6.2 Cross-field theory

The principle of operation of a single-phase induction motor can be explained from the cross-field theory. As soon as the rotor begins to turn, a speed emf E is induced in the rotor conductors, as they cut the stator flux Fs. This voltage increases as the rotor speed increases. It causes current Ir to flow in the rotor bars facing the stator poles as shown in figure 7.7 . These currents produce an ac flux FR which act at right angle to the stator flux Fs. Equally important is the fact that FR does not reach its maximum value at the same time as FS does, in effect, FR lags almost 90o behind FS, owing to the inductance of the rotor The combined action of Fs and FR produces a revolving magnetic field, similar to that in a three-phase motor. The value of FR increases with increasing speed, becoming almost equal to Fs at synchronous speed. The flux rotates counterclockwise in the same direction as the rotor and it rotates at synchronous speed irrespective of the actual speed of the rotor. As the motor approaches synchronous speed, FR becomes almost equal to Fs and a nearly perfect revolving field is produces.

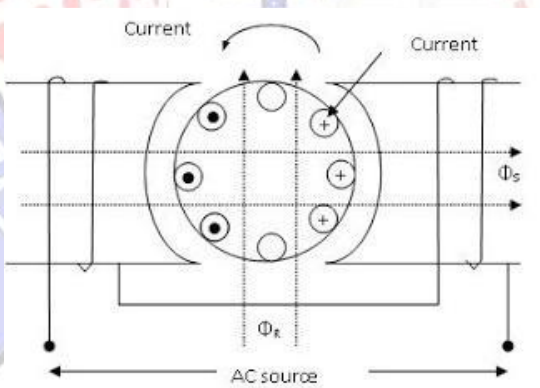

Figure 7 Current induced in the rotor bars due to rotation.

6.3 Double-field revolving theory

When the stator winding (distributed one as stated earlier) carries a sinusoidal current (Being fed from a single-phase supply), a sinusoidal space distributed mmf, whose peak or maximum value pulsates (alternates) with time, is produced in the air gap. This sinusoidal varying flux (φ) is the sum of two rotating fluxes or fields, the magnitude of which is equal

to half the value of the alternating flux (φ / 2), and both the fluxes rotating synchronously at the speed, in opposite directions. The first set of figures (Figure 8a (i-iv)) show the resultant sum of the two rotating fluxes or fields, as the time axis (angle) is changing from
θ = 0° to π °(180) . Figure 8b shows the alternating or pulsating flux (resultant) varying with time or angle.

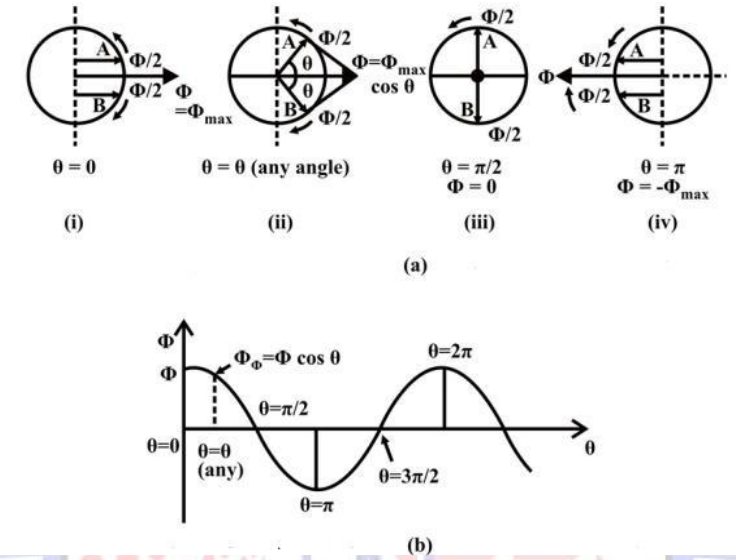

Figure 8 Double field revolving

The flux or field rotating at synchronous speed, say, in the anticlockwise direction, i.e. the same direction, as that of the motor (rotor) taken as positive induces EMF (voltage) in the rotor conductors. The rotor is a squirrel cage one, with bars short circuited via end rings. The current flows in the rotor conductors, and the electromagnetic torque is produced in the same direction as given above, which is termed as positive (+ve). The other part of flux or field rotates at the same speed in the opposite (clockwise) direction, taken as negative. So, the torque produced by this field is negative (-ve), as it is in the clockwise direction, same as that of the direction of rotation of this field. Two torques are in the opposite direction, and the resultant (total) torque is the difference of the two torques produced. Let the flux φ1 rotate in anti clockwise direction and flux φ2 in clockwise direction. The flux φ1 will result in the production of torque T1 in the anti clockwise direction and flux φ2 will result in the production of torque T2 In the clockwise direction. Thus the point of zero slip for one field corresponds to 200% slip for the other as explained later. The value of 100% slip (standstill condition) is the same for both the fields. This fact is illustrated in Figure 7.9. At standstill, these two torques are equal and opposite and the net torque developed is zero. Therefore, single-phase induction motor is not self-starting. Note that each rotating field tends to drive the rotor in the direction in which the field rotates.

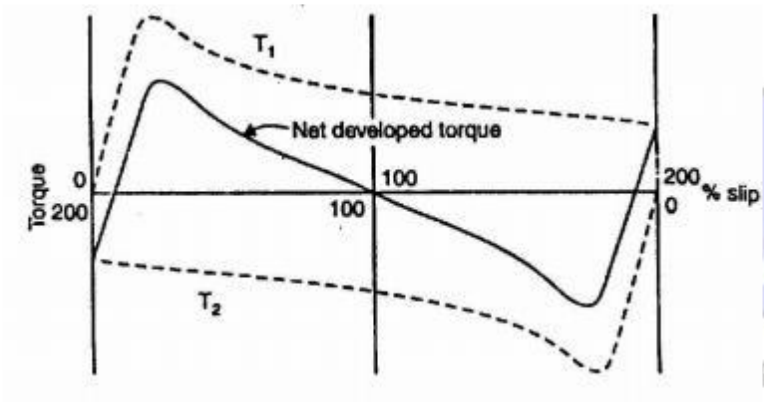

Figure 7.9 Speed Torque characteristics.

Now assume that the rotor is started by spinning the rotor or by using auxiliary circuit, in say clockwise direction. The flux rotating in the clockwise direction is the forward rotating flux (φf) and that in the other direction is the backward rotating flux (φb). The slip w.r.t. the forward flux will be

$$Sf = \frac{Ns - N}{Ns} = 1 - \frac{N}{Ns} \; or \; \frac{N}{Ns} = 1 - S$$

The rotor rotates opposite to the rotation of the backward flux. Therefore, the slip w.r.t. the backward flux will be

$$Sb = \frac{Ns - (-N)}{Ns} = \frac{Ns + N}{Ns} = 1 + \frac{N}{Ns} = 1 + (1 - S) = 2 - S$$

Thus fur forward rotating flux, slip is s (less than unity) and for backward rotating flux, the slip is 2 − s (greater than unity). Since for usual rotor resistance/reactance ratios, the torques at slips of less than unity arc greater than those at slips of more than unity, the resultant torque will be in the direction of the rotation of the forward flux. Thus if the motor is once started, it will develop net torque in the direction in which it has been started and will function as a motor.