



**R. C. Patel College of Engineering and Polytechnic,
Shirpur**

Class: TYEE (EE5K)

Course:

A.C. MACHINES PERFORMANCE (ACM)

(Course Code: 315333)

Prepared By:

Prof. Vishal P. Mahajan

Head of Department

Electrical Engineering Department

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Unit - III

Single phase induction motors (14 Marks)

Course Outcome:

CO3 - Use single phase induction motor for industrial applications.

* Single phase Induction Motors:

We know that, we use single phase A.C. supply for domestic purpose as well as for industrial purpose. So it is more convenient to use single phase ac motors instead of d.c. motors. Practically single phase induction motors are used in most of the applications.

* Construction of single phase induction motor: (W-14, S-15, W-15)

A single phase induction motor has two main parts namely stator (stationary) and rotor (rotating).

The stator winding is connected across a single phase ac supply. The ac supply produces a rotating magnetic field in the air gap between the stator and rotor. The field rotates at a speed called synchronous speed and it is denoted by N_s . It is mathematically expressed as:

$$N_s = \frac{120F}{P}$$

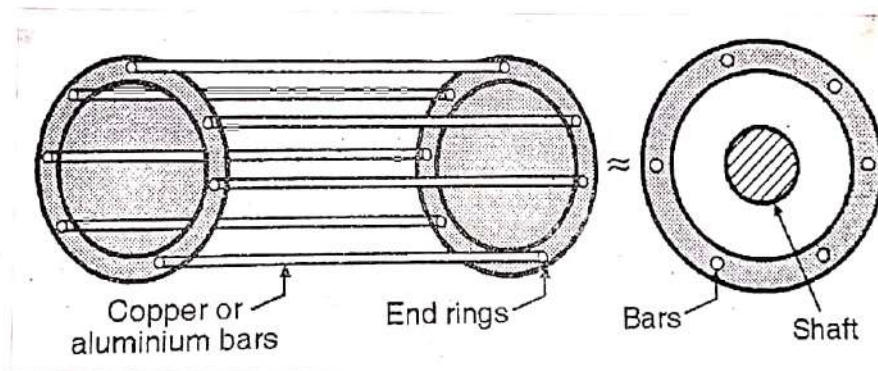


Fig: Construction of squirrel cage rotor.

The induction motor actually rotates at a speed which is slightly less than the synchronous speed.

The rotor is said to be of squirrel cage type. As the construction of rotor appears to be like the squirrel cage, the name squirrel cage rotor has been used.

As shown in Fig. the rotor consists of copper or aluminium bars which are permanently short circuited at both the ends using the conducting rings called end rings.

- principle of operation:

A single phase ac supply is connected to the stator winding. This forces an alternating current through the stator winding. This current produces an alternating flux in the air gap betn the stator and rotor.

The alternating flux passes over the rotor conductors and induces an emf into it due to the transformer action.

Due to this induced voltage, a current starts flowing through the rotor conductors. This current will then produces its own flux called as rotor flux. The main flux produced by the stator winding interacts with the rotor flux to produce the torque.

The rotor flux gets produced due to the principle of induction hence the name of the motor is induction motor.

It is important to note that the single phase induction motor are not self starting like the dc motors.

* Double Revolving Field Theory:

In order to make the induction motor self starting, it is necessary to produce a rotating magnetic field.

And in order to do so, there should be at least two magnetic fields which satisfy the following two conditions:

1. The two magnetic fluxes should be shifted by 90° with respect to each other in space i.e. if one flux is horizontal then the other one should be vertical.
2. Also the two magnetic fluxes should be in time quadrature. IF the fluxes are represented by phasors then there should be a 90° phase shift betn them.

A single phase stator winding can not satisfy these two conditions because a single winding can produce only one flux. Hence some modifications are required to be done, which will make motor to start.

→ Principle of Double Revolving Field Theory:

The double revolving field theory states that, any alternating quantity can be resolved into components which rotate in the opposite directions to each other with each one having a magnitude which is half of the peak magnitude of the alternating quantity.

Let us apply this theory to the single phase induction motors. Assume that the stator winding produces an alternating flux with the peak value of say Φ_m .

Then as per the revolving field theory, we can resolve this flux into two revolving flux components. One of them will be in the anticlockwise direction. Both these components are of magnitude $\Phi_m/2$, as shown in Fig below.

