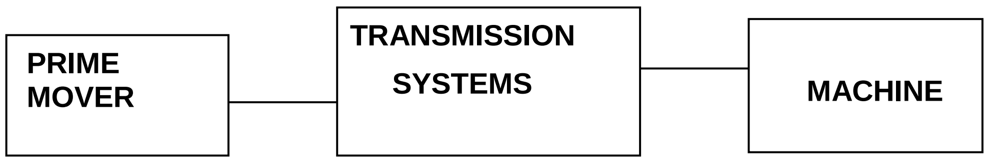
UNIT-4

ELECTRIC DRIVES



DRIVE: A drive is one, which provides mechanical energy to the machine. There are different types drives namely

(a) Diesel engine drives

(b) Electric drives e.t.c.

ELECTRIC DRIVE: An electric drive is defined as a form of machine equipment designed to convert electric energy into mechanical energy and provide electrical control of this process.

ADVANTAGES AND DISADVANTAGES OF ELECTRIC DRIVE OVER OTHER DRIVES:

ADVANTAGES:

1. The electric system is clean because there is no fuel is required for electric drive and it is free from air pollution.

2. The cost of the electric drive is very less compared to the other drives.

3. In electric drives remote control operation is possible where as in other drives it is not possible.

4. Speed control is possible only by means of electric drives.

5. Electric drives have flexibility in installation.

6. The maintenance required for the electric drives is less and of low cost.

7. Electric drives give long life operation.

8. The installation and maintenance charges are also less for electric drives.

9. Electric drives occupy less space compared to other drives.

10. The efficiency of electric drives is also high when compared to other drives.

DISADVANTAGES:

1. In the case of the failure of the supply, the electric drive comes to rest position which may paralyze the whole system.
2. The application of the electric drive system is limited to electric field area only. i.e electric drive are not used where the supply is not available.

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3. In the case of the faults like short circuits, break down of overhead conductors the electric drive system may get damaged and lead to several problems.

FACTORS GOVERNING SELECTION OF ELECTRIC MOTORS:

The basic elements of the electric drive are electric motor, the transmission and the electrical control system. Electric drive is becoming more and more popular for its simplicity, easy and smooth control, reliability and long life. Here the electric motor is very important one in the drive equipment. Now adays there are different types of motors are available with different features. So we have to select the motor as per our requirements. Some factors are to be considers while selecting the motor in the drives. Those factors are as fallows.

1. Nature of the electric supply.
2. Type of drive.
3. Nature of load.
4. Electrical characteristics.
   (a) Operating or Running characteristics.
   (b) Starting characteristics.
   (c) Speed control.
   (d) Breaking characteristics.
5. Mechanical considerations.
   (a) Type of enclosures.
   (b) Type of bearings.
   (c) Type of transmission for drive.
   (d) Noise level.
   (e) Heating and cooling time constants.
6. Service capacity and rating.
   (a) Requirement for continuous, intermittent or variable load cycle.
   (b) Pull-out torque and overload capacity.
7. Appearance.
8. Cost.
   (a) Capital or initial cost.
   (b) Running cost.

1. Nature of the electric supply:

The electric supply available may be 3-phase a.c. or single phase A.C or D.C

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In case of three phase a.c. supply is available, polyphase induction motors, squirrel cage type for small ratings and slip ring type for higher ratings may be used. In case where speed variation is required these can not be used, so pole changing motors or motors with stepped pulleys may be used. where accurate control of speed is required, scharge motors may be used. Use of single phase motors is limited to small loads only because of their limited outputs.

D.C. motors are not used so widely as a.c. motors. There are several reasons for this, some of those reasons are given below.

1. Additional equipment is required for converting existing a.c. supply into d.c. supply.

2. D.C. motors have commutators that are subject to trouble and resulting in sparking, brush wear, arc over and the presence of moisture and destructive fumes in the surrounding air.

3. D.C. motors are generally more expensive than a.c. machines for similar working conditions.

In some cases, such as in electric excavators, steel mills and cranes the speed control is important so dc supply is used by converting a.c. supply in to d.c. supply.

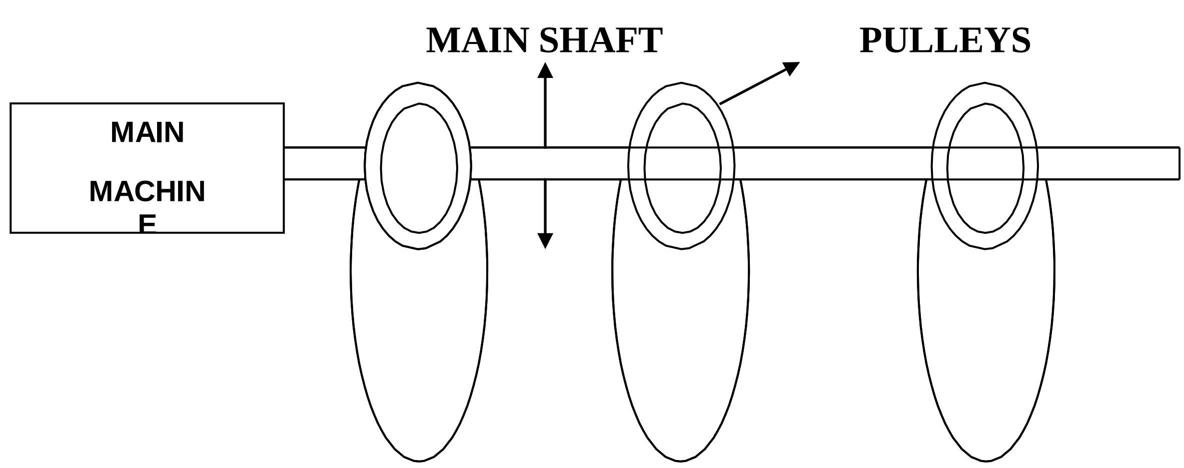
2. TYPES OF ELECTRIC DRIVES:

