12.23. SINGLE PHASE A.C. MOTOR

As we know that there are various domestic appliances used in home, for day-to-day service, which uses various kinds of motor to obtain rotational motion. But the power requirement of the home appliances is less, hence 1 phase a.c. supply system is used in residentital area. Hence due to availability of 1 phase a.c. supply, various motors used in home appliances to perform various tasks, which are known as single phase motors. Due to lesser loads these motors are designed for small power rating, hence are termed as *fractional horse power (or fractional kilowatt motors).* The fractional horse power motors are defined as "a motor built in a frame smaller than that having a continuous rating of 1 H.P., open type, at

short circuited coil known as shading coil. Such type of motor employees squirrel cage rotor. When main winding is connected to a.c. supply mains, then time varying flux is set up in the poles.

When the flux varies w.r.t. time, then due to transformer action, an emf is induced in short circuited shading coil. According to Lenz's law, the emf induced in shading coil which circulate current in such a direction to oppose the cause *i.e.* varying flux in shaded portion of pole. Hence the flux in shaded portion will lag behind, the flux in the unshaded portion displayed by some angle, gives rise to resultant rotating field, producing starting as well as running torque. The resultant is in the direction from unshaded to shaded portion of the pole face. Hence rotor always rotates from unshaded portion to shaded portion. Fig. 12.60 (*a*) shows schematic arrangement of shaded pole motor.

Torque speed characteristic. The starting torque of a shaded pole induction motor is very low *i.e.* 50% of full load torque. Such motors are less efficient and have higher slips than other type of single phase induction motors. Fig. 12.60 (*b*) shows speed torque characteristics.

Applications. Due to its low torque, such types of motors are used in various applications where requirement of starting is low. Hence these motors are used in small fans, electric clocks, hair dryers, time phonographs, toys, photocoyping machine etc.

Direction of rotation. The direction of rotation of such motor is always from unshaded portion to shaded portion of pole. Hence such motors rotates in a definite direction. In application where reversal of direction of rotation is essential, it can be achieved by providing two set of shading bands, one on each end of pole. The direction of rotation can be changed by open circuiting one set of shading coil and short circuiting the other set.

12.27. SINGLE PHASE COMMUTATOR MOTOR

Such motors are use commutator similar to commutator of d.c. motors. The commutator motors are :

1. Universal motor
2. A.C. series motor.

12.27.1. Universal motors. This is one kind of 1 phase commutator motor. These types of motor have wound rotor with brushes and commutator arrangement. This is a small series motor which is capable of working on both a.c. and d.c. supply. That's why it is called universal motor. There are two types of universal motors known as compensated and non-compensated.

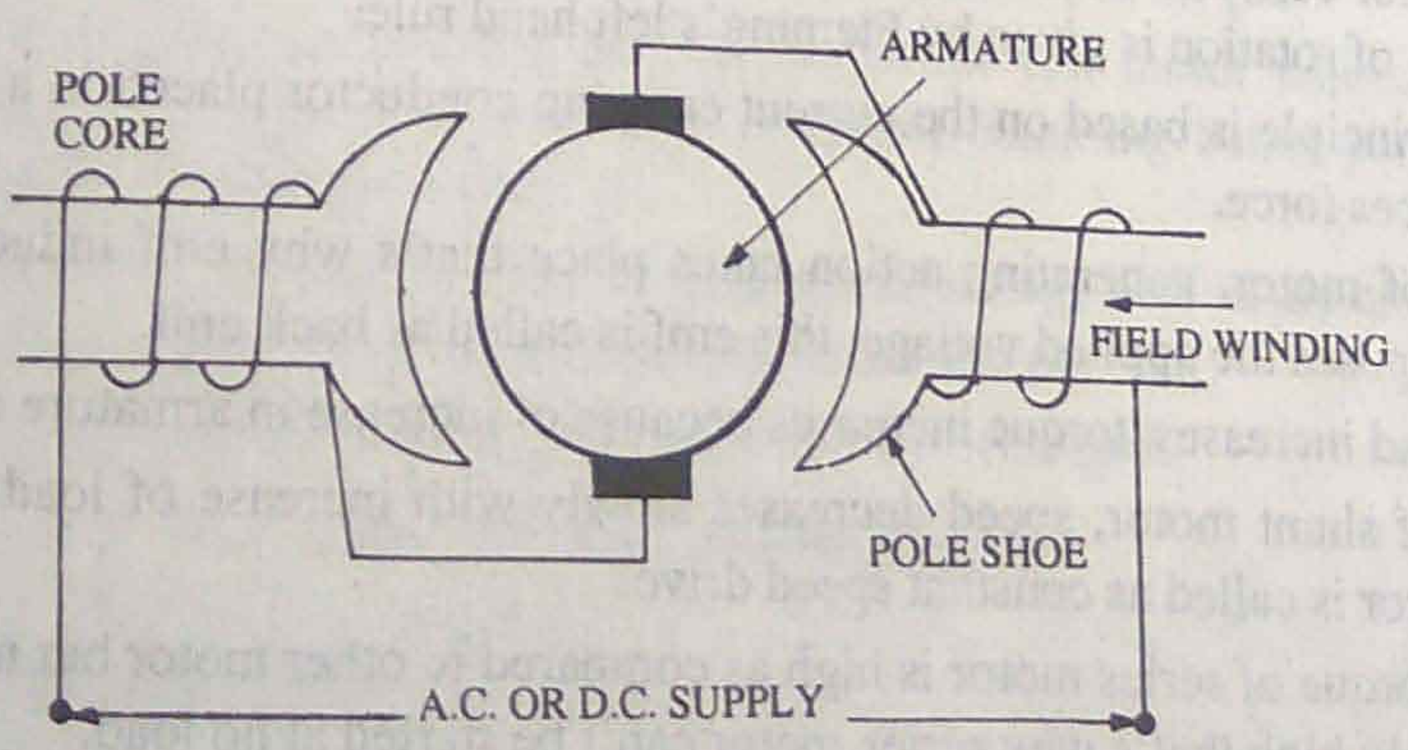


Fig. 12.61. Universal motor.

1700 to 1800 rpm. Single phase motors perform great variety of useful services in the home, the office business establishment such as these motors are used in fans, mixers, vacuum cleaners, washing machines, refrigerators, portable drills, sewing machine and small farming applications. Advances in single phase motors design, have made them to operate quite and satisfactorily in their operation. Hence single phase motor today became most popular motors used in various applications, where single phase a.c. supply is available.

