1.7 STARTING METHODS OF SINGLE-PHASE INDUCTION MOTORS:

A single-phase induction motor with main stator winding has no inherent starting torque, since main winding introduces only stationary, pulsating air-gap flux wave. For the development of starting torque, rotating air-gap field at starting must be introduced. Several methods which have been developed for the starting of single-phase induction motors, may be classified as follows:

a) Split-phase starting.
b) Shaded-pole starting.
c) Repulsion-motor starting and
d) Reluctance starting.

A single-phase induction motor is commonly known by the method employed for its starting. The selection of a suitable induction motor and choice of its starting method, depend upon the following:

(i) Torque-speed characteristic of load from standstill to the normal operating speed.
(ii) The duty cycle and
(iii) The starting and running line-current limitations as imposed by the supply authorities.

1.7 (a) SPLIT-PHASE STARTING:

Single-phase induction motors employing this method of starting are called Split-phase motors. All the split-phase motors have two stator windings, a main (or running) winding and an auxiliary (or starting) winding. Both these windings are connected in parallel but their magnetic axes are space displaced by 90^0 electrical.

It is known that when two windings spaced 90^0 apart on the stator, are excited by two alternating e.m.f. that are 90^0 displaced in time phase, a rotating magnetic field is produced. If two windings so placed are connected in parallel to a single phase source, the field produced will alternate but will not revolve since the two windings are equivalent to one single phase winding. If impedance is connected in series with one of these windings, the currents may be made to differ in time phase, thereby producing a rotating field. This is the principle of phase splitting. Split phase motors are of following types.

1. Resistor-split phase motors
2. Capacitor split-phase motors
3. Capacitor start and run motors
4. Capacitor-run motors

1.71 RESISTOR SPLIT-PHASE MOTORS:

The stator of a split-phase induction motor is provided with an auxiliary or starting winding S in addition to the main or running winding M. The starting winding is located 90° electrical from the main winding [See figure: 1.71(a)] and operates only during the brief period when the motor starts up. The two windings are so designed that the starting winding S has a high resistance and relatively small reactance while the main winding M has relatively low resistance and large reactance as shown in the schematic connections in figure: 1.71(b). Consequently, the currents flowing in the two windings have reasonable phase difference (25° to 30°) as shown in the phasor diagram in figure: 1.71(c).

Operation

(i) When the two stator windings are energized from a single-phase supply, the main winding carries current I_m while the starting winding carries current I_s

(ii) Since main winding is made highly inductive while the starting winding highly resistive, the currents I_m and I_s have a reasonable phase angle a (25° to 30°) between them as shown in figure: 1.71(c).Consequently, a weak revolving field approximating to that of a 2-phase machine is produced which starts the motor. The starting torque is given by;

$$Ts = k\, I_m\, I_s \sin\phi$$

Where k is a constant whose magnitude depends upon the design of the motor . When the motor reaches about 75% of synchronous speed, the centrifugal switch opens the circuit of the starting winding. The motor then operates as a single-phase induction motor and continues to accelerate till it reaches the normal speed. The normal speed of the motor is below the synchronous speed and depends upon the load on the motor.

Characteristics:

(i) The sinning torque is 15 to 2 times the full-loud torque mid (starting current is 6 to 8 times the full-load current.

(ii) Due to their low cost, split-phase induction motors are most popular single phase motors in the market.

(iii) Since the starting winding is made of fine wire, the current density is high and the winding heats up quickly. If the starting period exceeds 5 seconds, the winding may burn out unless the motor is protected by built-in-thermal relay. This motor is, therefore, suitable where starting periods are not frequent.