The various types of electric drives used in industry may be divided into three types. They are

1. Group drive
2. Individual drive
3. Multi-motor drive

1. Group Drive: The group drive is a drive in which a single electric motor drives the group of working machines. It comprises of a single lengthy shaft, to the shaft the different working machines are attached by means of pulleys and conveyor belts. Sometimes group drive is also known as LINE SHAFT DRIVE.

Group drive is often used in industries where successive operations are required like car manufacturing industries e.t.c.



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Advantages:

1. In group drive we require one machine with high capacity for to control the group of machines. i.e. here the cost of the one machine with high capacity is less than the number of machines. i.e. cost of a single 10HP motor is very less compared to 10 number of 1HP motors.

2. Different speeds can be obtained by providing pulleys of different diameters.

Disadvantages:

1. In group drive speed control of individual machine is difficult using stepped pulleys, belts e.t.c.

2. Owing to the use of line shafting pulleys and belts group drive does not give good appearance and is also less safe to operate.

3. The possibility of installation of additional machines to the existing system in group drive is limited.

4. If at a certain instance all the machines are not in operation , then the motor will at low capacity and therefore operation efficiency will be low.

5. If a fault occurs in the main machine then all the operations will be effected.

3.**Individual drive:** In individual drive a single electric motor is used to drive one individual machine. i.e In individual drive each working machine has the individual main machine.

Example: single-spindle drilling machines and various types of electrical hand tools and simple types of metal working tools.

Advantages:

1. Installation of individual drive is easy.

2. If a fault is occurred in one main machine then the whole operations are not effected because it has individual main machines.

3.Each main machine can be effectively utilized at rated capacity.

4. Full control and desired operation of each machine is obtained because of different machines are driven with their respective individual drive.

5. Machines can be located at convenient places

Disadvantages:

1. Cost is high because in this type of drive the number of machines required is high.

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2. More space is required because of each working machine has its individual main machine.

3.**Multimotor drive:** It consists of several individual drives each of which serves to operate one of many working members.

(OR)

Multi-motor drives means the number of operations are required to perform a task.

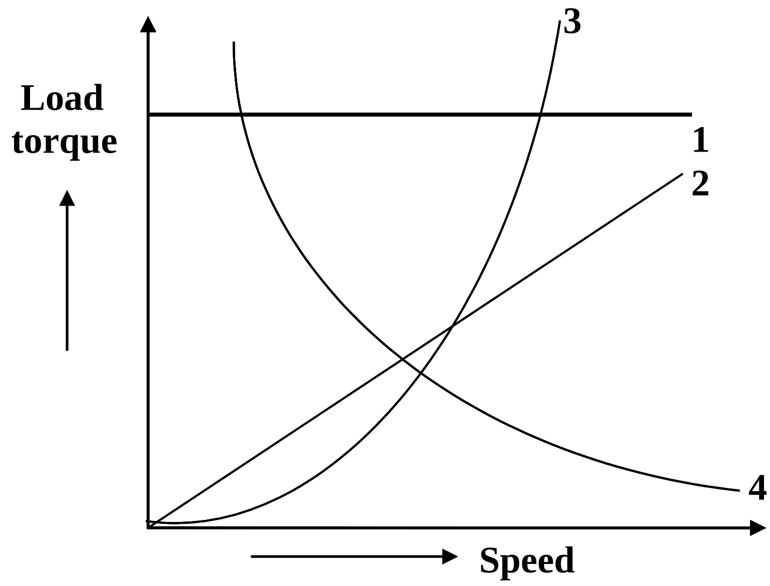
Example: The operation of CRANE.

3. Nature of the load:

The loads may be divided according to the speed-torque characterstics in to the fallowing categories.

(i) Loads required constant torque at all speeds, as shown by the horizontal line 1 in the fallowing figure. Such loads are cranes during hoisting, hoist winches, machine tool feed mechanisms, in piston pump operating against the pressure head.

(ii) Loads requiring torque which may increase in direct proportion to the speed as shown by straight line 2 in figure.



(iii) Loads requiring, which may increase with the square of speed. As shown by the curve3 in the above figure. Such loads are blowers, fans, centrifugal pumps, ship propellers e.t.c.

(iv) Loads requiring torque which may decrease with the increase in the speed as shown by the curve 4 in the above figure. Boring machines, milling machines and other types of metal cutting machines are examples of such loads.

4.Electrical characterstics:

(a)Running characterstics or operating characteristics:

While studying electrical behavior of a machine under normal operating conditions, the speed-torque characteristic, speed-current characteristic, and torque- current characteristic, losses,

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efficiency, magnetizing current and power factor at various loads are to be kept in the view. The last two factors i.e. magnetizing current and power factor are to be considered in case of a.c. motors.

