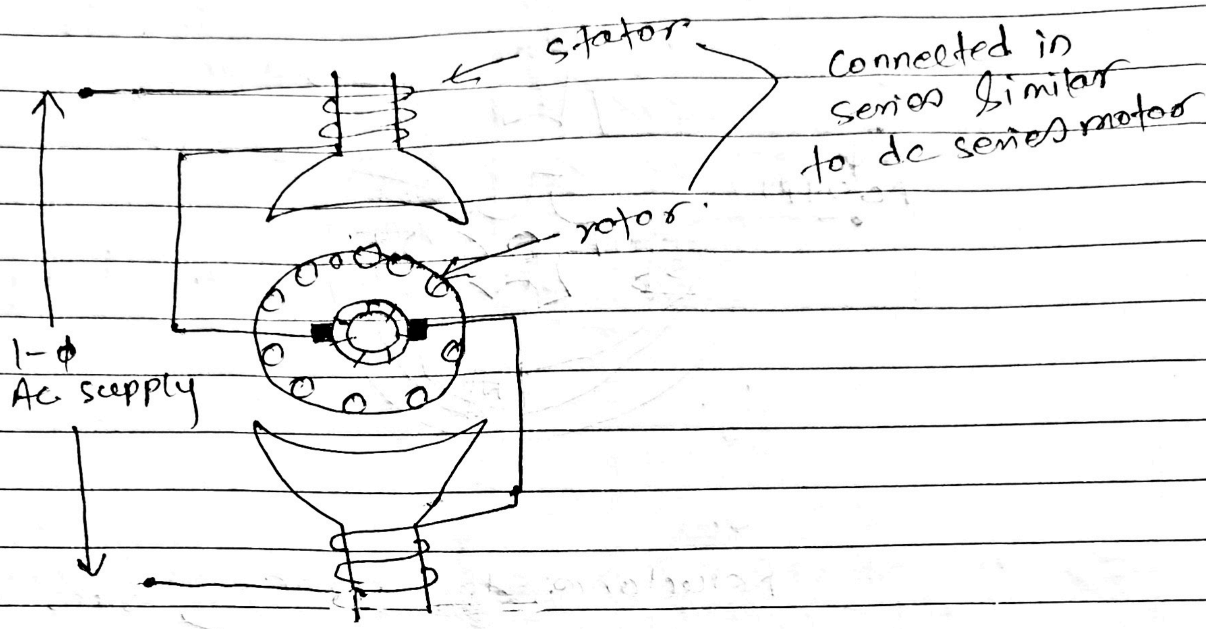
⇒ under, the action of the rotating flux a starting torque is developed on the cage rotor.

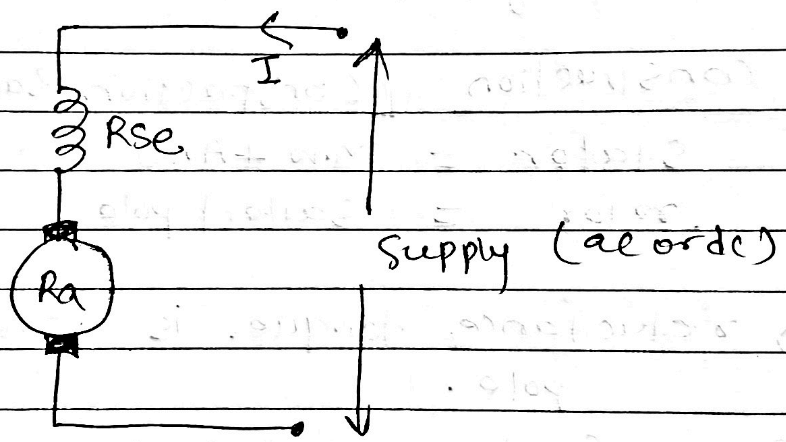
Application

The starting torque developed by a shaded motor is very low. The losses are high and power factor is low and also the efficiency is low. For this reasons, the shaded pole motors are built only in small size of power rating of 40W or less. For example - relays, fans of all kinds, hair driers, exhaust fan, etc.

Universal motor

(ac or dc)

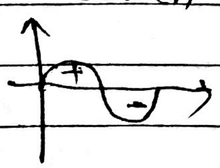




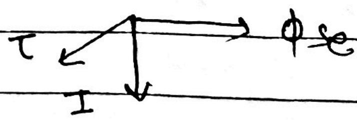
⇒ when dc supply

I_a , ϕ_{se} → torque developed.

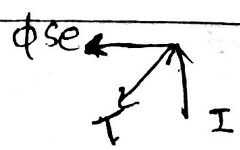
⇒ when Ac supply



+ve half →



-ve half →



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when fed with DC Supply

=> when universal motor is fed with DC supply, it works as a DC series motor. In this case, when the current flows in the field winding, it produces an electromagnetic field. This same current also flows in the armature conductors. when a current carrying conductor is placed in a magnetic field, the conductor experience a mechanical force. This mechanical force causes the rotor to rotate. Flemming left hand rule gives us the direction of this force.

when fed with an AC supply

=> A unidirectional torque is produced when the universal motor is supplied with AC power. This is because the armature winding and the field winding are connected in series and are in the same phase. Therefore, wherever the polarity of AC changes, the direction of the current in the armature and the field winding changes simultaneously. The direction of the magnetic field and direction of armature current reverses so that the direction of the force experienced by armature conductors remains the same. Thus, regardless of AC or DC supply, universal motors work on the same principle that DC series motor work on.

