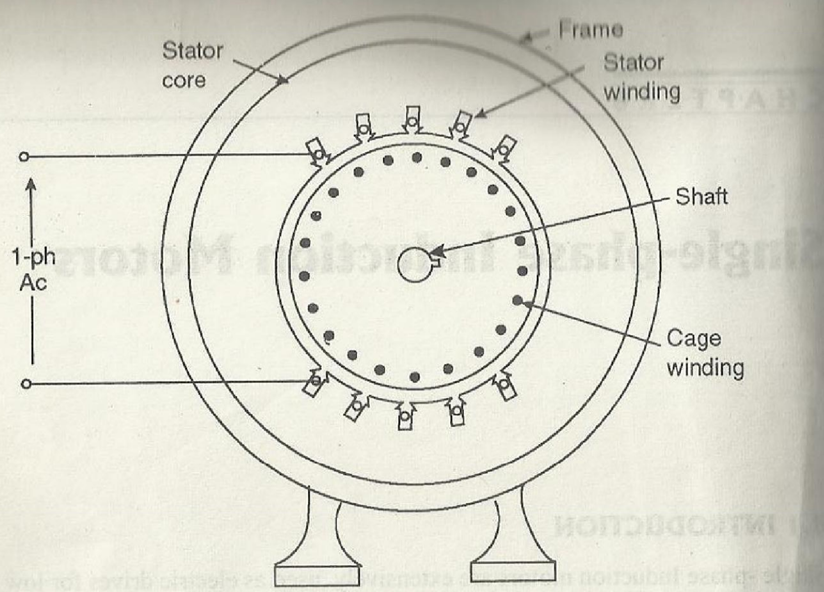


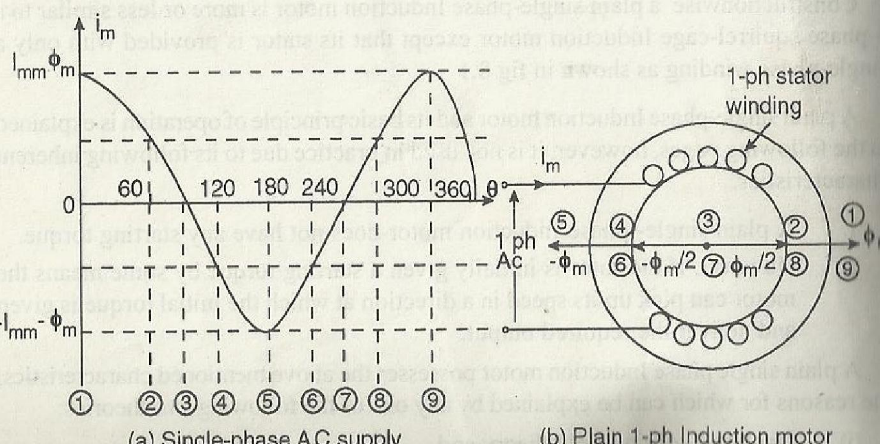
Fig 8.1 Plain single-phase-Induction motor

The following section describes about the double revolving field theory and the principle of operation of single-phase Induction motors.

8.2 DOUBLE REVOLVING FIELD THEORY

Unlike in 3-phase Induction motor, where a rotating magnetic field is setup in the stator core, a plain single-phase Induction motor, shown in fig 8.1, can setup only a pulsating magnetic field when single-phase AC supply is given to its single stator winding.

Double Revolving Field Theory, formulated by Ferrari, states that a single pulsating magnetic field of ϕ_m as its maximum value can be resolved into two rotating magnetic fields of $(\phi_m/2)$ as their magnitude rotating in opposite directions at synchronous speed proportional to the frequency of the pulsating magnetic field.



