UNIT-5

ELECTRICAL MACHINES

DC GENERATOR

D.C generator is a machine which converts the mechanical power into electrical power. It works on the principle of Faraday's Law of Electromagnetic induction. According to this law the conductor (Armature) are rotated in the magnetic field system and e.m.f. is induced in these conductors which is controlled from the commutator fitted on the shaft of armature. The D.C generator can work as D.C. motor if the electrical power is fed to this machine. Then this machine will give mechanical power.

D.C. GENERATOR WORKING PRINCIPLE

An electrical generator is a machine which converts mechanical energy into electrical energy. The energy conversion is based on the principle of the production of dynamically induced e.m.f., where a conductor cuts magnetic flux;dynamically induced e.m.f. is produced in it according to Faraday's Laws of electromagnetic Induction. This e.m.f. causes a current to flow if the conductor circuit is closed. Hence, two basic essential parts of an electrical generator are (*i*) a magnetic field and (*ii*) a conductor or conductors which can so move as to cut the flux. Thefollowing figure shows a single-turn rectangular copper coil rotating about its own axis in a magnetic field provided by either permanent magnets or electromagnets. The two ends of the coil are joined to two slip-rings '*a*' and '*b*' which are insulated from each other and from the central shaft. Two collecting brushes (of carbon or copper) press against the slip-rings. Their function is to collect the current induced in the coil and to convey it to the external load resistance *R*. The rotatingcoil may be called 'armature' and the magnets as 'field magnets'.

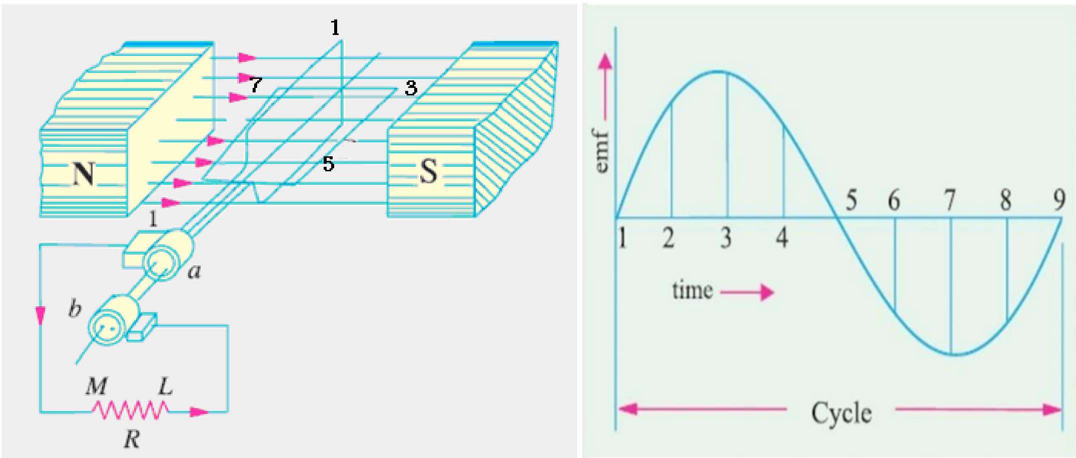

Fig.5.1: Working Principle of D.C Generator

As the coil rotates in clock-wise direction and assumes successive positions in the field the, flux linked with it changes. Hence, an e.m.f. is induced in it which is proportional to the rate of change of flux linkages (e =

Ndø/dt).

When the plane of the coil is at right angles to lines of flux i.e. when it is in position1, then flux linked with the coil is maximum, but rate of change of flux linkages is minimum. Hence, there is no induced e.m.f. in the coil.

As the coil continues rotating further, the rate of change of flux linkages (and hence induced e.m.f. in it) increases, till position 3 is reached where **i**= 90º, the coil plane is horizontal i.e. parallel to the lines of flux. The flux linked with the coil is minimum but rate of change of flux linkages is maximum. Hence, maximum e.m.f. is induced in the coil at this position.

From 90º to 180º, the flux linked with the coil gradually increases but the rate of change of flux linkages decreases. Hence, the induced e.m.f. decreases gradually till in position 5 of the coil, it is reduced to zero value.