An important characteristic of these motors is that they are essentially constant-speed motors. The speed variation is 2-5% from no-load to full-load

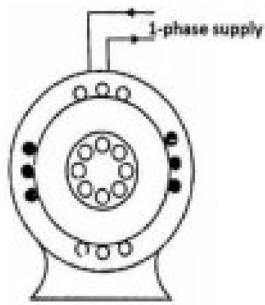


Fig: 1.71(a)

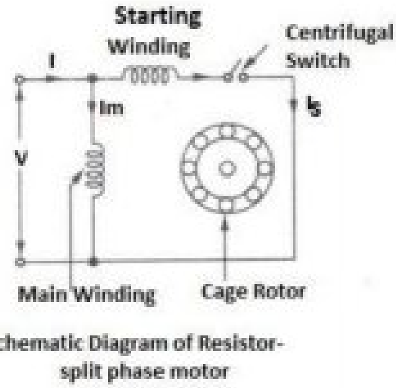


Fig: 1.71(b)

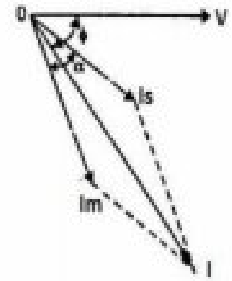
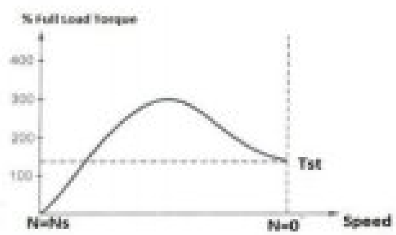


Fig: 1.71(c)



Applications:

These motors are suitable where a moderate starting torque is required and where starting periods are infrequent e.g., to drive:

a. Fans
b. washing machines
c. oil burners
d. Small machine tools etc.

The power rating of such motors generally lies between 60 W and 250 W .

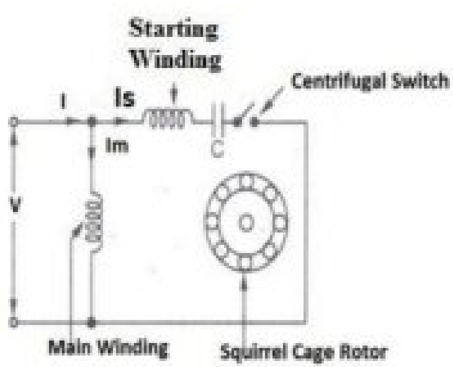
1.72 Capacitor split-phase motors (or) Capacitor start motors:

The capacitor split-phase motor is identical to a resistor split-phase motor except that the starting winding has as many turns as the main winding. Moreover, a capacitor C is connected in series with the starting winding as shown in figure: 1.72(a).The value of capacitor is so chosen that I_s leads I_m by about 80° (i.e., $\phi \sim 80°$) which is considerably greater than 25° found in resistor split-phase motor [See figure: 1.72(b).Consequently, starting torque ($T_s = k\, I_m\, I_s \sin\phi$) is much more than that of a split-phase motor Again, the starting winding is opened by the centrifugal switch when the motor attains about 75% of synchronous speed. The motor then operates as a single-phase induction motor and continues to accelerate till it reaches the normal speed.

Characteristics

(i) Although starting characteristics of a capacitor-start motor are better than those of a resistor split-phase motor, both machines possess the same running characteristics because the main windings are identical.

(ii) The phase angle between the two currents is about 80° compared to about 25° in a resistor split-phase motor. Consequently, for the same starting torque, the current in the starting winding is only about half that in a resistor split-phase motor. Therefore, the starting winding of a capacitor start motor heats up less quickly and is well suited to applications involving either frequent or prolonged starting periods.



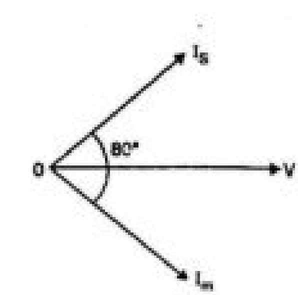
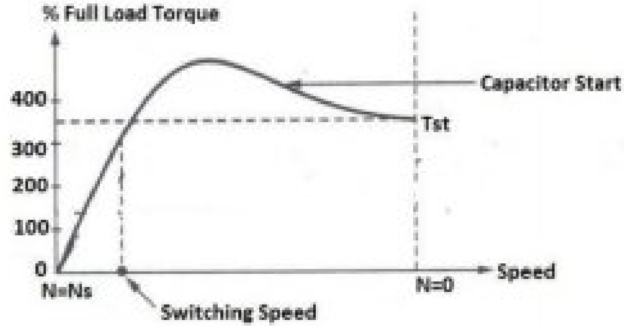


Fig: 1.72(a) **Fig**: 1.72(b)



Applications:

Since the motors possess high-starting torque, these motors are used for

a. Refrigerators
b. Air-conditioners
c. Compressors
d. Reciprocating pumps
e. Other loads requiring high-starting torques.

