Chapter Five

D.C. Machines

General arrangement of a D.C. machine

Figure 5.1 shows the general arrangement of a four-pole d.c. machine. The fixed part consists of four steel cores C, referred to as *pole cores*, attached to a steel ring R, called the *yoke*. Each pole core has pole tips, partly to support the field winding and partly to increase the cross-sectional area and thus reduce the reluctance of the air gap. Each pole core carries a winding F connected to excite the poles alternately N and S.

The armature core A consists of steel laminations insulated from one another and assembled on the shaft. The purpose of laminating the core is to reduce the eddy-current loss. Slots on the laminations to provide mechanical security to the armature winding.

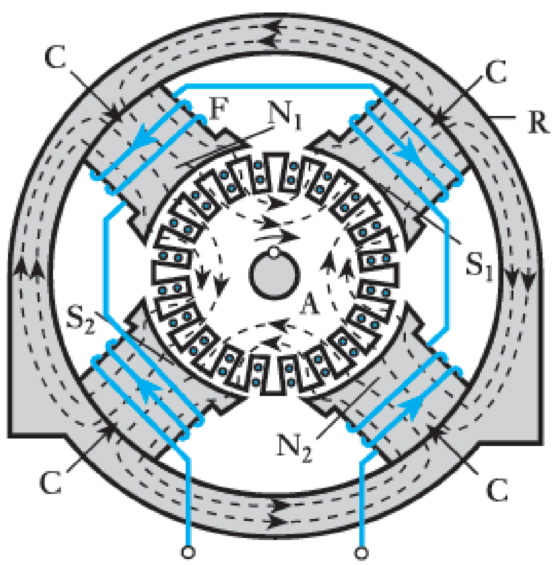


Fig.5.1. General arrangement of a four-pole d.c. machine

The term conductor, when applied to armature windings, refers to the active portion of the winding, namely that part which cuts the flux, thereby generating an e.m.f.; for example, if an armature has 40 slots and if each slot contains 8 wires, the armature is said to have 8 conductors per slot and a total of 320 conductors.

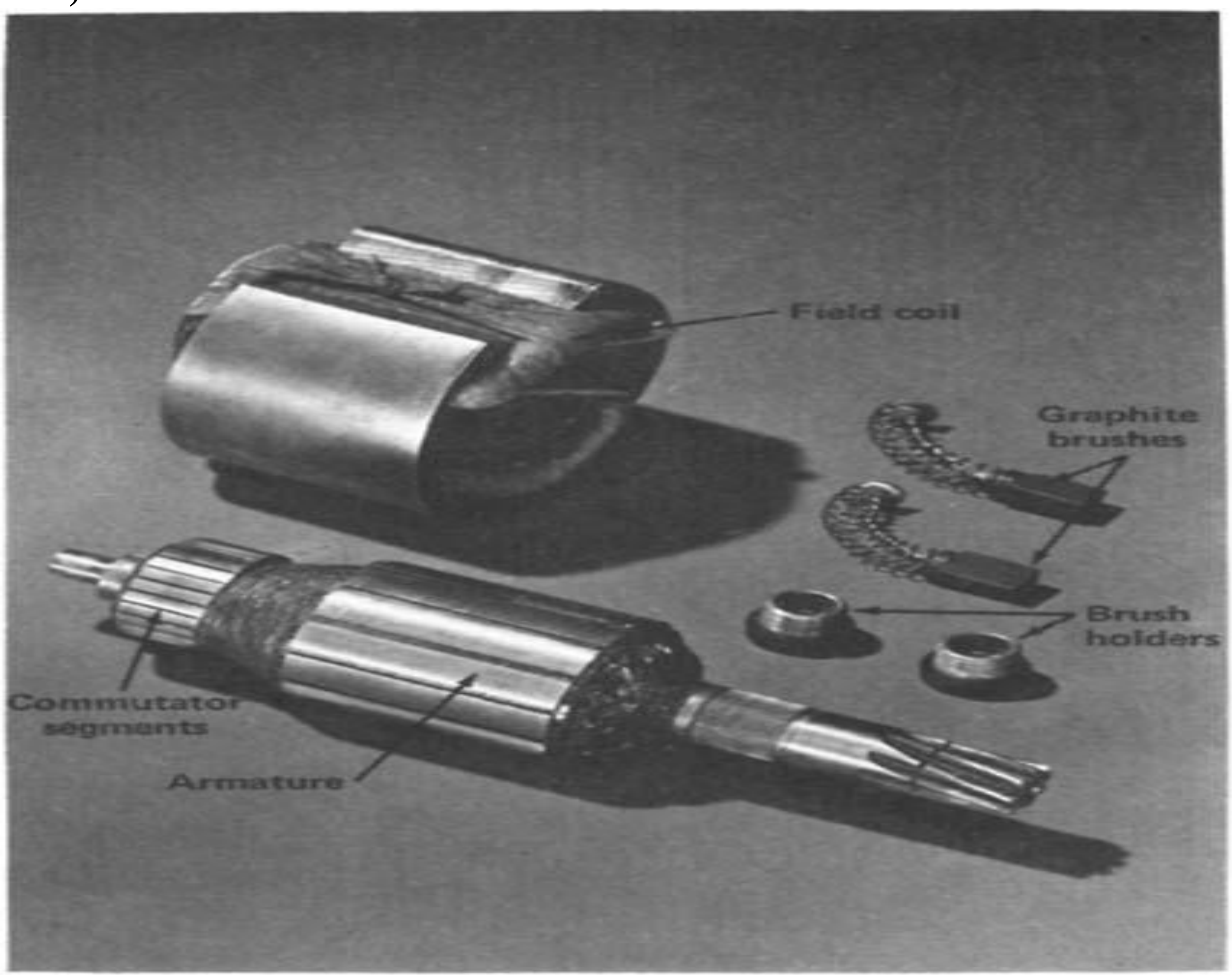
The dotted lines in Fig. 5.1 represent the distribution of the magnetic flux, namely that flux which passes into the armature core and is therefore cut by the armature conductors when the armature revolves. It will be seen from Fig. 5.1 that the magnetic flux which emerges from N_1 divides, half going towards S_1 and half towards S_2. Similarly, the flux emerging from N_2 divides equally between S_1 and S_2.