(a) Single-phase AC supply (b) Plain 1-ph Induction motor

Fig 8.2 Pulsating field

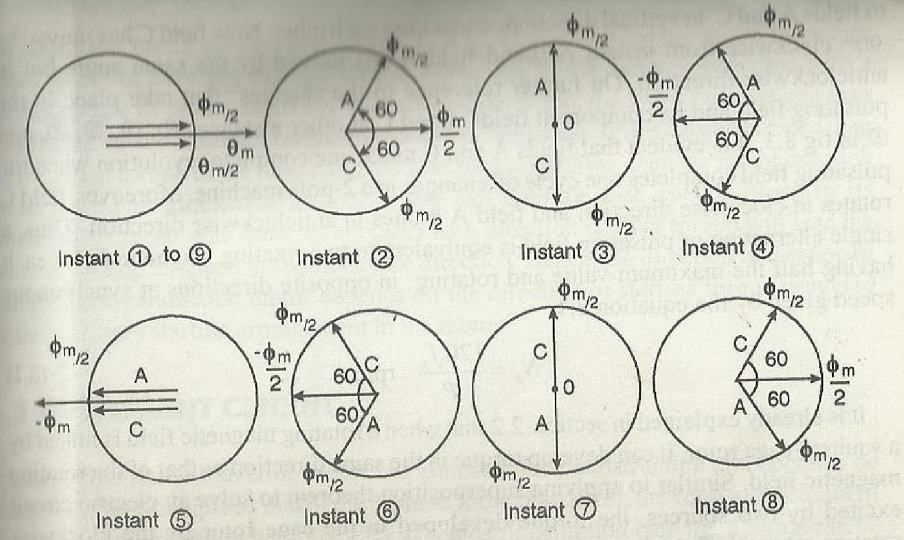


Fig 8.3 Double revolving field.

When a single-phase sinusoidal magnetising current I_m shown in fig. 8.2 (a) is passed through a single stator winding shown in fig. 8.2(b), a pulsating magnetic field is established along the winding axis. The field is positive maximum, ϕ_m when the magnetising current is positive maximum as I_{mm} in instant ①,

At instant ②, 60° later, the reduction of i_m to $(I_{mm}/2)$ causes the field to reduce to $(\phi_m/2)$. Similarly,

at instant ③, $\theta = 90°,\ i_m = 0,\ \phi = 0$

at instant ④, $\theta = 120°,\ i_m = -I_{mm}/2,\ \phi = \dfrac{-\phi_m}{2}$

at instant ⑤, $\theta = 180°,\ i_m = -I_{mm},\ \phi = -\phi_m$

at instant ⑥, $\theta = 240°,\ i_m = -I_{mm}/2,\ \phi = -\phi_{m/2}$

at instant ⑦, $\theta = 270°,\ i_m = 0,\ \phi = 0$

at instant ⑧, $\theta = 300°,\ i_m = +I_{mm}/2,\ \phi = -\phi_m/2$

at instant ⑨, $\theta = 360°,\ i_m = I_{mm},\ \theta = \theta_m$, similar to instant ①

after one complete cycle of change.

In fig 8.3, the single pulsating field having its maximum value of ϕ_m is resolved into two magnetic fields A and C, each having a modulus of $\phi_m/2$ at different instances. At instant ①, the pulsating field ϕ_m is positive maximum, and it is resolved into the two fields A and C acting in the same positive direction of the pulsating field. After 60°, i.e, at instant ②, the pulsating field attains a value of $+\phi_m/2$ and it is said to be equivalent to the field C moving clockwise by 60° contributing a horizontal component of $(\phi_m/2)\cos 60° = (\phi_m/4)$ and field A moving anticlockwise by 60° contributing another $\phi_m/4$ along the horizontal direction. Their vertical components cancel each other. At instant ③ when $\theta = 90°$, the value of pulsating field is zero and is equivalent to fields A and C in vertical direction, cancelling each other. Now field C has moved by 90° clockwise from instant A ③and field A has moved by the same angle but in anticlockwise direction. On further reference to the changes that take place in the pulsating field and its component fields A and C at other instances ④, ⑤, ⑥, ⑦, and ⑧ in fig 8.3, it is evident that fields A and C make one complete revolution when the pulsating field completes one cycle of changes in a 2-pole machine. Moreover, field C rotates in clockwise direction and field A rotates in anticlockwise direction. Thus, a single alternating or pulsating field is equivalent to two rotating magnetic fields each having half the maximum value and rotating in opposite directions at synchronous speed given by the equation 8.1.

$$N_s = \frac{120 f_s}{P} \text{ rpm} \tag{8.1}$$

It is already explained in section 2.2 that when a rotating magnetic field is linked by a squirrel-cage rotor, it can develop torque in the same direction as that of the rotating magnetic field. Similar to applying superposition theorem to solve an electric circuit excited by two sources, the torque developed in the cage rotor by the clockwise rotating magnetic field C can be drawn as torque-slip curve (i) and torque developed by the anticlockwise field A can be drawn as torque-slip curve (ii) as shown in fig. 8.4. Since the relative speed between the two fields C and A is $2N_s$, the slip of S for clockwise field C will correspond to slip of (2-S) for anticlockwise field A and vice-versa.