Running characteristics of d.c. motor:

$$E_b = V - I_aR_a \longrightarrow (1)$$

$$E_b = \frac{Z\emptyset NP}{60A} \longrightarrow (2)$$

From equation 1 and 2

$$E_b \ \alpha \ \emptyset N$$

$$N \ \alpha \ \frac{Eb}{\emptyset}$$

$$\text{i.e } N \ \alpha \ \frac{V - IaRa}{\emptyset}$$

Speed-current characterstics:

case 1: for dc shunt motor:

$$N \ \alpha \ \frac{V - IaRa}{\emptyset}$$

In shunt motor, $\emptyset$ is maintained to be constant since DC shunt motor is a constant speed motor. If V is also maintained to be constant then the speed the speed- current characteristics is obtained as shown in the fallowing figure.The dc shunt motor must be started under light load condition or no-load condition. Because if we started at full load condition the current will be maximum and then it may damage the motor windings and also it has low starting torque.

Applications:

1. Conveyer belts.
2. Centrifugal pumps.
3. Reciprocating pumps.
4. Grinders.
5. Polishers.
6. Small printing presses.
7. paper making machines.
8. Metal cutting machines.

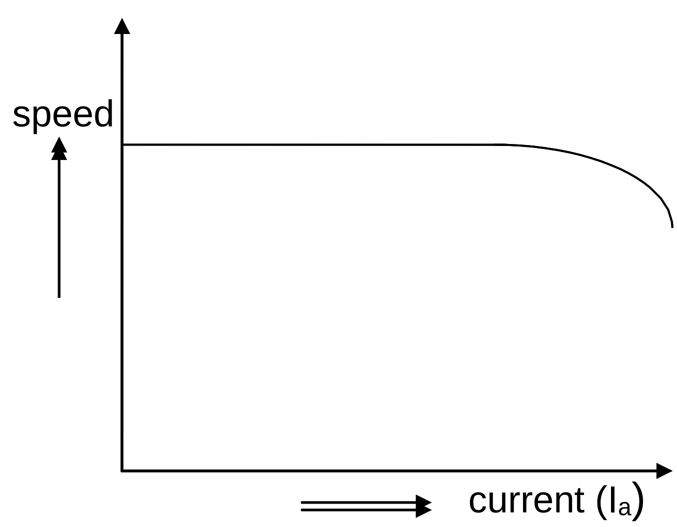

figure: speed-current characteristics of dc shunt motor

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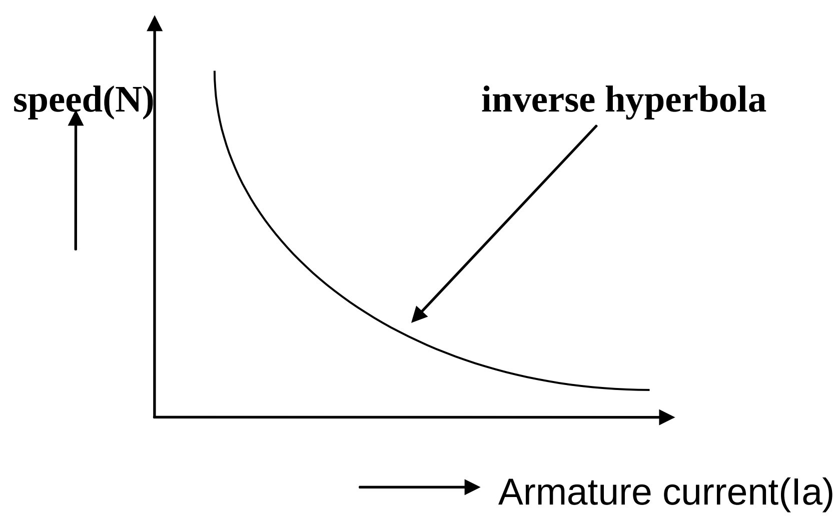
case 2: for dc series motor:

$$N \ \alpha \ \frac{Eb}{\emptyset}$$

$$\text{i.e } N \ \alpha \ \frac{V - IaRa}{\emptyset}$$

at constant voltage $N \ \alpha \ \frac{1}{\emptyset}$

$$\text{i.e } N \ \alpha \ \frac{1}{Ia} \quad (\text{since } \emptyset \ \alpha \ Ia)$$



A dc series motor should always be started at full load. Because if it is started at no load (less Ia) the speed is high and the motor may break.

Applications:

Electric traction

case 3: for dc compound motor:

cumulative compound:

$\emptyset = \emptyset_{sh} + \emptyset_{sc}$

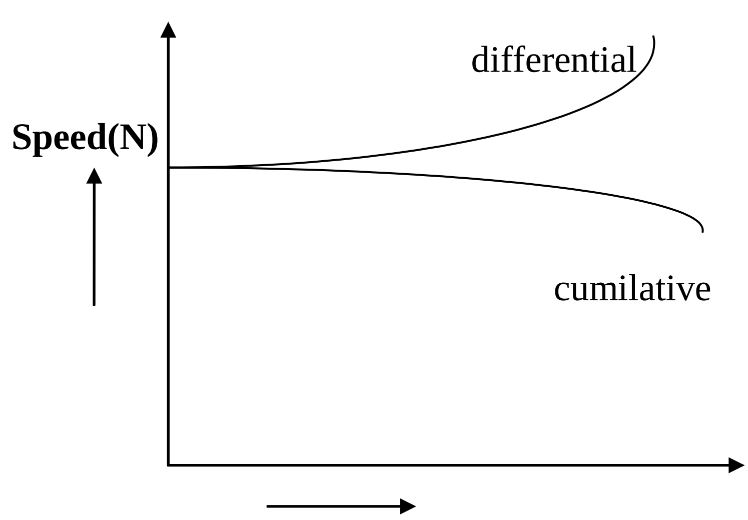
$N \ \alpha \ \frac{1}{\emptyset}$

differential compound:

$\emptyset = \emptyset_{sh} - \emptyset_{sc}$

$N \ \alpha \ \frac{1}{\emptyset}$

$\emptyset$ is maximum then N is low



The cumulative compound motors are used in the driving machines. Which are subjected to the sudden application of heavy loads. These motors are used where a large starting torque is required.