DC machines divided into:-

DC motors and DC generators. A motor is a machine that converts electric energy into mechanical energy. Motors turn washing machines, travelling cranes, rolling mills, and much of the machinery found in industry. A generator, on the other hand, is a machine that converts mechanical energy into electric energy. The mechanical energy might be supplied by a waterfall, steam, wind, diesel engine, or an electric motor.

Components

The main parts of direct-current motors and generators are basically the same (Fig. 5-2).

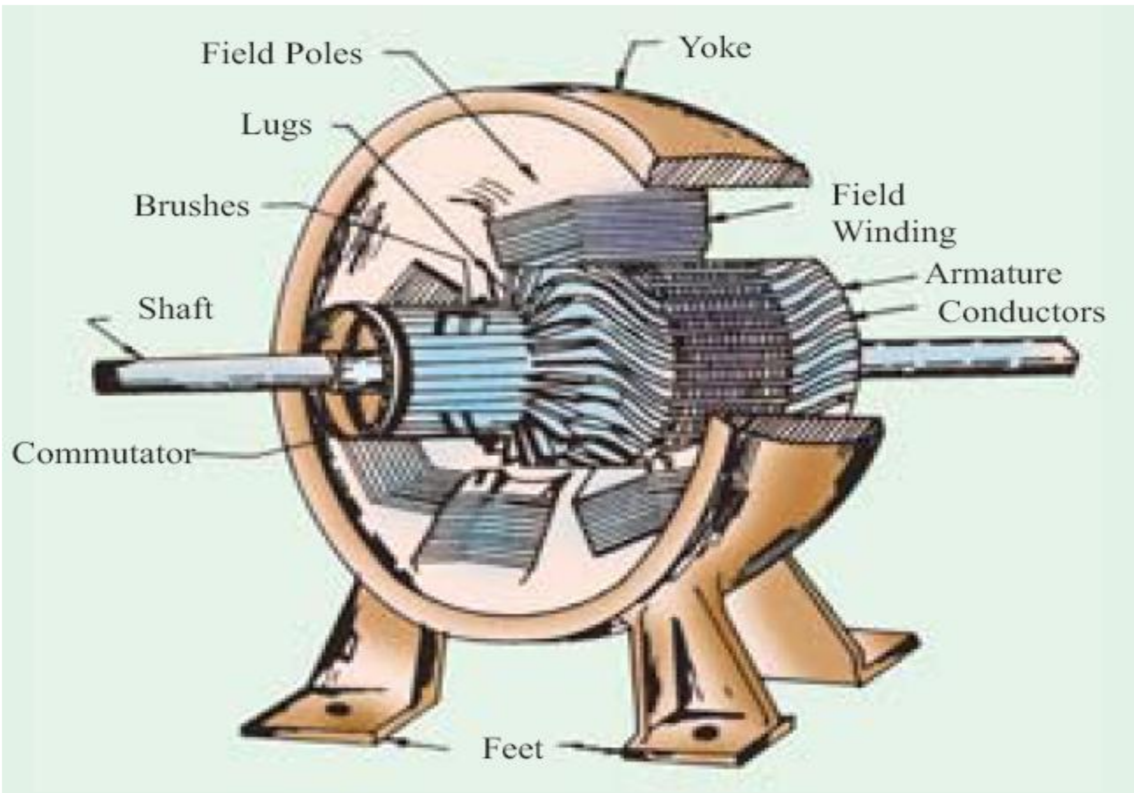


The construction of a DC machines

They consist of the following essential parts:

1. Magnetic Frame or Yoke
2. Pole-Cores and Pole-Shoes
3. Pole Coils or Field Coils
4. Armature Core
5. Armature Windings or Conductors
6. Commutator
7. Brushes and Bearings

Of these, the yoke, the pole cores, the armature core and air gaps between the poles and the armature core or the magnetic circuit whereas the rest form the electrical circuit.

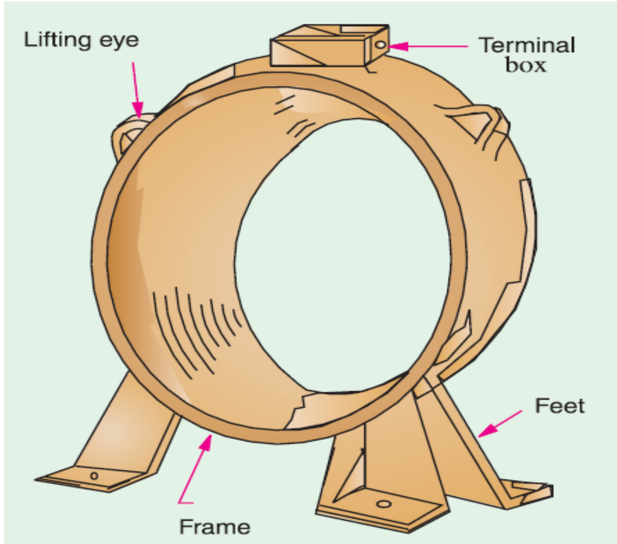


1)Yoke

The outer frame or yoke serves double purpose :

(*i*) It provides mechanical support for the poles and acts as a protecting cover for the whole machine.

