<u>**AC Machines:**</u>
Single-Phase Motors

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Single phase motors

- Single phase motors have a similar construction to the three phase motor, including an AC winding that is placed on the stator, and short-circuited conductors that are placed in a cylindrical rotor.
- Single-phase motors need less maintenance than three-phase motors, and will often last for years longer.
- Single-phase motors are used in equipment and machines that are smaller in size and require lower horsepower (for example, one horsepower). This include equipment such as pumps, refrigerators, fans, compressors, portable drills, space vehicles, aircrafts, business machines and power tools etc.
- Single-phase motors may be classified as under, depending on their construction and method of starting :

1. Induction Motors (split-phase, capacitor and shaded-pole etc.)
2. Repulsion Motors (sometime called Inductive-Series Motors)
3. A.C. Series Motor
4. Un-excited Synchronous Motors

Single phase induction motors

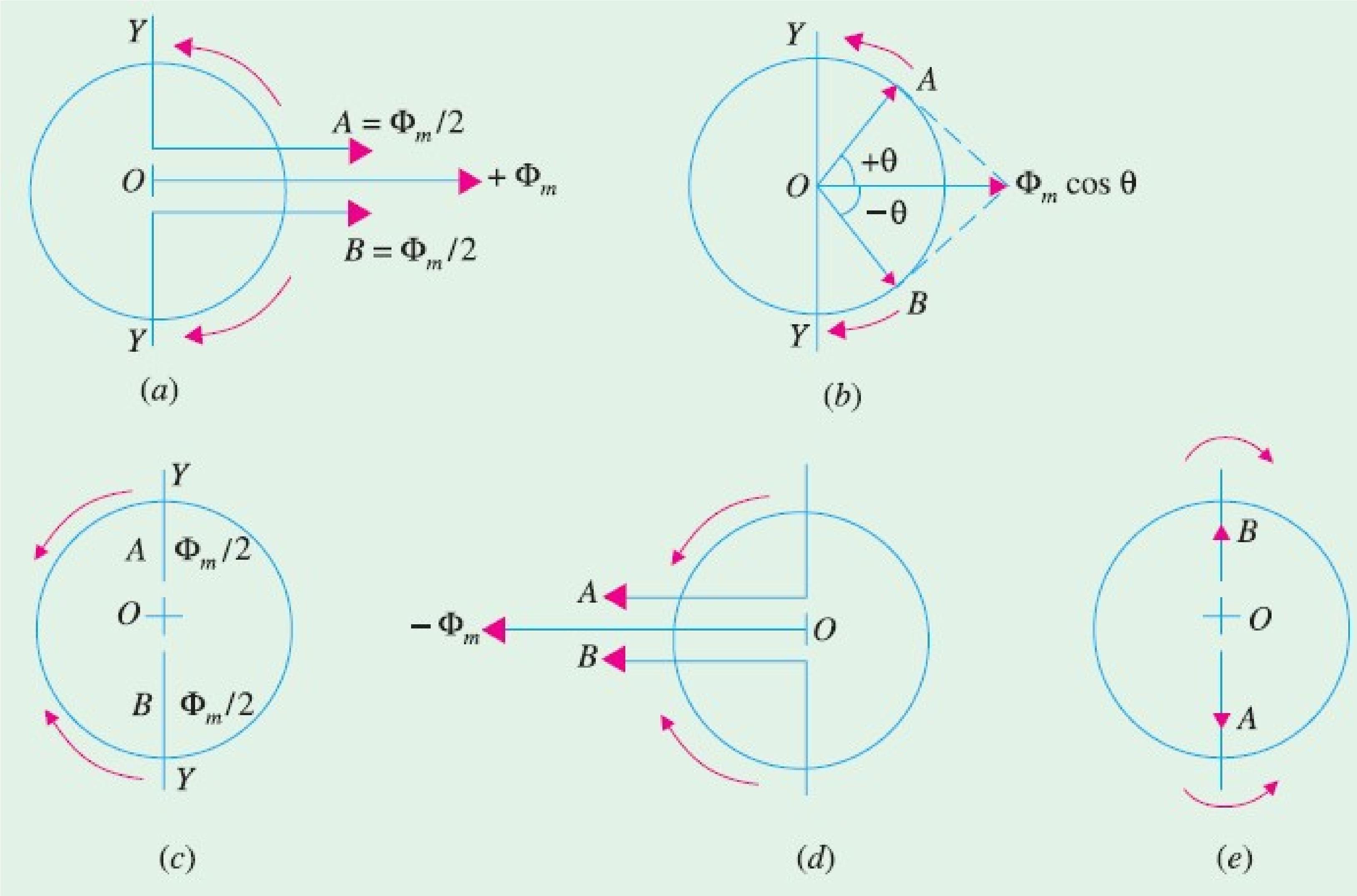
- A single-phase motor is not self-starting.
- Constructionally, this motor is, more or less, similar to a polyphase induction motor, except that (i) its stator is provided with a single-phase winding and (ii) a centrifugal switch is used in some types of motors, in order to cut out a winding, used only for starting purposes.
- It has distributed stator winding and a squirrel-cage rotor.
- When fed from a single-phase supply, its stator winding produces a flux (or field) which is only alternating i.e. one which alternates along one space axis only.
- It is not a synchronously revolving (or rotating) flux, as in the case of a three-phase stator winding, fed from 3-phase supply.
- Now, an alternating or pulsating flux acting on a stationary squirrel-cage rotor cannot produce rotation (only a revolving flux
- can).
- That is why a single-phase motor is not self-starting.