Applications: Rolling mills

In differential compound motor the speed remains constant and sometimes increase with increase in the load. This motor may rotate in opposite direction at high loads that is why this motor is seldom used practically.

Torque-Current Characteristics:

In all d.c. motors torque is given by

$$T = \frac{\emptyset Z P I a}{2\pi A}$$

$$T \ \alpha \ \emptyset I a$$

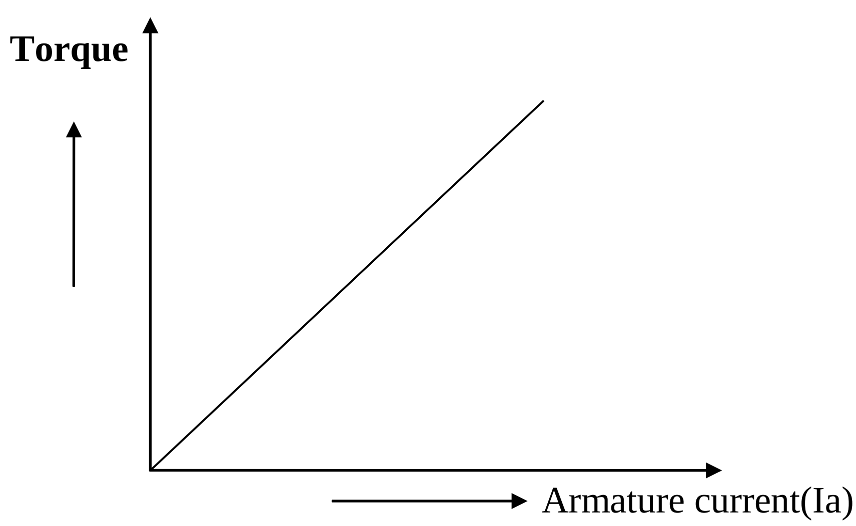
case 1: for dc shunt motor:

for a dc shunt motor flux is constant ($\emptyset = k$)

$$T \ \alpha \ Ia$$

$$T = kIa$$

In dc shunt motor it is deserved that the torque varies directly as the load current is varying. Hence the characteristics fallows the linear law.



case 2: for dc series motor:

for a dc series motor

$$T \ \alpha \ \emptyset Ia$$

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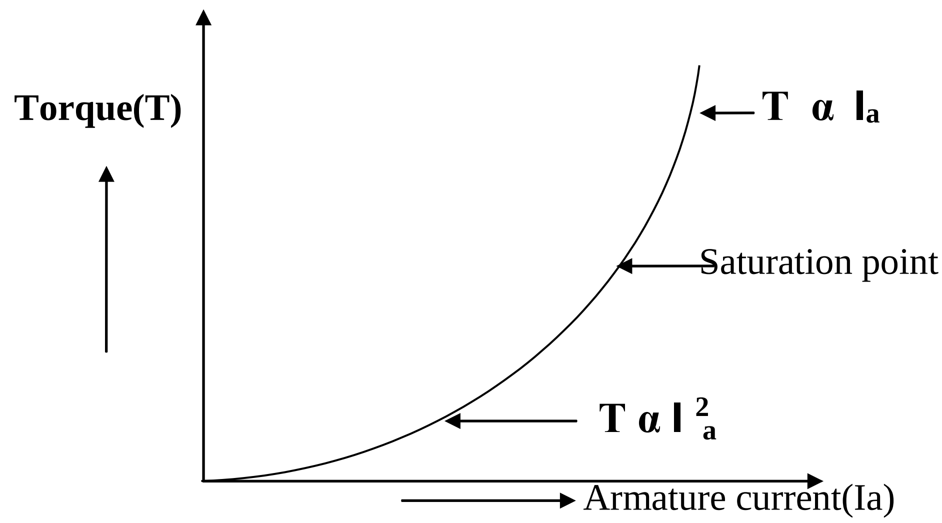
$$\emptyset \ \alpha \ Ia$$