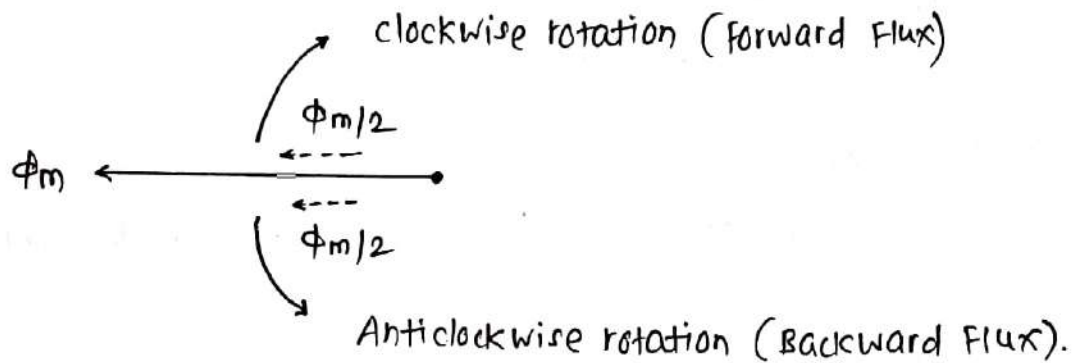


Fig: Φ_m resolved into two revolving components.

The resultant of these two components will be the resultant stator flux, at any given instant of time and the continuous rotation of the two components will result in the original stator flux.

Both the revolving flux components will cut the armature conductor and induce EMF in them. The rotor current induced due to these components will circulate in the rotor in opposite direction to each other.

Hence rotor flux corresponding to both the revolving components will be produced. The torque produced due to the interaction of main

flux with these two flux components will be in opposite directions to each other.

Hence the net torque ~~ex~~ exerted on the rotor will be zero at the time of starting the motor. Therefore the single phase ac motors are not self starting motors.

* Torque speed characteristics of single phase induction motor:

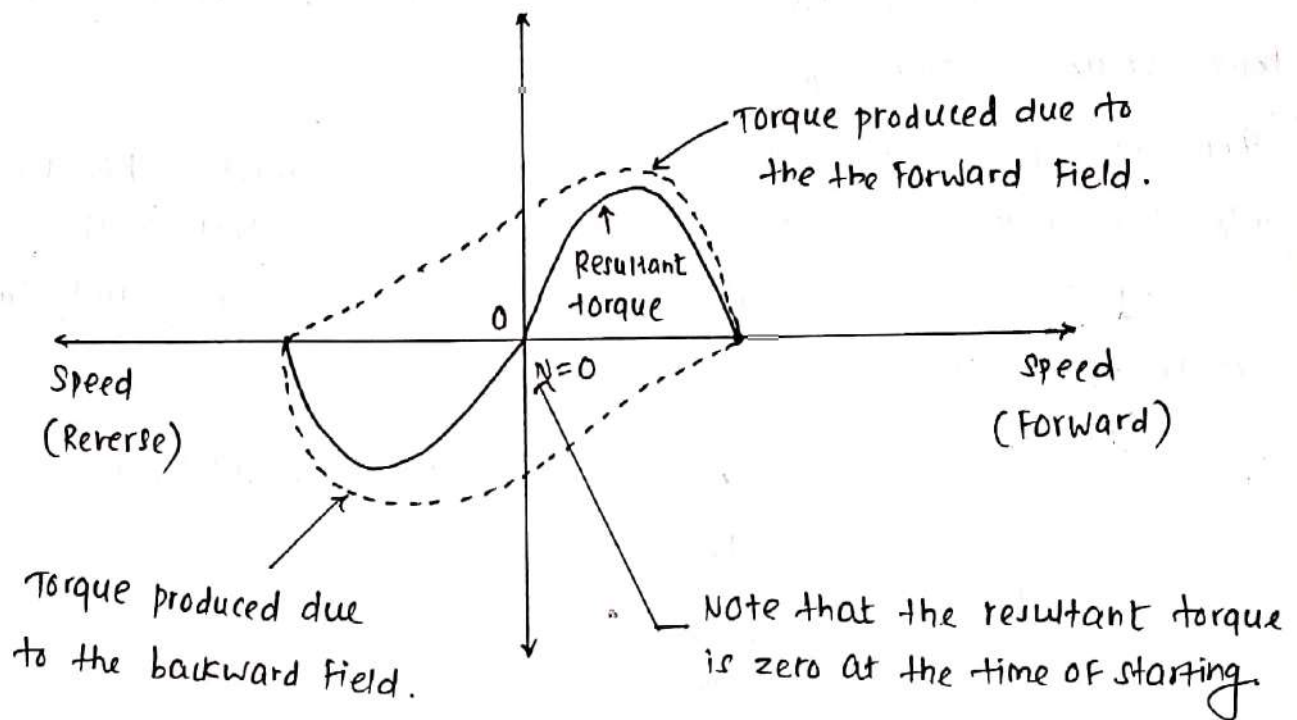


Fig. Torque speed characteristics

The torque speed characteristics of a single phase induction motor is shown in Fig.