Single phase induction motors

- However, if the rotor of such a machine is given an initial start by hand (or small motor) or otherwise, in either direction, then immediately a torque arises and the motor accelerates to its final speed (unless the applied torque is too high).
- This peculiar behaviour of the motor has been explained in two ways : (i) by two -field or double field revolving theory and (ii) by cross-field theory.

Double field revolving theory

- This theory makes use of the idea that an alternating uni-axial quantity can be represented by two oppositely-rotating vectors of half magnitude.
- Accordingly, an alternating sinusoidal flux can be represented by two revolving fluxes, each equal to half the value of the alternating flux and each rotating synchronously ($N_s = 120f/P$) in opposite direction



As shown in Fig. (*a*), *let the alternating flux have a maximum value of Φm.*

Its component fluxes *A and B will each be equal to Φm /2 revolving in anticlockwise and clockwise directions respectively.*

After some time, when A and B would have rotated through angle $+\theta$ and $-\theta$, as in Fig. 36.1 (*b*), the resultant flux would be

$$= 2 \times \frac{\Phi_m}{2} \cos \frac{2\theta}{2} = \Phi_m \cos \theta$$

After a quarter cycle of rotation, fluxes A and B will be oppositely-directed as shown in Fig. 36.1 (*c*) so that the resultant flux would be zero.

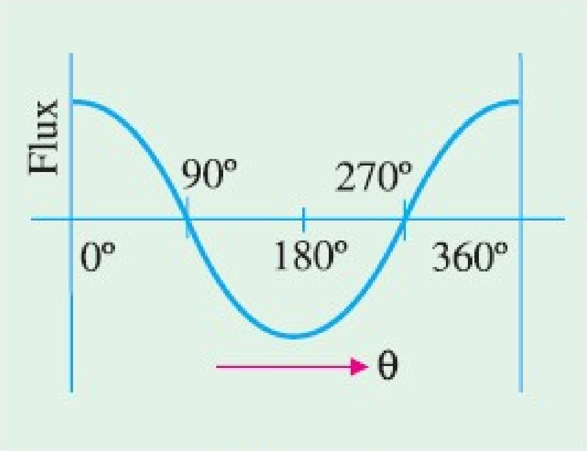


Fig. 36.2

After half a cycle, fluxes A and B will have a resultant of $-2 \times \Phi_m/2 = -\Phi_m$. After three-quarters of a cycle, again the resultant is zero, as shown in Fig. 36.1 (*e*) and so on. If we plot the values of resultant flux against θ between limits $\theta = 0°$ to $\theta = 360°$, then a curve similar to the one shown in Fig. 36.2 is obtained. That is why an alternating flux can be looked upon as composed of two revolving fluxes, each of half the value and revolving synchronously in opposite directions.