Hence $T \ \alpha \ I_a^2$

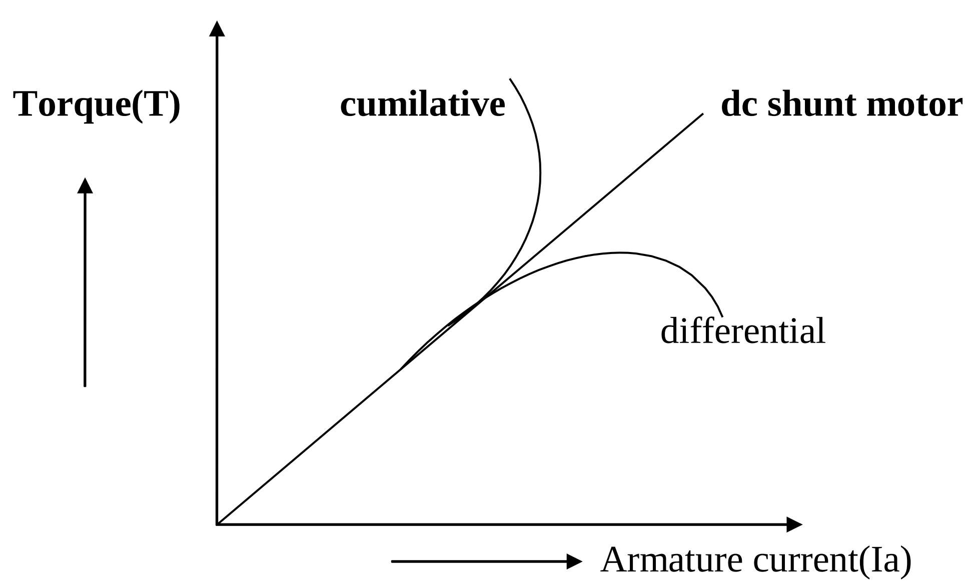
As we know a dc series motor has high starting torque. So, therefore initially at starting $\emptyset \ \alpha \ Ia$ and $T \ \alpha \ I_a^2$.

After sometime interval the core gets saturated and at that instant $T \ \alpha \ I_a$



case 2: for dc compound motor:

In cumulative compound motor flux is more, hence torque developed is more. Where as in differential compound motor flux is less and hence torque developed is less.



Applications:

Cumulative compound motors are used in driving machines. Which are subjected to sudden application of heavy loads such as in rolling mills. This type of motor is also used, when high starting torque is required such as in cranes.

Speed-Torque characteristics:

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In dc motors

$$T \ \alpha \ \emptyset Ia$$

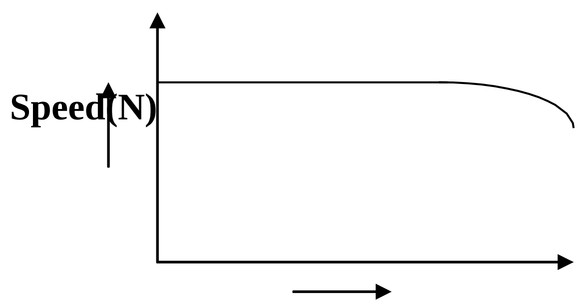
$$N \ \alpha \ \frac{Eb}{\emptyset}$$

$$\text{i.e} \quad N \ \alpha \ \frac{V - IaRa}{\emptyset}$$

case 1: for dc shunt motor:

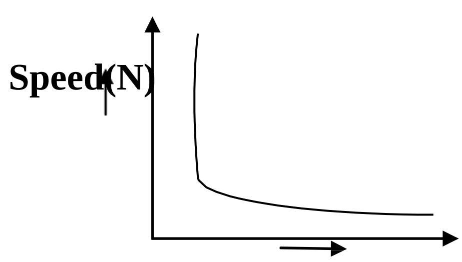
In a dc shunt motor when the supply voltage is constant the field flux and armature flux is also constant and speed of the motor mainly depends upon the armature current. The speed decrease with the increase in armature current.

Hence T-N characteristics of a dc shunt motor will be straight line as shown in the fallowing figure.



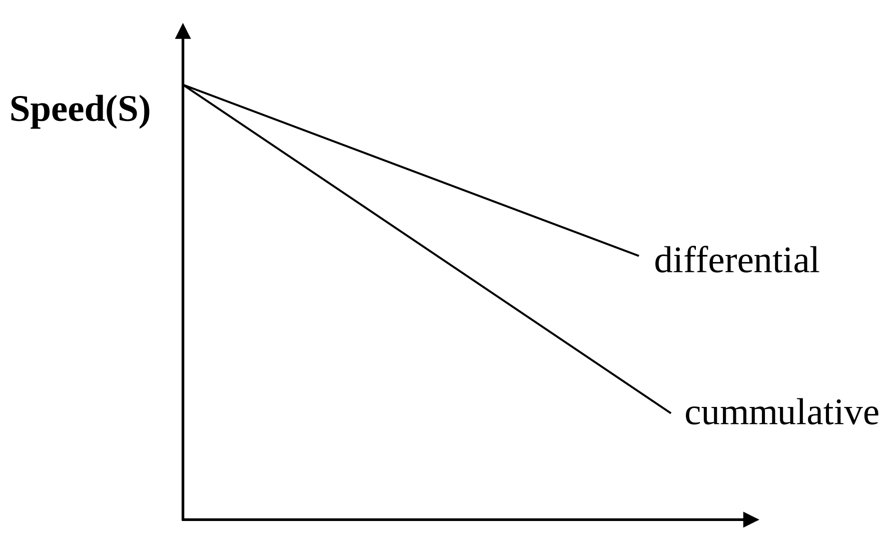
case 2: for dc series motor:

As the current increases the torque also increases, where as the speed falls. Hence it is observed from the characteristics during starting the torque is less and the speed is dangerously high. The motor must always be started on full load.



Torque(T)

case 2: for dc compound motor:



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Running characteristics of A.C. motors:

Basically the a.c. motors are classified as fallows.