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Properties of universal motor

1) They run at high speed
2) They have high starting torques
3) Compact size and are light weight.
4) They are noisy because of the commutator and brushes
5) Smaller universal motor efficiency is 30%. where as larger universal motor efficiency is 70-75 %.

Application

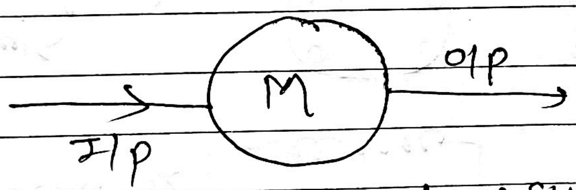
1) Vaccum cleaners
2) food processors
3) mixers
4) hair driers
5) coffee grinder
6) electric shavers etc.
7) blowers
8) drilling machines

Servo motor

↳ means automatic motor

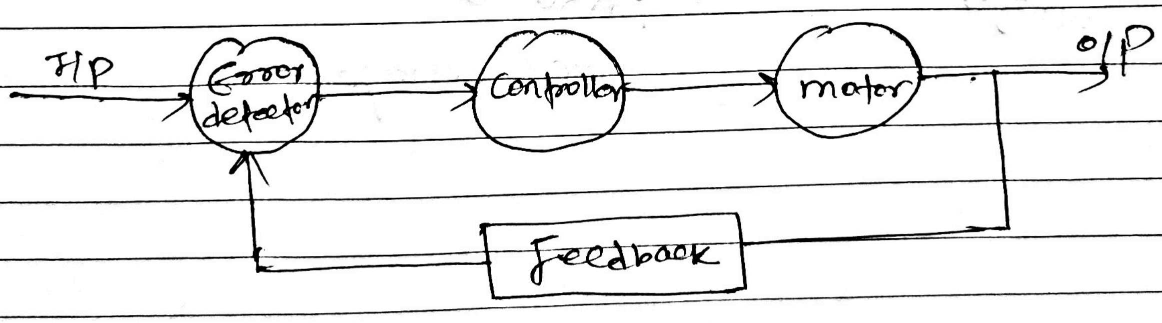
⇒ we can use any motor as servo motor

⇒ Servo mechanism → any physical quantity can be controlled automatically
⇓
loss error
⇓
precise work
⇓
better accuracy



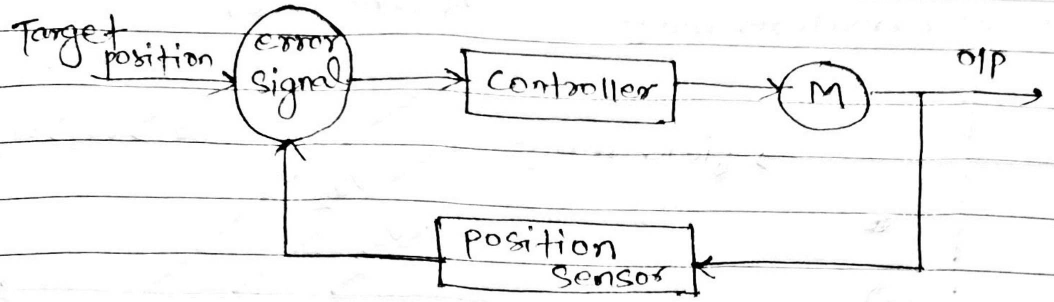
(no feedback).

open loop system



closed loop system

servo motor can be AC or DC
- → encoder → position sensor
- ↳ potentiometer



DC Servo motor

⇒ DC Servo motors are seperately excited dc motors or permanent magnet dc motors. Fig (a) shows a schematic diagram of a separetely excited dc servomotor. The speed of dc servomotor is normally controlled by varying the armature voltage. The armature of a dc servomotor has a large resistance so that the torque - speed characteristics are linear and have a large negative slope (torque reducing with increasing speed) as shown in fig (b). The negative slope provides viscous damping for the servo-drive system. Fig (c) shows that the armature mmf and the excitation field mmf are in quadrature in dc m/c.