(*ii*) It carries the magnetic flux produced by the poles.



2)Pole Cores and Pole Shoes

The field magnets consist of pole cores and pole shoes. The pole shoes serve two purposes:

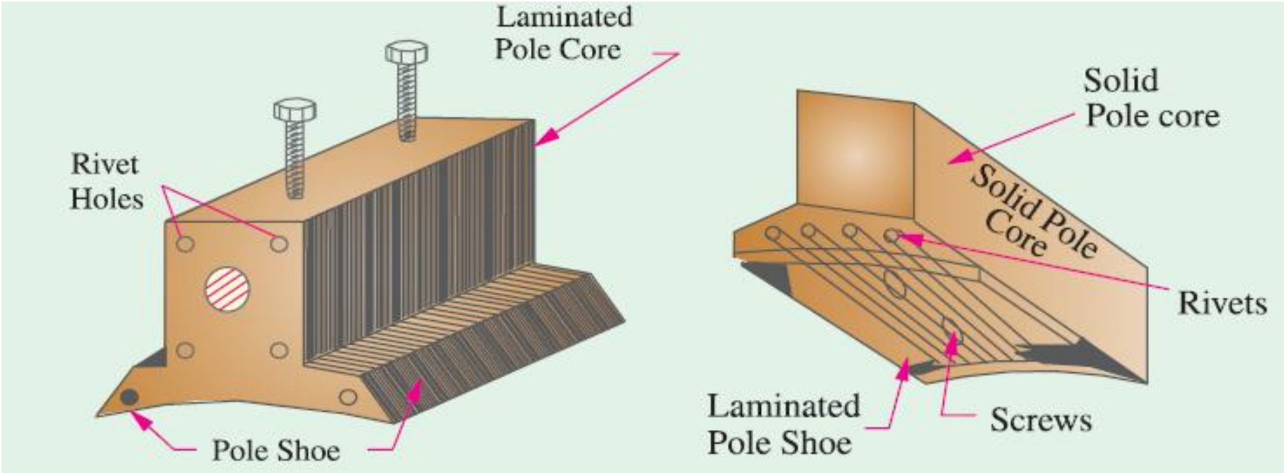
(i) they spread out the flux in the air gap and also, being of larger cross-section, reduce the reluctance of the magnetic path.

(ii) they support the exciting coils (or field coils).

There are two main types of pole construction.

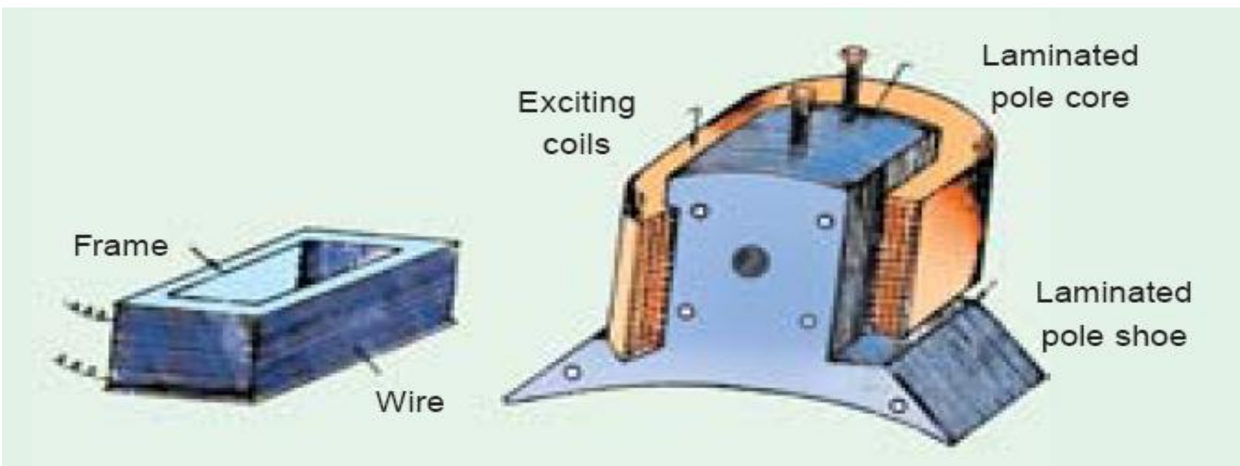
(*a*) The pole core itself may be a solid piece made out of either cast iron or cast steel but the pole shoe is laminated and is fastened to the pole face by means of counter sunk screws.

(*b*) In modern design, the complete pole cores and pole shoes are built of thin laminations of annealed steel which are rivetted together under hydraulic pressure. The thickness of laminations varies from 1 mm to 0.25 mm.