(i)Synchronous motors
(ii) Induction motors

Single phase

Universal motor, schrage motor

Repultion motor, AC commutation motor

Three phase

squirrel cage

Slip commutation motor

Double cage

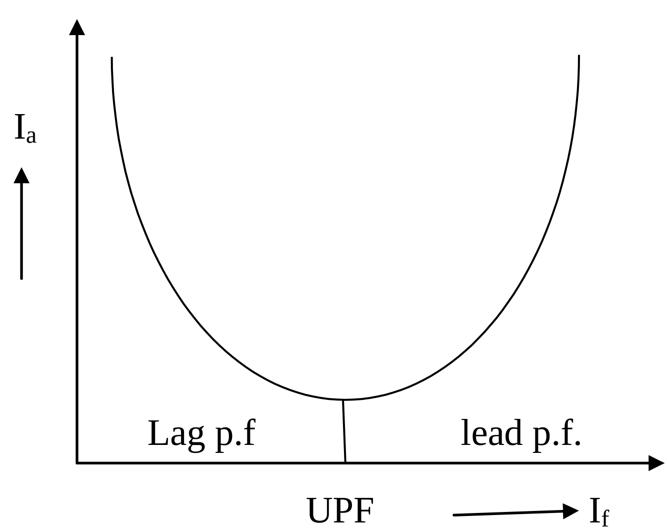
Synchronous motor:

It is the motor which always runs at constant speed known as synchronous speed.

1. The speed of the motor is independent of load.
2. It is not a self starting motor.
3. The power factor of this motor can be varied by changing its fileld current.

Applications:

In rolling mills, motor-generator sets, pumps



Single-phase induction motor:

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The constructional features of the single-phase induction motor are similar to that of three-phase induction motor with the exemption that starting is not provided. The speed-torque characteristics are similar to that of three-phase induction motor. As this motors are not self starting separate methods are adopted to make a single phase induction motor self starting. The fallowing are the methods to make it self start

1. Split phase starting.
2. Capacitor starting.
3. Shaded pole starting.
4. Repulsion starting.

The single-phase induction motors are quietly costly and are comparatively bulkey in size, with the help of separate starting devices we can only obtain small amounts of starting torque. Hence single phase induction motor is employed in some of the domestic applications like refrigerators, vaccum cleaners e.t.c.

Three-phase induction motors:

The three phase induction motors are broadly classified in to fallowing types.

1. Squirral cage 2. slip ring 3.double cage

Squirral cage induction motor:

all the above three types of the motorsthe basic equation for the torque is

$$T_S = KV^2 R_L' / (R_1 + R_L')^2 + (X_1 + X_L')^2$$

From the For above equation,

K = constant; V = voltage

R_1 = stator resistance X_1 = stator reactance

R_L' = rotor resistance referred to stator

X_L' = rotor reactance referred to stator

From the above equations it is clear that starting torque is directly proportional to resistance.

case 1: Squarrel cage induction motor:

In case of squarrel cage induction motor the rotor conductors are short circuited at both ends. Hence there is no chance for including any external resistance. Hence compared to slip ring induction motor this motor has low starting torque, of course the running characteristics of both the motors are same.

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case 2: Slip ring induction motor:

For these motors it is possible to include external resistance and hence we can achieve high starting torque.

case 3: Double cage induction motor:

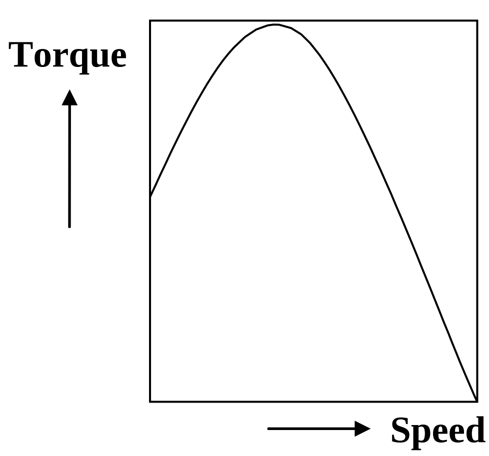
The rotor of this motor consists of two layers of conductors. i.e. outer cage and inner cage. The inner cage has high inductance and low resistance winding where as outer cage has high resistance and low inductance winding. At the time of starting the inner cage offers high inductance to the high frequency currents hence this currents are divided to the outer cage due to which high starting torque is achieved. As soon motors picks up rated speed the frequency of flowing in outer cage if flows in inner cage this reducing the losses.

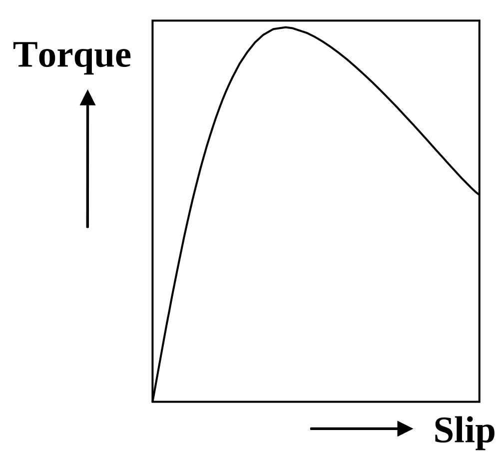
The power factor of these motors is very less when they are operated at no load or high load. But the power factor improves as the motors tend to near full load. The speed-torque characteristics of all these motors are similar to those of shunt motors.

Applications of squirrel cage induction motor:

To drive pumpsets, machine tools and other operations where constant speed is desired.

For slip ring induction motor:





Compensated induction motor or no lag motor:

It is an improved induction motor which always works at unity power factor over wide range of loads. The primary winding is placed on the rotor and secondary winding on the ststor. The rotor has an additional winding known as commutator winding whose e,m.f's are collected by the brushes from the commutator and injected into the secondary winding in such a way to improve the power factor.