It may be noted that if the slip of the rotor is s with respect to the forward rotating flux (*i.e.* one which rotates in the same direction as rotor) then its slip with respect to the backward rotating flux is $(2 - s)$*.

Each of the two component fluxes, while revolving round the stator, cuts the rotor, induces an e.m.f. and this produces its own torque. Obviously, the two torques (called forward and backward torques) are oppositely-directed, so that the net or resultant torques is equal to their difference as shown in Fig. 36.3.

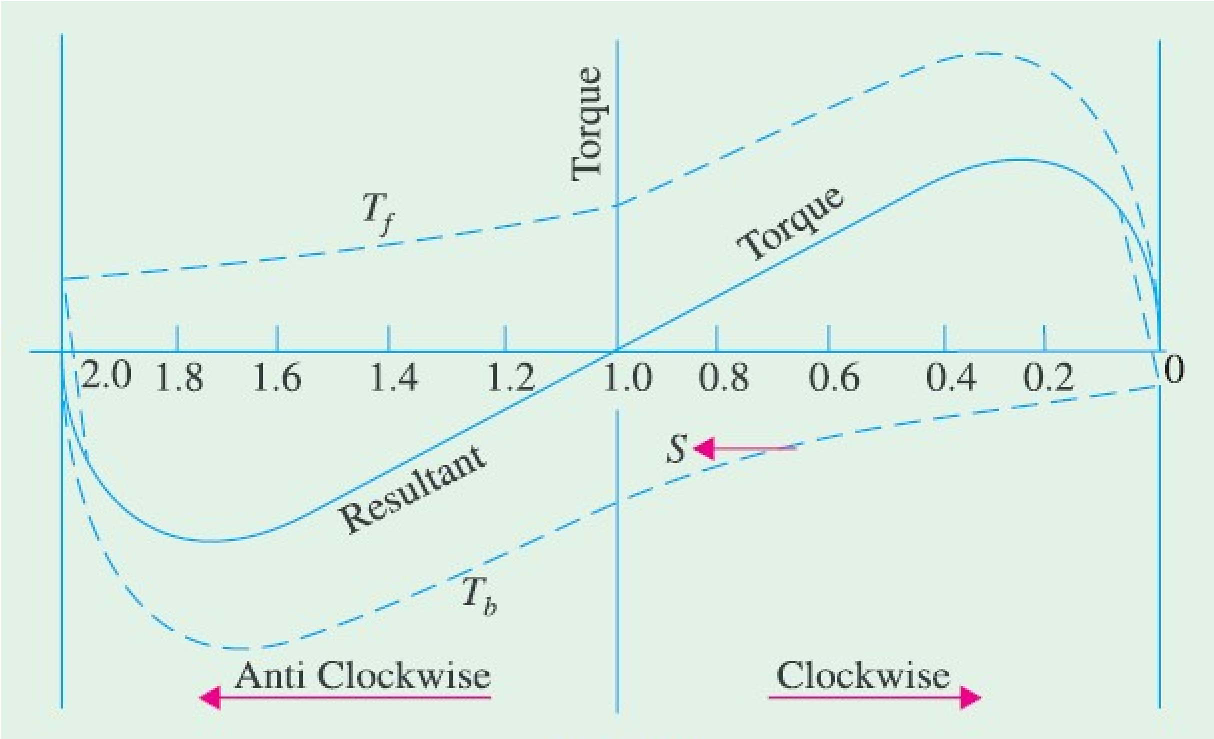


Fig. 36.3

Fig. 36.3 shows both torques and the resultant torque for slips between zero and +2.

At standstill, *s = 1 and (2 − s) = 1.*

Hence, Tf and Tb are numerically equal but, being oppositely directed, produce no resultant torque.