3)Pole Coils

The field coils or pole coils, which consist of copper wire or strip, are former-wound for the correct dimension. Then, the former is removed and wound coil is put into place over the core as shown in Fig. below. When current is passed

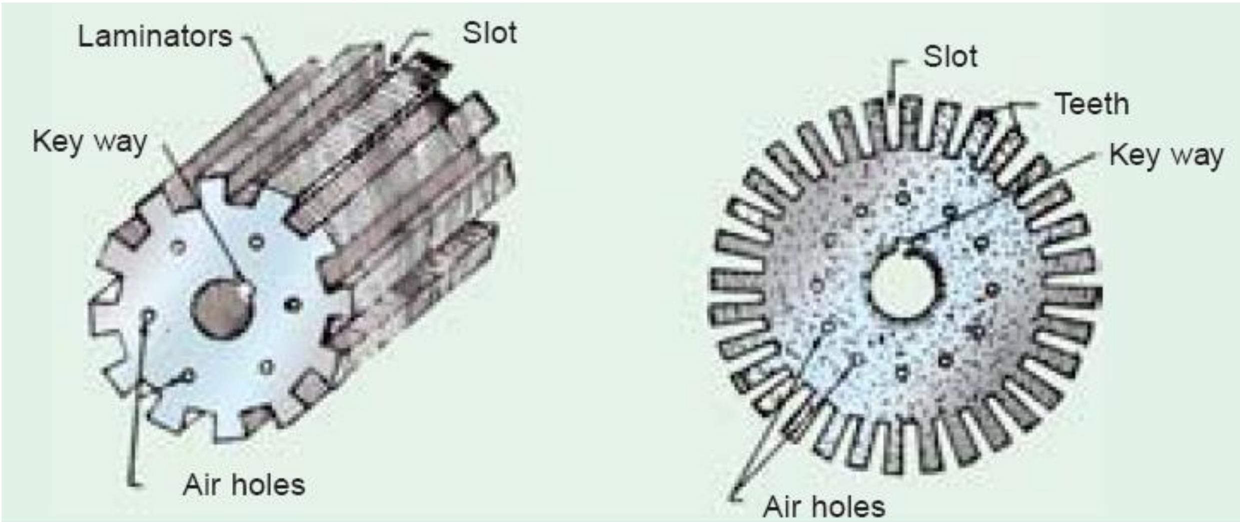


through these coils, they electromagnetise the poles which produce the necessary flux that is cut by revolving armature conductors.

4)Armature Core

It houses the armature conductors or coils and causes them to rotate and hence cut the magnetic flux of the field magnets. It is cylindrical-shaped and is built up of usually circular sheet steel discs or laminations approximately 0.5 mm thick. It is keyed to the shaft. The slots are punched on the outer periphery of the disc and the keyway is located on the inner diameter as shown.

Usually, these laminations are perforated for air ducts which permits axial flow of air through the armature for cooling purposes. Such ventilating channels are clearly visible in the laminations shown in Fig. below.

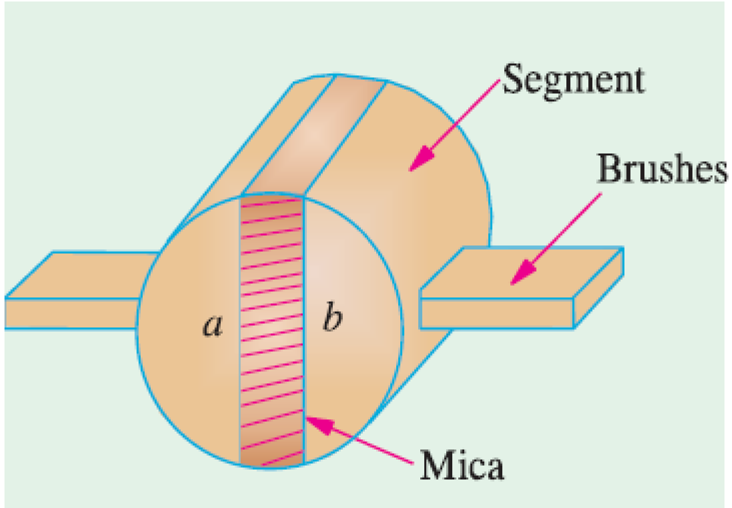


5)Armature Windings

The armature windings are usually former-wound. These are first wound in the form of flat rectangular coils and are then pulled into their proper shape in a coil puller. Various conductors of the coils are insulated from each other. The conductors are placed in the armature slots which are lined with tough insulating material. This slot insulation is folded over above the armature conductors placed in the slot and is secured in place by special hard fiber wedges.

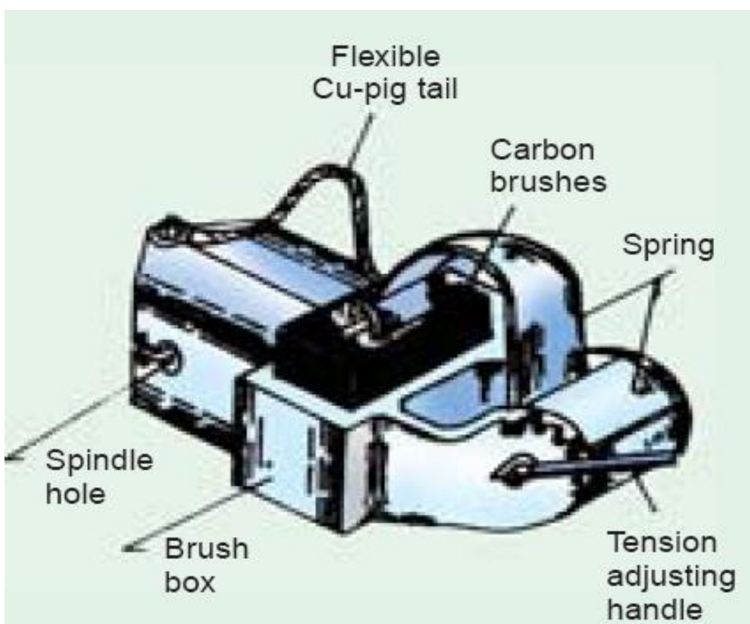
6)Commutator

The function of the commutator is to facilitate collection of current from the armature conductors. As shown in fig.below, it rectified i.e. converts the alternating current induced in the armature conductors into unidirectional current in the external load circuit. It is of cylindrical structure and is built up of wedge-shaped segments of high-conductivity hard-drawn. These segments are insulated from each other by thin layers of mica. The number of segments is equal to the number of armature coils. Each commutator segment is connected to the armature conductor by means of a copper strip. To prevent them from flying out under the action of centrifugal forces.