It shows that the torque produced by the two oppositely rotating flux component, are exactly opposite to each other.

Fig. shows that the resultant torque is equal to zero at $N=0$ i.e. at the time of starting. Hence the induction motor is not self starting. But if we rotate the rotor in any direction by some external means then the motor will start rotating in that direction.

But practically it is not possible to rotate the motor by giving the initial thrust therefore it is necessary to modify the construction of the single phase induction motors in order to make them self starting.

* Split phasing principle of starting: (W-15) (4M)

Squirrel cage rotor

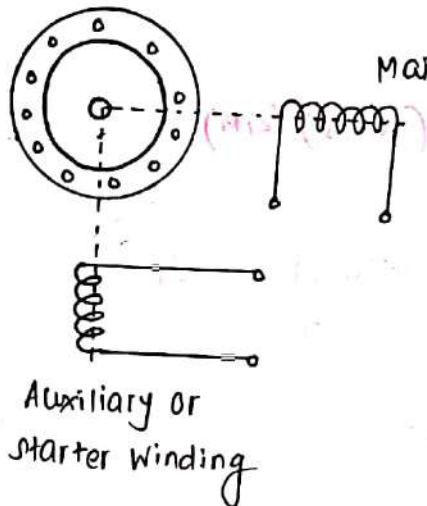


Fig: Split phase motor

In order to make the single phase motor self starting two windings are provided instead of one winding as shown in fig.

The axes of stator winding are displaced by of 90° electrical.

The winding currents are 90° phase shifted with respect to each other.

The two winding produce a rotating magnetic field in the air gap between stator and rotor.

This rotating field is then make the rotor rotate in the same direction as per the principle of induction. Thus the split phasing principle makes the single phase induction motor self starting.

The ~~pin~~ currents flowing through the two windings should be approximately phase shifted in order to produce the rotating magnetic field.

There are various methods used for obtaining these phase shifted currents. Some of these methods are:

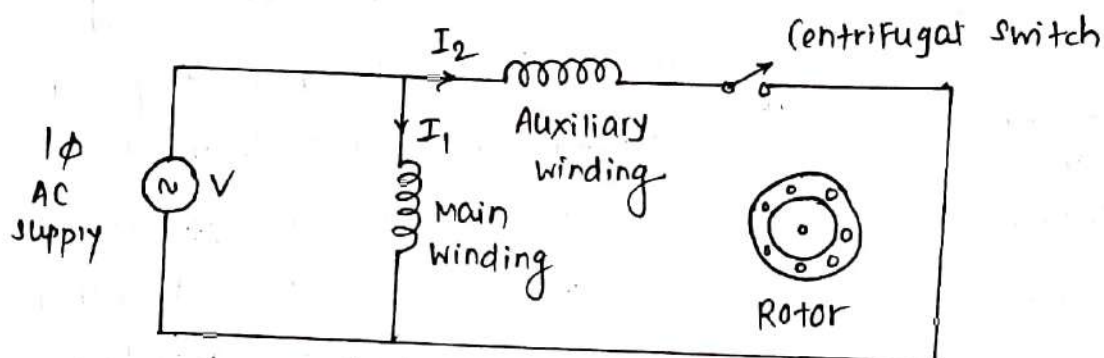
1. Resistance split phase motor
2. Capacitor split phase motor.

* Types of single phase Induction Motors:

There are following types of induction motors:

1. Resistance start induction run motor
2. capacitor start induction run. motor
3. Capacitor start capacitor run motor
4. shaded pole induction motor.

① Resistance start induction run motor: (W-15) (4M) (Split phase I.M.)



Fig(a) Resistance start induction motor
(split phase I.M.)

The construction of a split phase induction motor is as shown in Fig(a). This motor consists of two windings namely the main winding and the auxiliary or starting winding.

The main winding is highly inductive whereas the auxiliary winding is resistive.

→ Principle:

The current flowing through the main winding (I_1) lags behind V by 90° since the main winding is highly inductive.

The current flowing through the starting winding (I_2) is almost in the phase with the supply voltage V as this winding is resistive.

The fluxes produced by these currents will be placed at about 90° with respect to each other. And the resultant of these fluxes will be

- a rotating magnetic field. Due to the rotating magnetic field
 - a non-zero starting torque, acting in one direction will be produced.
- The centrifugal switch connected in series with the starting winding gets automatically open circuited when the motor speed reaches about 70% to 80% of the synchronous speed.