That explains why there is no ***starting*** torque in a single-phase induction motor

- ❖ However, if the rotor is started somehow, say, in the clockwise direction, the clockwise torque starts increasing and, at the same time, the anticlockwise torque starts decreasing.
- ❖ Hence, there is a certain amount of net torque in the clockwise direction which accelerates the motor to full speed.
- ❖ To make the single phase motor self-starting, it is temporarily converted into a two-phase motor during starting period.
- ❖ For this purpose, the stator of a single-phase motor is provided with an extra winding, known as starting (or auxiliary) winding, in addition to the main or running winding.
- ❖ The two windings are spaced 90º electrically apart and are connected in parallel across the single-phase supply
- ❖ It is so arranged that the phase-difference between the currents in the two stator windings is very large (ideal value being 90º).
- ❖ Hence, the motor behaves like a two phase motor.
- ❖ These two currents produce a revolving flux and hence make the motor self-starting.

Methods of starting: (i) Split phase

(i) In split-phase machine, shown in Fig. 36.5 (a), the main winding has low resistance but high reactance whereas the starting winding has a high resistance, but low reactance.

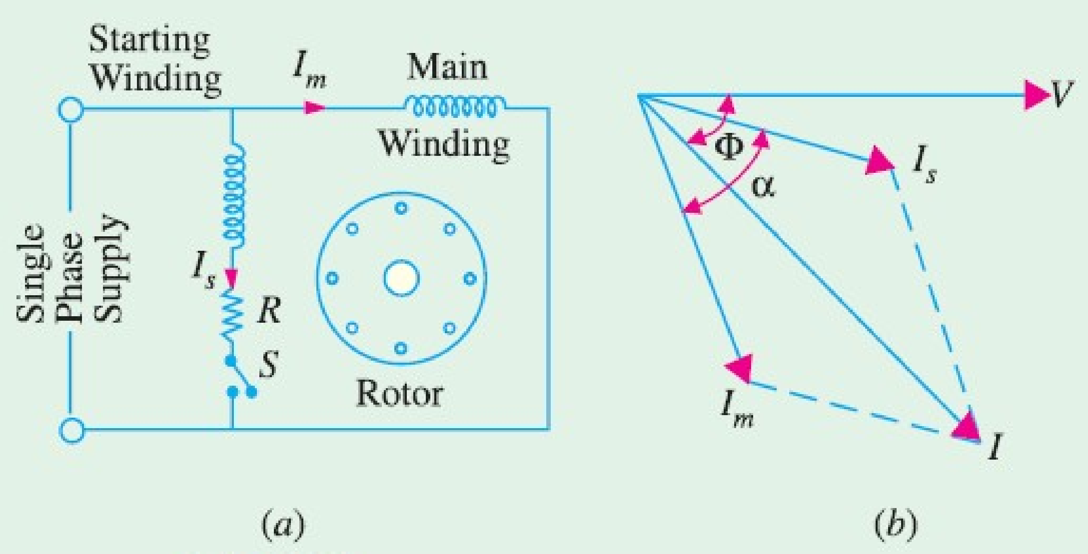
(ii) As shown in Fig. 36.5 (b), the current Is drawn by the starting winding lags behind the applied voltage V by a small angle whereas current Im taken by the main winding lags behind V by a very large angle.

(iii) Phase angle between Is and Im is made as large as possible because the starting torque of a split-phase motor is proportional to sin α.

(iv) A centrifugul switch S is connected in series with the starting winding and is located inside the motor.

(v) Its function is to automatically disconnect the starting winding from the supply when the motor has reached 70 to 80 per cent of its full-load speed.