Repulsion motor:

The construction of this motor is similar to that of series motor except that its armature is short circuited on it self instead of being connected in series with stator, its speed can be adjusted.

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Schrage motors:

It is also called brush shifting motor in which power factor correction and speed control are possible. It is an inversed wound rotor induction motor in which stator windings is connected in wye and the primary winding is supplied from three phase supply through slip rings. The torque speed characteristics of this motor are similar to those of a shunt motor.

Applications:

1. High starting torques- lefts, pumps, convayors e.t.c.
2. Adjustable speed- paper mills. Printing presswes e.t.c.

Universal motor:

The motor operates at approximate by the same speed on eighter d.c. or a.c. supply.

It is a series wound motor. The characteristics of this motor are similar to that of dc series motors. These motors are built up in fractional H.P. to one fourth H.P.

Applications:

Sewing machines, table fans, vaccum cleaners, portable drill machine e.t.c.

STARTING CHARACTERISTICS:

The study of starting characteristics of a motor is essential to know weather the starting torque that the motor is capable of developing is sufficient to start and accelerate the motor.

The torque for accelerating depends upon the load torque. The loads which are usually met with, may be divided according to accelerating torque requirements into the fallowing categories:

1. Load requiring very small accelerating torque in comparison with full load torque such as when the motor is to be run light.
2. Load requiring the torque which may increase with speed and it may be proportional to $(\text{speed})^2$ as in case of fan.
3. Load having constant load torque at all speeds in case of lifts.
4. When the motors have to start and accelerate against full load torque and in addition to accelerate since some heavy moving parts as in case of rolling mills.

For D.C motors: The torque of a d.c. motor is directly proportional to the product of flux and armature current and is quite independent of speed. Hence in order to having a high starting torque for a given armature current, the flux must be increased to the maximum value possible.

In case of a d.c shunt motor the flux remains constant as the field is connected directly across the constant voltage supply mains and the armature current is controlled by connecting a starting resistance in series with the armature as shown in the figure. The torque, which is directly proportional to the armature current is limited by the maximum allowable starting current.

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In case of a d.c series motor the field winding is connected in series with the armature therefore, the current in the series field winding and armature is the same. Since upto saturation point the flux is directly proportional to the current flowing through the field and after saturation point the flux is independent of current and remains almost constant. Therefore, the torque varies as the square of the armature current upto saturation point.

For A.C motors: In case of three phase induction motor

All the above three types of the motors the basic equation for the torque is

$$T_S = KV^2 R_L' / (R_1 + R_L')^2 + (X_1 + X_L')^2$$

From the For above equation,

K = constant; V = voltage

R_1 = stator resistance X_1 = stator reactance

R_L' = rotor resistance referred to stator

X_L' = rotor reactance referred to stator

From the above equations it is clear that starting torque is directly proportional to resistance.

The starting torque becomes maximum when the rotor resistance is made equal to the leakage reactance. Since the rotor resistance is not more than 1 or 2 percent of its leakage reactance. Therefore, in order to obtain high starting torque resistance must be inserted in the rotor circuit as start and cutout gradually as the motor picks up speed. The additional resistance in the rotor circuit is not only for high starting torque also for to limit the starting current. This method is useful in case of slip ring induction motor only, in which the external resistance at the starting instant is introduced in the rotor circuit by taking the rotor winding terminals out to the slip rings mounted on the shaft with brushes resting on them.

In case of single phase induction motor the fallowing methods are employed for starting.

Pole shading: A short circuited copper coil is placed round a portion of each pole, and this coil has currents induced in it by transformer action; these cause the flux in that proportion of the pole to lag on the main flux so that the rotating field is produced, enabling the motor to start.

Phase splitting devices: Another method of obtaining a rotating field at starting is to employ a phase splitting devices which produces a two-phase supply so that the motor can be started.

Repulsion motor starting: the repulsion motor has a high starting torque, and in order to be able to combine this with the constant speed torque characteristic of the induction motor, two types of repulsion start induction motor have been developed.

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One of these employs an ordinary repulsion motor winding on the rotor with a centrifugally operated device which short circuits all the commutator segments and rises the brushes when the motor reached nearly full speed, thus converting it into a squirrel cage induction motor.

Speed control:

D.C motors:

$$N \; \alpha \; \frac{V - IaRa}{\emptyset}$$

While selecting a motor for a particular drive special care has to be taken for the speed variations. If we consider the entire range of loads out of which some loads may require constant speed drives, some may require smooth variation on speed and some may require step changes in speed.

Speed control of D.c. motors:

$$N \; \alpha \; \frac{V - IaRa}{\emptyset}$$

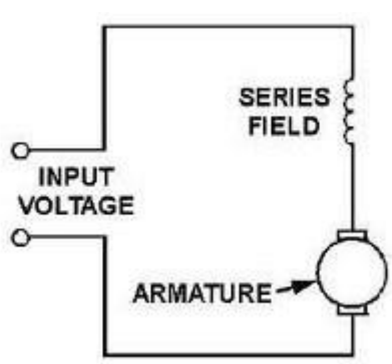
The speed control of dc motors is possible in three ways.

1. By varying field flux.
2. By varying applied voltage.
3. By varying resistance in armature circuit.

1. By varying field flux($\emptyset$):

The field flux is directly proportional to field current. Hence by varying field current the flux can be varied to obtain the variable speed. The field current can be varied by introducing a variable resistance in the field circuit.