7)Brushes and Bearings

The brushes whose function is to collect current from commutator, are usually made of carbon or graphite and are in the shape of a rectangular block. These brushes are housed in brush-holders usually of the box-type. As shown in Fig. below, the brush-holder is mounted on a spindle and the brushes can slide in the rectangular box open at both ends. The brushes are made to bear down on the commutator by a spring whose tension can be adjusted by changing the position of lever in the notches. A flexible copper pigtail mounted at the top of the brush conveys current from the brushes to the holder.



Because of their reliability, ball-bearings are frequently employed, roller bearings are preferable. They are generally packed in hard oil for quieter operation and for reduced bearing wear.

Shunt, Series and Compound DC Machines

When the field winding of a d.c. machine is connected in parallel with the armature, as shown in Fig. 5.4(a), the machine is said to be **shunt** wound. If the field winding is connected in series with the armature, as shown in Fig. 5.4(b), then the machine is said to be **series** wound. A compound wound machine has a combination of **series** and **shunt** windings.

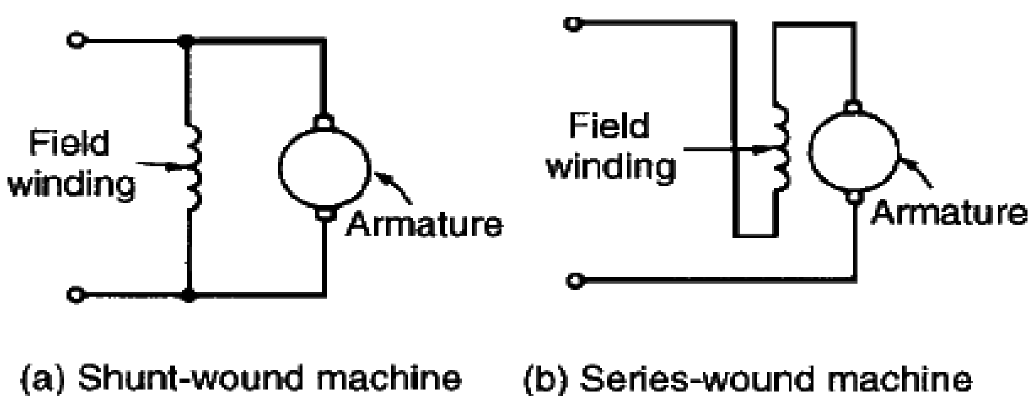


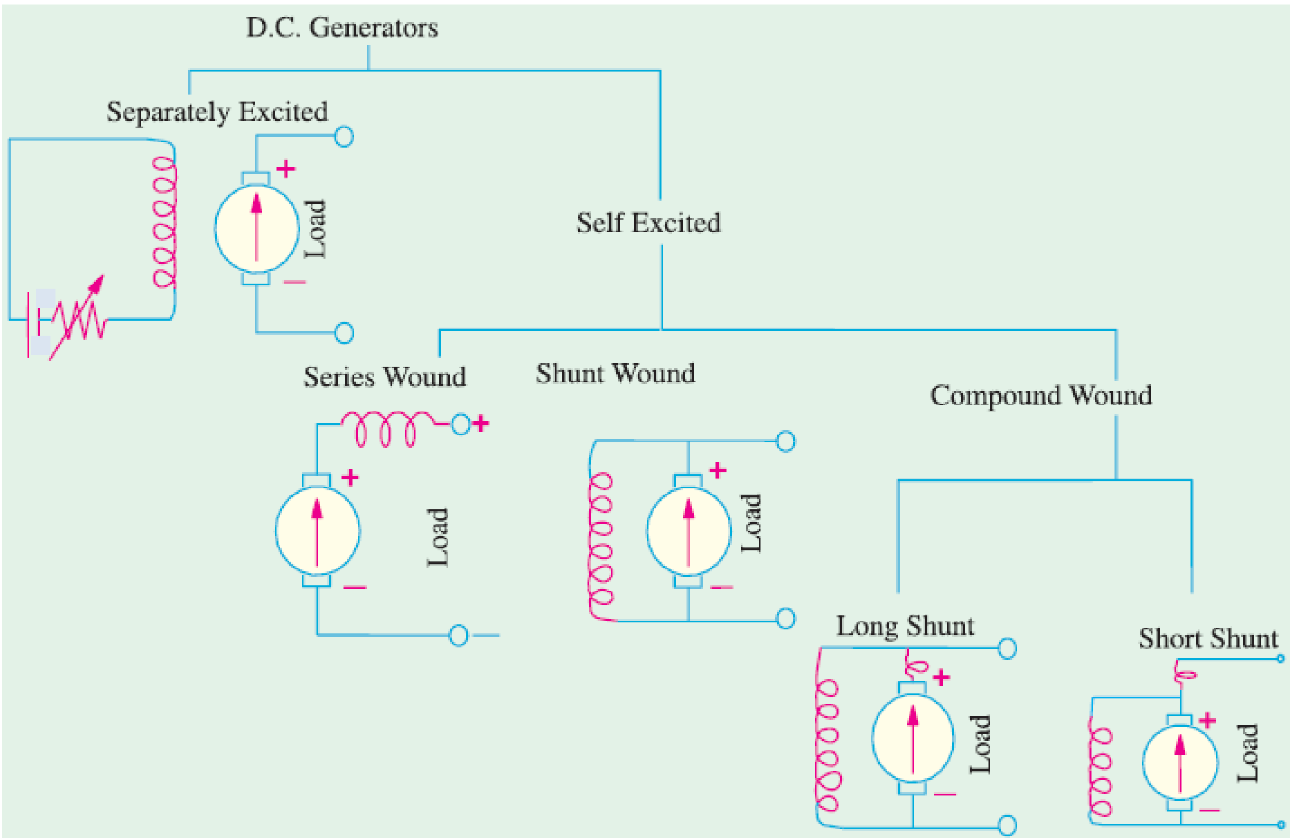
Fig.5.4.