Methods of starting: (i) Split phase



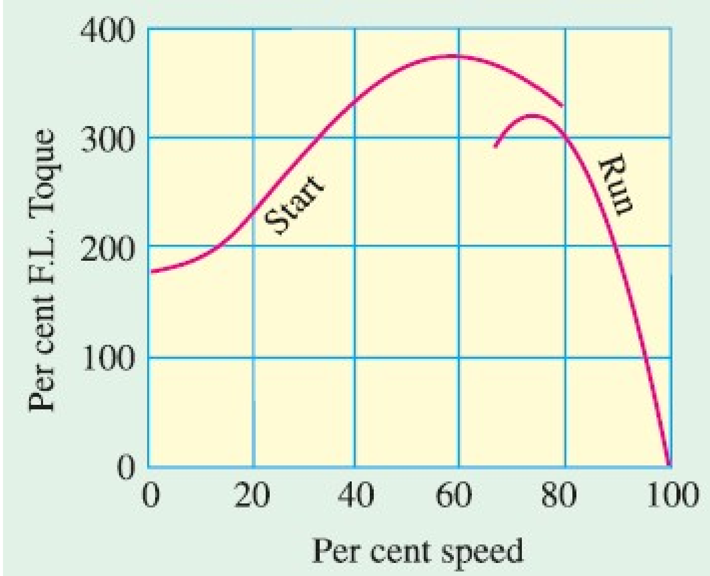


Fig. 36.5

A typical torque/speed characteristic of such a motor is shown in Fig. 36.7. As seen, the starting torque is 150 to 200 per cent of the full-load torque with a starting current of 6 to 8 times the full-load current. These motors are often used in preference to the costlier capacitor-start motors. Typical applications are : fans and blowers, centrifugal pumps and separators, washing machines, small machine tools, duplicating machines and domestic refrigerators and oil burners etc. Commonly available sizes range from 1/20 to 1/3 h.p. (40 to 250 W) with speeds ranging from 3,450 to 865 r.p.m.

the direction of rotation of such motors can be reversed by reversing the connections of one of the two stator windings (not both)

Speed regulations of such motors are low: 2-5%: Used as constant speed motors

Split-Phase(ii) Capacitor-start Induction-run motors

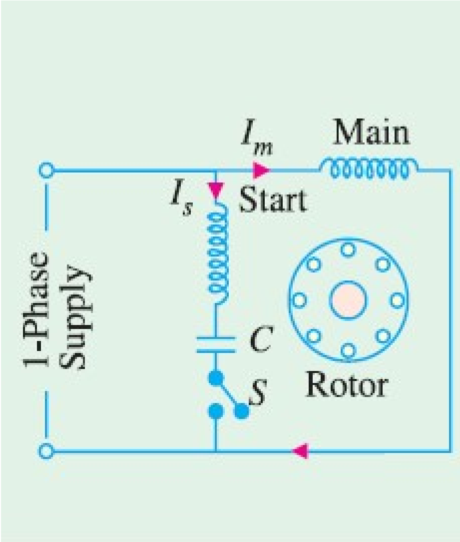


Fig. 36.10

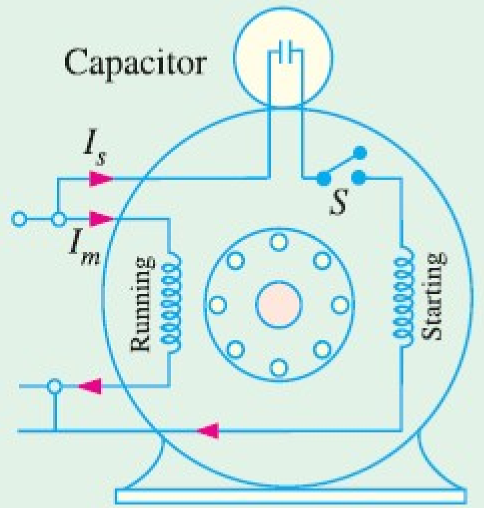


Fig. 36.11

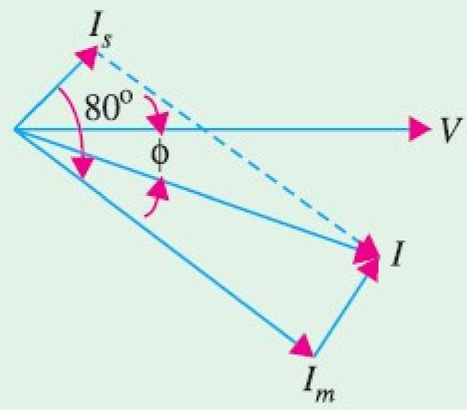


Fig. 36.12

(*ii*) Capacitor-start Induction-run motors. In these motors, the necessary phase difference between I_s and I_m is produced by connecting a capacitor in series with the starting winding as shown in Fig. 36.10. The capacitor is generally of the electrolytic type and is usually mounted on the outside of the motor as a separate unit (Fig. 36.11).

