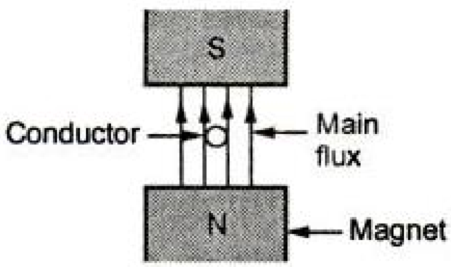
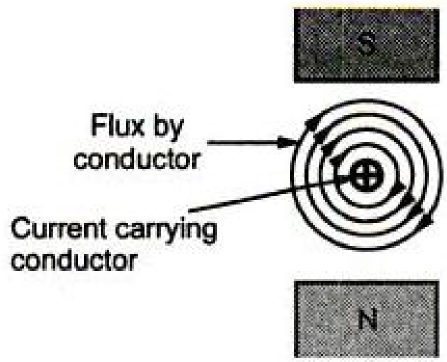
4-2 Principle of Operation of a D.C. motor

The principle of operation of a d.c. motor can be stated in a single statement as 'when a current carrying conductor is placed in a magnetic field; it experiences a mechanical force'. In a practical d.c. motor, field winding produces a required magnetic field while armature conductors play a role of a current carrying conductors and hence armature conductors experience a force. As conductors are placed in the slots which are on the periphery, the individual force experienced by the conductors acts as a twisting or turning force on the armature which is called a **torque**. The torque is the product of force and the radius at which this force acts. So overall armature experiences a torque and starts rotating. Let us study this motoring action in detail.

Consider a single conductor placed in a magnetic field as shown in the Fig. 2.1 (a). The magnetic field is produced by a permanent magnet but in a practical d.c. motor it is produced by the field winding when it carries a current.



(a) Conductor in a magnetic field



(b) Flux produced by current carrying conductor

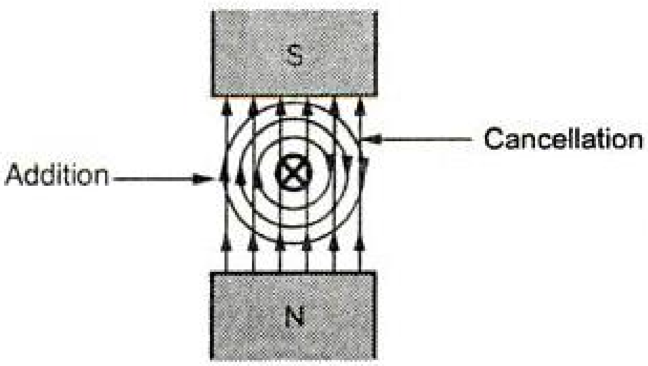
Fig. 2.1

Now this conductor is excited by a separate supply so that it carries a current in a particular direction. Consider that it carries a current away from an observer as shown in the Fig. 2.16 (b). Any current carrying conductor produces its own magnetic field around it, hence this conductor also produces its own flux, around. The direction of this flux can be determined by right hand thumb rule. For direction of current considered, the direction of flux around a conductor is clockwise. For simplicity of understanding, the main flux produced by the permanent magnet is not shown in the Fig. 2.1 (b).

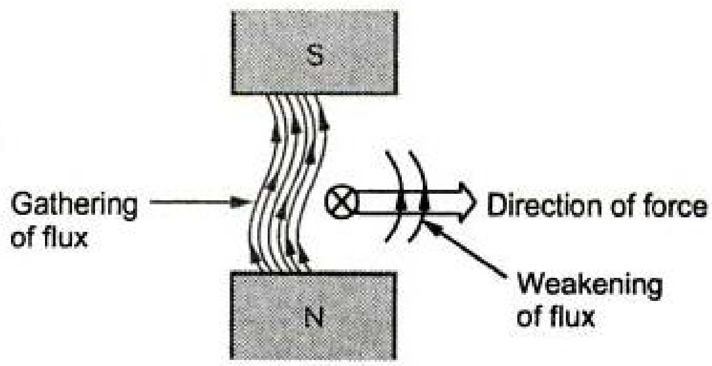
Now there are two fluxes present,

1. The flux produced by the permanent magnet called main flux.
2. The flux produced by the current carrying conductor.

These are shown in the Fig. 2.2 (a). From this, it is clear that on one side of the conductor, both the fluxes are in the same direction. In this case, on the left of the conductor there is gathering of the flux lines as two fluxes help each other. As against this, on the right of the conductor, the two fluxes are in opposite direction and hence try to cancel each other. Due to this, the density of the flux lines in this area gets weakened. So on the left, there exists high flux density area while on the right of the conductor there exists low flux density area as shown in the Fig. 2.2 (b).