From 180º to 360º, the variations in the magnitude of e.m.f. are similar to those in the first half revolution. Its value is maximum when coil is in position 7 and minimum when in position 1. But it will be found that the direction of the induced current is the reverse ofthe previous direction of flow.

For making the flow of current unidirectional in the external circuit, the slip-rings are replaced by split-rings. The split-rings are made out of a conducting cylinder which is cut into two halves or segments insulated from each other by a thin sheet of mica or some other insulating material. As before, the coil ends are joined to these segments on whichrest the carbon or copper brushes. It is seen that in the first half revolution current flows along (ABMLCD) i.e. the brush No.1 in contact with segment ‘a’ acts as the positive end ofthe supply and ‘b’ as the negative end. In the next half revolution, the direction of the induced current in the coil has reversed. But at the same time, the positions of segments ‘a’ and ‘b’ have also reversed with the result that brush No.1comes in touch with the segment which is positive i.e. segment ‘b’ in this case. Hence, current in the load resistance again flows from M to L. The waveform of the current through the external circuit is as shown in below. This current is unidirectional but not continuous like pure direct current.

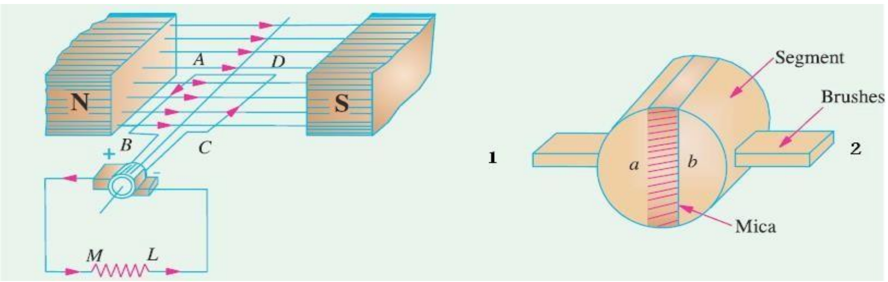

Fig.5.2: Split rings

The position of brushes is so arranged that the changeover of segments ‘a’ and ‘b’ from one brush to the other takes place when the plane of the rotating coil is at right angles to the plane of the lines of flux. It is so because in that position, the induced e.m.f. in the coil is zero.

The current induced in the coil sides is alternating as before. It is only due to the rectifying action of the split-rings (also called commutator) that it becomes unidirectional in the external circuit.

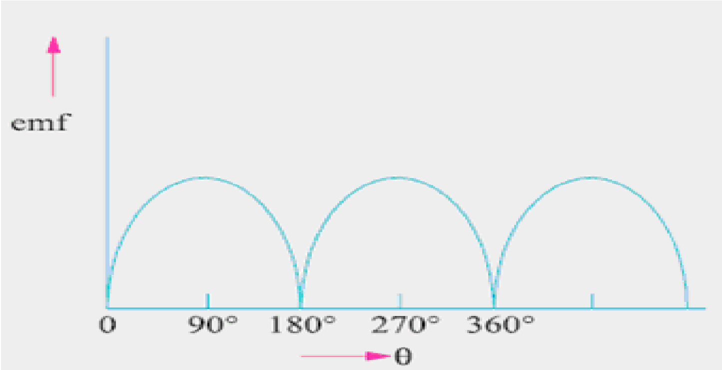

Fig.5.3: E.M.F Vs. Θ

PARTS OF GENERATOR:

The actual generator which consists 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

8.Bearings.