12.24. CLASSIFICATION OF SINGLE PHASE MOTORS

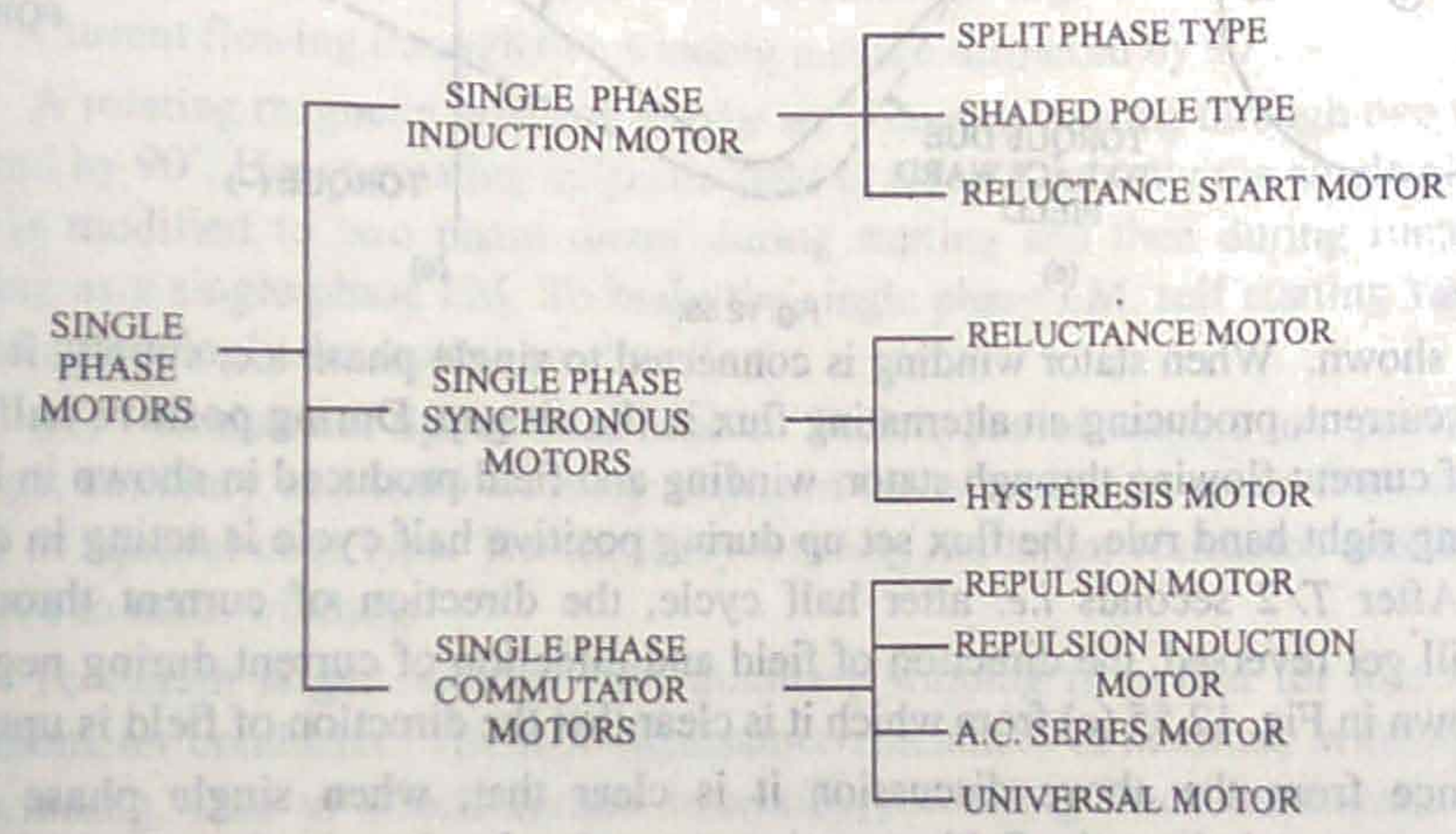
The requirement of various applications differs from each other, hence to fulfill the requirement of each application, great variety of single phase motors are developed. Due to availability of variety of single phase motors, depending upon the requirement of load *i.e.*, starting torque and maximum torque etc. they are selected to meet the specific requirement of load. Single phase motors are classified according to their construction and starting methods employed. Hence single phase motors can be mainly classified as below :

(*a*) Induction motors,

(*b*) Synchronous motors,

(*c*) Commutator motors.

The various type of motor in each class are further classified as below :

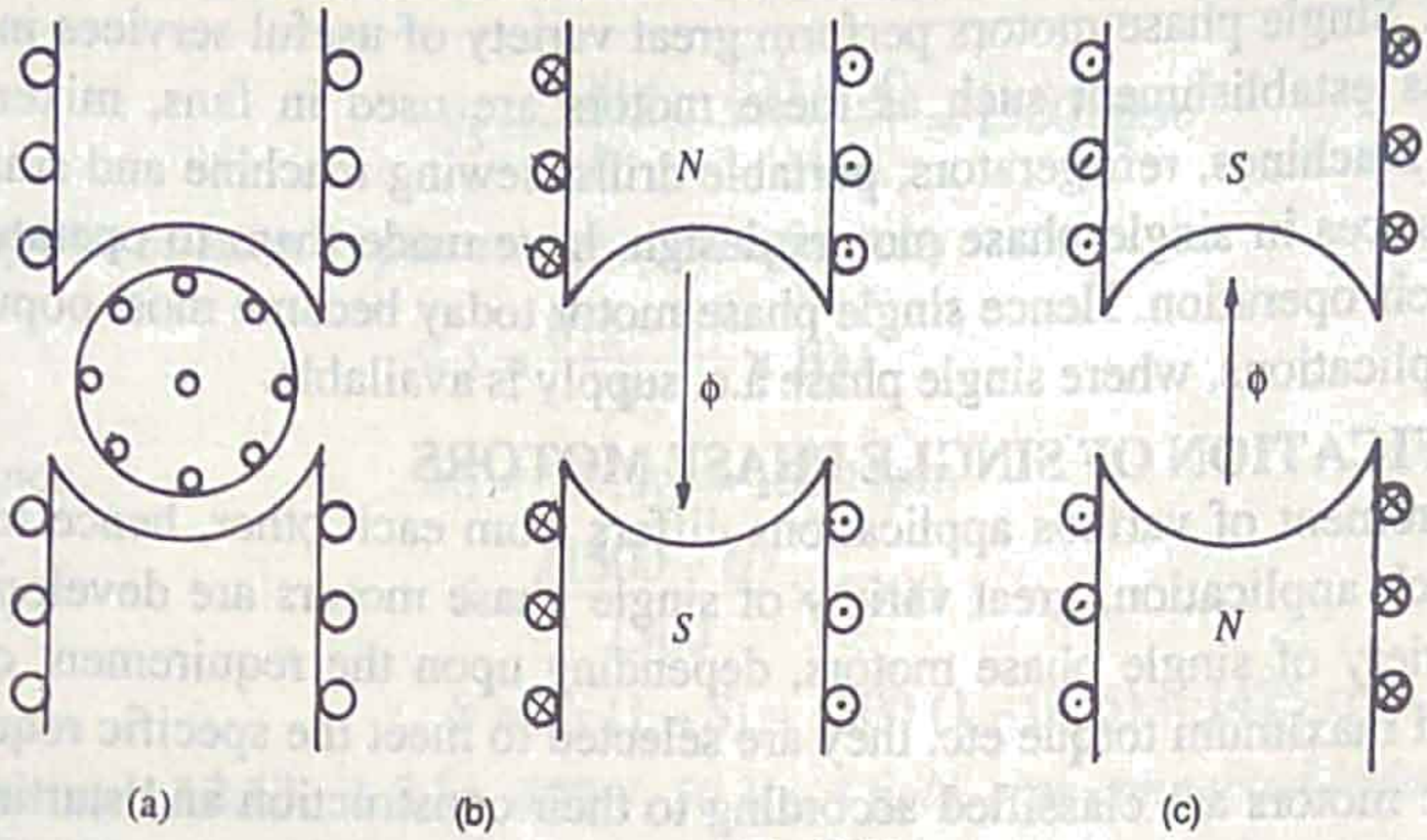


12.25. SINGLE PHASE INDUCTION MOTOR

As the name implies, single phase induction motor has a single phase winding on stator and squirrel cage type of rotor. Fig. 12.55 (*a*) shows simplified diagram of 2 pole single phase induction motor.