(a) Interaction of two fluxes



(b) Force experienced by the conductor

Fig. 2.2

This flux distribution around the conductor acts like a stretched rubber band under tension. This exerts a mechanical force on the conductor which acts from high flux density area towards low flux density area, i.e. from left to right for the case considered as shown in the Fig. 2.2 (b).

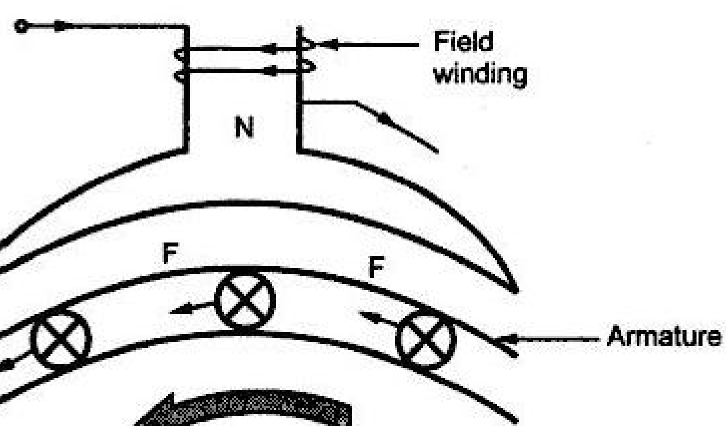


Fig. 2.3 Torque exerted on armature

2.10 D.C. Compound Motor

The compound motor consists of part of the field winding connected in series and part of the field winding connected in parallel with armature. It is further classified as long shunt compound and short shunt compound motor.

2.10.1 Long Shunt Compound Motor

In this type, the shunt field winding is connected across the combination of armature and the series field winding as shown in the Fig. 2.11.

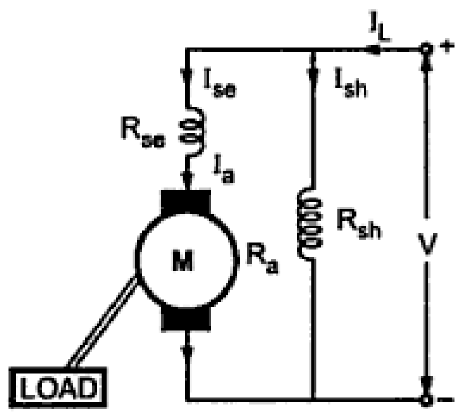


Fig. 2.11 Long shunt compound motor

Let R_{se} be the resistance of series field and R_{sh} be the resistance of shunt field winding. The total current drawn from supply is I_L.

So $$I_L = I_{se} + I_{sh}$$

But $$I_{se} = I_a$$

$\therefore$ $$I_L = I_a + I_{sh}$$

And $$I_{sh} = \frac{V}{R_{sh}}$$

And $$V = E_b + I_a R_a + I_{se} R_{se} + V_{brush}$$

But as $$I_{se} = I_a,$$

$\therefore$ $$V = E_b + I_a (R_a + R_{se}) + V_{brush}$$

2.10.2 Short Shunt Compound Motor

In this type, the shunt field is connected purely in parallel with armature and the series field is connected in series with this combination shown in the Fig. 2.12.

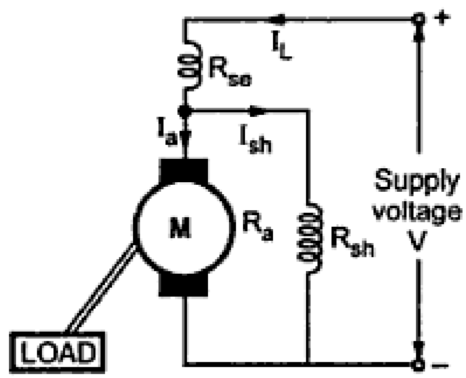


Fig. 2.12 Short shunt compound motor

$$I_L = I_{se}$$

The entire line current is passing through the series field winding.

and $$I_L = I_a + I_{sh}$$

Now the drop across the shunt field winding is to be calculated from the voltage equation.