The power rating of such motors lies between 120 W and 750W.

1.73 Capacitor-Start and Capacitor-Run motors:

This motor is identical to a capacitor-start motor except that starting winding is not opened after starting so that both the windings remain connected to the supply when running as well as at starting. Two designs are generally used.

(i) In one design, a single capacitor C is used for both starting and running as shown in fig: 1.73(a).This design eliminates the need of a centrifugal switch and at the same time improves the power factor and efficiency of the motor.

(ii) In the other design, two capacitors C1 and C2 are used in the starting winding as shown in fig: 1.73(b).. The smaller capacitor C1 required for optimum running conditions is permanently connected in series with the starting winding. The much larger capacitor C2 is connected in parallel with C1 for optimum starting and remains in the circuit during starting. The starting capacitor C1 is disconnected when the motor approaches about 75% of synchronous speed. The motor then runs as a single-phase induction motor.

Characteristics

(i) The starting winding and the capacitor can be designed for perfect 2-phase operation at any load. The motor then produces a constant torque and not a pulsating torque as in other single-phase motors.

(ii) Because of constant torque, the motor is vibration free.

Applications:

a. Hospitals
b. Studios and
c. Other places where silence is important.

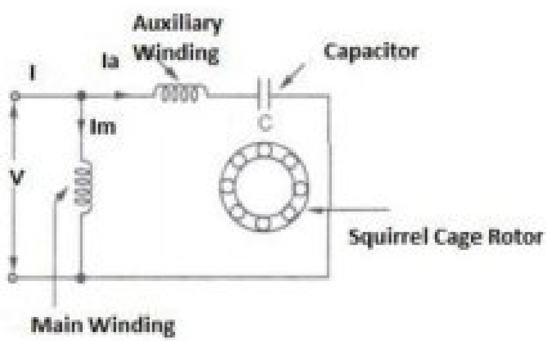


Fig: 1.73(a)

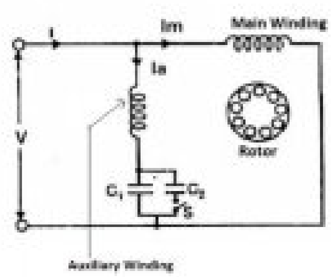
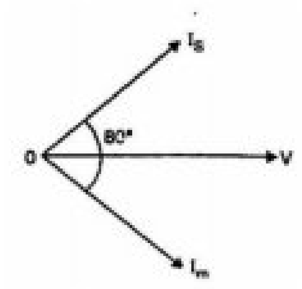


Fig: 1.73 (b)



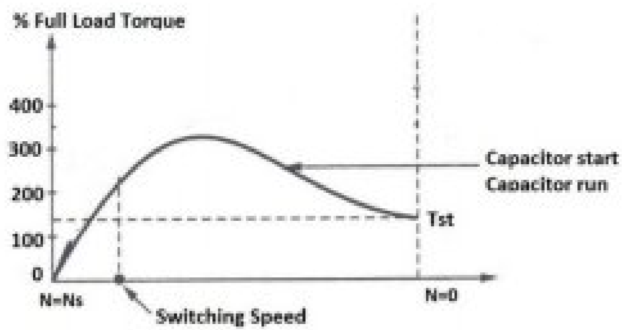


Fig: 1.73 (c) **Fig:** 1.73 (d)

The power rating of such motors lies between 100 to 400 watts

1.74 Capacitor-run motors:

This motor is also called permanent split capacitor motor. The same capacitor is kept permanently in series with auxiliary winding both at starting and under running conditions as illustrated in figure: 1.74 (a). There is no centrifugal switch. At a particular desired load, the capacitor and auxiliary winding can be so designed as to result in 90^0 time-phase displacement between the two winding currents. In such a case, the motor would operate as a balanced two phase induction motor, backward rotating flux would, therefore, be absent and the motor would have improved efficiency and better operating power factor. Since backward rotating field can be reduced to zero, the pulsating torque due to interaction between forward and backward rotating fields is absent and this results in a quiet motor.