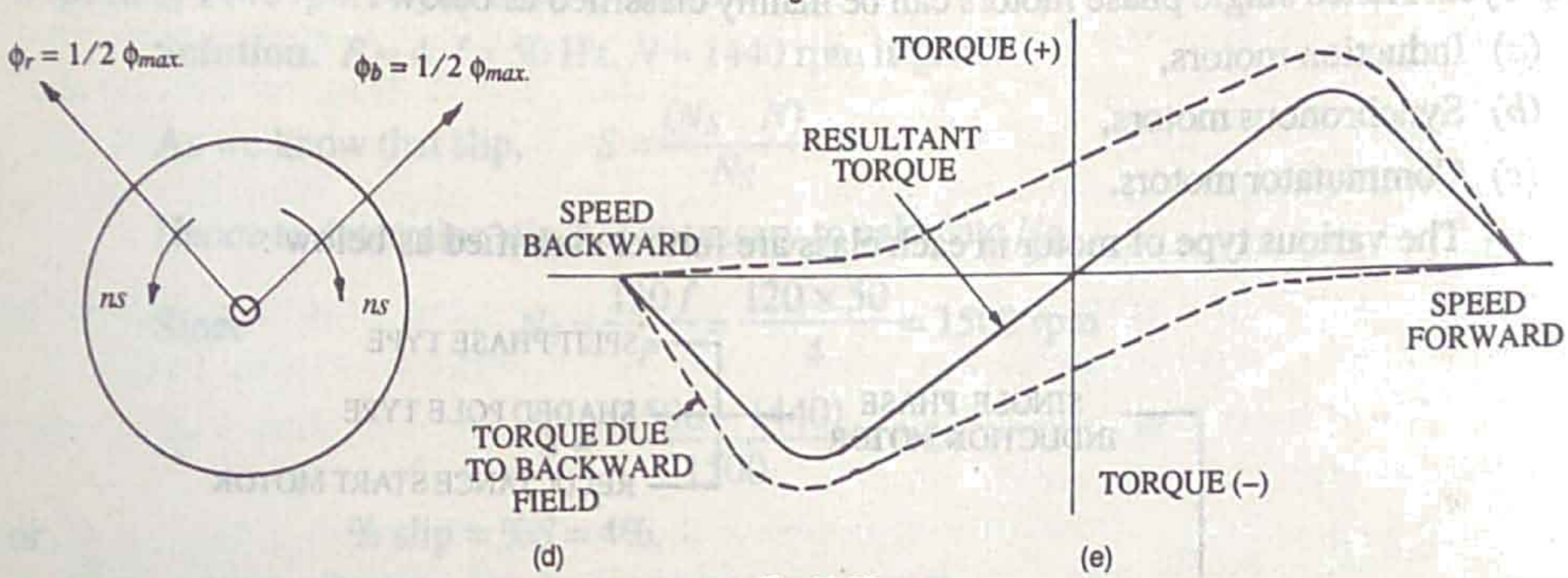
Construction. The construction of single phase induction motor is similar to 3-phase squirrel cage induction motor, except that the stator is provided with a single phase winding. The rotor of single phase induction motor is of squirrel cage type. The stator winding is of distributed type.

Operating principle. To study the operating principle of single phase induction motor, let us consider Fig. 12.55 (*b*), in which for convenience concentrated type of stator



(a) (b) (c)

Fig. 12.55.



(d) (e)

Fig. 12.55.

winding is shown. When stator winding is connected to single phase a.c. supply, it carries an alternating current, producing an alternating flux in the air gap. During positive half cycle the direction of current flowing through stator winding and field produced in shown in Fig. 12.55 (*b*). By using right hand rule, the flux set up during positive half cycle is acting in downward direction. After *T*/2 seconds *i.e.* after half cycle, the direction of current through stator winding will get reversed, the direction of field and direction of current during negative half cycle is shown in Fig. 12.55 (*c*) from which it is clear that the direction of field is upward.

Hence from the above discussion it is clear that, when single phase supply is connected to stator winding, the field set up is not rotating but is pulsating. Such arrangement results in zero starting torque; therefore, these motors are not self starting.

It is however experienced that when the rotor is given an initial rotation in any direction it continues to pick up speed in that direction. A starting torque is therefore necessary to enable the rotor to pick up speed in any direction. Following are the two theories explains how rotor develops torque when initial rotation is given :

(*a*) Cross field theory.

(*b*) Double revolving field theory.

Here we will study only double revolving field theory.

Double revolving field theory. As we know that, when single phase stator winding

is connected to single phase a.c. supply, a pulsating field is set up. According to double revolving field theory such a flux can be resolved into two components of half of its amplitude and rotating in opposite direction with synchronous speed. Clockwise component of field will result in production of torque in clockwise direction and counter clockwise direction of field will produce torque in opposite direction as shown in Fig. 12.55 (*e*).

At standstill *i.e.*, when slip is unity the two torque acting on rotor are equal and opposite. Due to which rotor will not rotate. If the machine is started by some external means in any direction, say clockwise, the torque developed by counter clockwise component, causing the rotation of rotor in clockwise direction. As rotor picks up speed the magnitude of torque developed by clockwise component goes on increasing due to which rotor approaches near to synchronous speed easily. Fig. 12.55 (*e*) shows torque slip characteristics of single phase induction motor.

12.25.1. Types of Single Phase Induction Motors. As we know that the single phase induction motor does not have starting torque. To make them self starting, some modifications are done in their construction, such that it behaves like a two phase motor during starting period. To obtain a revolving field in a two phase induction motors, two conditions must be satisfied :

1. Two windings must be displaced by 90 electrical degrees
2. Current flowing through two winding must be displaced by 90°.

A rotating magnetic field can also be set if current flowing through two winding is not displaced by 90°. Hence rotating magnetic field is set up if initially the single phase induction motor is modified to two phase motor during starting and then during running condition operating as a single phase I.M. To make the single phase I.M. self starting various methods are used accordingly the motors are classified.

(A) Resistance Split Phase Motor. Such types of motors are provided with two windings, auxiliary and main winding displaced 90° electrical in space from each other. The rotor is of squirrel cage type. The auxiliary winding has larger resistance and lesser reactance compared to main winding.

To obtain larger resistance the auxiliary winding is wound for less turns by using lesser diameter conductor. The R/X (Resistance/reactance) of auxiliary winding is more than main winding. Due to which current in auxiliary winding leads the current through main winding by an angle 'α'. The auxiliary and main windings are designed in such a way to obtain the value of α in range of 20° to 45°. Due to such arrangement, though the supply connected to two windings is single phase, current flowing through two windings to some extent are similar to two phase currents. Hence a rotating magnetic field will be produced, which will develop starting torque on rotor. Once the motor attains 75% to 80% of synchronous speed, the auxiliary winding is disconnected with the help of centrifugal switch automatically connected in series with it. Since different resistance of the winding are responsible to obtain phase displacement between two winding currents, hence such motors are known as *resistance split phase motor*. The connection diagram and vector diagram of such motor is as shown in Fig. 12.56 (*a*).