D.C. generators

D.C. generators are classified according to the method of their field excitation. These groupings are:

(i) **Separately-excited generators**, where the field winding is connected to a source of supply other than the armature of its own machine.

(ii) **Self-excited generators**, where the field winding receives its supply from the armature of its own machine, and which are sub-divided into (a) shunt, (b) series, and (c) compound wound generators.



connected across the armature terminals, a load current I_a will flow. The terminal voltage V will fall from its open-circuit e.m.f. E due to a volt drop caused by current flowing through the armature resistance, shown as R_a.

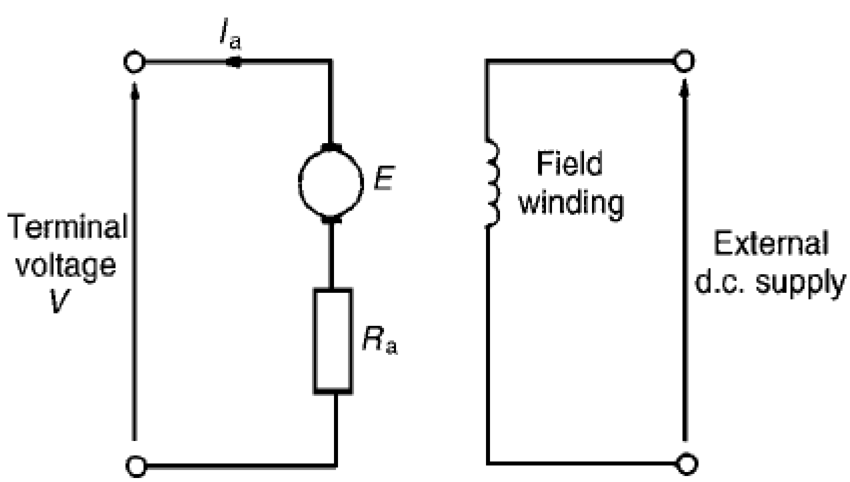


Fig.5.5.

i.e. terminal voltage, $V = E - I_a R_a$

or generated e.m.f., $E = V + I_a R_a$

(a) Shunt wound generator

In a shunt wound generator the field winding is connected in parallel with the armature as shown in Fig. 5.6. The field winding has a relatively high resistance and therefore the current carried is only a fraction of the armature current.

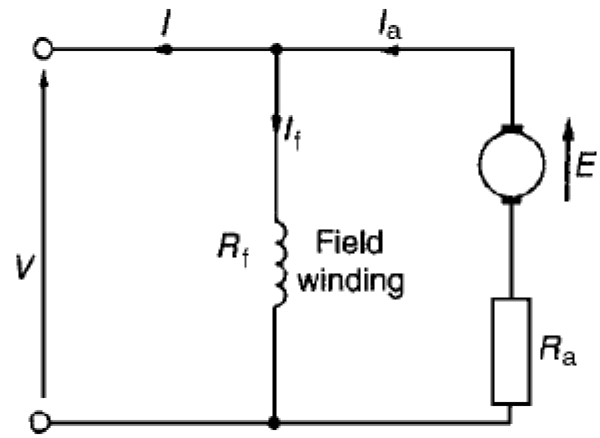


Fig.5.6.

terminal voltage, $V = E - I_a R_a$

or generated e.m.f., $E = V + I_a R_a$

$I_a = I_f + I$ from Kirchhoff's current law, where I_a = armature current, I_f =field current $(=V/R_f)$ and I =load current.

(b) Series-wound generator

In the series-wound generator the field winding is connected in series with the armature as shown in Fig.5.7.

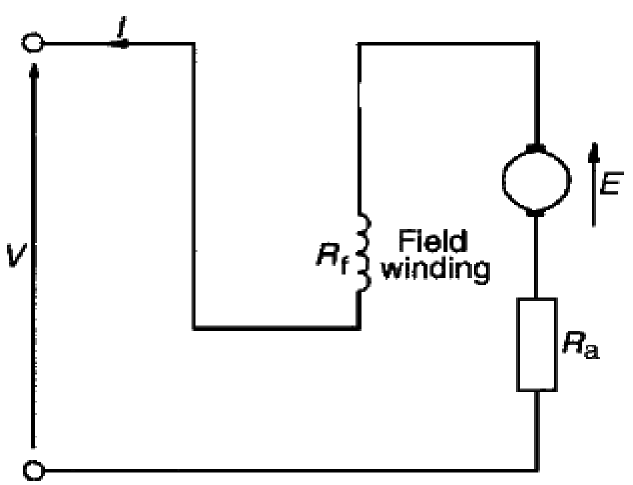


Fig.5.7.