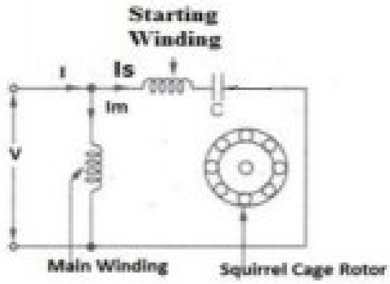


Fig: 1.74 (a)

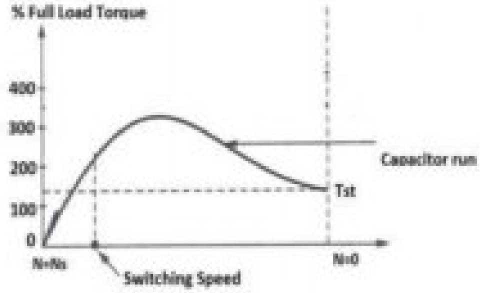


Fig: 1.74 (b)

In these motors, the value of permanent capacitor is so chosen as to obtain a compromise between the best starting and running conditions. A typical torque-speed characteristic is shown in fig: 1.74 (b)

These motors are used where quiet operation is essential as in

a. Offices
b. Class rooms
c. Theaters
d. Ceiling fans, in which the value of capacitance varies from 2 to 3μF.

1.8 Shaded-Pole Motor:

The shaded-pole motor is very popular for ratings below 0.05 H.P. (~40 W) because of its extremely simple construction. It has salient poles on the stator excited by single-phase supply and a squirrel cage rotor as shown in figure: 1.8(a). A portion of each pole is surrounded by a short-circuited turn of copper strip called shading coil.

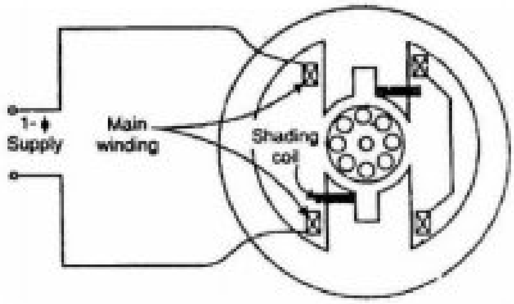


Fig: 1.8(a)

The operation of the motor can be understood by referring to figure: 1.8(b) which shows one pole of the motor with a shading coil.

(i) During the portion OA of the alternating-current cycle [See figure: 1.8(b)(i)], the flux begins to increase and an e.m.f. is induced in the shading coil. The resulting current in the shading coil will be in such a direction (Lenz's law) so as to oppose the change in flux. Thus the flux in the shaded portion of the pole is weakened while that in the unshaded portion is strengthened as shown in figure: 1.8(b)(ii)

(ii) During the portion AB of the alternating-current cycle, the flux has reached almost maximum value and is not changing. Consequently, the flux distribution across the pole is uniform [See figure: 1.8(b)(iii)] since no current is flowing in the shading coil. As the flux decreases (portion BC of the alternating current cycle), current is induced in the shading coil so as to oppose the decrease in current. Thus the flux in the shaded portion of the pole is strengthened while that in the unshaded portion is weakened as shown in figure: 1.8(b)(iv)

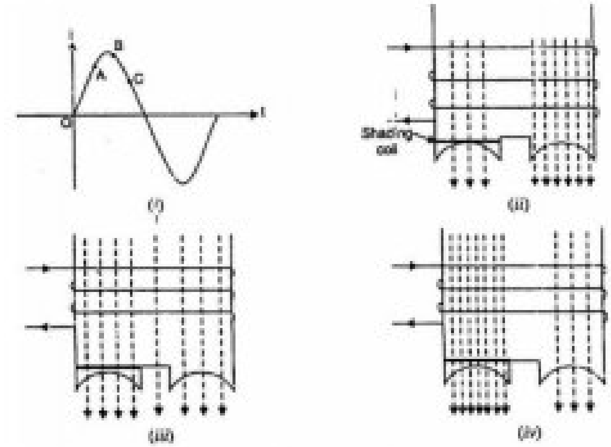


Fig: 1.8(b)

(iii) The effect of the shading coil is to cause the field flux to shift across the pole face from the unshaded to the shaded portion. This shifting flux is like a rotating weak field moving in the direction from unshaded portion to the shaded portion of the pole.