After that the motor rotates only on the main winding. Thus under the running condition the auxiliary winding remains out of the circuit.

The direction of rotation of split phase motor can be reversed by reversing the terminals of either main winding or the starter winding. The direction of rotation changes due to the reversal in direction of rotating magnetic field.

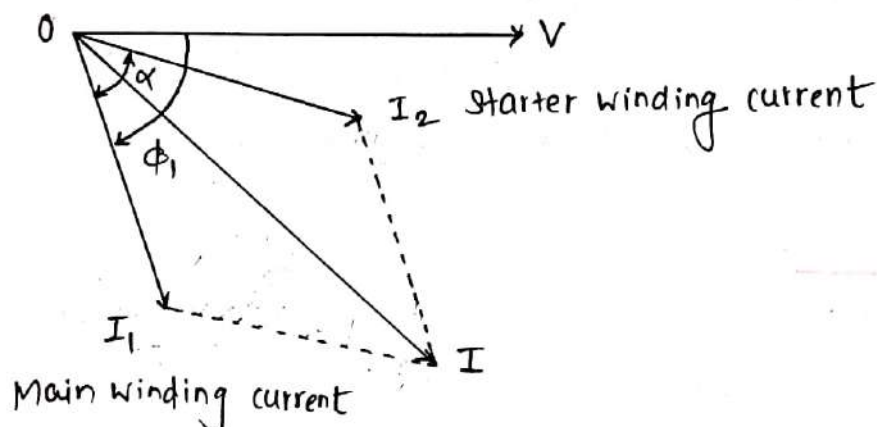


Fig b) phasor diagram.

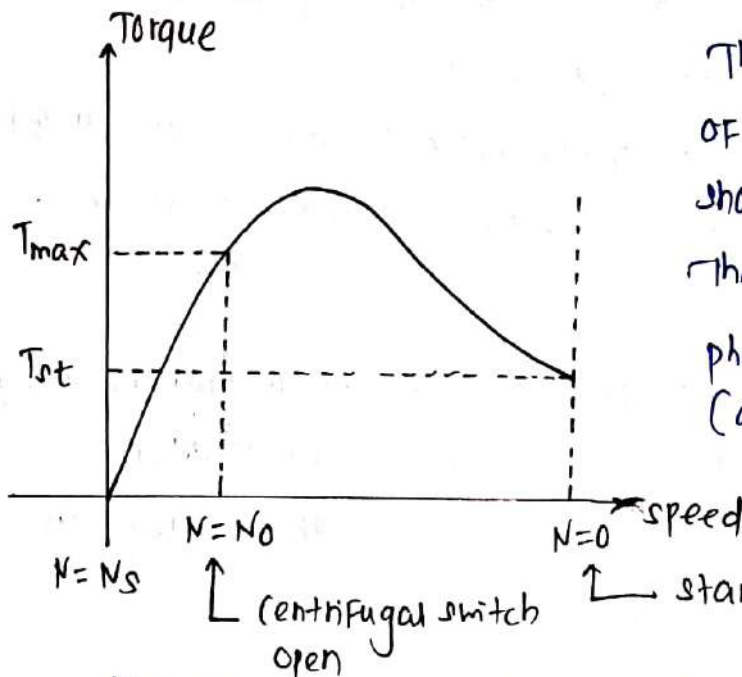
The phasor diagram for split phase induction motor is as shown in Fig b).

V is the supply voltage and it is being treated as reference phasor. The main winding is inductive, so the current through it (I_1) lags behind V by an angle Φ_1 , which is large in value. The current through starting winding (I_2) is almost in phase with V because this winding is resistive.

The phase difference between I_1 and I_2 is large (α). So there will be a large phase difference between the fluxes produced by these windings.

These two Fluxes add and subtract to produce a resultant Flux which is rotating magnetic field.

→ Torque speed characteristics:



The torque speed characteristics of split phase induction motor is shown in fig.

The starting torque T_{st} of split phase induction motors is poor (about 1.25 to 1.5 times of full load torque).

The centrifugal switch opens at a speed $N=N_0$ and for speed above this,

Fig: Torque speed characteristics

the motor operates on only the main winding.