(c) Compound-wound generator

In the compound-wound generator two methods of connection are used, both having a mixture of shunt and series windings, designed to combine the advantages of each. Fig.5.8(a) shows what is termed a **long-shunt** compound generator, and Fig.5.8(b) shows a **short-shunt** compound generator.

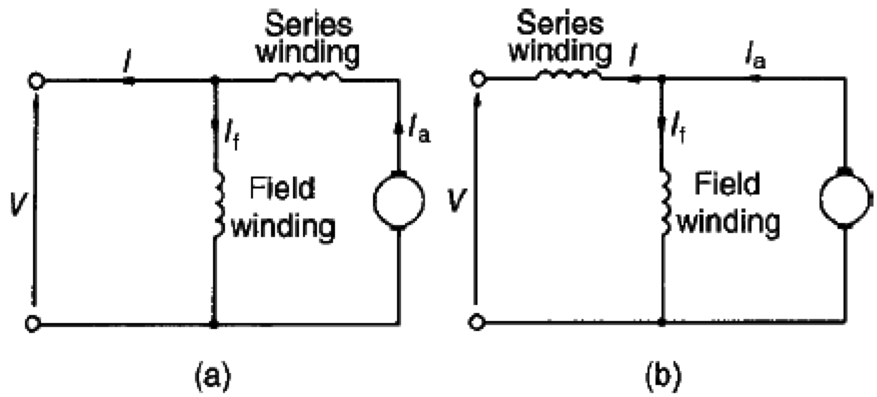
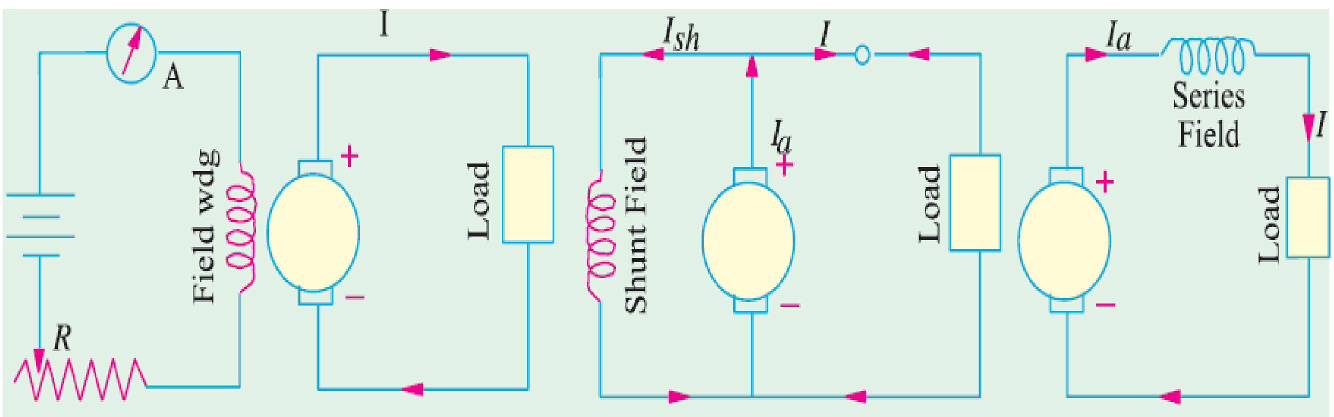
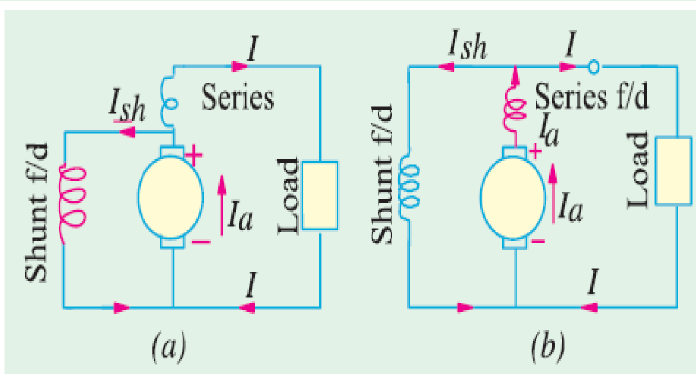


Fig.5.8.





D.C. motors

The only difference between d.c. motor and d.c. generator is that in a generator the generated e.m.f. is greater than the terminal voltage, whereas in a motor the generated e.m.f. is less than the terminal voltage.

Back e.m.f.

When a d.c. motor rotates, an e.m.f. is induced in the armature conductors. By Lenz's law this induced e.m.f. E opposes the supply voltage V and is called a **back e.m.f.**, and the supply voltage, V is given by:

$$V = E + I_a R_a \quad \text{or} \quad E = V - I_a R_a$$

Types of D.C. motor

1-Self Excited DC Motor

In case of self excited dc motor, the field winding is connected either in series or in parallel or partly in series, partly in parallel to the armature winding, and on this basis its further classified as:-

a-**Shunt wound DC motor**.

b-**Series wound DC motor**.

c-**Compound wound DC motor**.

(a) Shunt wound motor

In the shunt wound motor the field winding is in parallel with the armature across the supply as shown in Fig. 5.9.