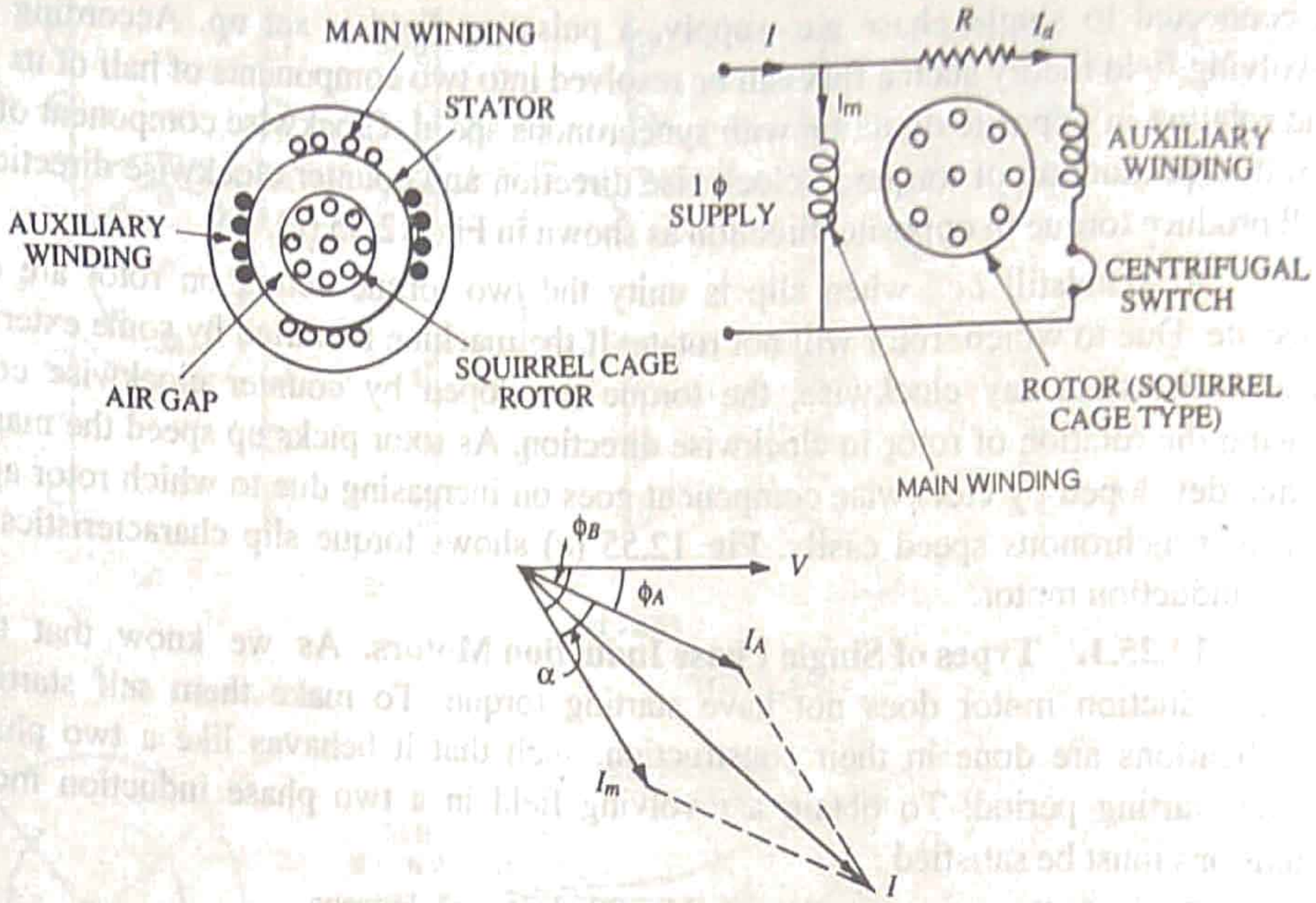


Fig. 12.56 (a).

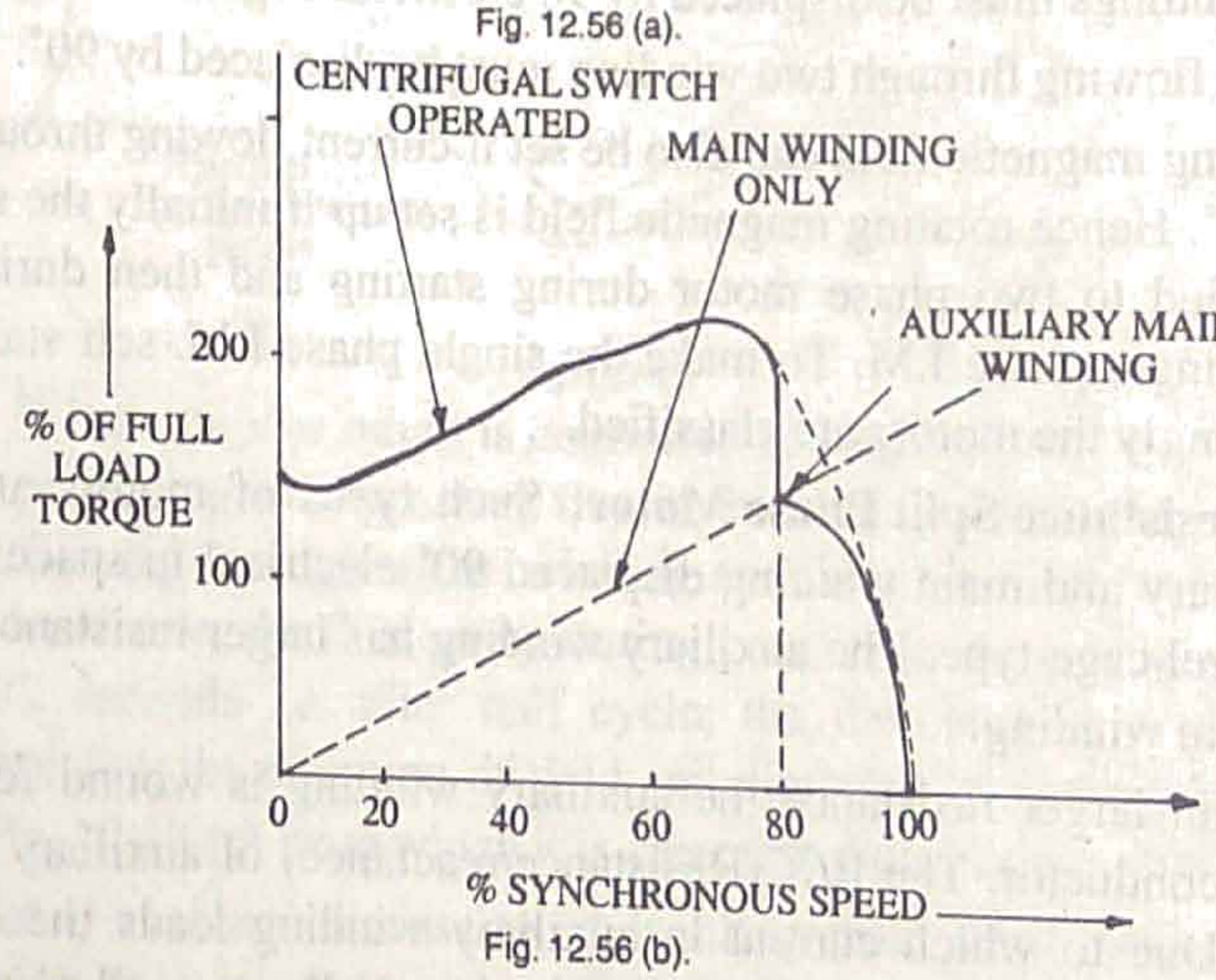


Fig. 12.56 (b).

Torque speed characteristics. Fig. 12.56 (*b*) shows torque speed characteristics of resistance split phase motor. The starting torque of such motor is 150 to 200% of full load running torque and starting current is 6 to 8 times full load current.

Reversal of rotation. The direction of rotation of a split phase type induction motor depends upon the way of connection of auxiliary and main winding w.r.t. supply terminals. Hence the direction of rotation can be changed by reversing terminal connections of either the main or auxiliary winding.

Applications. Starting torque of such motor is moderate, hence are suitable for washing machines, drills, press, fans blowers, certrifugal pumps, duplicating machine, grinders, oil bruners, etc.

12.26. CAPACITOR SPLIT PHASE MOTORS

Such motors uses capacitor to obtain phase displacement between two winding currents and same in construction as that of resistance split phase I.M. Due to use of capacitor, the current in the two winding is diplayed by exactly 90°, causing the motor to behave like two phase motor, giving larger starting torque. Power factor of such motor is good due to use of capacitor.

The capacitor split phase motors are mainly three types :

(*a*) Capacitor start motors. (*b*) Capacitor start capacitor run.

(*c*) Permanent capacitor motor.

Now let us study each type one by one in detail.

12.26.1. Capacitor Start Motor. In this type of motor, an electrolytic capacitor is connected in series with auxiliary winding. Due to use of capacitor, current through two windings are displaced by 90°, causing rotating magnetic field. Once the speed of rotor comes nearer to 75% to 80% of synchronous speed, the centrifugal switch operates automatically to disconnect auxiliary winding from supply. Fig. 12.57 (*a*) shows connection diagram and vector diagram.