(iv) The rotor is of the squirrel-cage type and is under the influence of this moving field. Consequently, a small starting torque is developed. As soon as this torque starts to revolve the rotor, additional torque is produced by single-phase induction-motor action. The motor accelerates to a speed slightly below the synchronous speed and runs as a single-phase induction motor.

Characteristics

(i) The salient features of this motor are extremely simple construction and absence of centrifugal switch.

(ii) Starting torque, efficiency and power factor are very low

Applications:

These motors are only suitable for low power applications e.g., to drive:

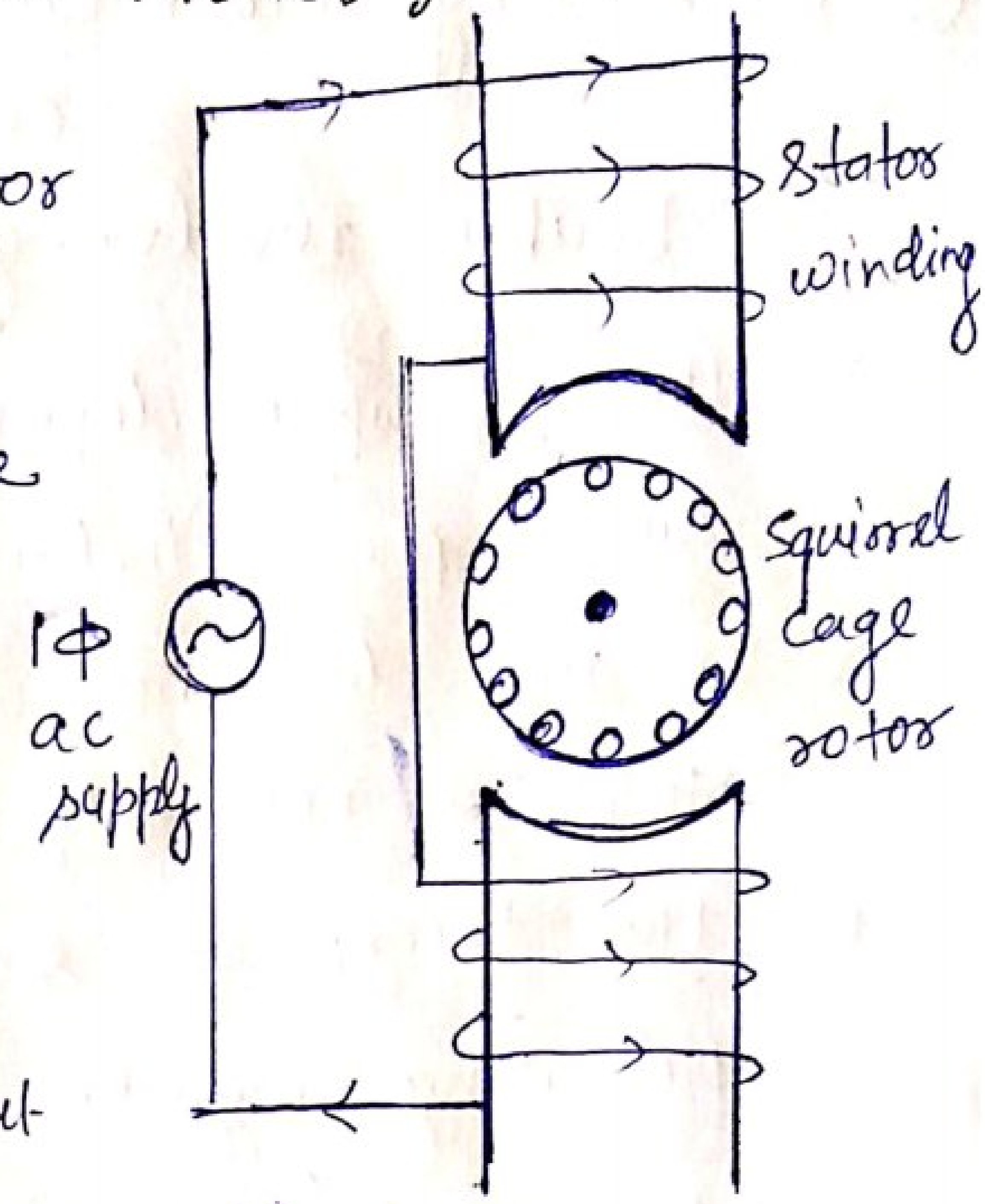
a. small fans
b. Toys
c. Hair driers
d. Desk fans etc.