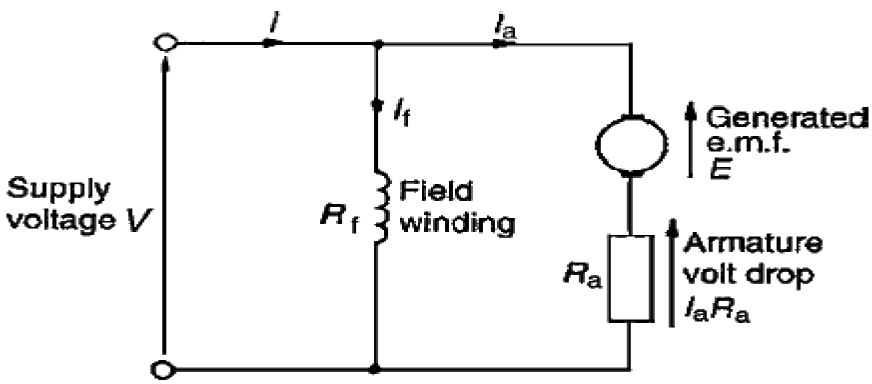


Fig.5.9.

$$\text{Supply voltage, } V = E + I_a R_a$$

$$\text{or generated e.m.f., } E = V - I_a R_a$$

$$\text{Supply current, } I = I_a + I_f$$

from Kirchhoff's current law

(b) Series-wound motor

In the series-wound motor the field winding is in series with the armature across the supply as shown in Fig.5.10.

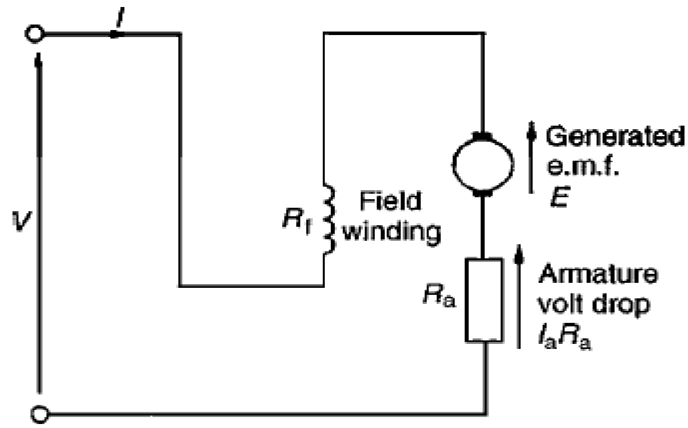


Fig.5.10.

$$\text{Supply voltage } V = E + I(R_a + R_f)$$

$$\text{or generated e.m.f. } E = V - I(R_a + R_f)$$

(c) Compound wound motor

The compound wound self excited dc motor or simply **compound wound dc motor** essentially contains the field winding connected in series and in parallel to the armature winding.

Figure 5.11(a) shows a **long-shunt** compound motor and Fig.5.11(b) a **short-shunt** compound motor.

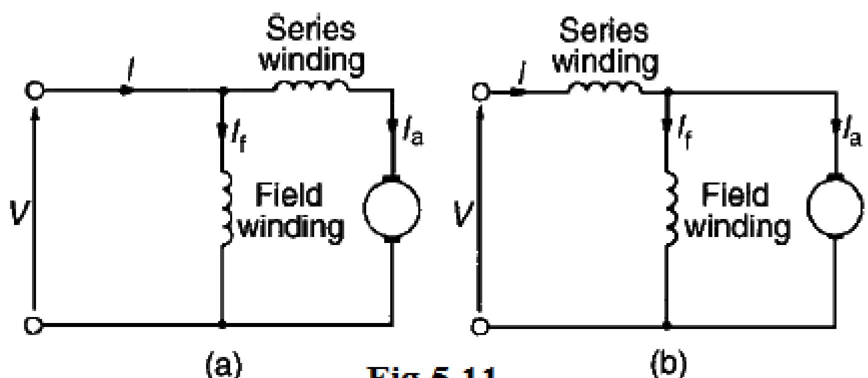


Fig.5.11.

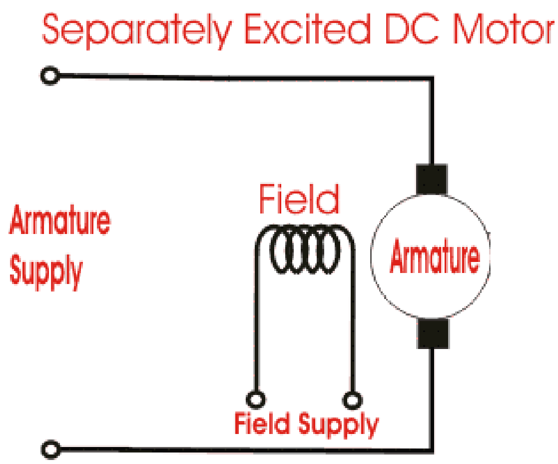
Short Shunt DC Motor

If the shunt field winding is only parallel to the armature winding and not the series field winding then its known as short shunt dc motor or more specifically short shunt type compound wound dc motor.

Long Shunt DC Motor

If the shunt field winding is parallel to both the armature winding and the series field winding then it's known as long shunt type compound wound dc motor or simply long shunt dc motor.

2- Separately excited DC motor



As the name suggests, in case of a separately excited DC motor the supply is given separately to the field and armature windings. The main distinguishing fact in these types of dc motor is that, the armature current does not flow through the field windings, as the field winding is energized from a separate external source of dc current as shown in the figure above.