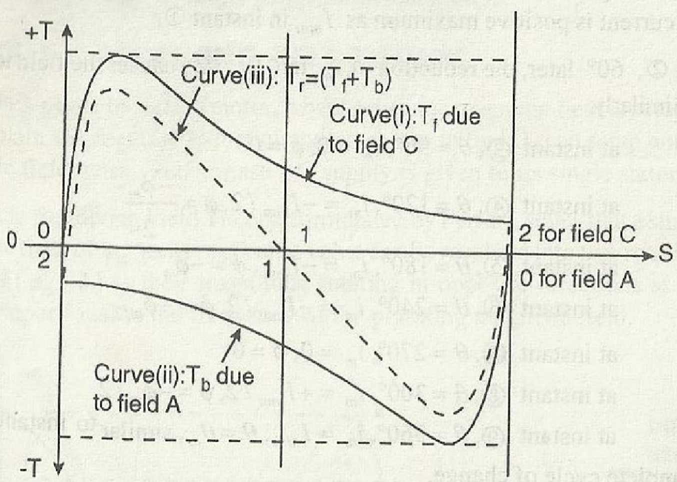


Fig 8.4 Torque-slip curves—plain 1-phase Induction motor

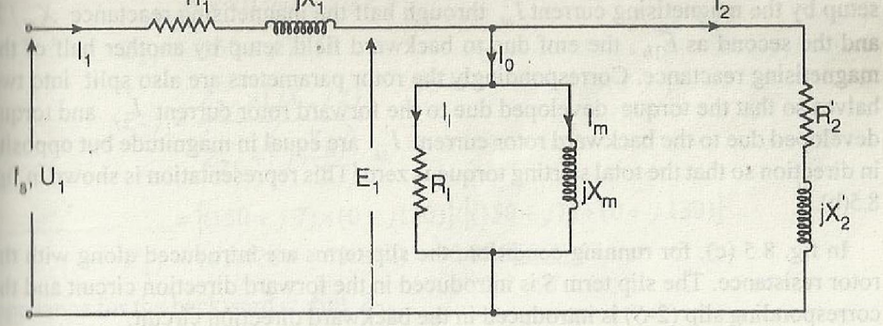
At every slip the rotor of a single-phase Induction motor is subjected to two torques; viz (i) a forward torque T_f in clockwise direction due to clockwise field C and a backward torque T_b in anticlockwise direction due to anticlockwise field A. The resultant torque T_r at any slip can therefore be obtained by adding T_f and T_b both in magnitude and direction and is represented by curve (iii) in fig 8.4.

At standstill or starting condition, which corresponds to slip $S=1$, the clockwise field C and anticlockwise field A develop same amount of torque, but in opposite

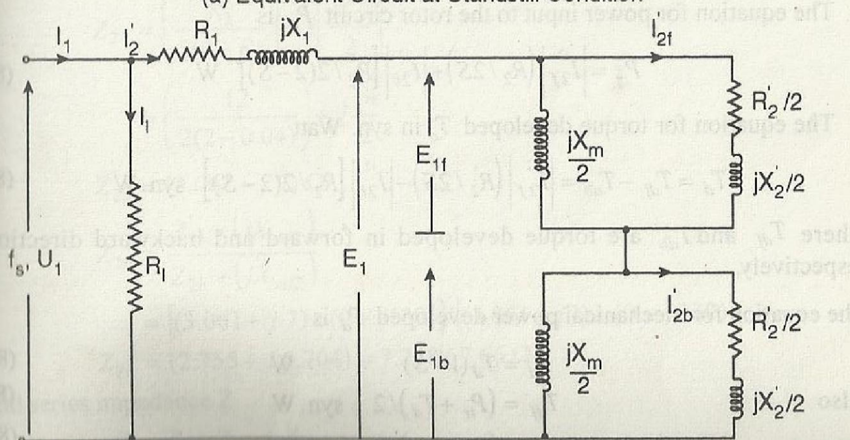
directions and hence the resultant torque $T_r = 0$. Thus a plain single-phase Induction motor does not have any starting torque. However, if this motor is provided with a starting torque by some means say in clockwise direction, the slip S become less than 1 and there exist a resultant torque in clockwise direction. If this torque is more than the frictional torque of the motor and the load torque together, then the motor can pick up its speed in clockwise direction and can operate with speeds close to its synchronous speed. Similarly, an anticlockwise direction starting torque will lead the motor to pickup its speed in anticlockwise direction. Hence, the direction of rotation of a single-phase Induction motor depends on the direction of starting torque provided by the auxiliary starting arrangement in the motor.

8.3 EQUIVALENT CIRCUIT

As the single-phase Induction motor has almost similar construction and operates on almost similar principle as that of the 3-phase Induction motor, the equivalent circuit of the plain single-phase Induction motor at standstill condition (see fig. 8.5 (a)) can be considered as similar to that of the 3-phase Induction motor derived in chapter 4.



(a) Equivalent Circuit at Standstill Condition



(b) Standstill Condition Using Doub le Revolving Field Theory