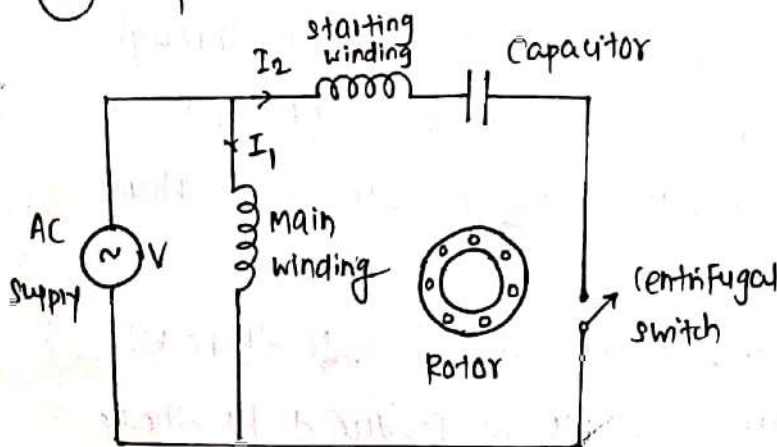
The starting torque is proportional to the angle α .

→ Applications:

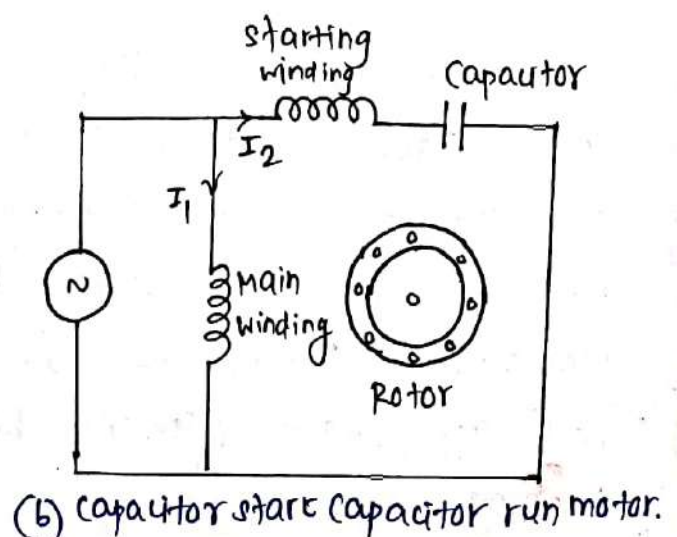
The starting torque of these motors is poor. Hence they are preferred for the following applications:

1. Fans and blowers
2. Washing machines
3. Centrifugal pumps.

② Capacitor start induction run motors:



(a) capacitor start motor



(b) capacitor start capacitor run motor.

Fig a) shows the capacitor start induction run motor.

It shows that construction of this motor is similar to that of split phase type induction motor.

Fig. b) shows capacitor start capacitor run motor. In this type the centrifugal switch is absent.

The auxiliary winding connected in series with the capacitor draws a leading current.

Due to this the fluxes produce a rotating magnetic field, which results in the rotation of the motor.

The construction of capacitor start motor is as shown in fig a)

The current (I_1) through the main winding will lag behind the source voltage as the main winding is inductive. But the current I_2 through the auxiliary winding (I_2) leads the supply voltage by some angle due to the presence of capacitor. Hence the angle between the fluxes produced by I_1 and I_2 will be large.

Due to this large angle, the starting torque produced by the capacitor start motor produces a larger starting torque as compared to that produced by the split phase induction motor.

As soon as the speed reaches 75% to 80% of the maximum speed, the centrifugal switch is automatically open circuited and the auxiliary winding along with the capacitor goes out of circuit. Thus, the induction motor will then be running only on the flux produced by the main winding.

→ Phasor diagram:

Fig. below shows the phasor diagram of the capacitor start induction motor.

The main winding is inductive so its current I_1 lags behind the AC supply voltage (V) by an angle ϕ_1 .

The current I_2 through the starting winding now leads v by an angle ϕ_2 . This happens due to the presence of capacitor in series with the starter winding.

Due to this arrangement the phase angle between I_1 and I_2 i.e. α is very large. It almost approaches 90° .

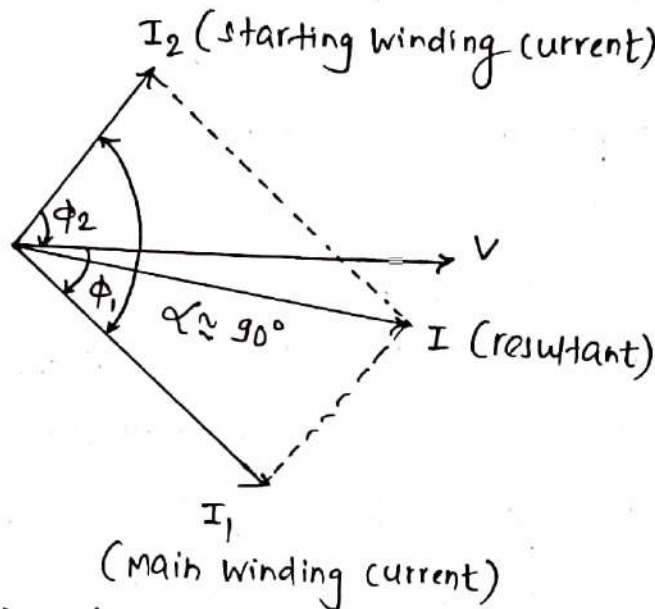


Fig. Phasor diagram

* Torque speed characteristics:

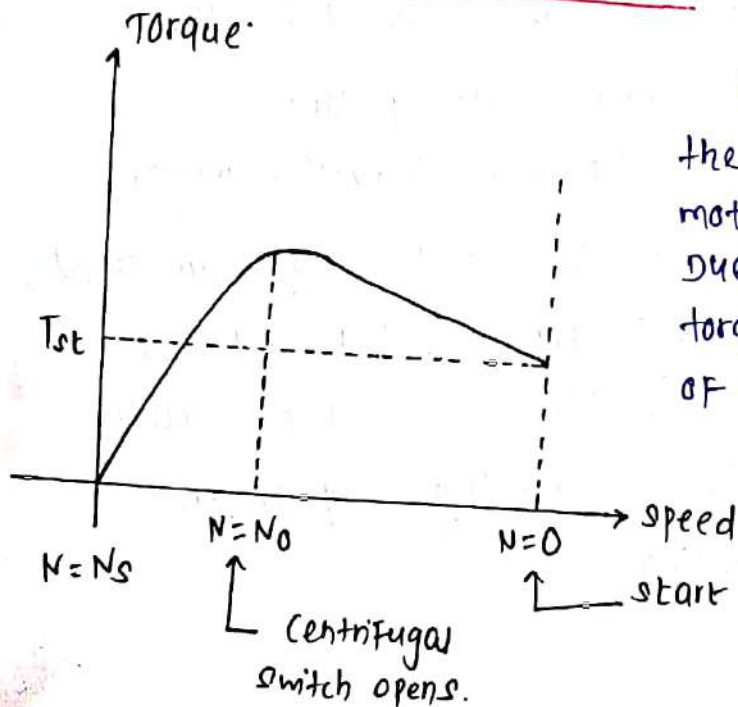


Fig. shows the torque speed chs of the capacitor start split phase induction motor.

Due to increase value of ' α ' the starting torque of this motor higher than that of the split phase induction motor.

At the speed $N=N_0$ the centrifugal switch will be open circuited and the motor will operate only on the main winding.

Fig. Torque speed chs.

starting torque of I.M. (single phase)

is given by

$$T_s = k I_s I_m \sin \alpha$$

③ capacitor start capacitor run motor: (W-14S-15) (4M) ④7

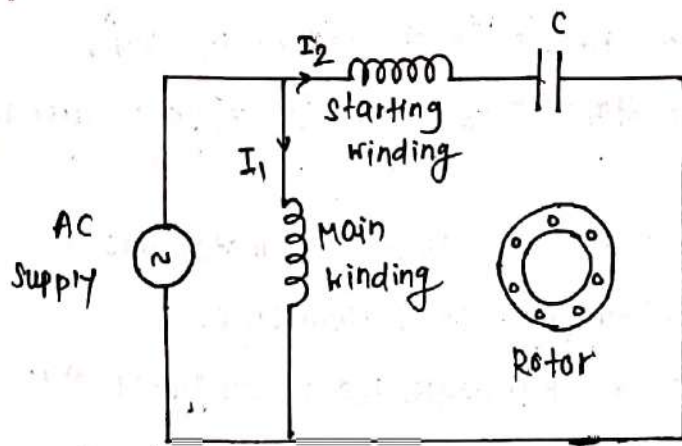


Fig: Capacitor start capacitor run motor.

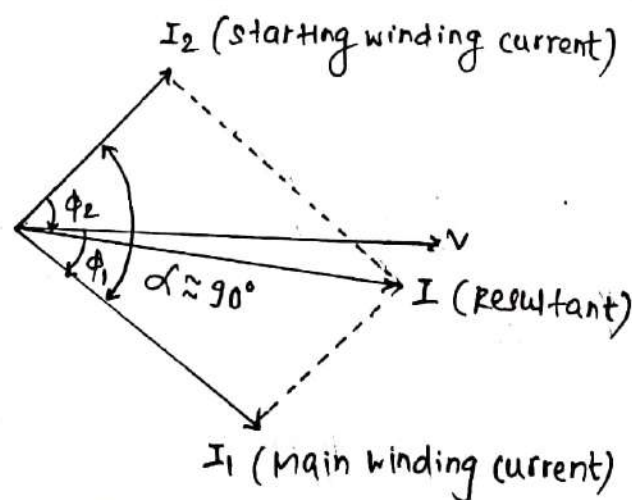
The capacitor start capacitor run motor is shown in above fig. Note that there is no centrifugal switch, hence the capacitor will not go out of circuit at all.