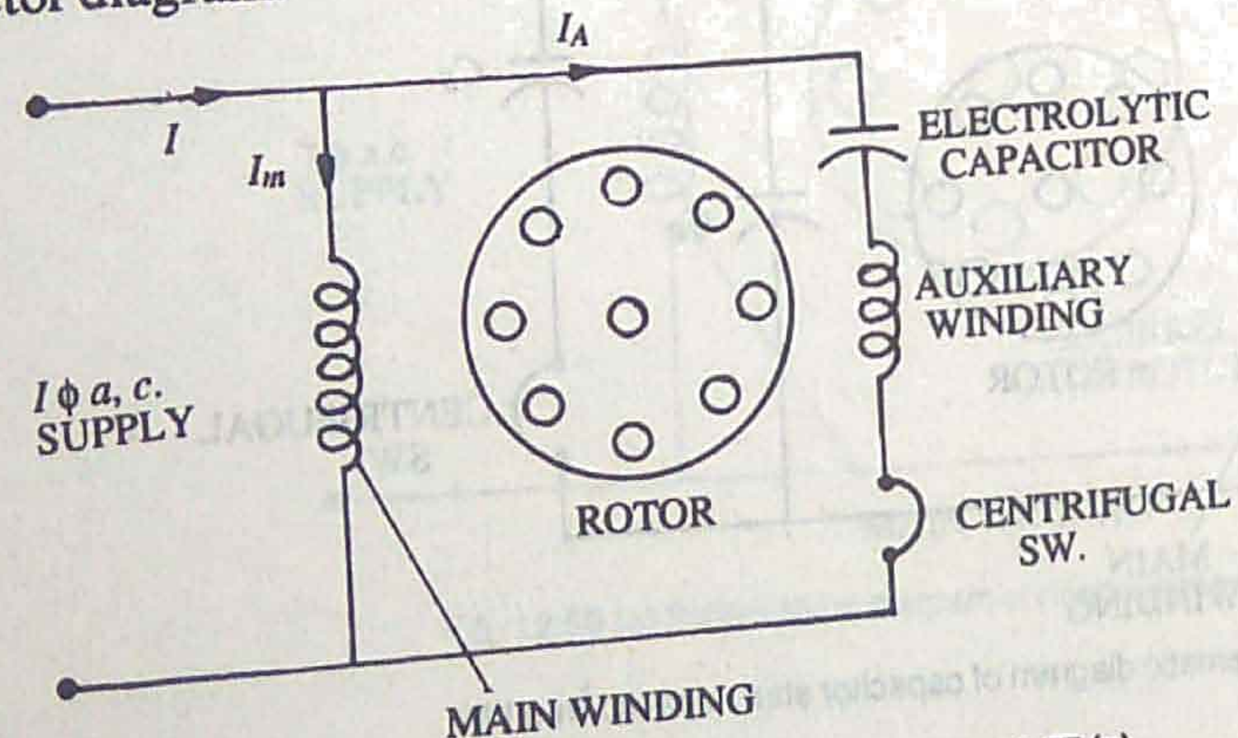


Fig. 12.57 (a).

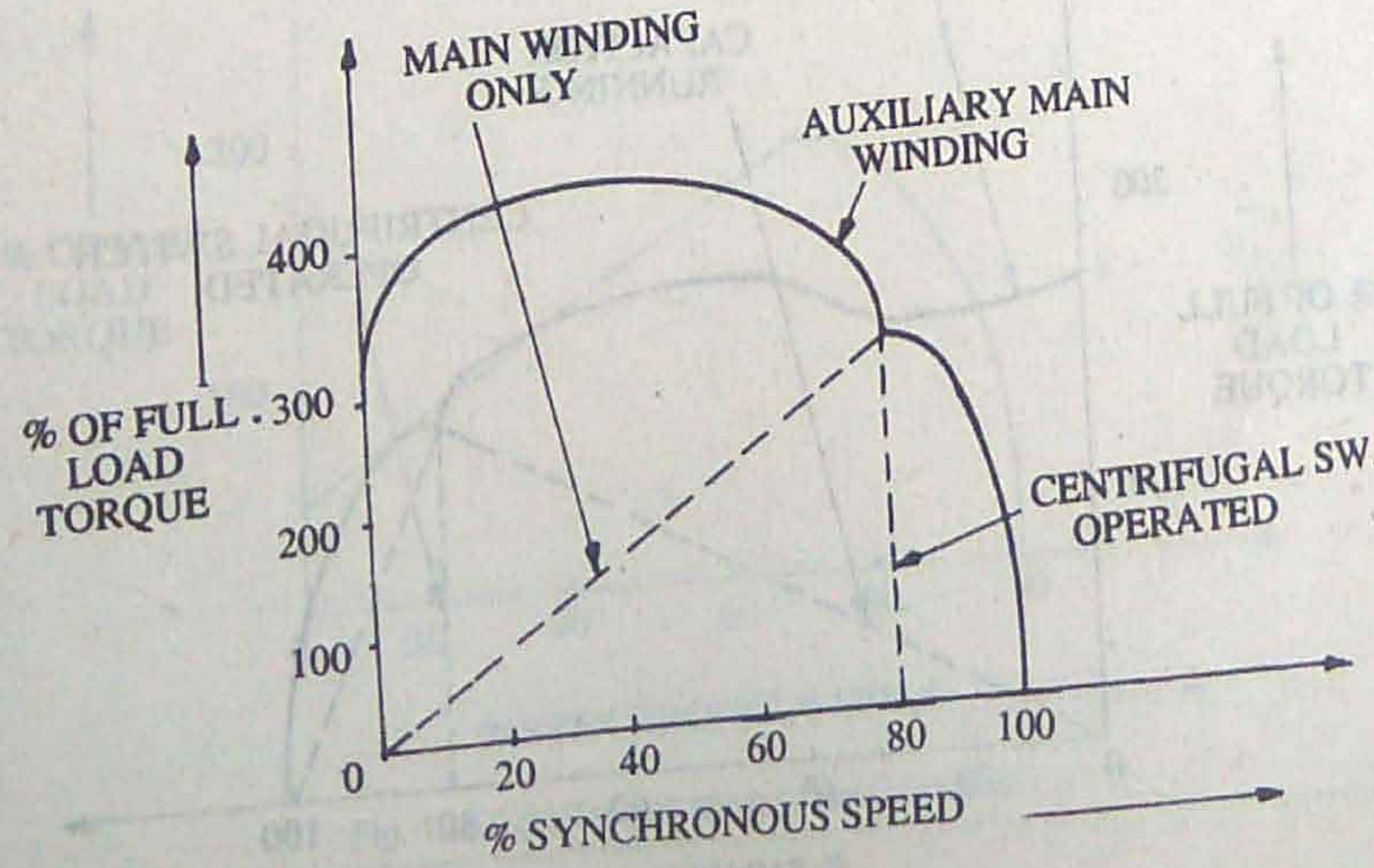


Fig. 12.57 (b).

Torque speed characteristics. Due to use of capacitor, the starting torque of this type of motor is 400% of full load torque.

Direction of rotation. The direction of rotation can be changed by reversing the connection of any *i.e.* auxiliary or main winding w.r.t. supply terminals.

Applications. Due to very large starting torque, such motors are used in application such as refrigerator or compressor or small hoist.

12.26.2. Capacitor Start Capacitor Run Motor. In this type of motor, two capacitors are used in auxiliary winding circuit. One is of large value, short duty capacitor connected in series with centrifugal switch and other small value, continuous rating oil capacitor. The capacitor connected in series with centrifugal switch is used to obtain very large starting torque and is disconnected at 75% to 80% of synchronous speed with the help of centrifugal switch. After the operation of centrifugal switch, still the auxiliary winding in series with small continuous rating capacitor remains in circuit during running conditions. The use of other capacitor causes the motor to behave like two phase motor during running