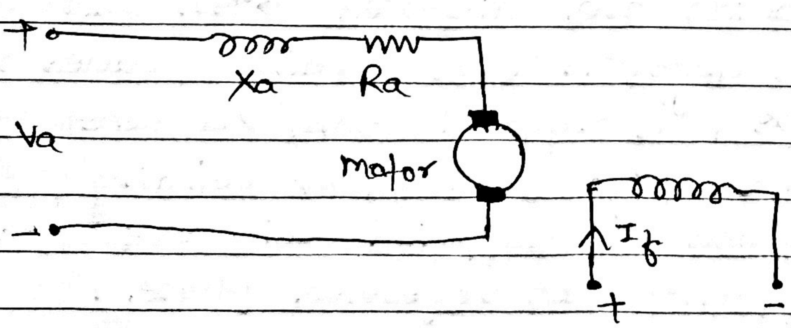


Fig (a)

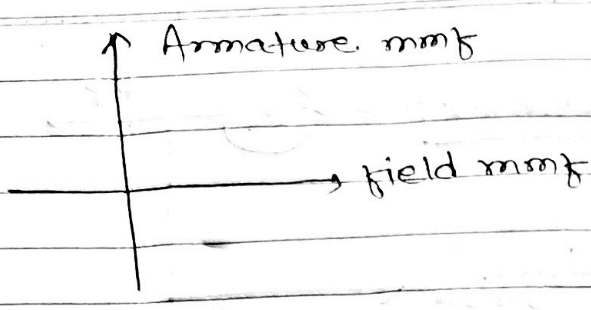


Fig (c)

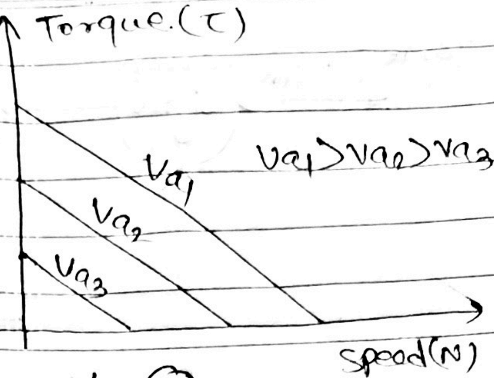


Fig (b)

⇒ This provides a fast torque response because torque and flux becomes decoupled. Therefore, a step change in the armature voltage or current produce a quick change in the position or speed of the rotor.

AC Servo motors

⇒ AC Servo motors are of two-phase squirrel cage induction for low power applications.

⇒ fig (i) shows the schematic diagram of a two-phase ac servo motor. The Stator has two distributed windings which are displaced from each other by 90° electrical degree. one winding, called reference or fixed phase, is supplied from a constant voltage voltage source $V_m \angle 0°$. The other winding, called the control phase, is supplied with variable voltage of same frequency as reference phase.

⇒ The control phase is usually supplied from a servo amplifier.

⇒ The speed and torque of the rotor are controlled by the phase difference between the control voltage and the reference phase voltage.

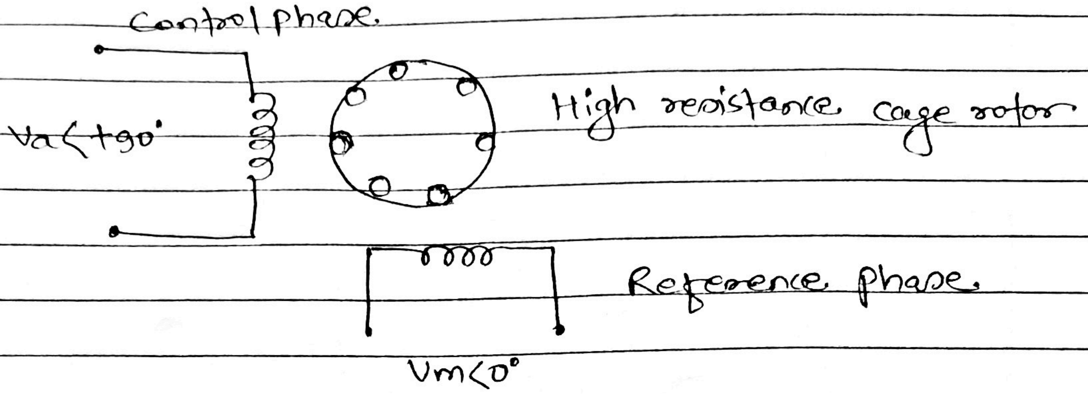


Fig (i) Schematic diagram of ac servo motor

⇒ The torque-speed characteristics for various control voltages are almost linear as shown in fig (ii)

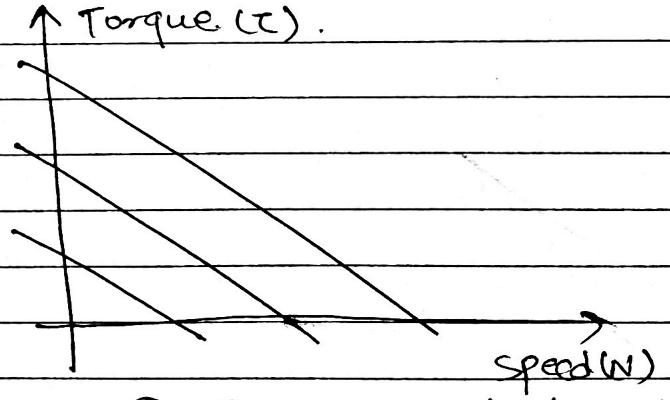


fig (ii) Torque-speed characteristics

Applications

⇒ Servomotors are widely used in radars, computers, robots, machine tools, tracking and guidance systems, process controllers etc.