So $$V = E_b + I_{se} R_{se} + I_a R_a + V_{brush}$$

but $$I_{se} = I_L$$

$\therefore$ $$V = E_b + I_L R_{se} + I_a R_a + V_{brush}$$

$\therefore$ Drop across shunt field winding is,

$$= V - I_L R_{se} = E_b + I_a R_a + V_{brush}$$

$\therefore$ $$I_{sh} = \frac{V - I_L R_{se}}{R_{sh}} = \frac{E_b + I_a R_a + V_{brush}}{R_{sh}}$$

Apart from these two, compound motor can be classified into two more types,

i) Cumulatively compound motors and ii) Differential compound motors.

Key Point : *If the two field windings are wound in such a manner that the fluxes produced by the two always help each other, the motor is called* ***cumulatively compound.*** *If the fluxes produced by the two field windings are trying to cancel each other i.e. they are in opposite direction, the motor is called* ***differential compound.***

A long shunt compound motor can be of cumulative or differential type. Similarly short shunt compound motor can be cumulative or differential type.

2.16 Characteristics of D.C. Compound Motor

Compound motor characteristics basically depends on the fact whether the motor is cumulatively compound or differential compound. All the characteristics of the compound motor are the combination of the shunt and series characteristic.

Cumulative compound motor is capable of developing large amount of torque at low speeds just like series motor. However it is not having a disadvantage of series motor even at light or no load. The shunt field winding produces the definite flux and series flux helps the shunt field flux to increase the total flux level.

So cumulative compound motor can run at a reasonable speed and will not run with dangerously high speed like series motor, on light or no load condition.

In differential compound motor, as two fluxes oppose each other, the resultant flux decreases as load increases, thus the machine runs at a higher speed with increase in the load. This property is dangerous as on full load, the motor may try to run with dangerously high speed. So differential compound motor is generally not used in practice.

The various characteristics of both the types of compound motors cumulative and the differential are shown in the Fig. 2.19 (a), (b) and (c).

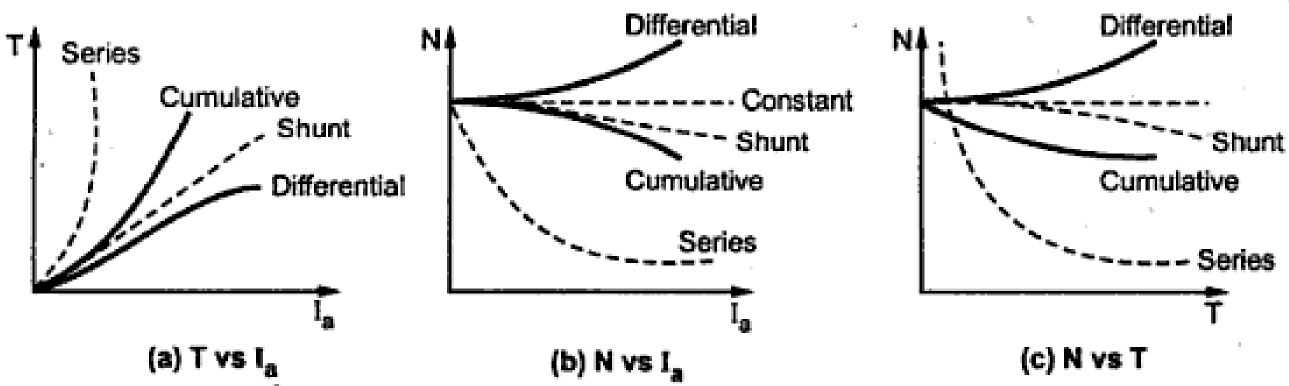


Fig. 2.19 Characteristics of d.c. compound motor

The exact shape of these characteristics depends on the relative contribution of series and shunt field windings. If the shunt field winding is more dominant then the characteristics take the shape of the shunt motor characteristics. While if the series field winding is more dominant then the characteristics take the shape of the series characteristics.