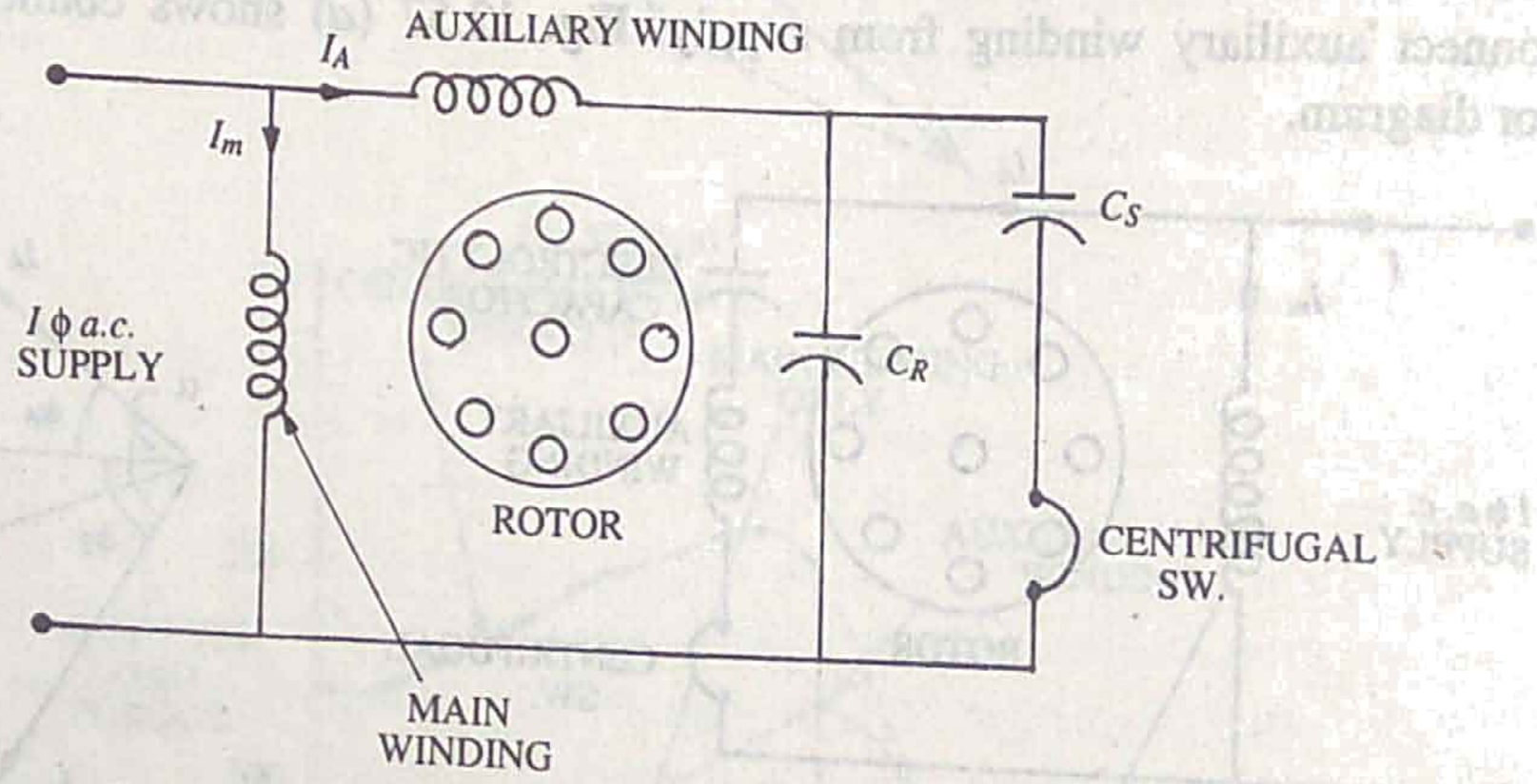


Fig. 12.58 (a) Schematic diagram of capacitor start capacitor run LM.

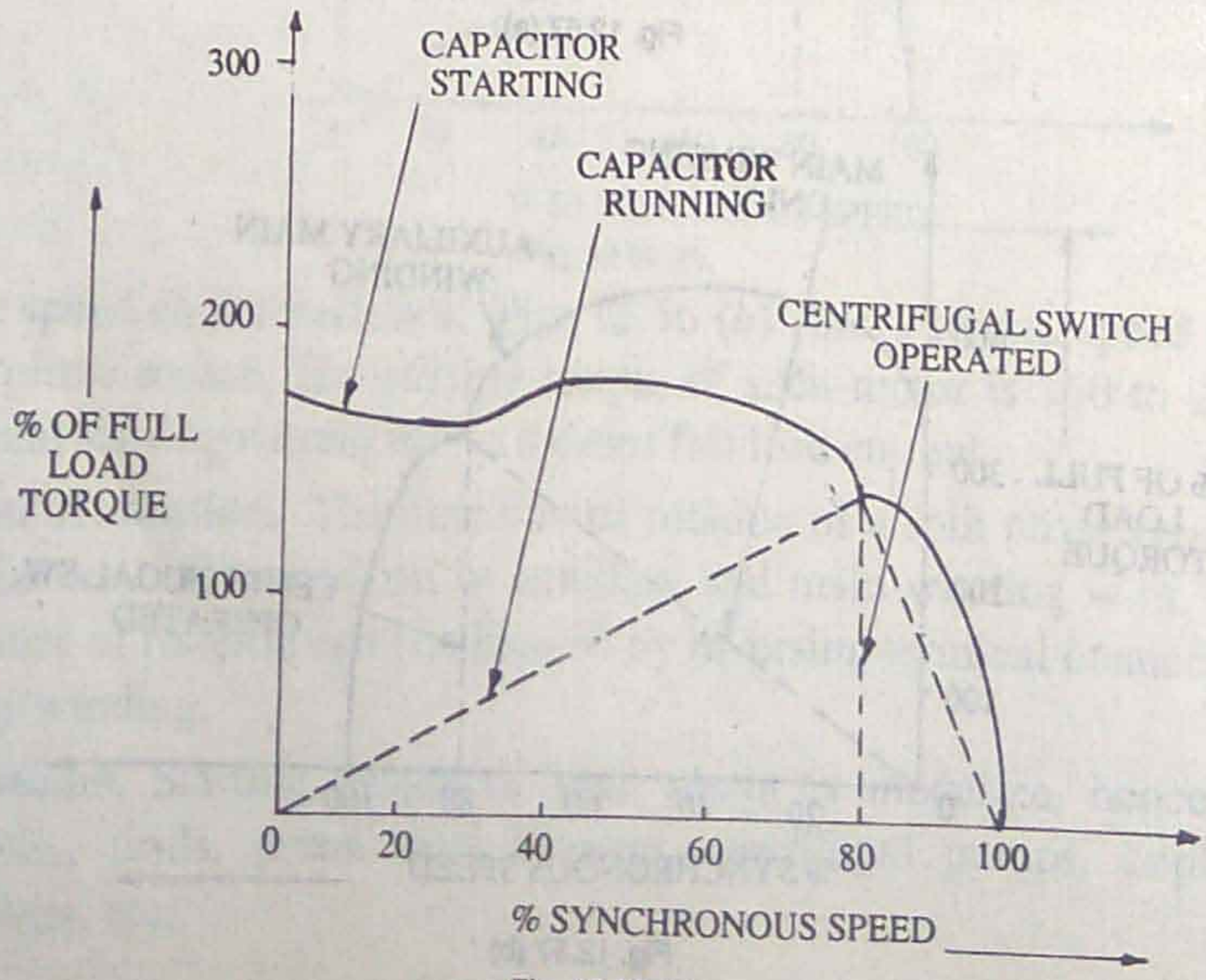


Fig. 12.58 (b).

condition, obtaining better performance, less noise, higher efficiency and better power factor. Fig. 12.58 (*a*) shows schematic diagram of capacitor start capacitor run motor.

Torque speed characteristics. Such motor have better torque during starting as well as during running conditions. Fig. 12.58 (*b*) shows torque speed characteristics of capacitor start capacitor run Induction motor.

Direction of rotation. Direction of rotation can be changed by changing connections of main or auxiliary winding w.r.t. supply terminals.

Applications. These motors are used in refrigerator and compressor etc.