Hence the name of this motor is capacitor start capacitor run motor.

The direction reversal for capacitor type motors can be achieved by interchanging the connections of main and auxiliary windings. This will interchange the fields produced by the two winding. The interchanged phase shifted field will reverse the direction of the motor.

The main advantage of these capacitor type motors is the high starting torque that they can produce. The starting torque can be as high as 300 to 400% of the full load torque.

→ phasor diagram:

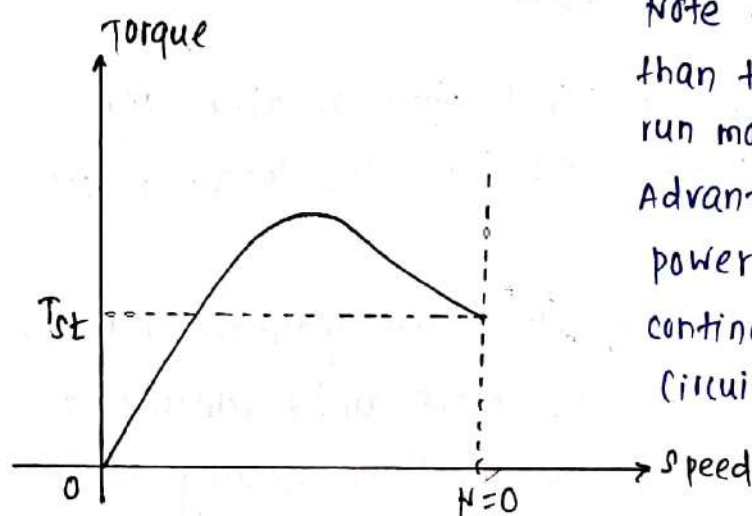


→ Role of capacitor:

The capacitor always remains in the circuit. Therefore it decides the performance of the motor at the time of starting as well as during the running mode.

The value of capacitor C is so decided that the motor should have high starting torque and better running performance.

Fig. below shows the torque speed characteristics of capacitor start capacitor run motor.



Note that the starting torque is less than that of the capacitor start capacitor run motor.

Advantage of this motor is its high power factor which is due to the continuous presence of capacitor in the circuit.

Disadvantage is its higher cost.

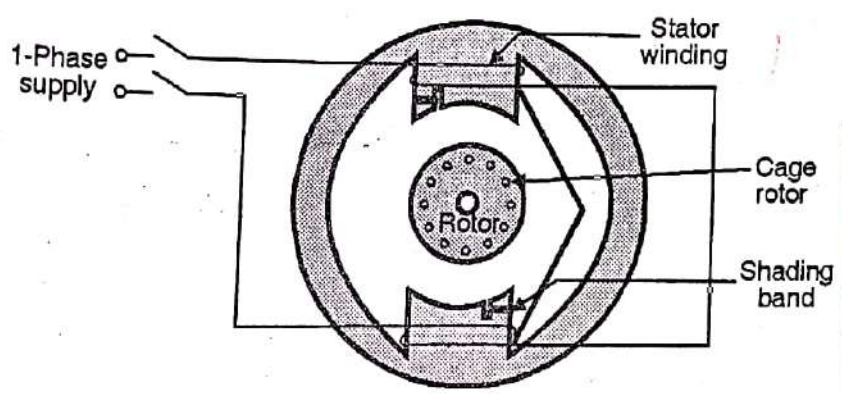
Fig: Torque-Speed chs of capacitor start capacitor run motor.

→ Applications:

Due to high starting torque, the capacitor start or capacitor start and capacitor run motors are used for the following applications:

1. Grinder
2. Compressors
3. Conveyers
4. Fans and air conditions
5. Refrigerators.

④ Shaded pole Induction Motors: (W-14, S-15, W-15)



(A-1111) Fig. 2.6.1 : Shaded pole I.M

Fig 1) shows the construction of shaded pole induction motor. It has usually squirrel cage rotor.

Every stator pole is divided into two parts by keeping a small slit (gap) in the pole face and the smaller portion is covered with a thick short circuited copper wire called copper band or shading band.

When stator winding carries current the main poles produce a flux ϕ_m .

This flux links with the shading band and this band acts as a shorted secondary, stator winding being its primary. Circulating currents, induced in the band produce another flux ϕ_s .

