Speed Torque Characteristics

Uptill now, we have seen torque - slip characteristics of an induction motor. To compare the performance of induction motor with d.c. shunt and series motors, it is possible to plot speed-torque curve of an induction motor.

At N = T_s, the motor stops as it can not produce any torque, as induction motor can not rotate at synchronous motor.

At N = 0, the starting condition, motor produces a torque called starting torque.

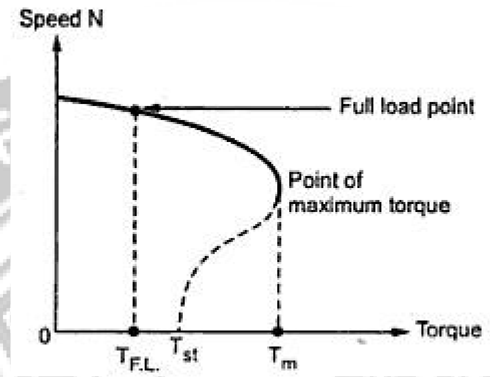

Fig. Speed Torque characteristics

For low slip region, i.e. speeds near the region is stable and the characteristics is straight in nature. Fall in speed from no load to full load is about 4 to 6 %. The characteristics is shown in the Fig.1. It can be seen from that the figure that for the stable region of operation, the characteristics is similar to that of d.c. shunt motor. Due to this, three phase induction motor is practically said to be 'constant speed' motor as drop in speed from no load to full load is not significant.

Effect of Change in Rotor Resistance on Torque

It is shown that in slip ring induction motor, externally resistance can be added in the rotor. Let us see the effect of change in rotor resistance on the torque produced.

Let R_2 = Rotor resistance per phase

Corresponding torque, $T \propto (s E_2^2 R_2)/\sqrt{(R_2^2 + (s X_2)^2)}$

Now externally resistance is added in each phase of rotor through slip rings. Let R_2' = New rotor resistance per phase

Corresponding torque $T' \propto (s E_2^2 R_2')/\sqrt{(R_2'^2 + (s X_2)^2)}$ Similarly the starting torque at s = 1 for R_2 and R_2' can be written as

$$T_{st} \propto (E_2^2 R_2)/\sqrt{(R_2^2 + (X_2)^2)}$$

and $T'st \, \alpha \, (E_2^2 R'_2)/\sqrt{(R'^2_2 + (X_2)^2)}$

Maximum torque $T_m \, \alpha \, (E_2^2)/(2X_2)$

Key Point : It can be observed that T_m is independent of R_2 hence whatever may be the rotor resistance, maximum torque produced never change but the slip and speed at which it occurs depends on R_2.

For R_2, $s_m = R_2/X_2$ where T_m occurs

For R_2', $s_m' = R_2'/X_2'$ where same T_m occurs

As $R_2' > R_2$, the slip $s_m' > s_m$. Due to this, we get a new torque-slip characteristics for rotor resistance . This new characteristics is parallel to the characteristics for with same but T_m occurring at s_m'. The effect of change in rotor resistance on torque-slip characteristics shown in the Fig. 1.

It can be seen that the starting torque T'st for R_2' is more than Tst for R_2.
Thus by changing rotor resistance the starting torque can be controlled.

If now resistance is further added to rotor to get resistance as R_2' and so on, it can be seen that T_m remains same but slip at which it occurs increases to s_m' and so on. Similarly starting torque also increases to T'st and so on.