12.26.3. Permanent Capacitor Motor. In case of such motor, only one capacitor is connected in series with auxiliary winding, which remians in circuit during starting as well as running condition, hence known as permanent capacitor motor. The value of capacitor is selected to obtain better starting as well as running performance of motor, providing phase difference of 90° between the currents, so that the motor behaves like a 2 phase motor. Hence such motor will have higher power factor and a smoother torque. The capacitor and auxiliary

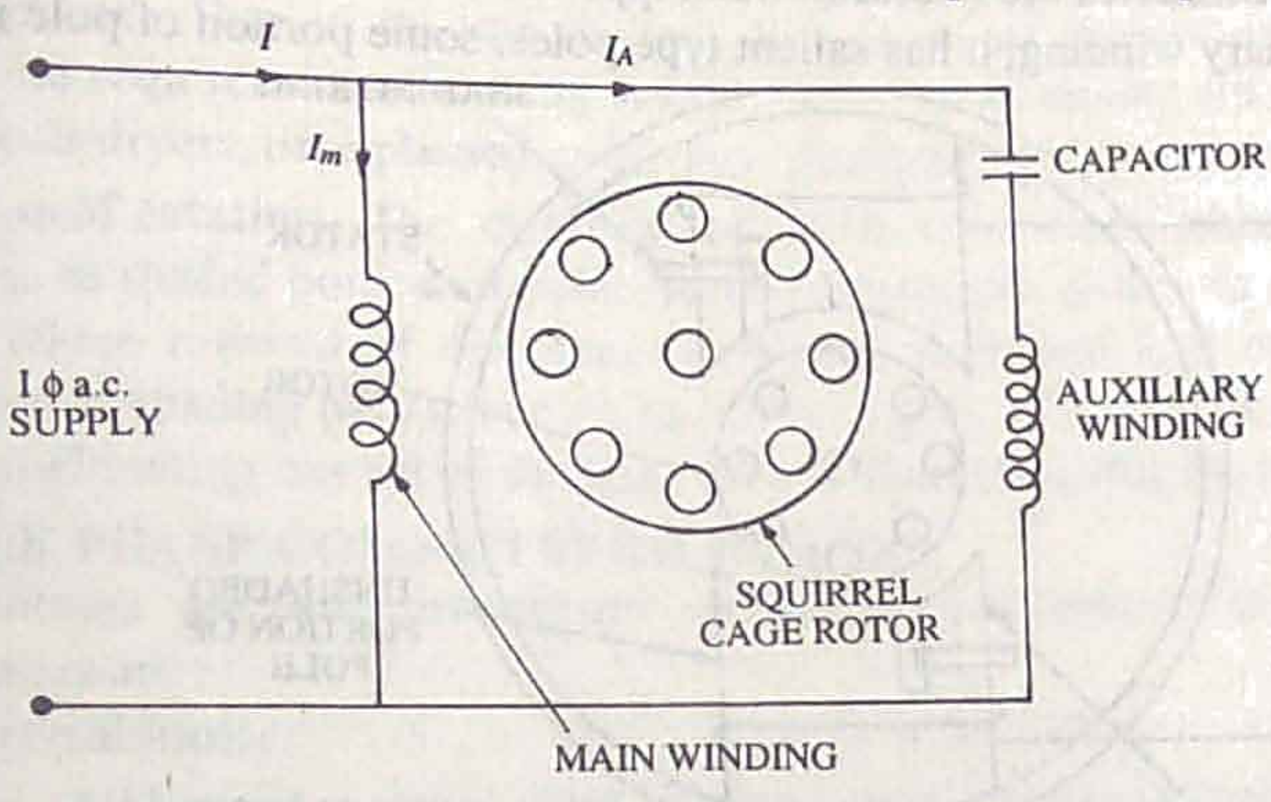


Fig. 12.59 (a) Schematical diagram of permanent capacitor motor.

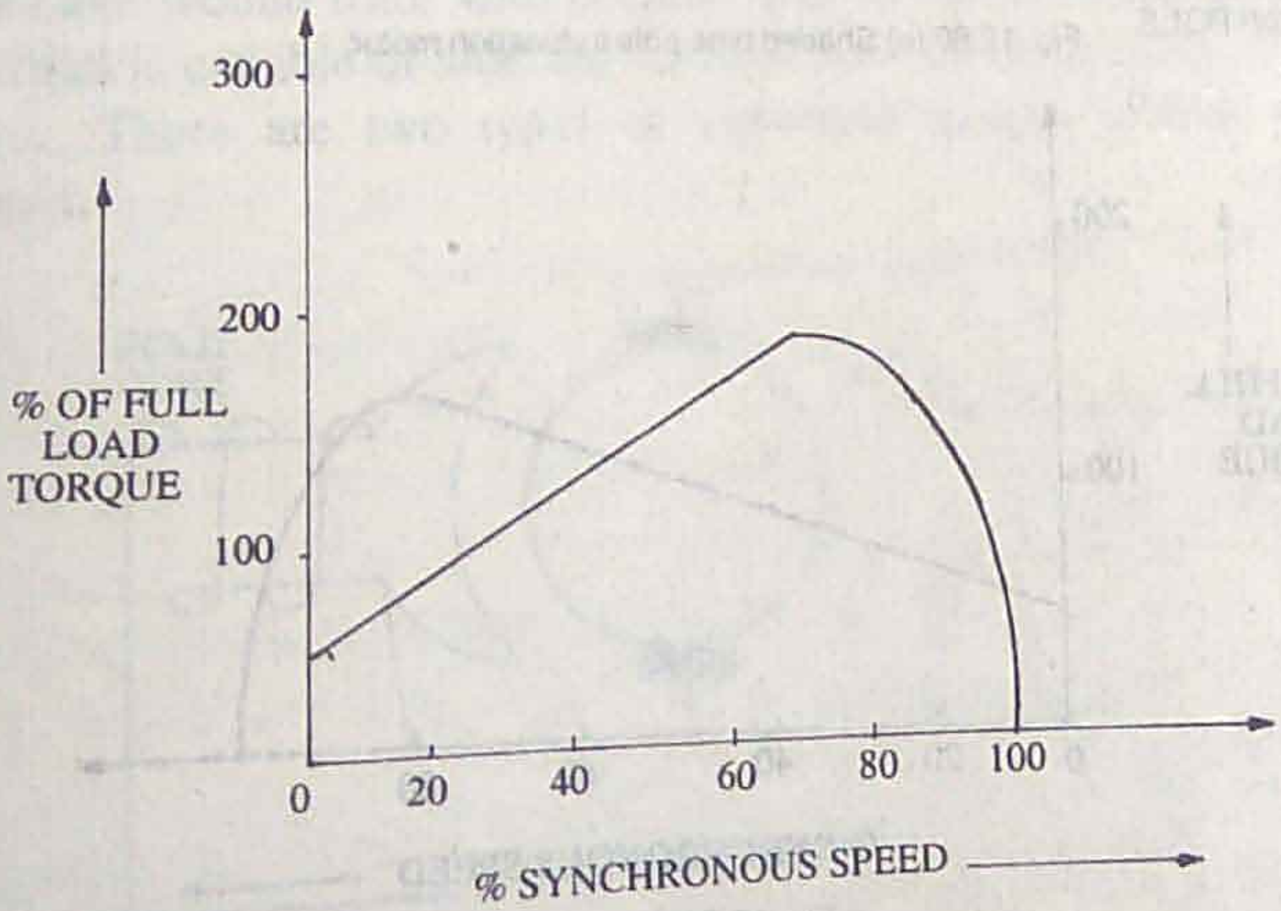


Fig. 12.59 (b) Torque speed characteristics.

winding are designed for continuous rating, because they remains in circuit during running condition also. No centrifugal switch is required and due to which, such motors are simpler than capacitor start motors.

The drawback of such type of motor is, lower starting torque than the capacitor starts motors. Fig. 12.59 (*a*) shows connection diagram of permanent capacitor motor.

Torque speed characteristic. In such type of motor, the value of capacitor selected is to obtain compromise between good starting as well as good running performance. Hence the starting torque of such motor is very low, in the range of 50% to 100% of full load torque. Fig. 12.59 (*b*) shows torque speed characteristics.

The direction of rotation of such motors can be changed by changing the connections of main or auxiliary winding terminals w.r.t. supply terminals.