For series motor variable resistance is connected in parallel with field winding



2. By varying applied voltage

By varying the applied voltage of the motor the speed is controlled and another method is by using the tap changing field windings as shown in figure2 the speed is controlled in this method by changing the tapping of the field winding the field current can be varied and therefore the speed is varied.

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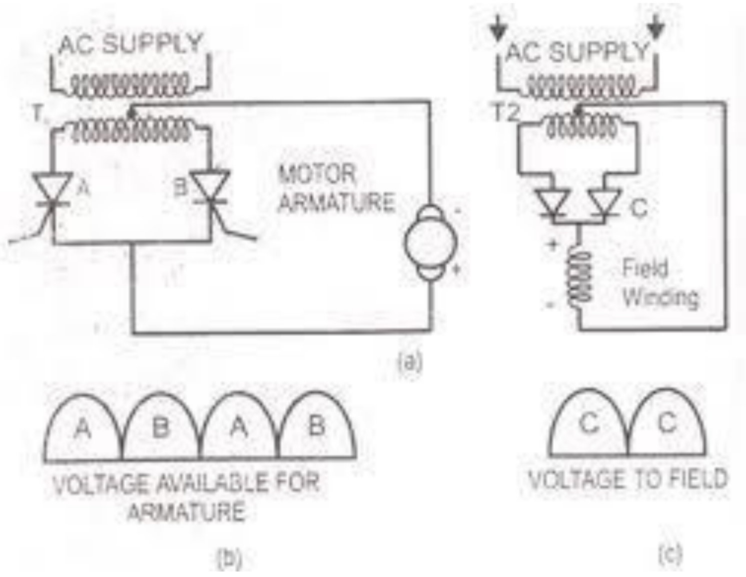
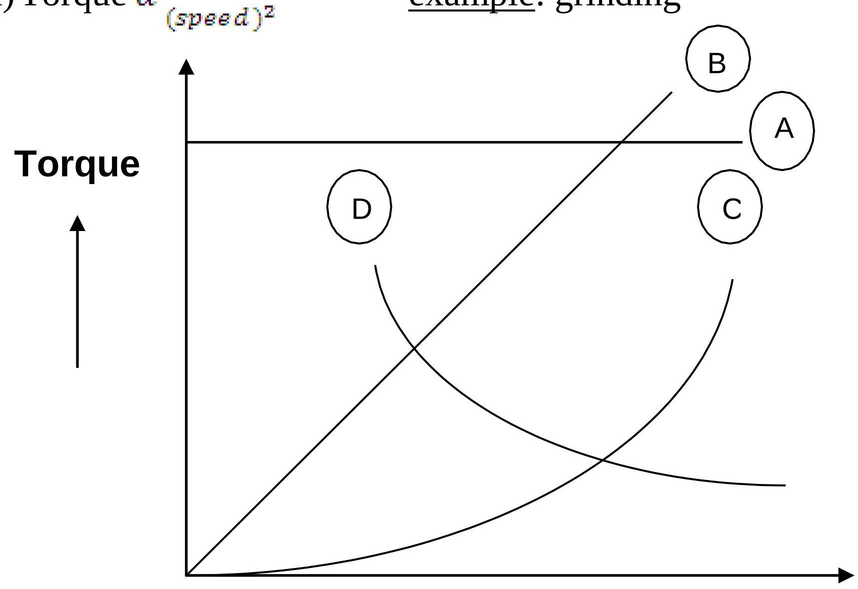


Types of loads:

1. Based on influence of gravity, compression on tension.
   (a) Active loads (gravity) example: lifts and hoisters.
   (b) Passive loads (friction) example: mills.

2. Based upon time of operation
   (a) Continuous and constant loads example: centrifugal pumps
   (b) Continuous and variable loads example: convayors, hoisters
   (c) Pulsating example: reciprocating pumps and textile loams
   (d) Impact loads example: rolling mills, shearing mills
   (e) Intermitted loads example: cranes and hoisters
3. Based upon the speed of the motor (shown in the fallowing figure)
   (a) Constant load torque example: hoisters and cranes
   (b) Torque α speed example: fluid friction
   (c) Torque α speed^2 example: fans
   (d) Torque $\alpha \frac{1}{(speed)^2}$ example: grinding



LOAD EQUALISATION:

In many industrial drives, such as in rolling mills, planning machines, electric hammers, reciprocating pumps, the load fluctuates over a wide range. It is desirable to smooth out the fluctuating load, otherwise during intervals of peak load it will draw a heavy current from the supply either producing large voltage drop in the system or requiring cables and wires on heavy section. The process of smoothing out the fluctuating load is known as load equalization. In this process, energy is stores during the interval of light load and given out during the interval of peak load thus power from the supply remains approximately constant.

The most common method of load equalization is by use of fly wheel. During the light load period the fly wheel accelerates and stores the excess energy drawn from the supply and during peak load period the fly wheel de accelerates and supplies some of its stored energy to the load in addition to the energy supplied from the supply. Thus the load demand is reduced.

The motors used for such loads should have dropping characteristics, so that the speed may fall with the increase in load and enables the fly wheel to give up its stored energy. for the loads in which the motor have to run in the same direction and is not to be stopped and started frequently, flywheel may be mounted on the motor shaft.

For a reversing drive, such as for colliery winders, the ward leonard control system is generally used for reversing and speed control, so flywheel can be mounted on the shaft of the motor-generator.

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