The power rating of such motors is upto about 30 W.

Single Phase induction motor:

Working Prinuiple:-

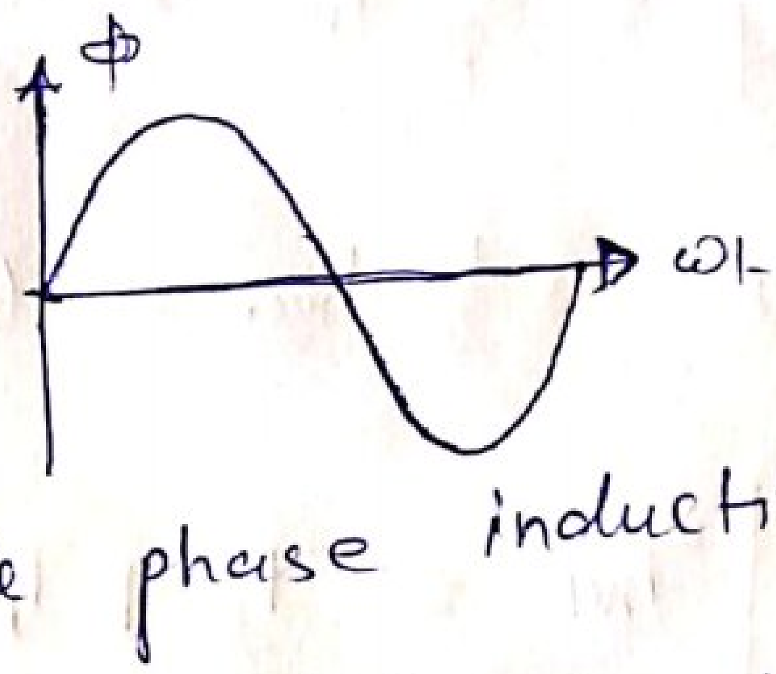
→ A single phase inducton motor consists of single phase distributed winding on the stator and normal squirrel cage rotor.



→ When single phase supply is given to stator winding, it produces a magnetic field that pulsates in strength in a sinusoidal manner.

→ The field polarity reverses after each half cycle but the field does not rotate. Consequently the alternating flux can not produce rotation in a stationary r sequirrel cage rotor.

→ However if the rotor is rotated in one direction by some mechanical means, it will continue to run in the direction of rotation.



→ ~~Hence~~ ~~A~~ single phase induction motor is not self starting but requires some starting means.

(a) Pulsating field as Two Rotating field
or
Double revolving field Theory.

→ This Theory describes the starting principle of single phase induction motor.

→ It also describes that why a single phase induction motor is not self starting.

→ This theory for single phase IM states that a stationary pulsating magnetic field can be resolved into two rotating magnetic field, each of equal magnitude but rotating in the opposite direction with same speed N_s.

→ The induction machine responds to each magnetic field seprately, and the net torque in the motor is equal to some of torque due to each of two magnetic fields.