Applications. Such motor are used in table fan, ceiling fans, blowers, oil burners, where low starting torque is required.

12.26.4. Shaded Pole Motors. Such type of motor have only main winding. Instead of having an auxiliary winding, it has salient type poles, some portion of pole is surrounded by

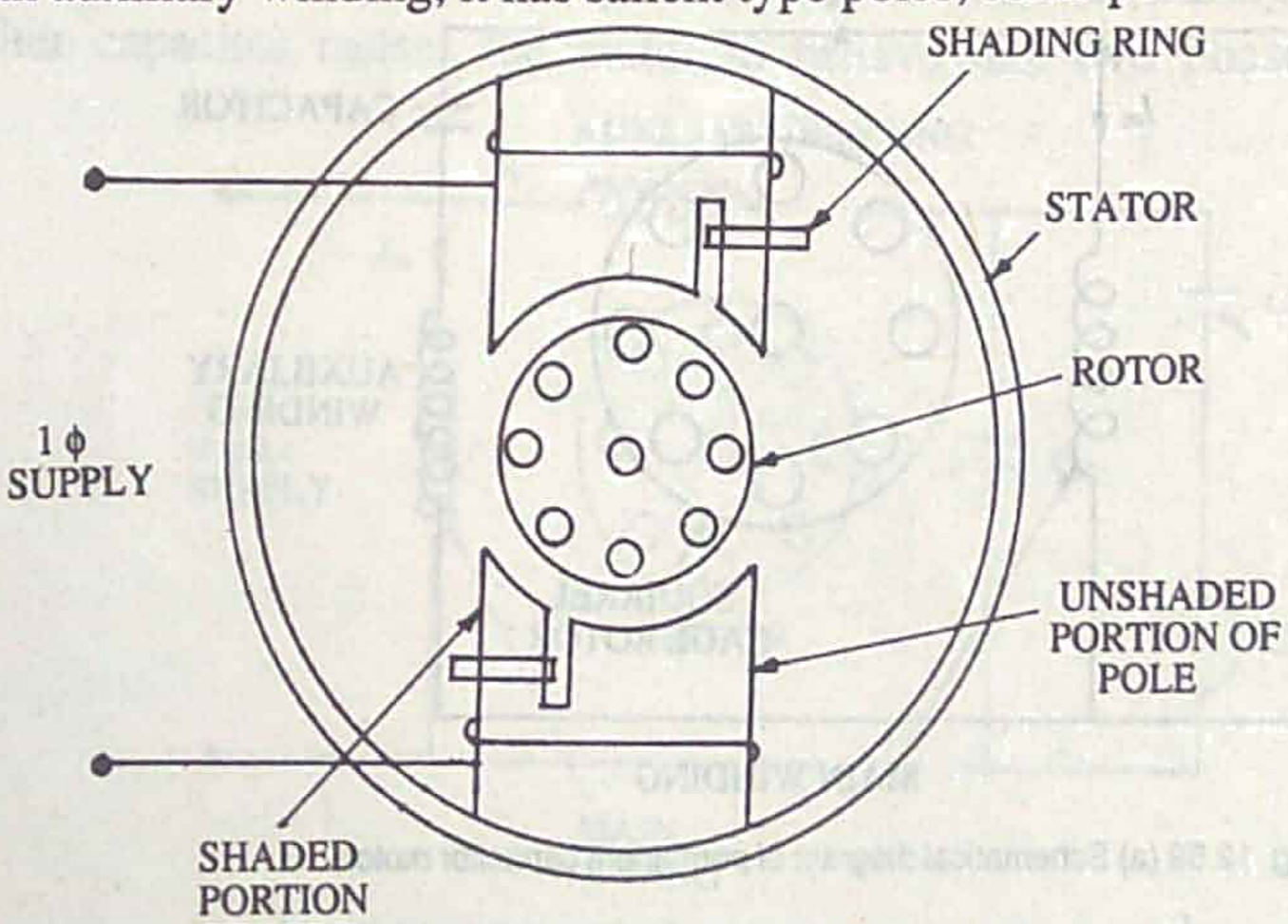


Fig. 12.60 (a) Shaded type pole indication motor.

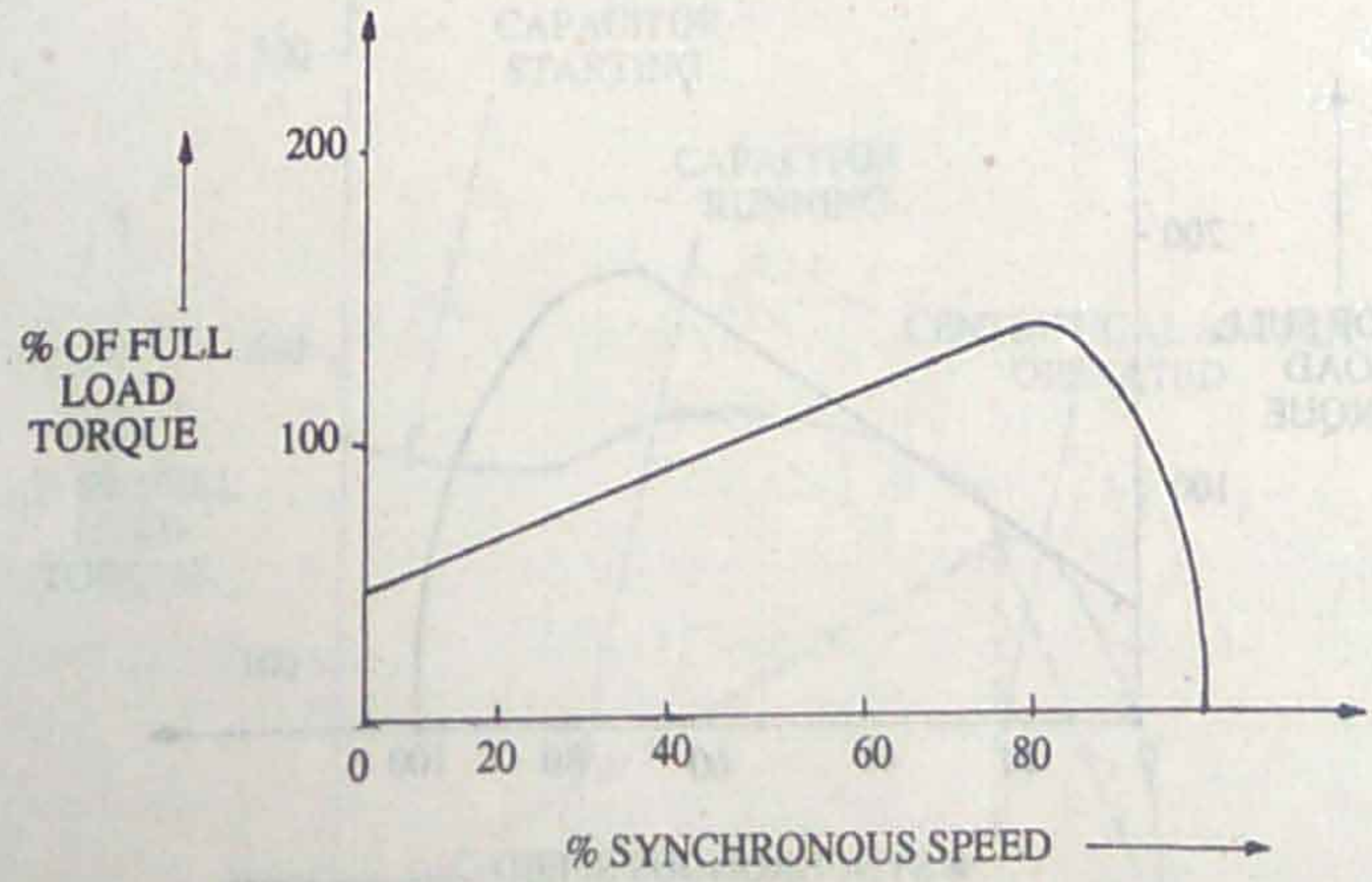


Fig. 12.60 (b).