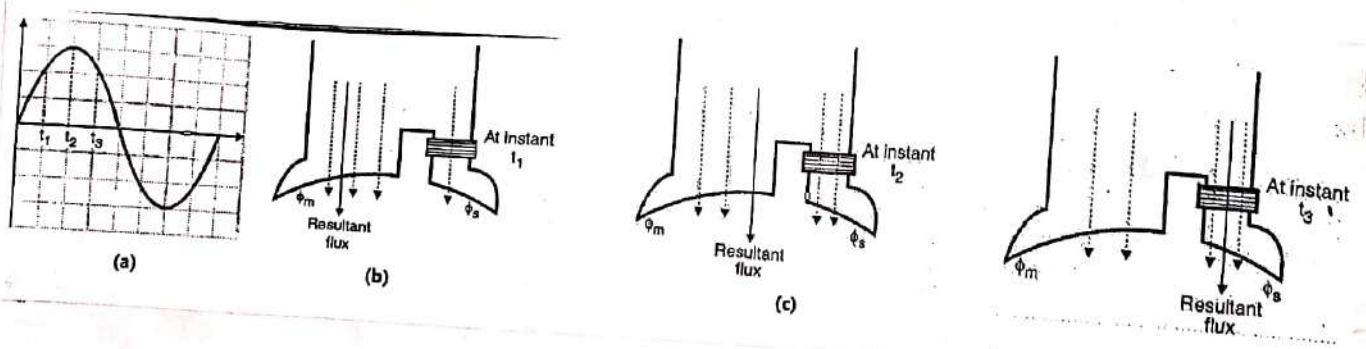


Fig: Resultant Flux

At instant t_1 current is increasing. The induced emf tries to oppose it.

Thus flux ϕ_s opposes it and resultant flux is in unshaded part.

At instant t_2 current is almost constant. Induced emf and flux ϕ_s are negligible. Resultant flux is almost at the centre of the pole. Thus it has shifted its position.

At instant t_3 current is decreasing. The induced current and flux ϕ_s try to oppose this decrease.

Hence there is crowding of flux in shaded part. Resultant flux lies in shaded part.

Thus it moves further. This action continues and the resultant field rotates from unshaded part to shaded part.

Hence rotor also rotates in the same direction. The direction of rotation cannot be reversed unless position of shaded ring is changed from one part of pole to another part of pole.

Such a motor develops low starting torque and it has a low power factor. However it is cheaper in cost and commonly used in practice.

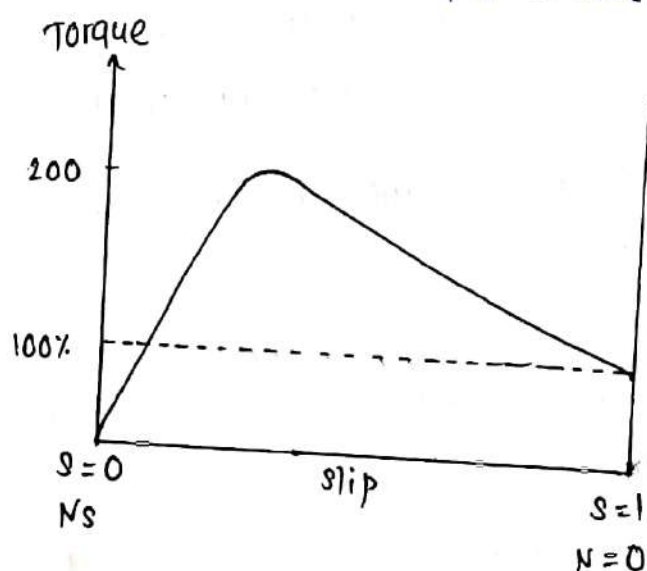


Fig. Torque speed chs.

→ Advantage:

1. cheap
2. Simple in construction.

→ Disadvantage:

1. Low starting torque
2. Low power Factor.

→ Applications:

1. Table fans
2. Blowers
3. Washing machines
4. Refrigerators.

* Comparison of Resistance split phase motor and capacitor split phase motor: (W-15) (4M)

Sr. No	parameter	Resistance split phase motor	capacitor split phase motor
1.	output	Designed For low output upto $\frac{1}{3}$ to $\frac{1}{2}$ HP	Can be designed upto 5HP
2.	starting torque	Less starting torque	Better starting torque.
3.	Cost	very cheap in cost	cost is more.
4.	Reliability	Needs no capacitor and hence give reliable service	Needs capacitor and hence reduces reliability.
5.	power factor	p.f. is poor	p.f. is better.
6.	uses	washing machines, refrigerators, fans etc.	compressors, air conditioners, grinder, pumps etc.