forward slip,

$$s_f = s$$

$$F_f = \frac{1}{2} F_{max} \cos(\theta - \omega t)$$ → forward rotating field

backward slip

$$s_b = 2 - s$$

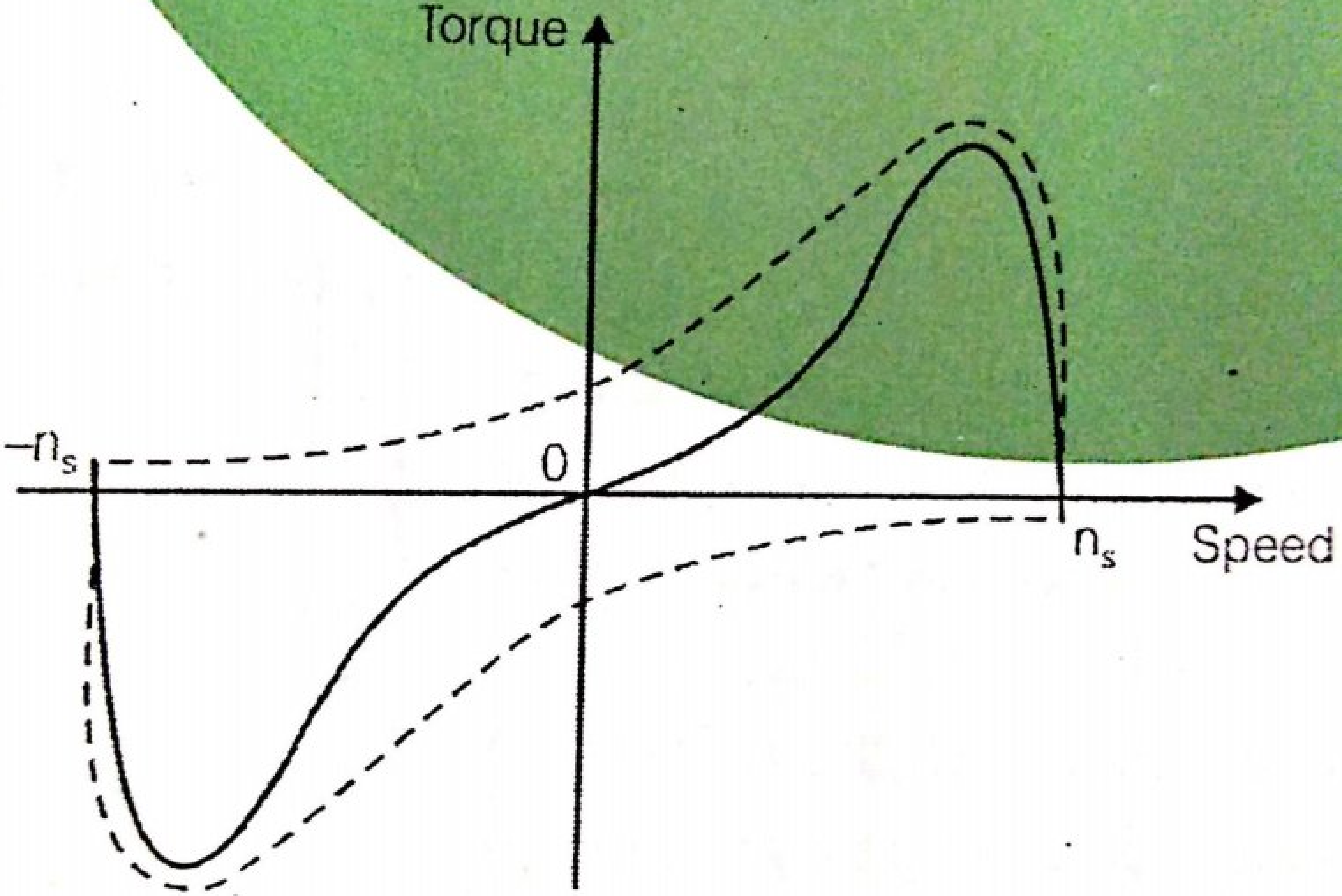
$$F_b = \frac{1}{2} F_{max} \cos(\theta + \omega t)$$ → backward rotating field.

$$T_{net} = T_f + T_b$$

* both field rotates at synchronous speed N_s.

Under stationary rotor condition, both rotating fields induce equal currents in opposite direction, Hence at the time of starting both fields produce equal and opposite torque in squirrel cage rotor, which makes resultant starting torque zero. Hence single phase induction motor is not self starting.

- The complete torque-speed characteristic as the sum of the two forward and backward torque-speed characteristic is shown in figure.



- The two fields move in opposite directions with relative speeds of $2n_s$ producing second harmonic pulsating torques with zero average value. Due to this a single-phase motor is noisier than a 3-phase which has no pulsating torque.