The capacitor is designed for extremely short-duty service and is guaranteed for not more than 20 periods of operation per hour, each period not to exceed 3 seconds. When the motor reaches about 75 per cent of full speed, the centrifugal switch *S* opens and cuts out both the starting winding and the capacitor from the supply, thus leaving only the running winding across the lines. As shown in Fig.

starting torque of such motors is high: 350 to 450 per cent of full load torque

Shaded-pole Single-phase Motor

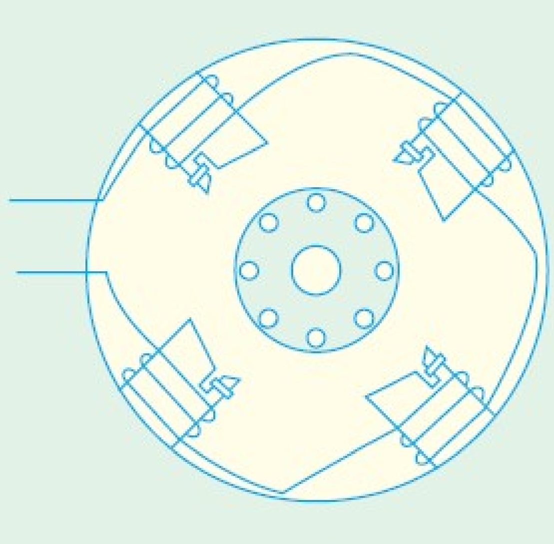


Fig. 36.33

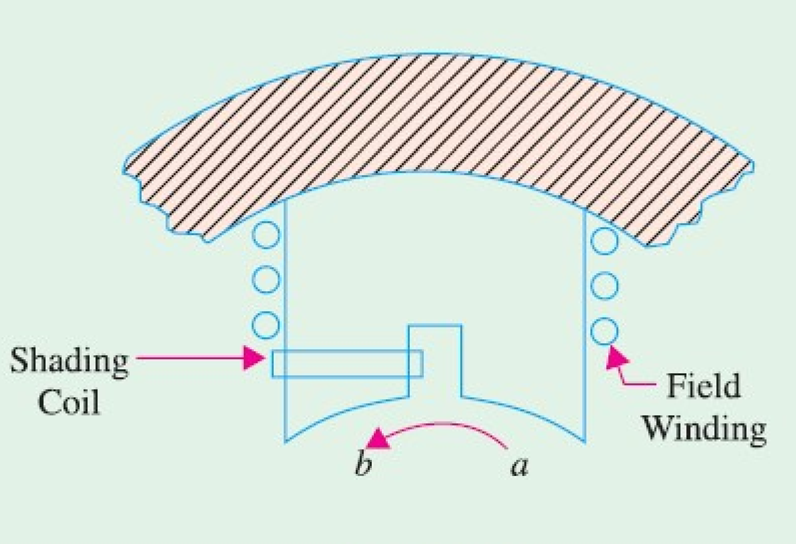


Fig. 36.34

The laminated pole has a slot cut across the laminations approximately one-third distance from one edge. Around the small part of the pole is placed a short circuited Cu coil known as shading coil. This part of the pole is known as shaded part and the other as unshaded part. When an alternating current is passed through the exciting (or field) winding surrounding the whole pole, the axis of the pole shifts from the unshaded part a to the shaded part b. This shifting of the magnetic axis is, in effect, equivalent to the actual physical movement of the pole. Hence, the rotor starts rotating in the direction of this shift i.e. from unshaded part to the shaded part.

Shaded-pole Single-phase Motor

- Shaded pole motors are built commercially in very small sizes, varying approximately from 1/250 h.p. (3W) to 1/6 h.p. (125 W).
- Although such motors are simple in construction, extremely rugged, reliable and cheap, they suffer from the disadvantages of (i) low starting torque (ii) very little overload capacity and (iii) low efficiency.
- Efficiencies vary from 5% (for tiny sizes) to 35 (for higher ratings).
- Because of its low starting torque, the shaded-pole motor is generally used for small fans, toys, instruments, hair dryers, ventilators, circulators and electric clocks.
- It is also frequently used for such devices as churns, phonograph turntables and advertising displays etc.
- The direction of rotation of this motor cannot be changed, because it is fixed by the position of copper rings.