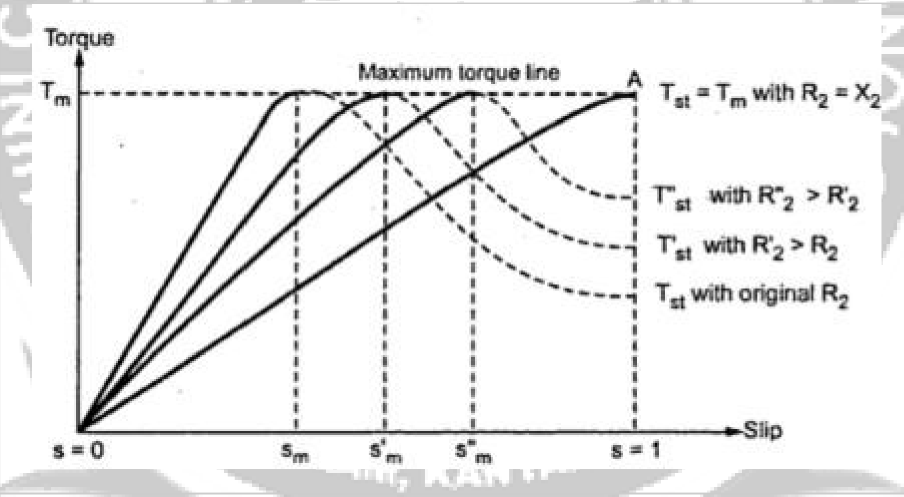

Fig. 3.22 Effect of rotor resistance on torque-slip curves

If maximum torque Tm is required at start then $s_m = 1$ as at start slip is always unity,

Key Point : Thus by adding external resistance to rotor till it becomes equal to X_2, the maximum torque can be achieved at start.

It is represented by point A in the Fig. 1.

If such high resistance is kept permanently in the circuit, there will be large copper losses (I^2 R) and hence efficiency of the motor will be very poor. Hence such added resistance is cut-off gradually and finally removed from the rotor circuit, in the normal running condition of the motor. So this method is used in practice to achieve higher starting torque hence resistance in rotor is added only at start.

Thus good performance at start and in the running condition is ensured.

Key Point : This is possible only in case of slip type of induction motor as in squirrel cage due to short circuited rotor, extra rotor resistance can not be added.

Example : Rotor resistance and standstill reactance per phase of a 3 phase induction motor are 0.04 Ω and 0.2 Ω respectively. What should be the external resistance required at start in rotor circuit to obtain.

i) maximum torque at start ii) 50% of maximum torque at start.

Solution :

$R_2 = 0.04\ \Omega,\ X_2 = 0.2\ \Omega$

i) For $T_m = T_{st}$, $s_m = R_2'/X_2 = 1$

∴ $R_2' = X_2 = 0.2$

Let R_{ex} = external resistance required in rotor.

$R_2' = R_2 + R_{ex}$

∴ $R_{ex} = R_2' - R_2 = 0.2 - 0.04 = 0.16\ \Omega$ per phase

ii) For $T_{st} = 0.5\ T_m$,

Now $T_m = (k\ E_2^2)/(2\ X_2)$ and

$T_{st} = (k\ E_2^2\ R_2)/(R_2^2 + X_2^2)$

But at start, external resistance R_{ex} is added. So new value of rotor resistance is say R_2'.

$R_2' = R_2 + R_{ex}$

∴ $T_{st} = (k\ E_2^2\ R_2')/(R_2'^2 + X_2^2)$ with added resistance

but $T_{st} = 0.5 T_m$ required.

Substituting expressions of T_{st} and T_m, we get

$(k\ E_2^2\ R_2')/(R_2'^2 + X_2^2) = 0.5\ (k\ E_2^2)/\ (2X_2)$

∴ $4\ R_2'\ X_2 = (R_2'^2 + X_2^2)$

∴ $(R_2'^2) - 4 \times 0.2 \times R_2' + 0.2^2 = 0$

∴ $(R_2'^2) - 0.8\ R_2' + 0.04 = 0$

∴ $R_2' = \{0.8 + \sqrt{(0.8^2 - 4 \times 0.04)}\}/2$

∴ $R_2' = 0.0535\ ,\ 0.7464\ \Omega$

But R_2' can not greater than X_2 hence, R_2' =

$0.0535 = R_2 + R_{ex}$

∴ $0.0535 = 0.04 + R_{ex}$

∴ $R_{ex} = 0.0135\ \Omega$ per phase

This is much resistance is required in the rotor externally to obtain $T_{st} = 0.5\ T_m$.