Repulsion Type Motors

Constructionally, it consists of the following :

1. Stator winding of the distributed non-salient pole type housed in the slots of a smooth-cored stator (just as in the case of split-phase motors). The stator is generally wound for four, six or eight poles.
2. A rotor (slotted core type) carrying a distributed winding (either lap or wave) which is connected to the commutator. The rotor is identical in construction to the d.c. armature.
3. A commutator, which may be one of the two types : an axial commutator with bars parallel to the shaft or a radial or vertical commutator having radial bars on which brushes press horizontally.
4. Carbon brushes (fitted in brush holders) which ride against the commutator and are used for conducting current through the armature (i.e. rotor) winding.

Repulsion Type Motors

If the brushes are set in position shown in Fig. 36.38 (a) so that the brush axis is neither in line with nor 90º from the magnetic axis YY′ of the main poles, a net voltage will be induced between the brush terminals which will produce armature current.

The armature will again act as an electromagnet and develop its own N-and S-poles.

Hence, rotor N-pole will be repelled by the main N-pole and the rotor S-pole will, similarly, be repelled by the main S-pole. Consequently, the rotor will rotate in clockwise direction.

Since the forces are those of repulsion, it is appropriate to call the motor as repulsion motor.

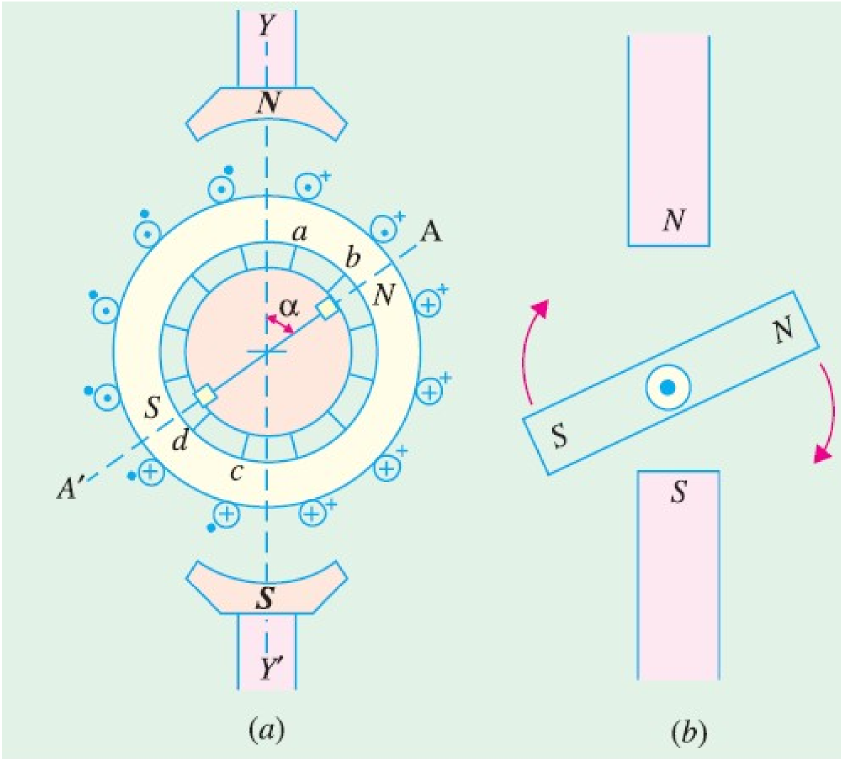


Fig. 36.38

Principal shortcomings of such a motor are :

1. speed varies with changing load, becoming dangerously high at no load.
2. low power factor, except at high speeds.
3. tendency to spark at brushes.

Repulsion Type Motors

- Suppose that the direction of flow of the alternating current in the exciting or field (stator) winding is such that it creates a N-pole at the top and a S-pole at the bottom.
- The alternating flux produced by the stator winding will induce e.m.f. in the armature conductors by transformer action.
- The direction of the induced e.m.f. can be found by using Lenz's law and is as shown in Fig. 36.37 (a).
- However, the direction of the induced currents in the armature conductors will depend on the positions of the short-circuited brushes.
- If the brushes are as shown in Fig (a) no torque will be developed