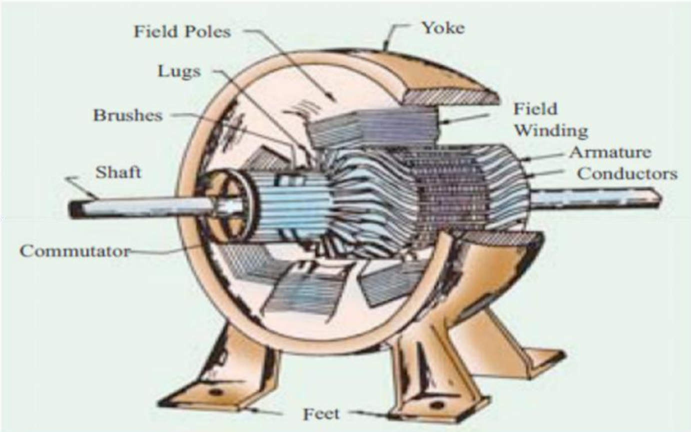

Fig.5.4: Parts of Generator

1. Magnetic frame or 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. In small generators where cheapness rather than weight is the main consideration, yokes are made of cast iron. But for large machines usually cast steel or rolled steel is employed.

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) Theysupport the exciting coils (or field coils) as shown below.

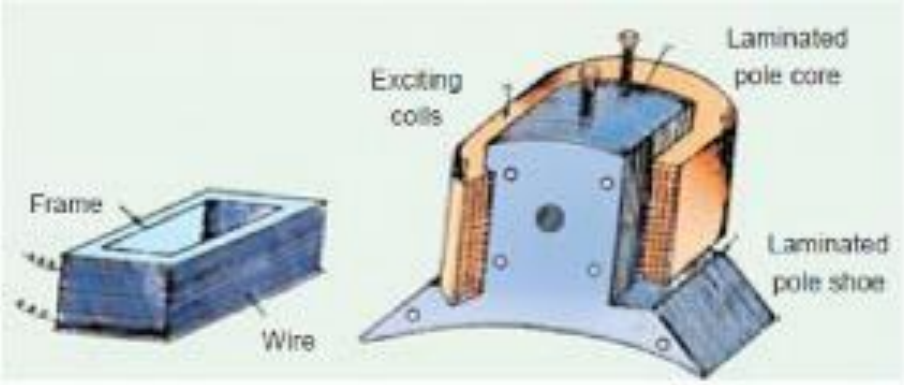

Fig.5.5: Pole Shoes

3. Pole Coils or field 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. When current is passed through these coils, they electro magnetise 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. In addition to this, its most important function is to provide a path of very low reluctance to the flux through the armature from a N-pole to a S-pole. It is cylindrical or drum-shaped and is built up of usually circular sheet steel discs or laminations approximately 0.5 mm thick. The slots are either die-cut or punched on the outer periphery of the disc and the keyway is located on the inner diameter as shown. In small machines, the armature stampings are keyed directly to the shaft. Usually, these laminations are perforated for air ducts which permit axial flow of air through the armature for cooling purposes.

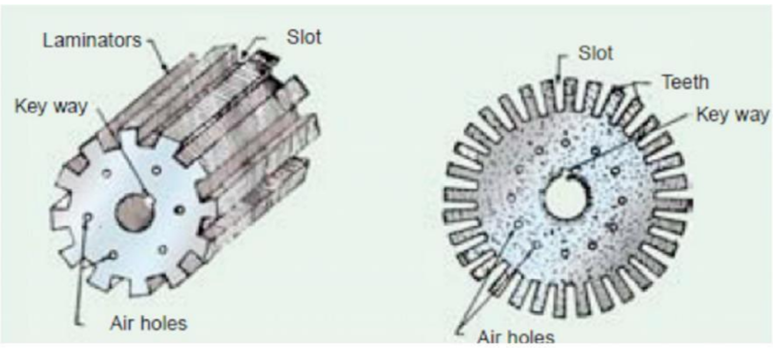

Fig.5.6: Armature Core

The purpose of using laminations is to reduce the loss due to eddy currents. Thinner the laminations, greater is the resistance offered to the induced e.m.f., smaller the current andhence lesser the I^2 R loss in the core.

5.* Armature Windings or conductors*:

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 placedin the slot and is secured in place by special hard wooden or fiber wedges.

6. Commutator:

The functions of the commutator are to facilitate collection of current from the armature conductors, and to convert 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 or drop forged copper. 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 lug or riser. To prevent them from flying out under the action of centrifugal forces, the segments have V-grooves, these grooves being insulated by conical micanite rings.

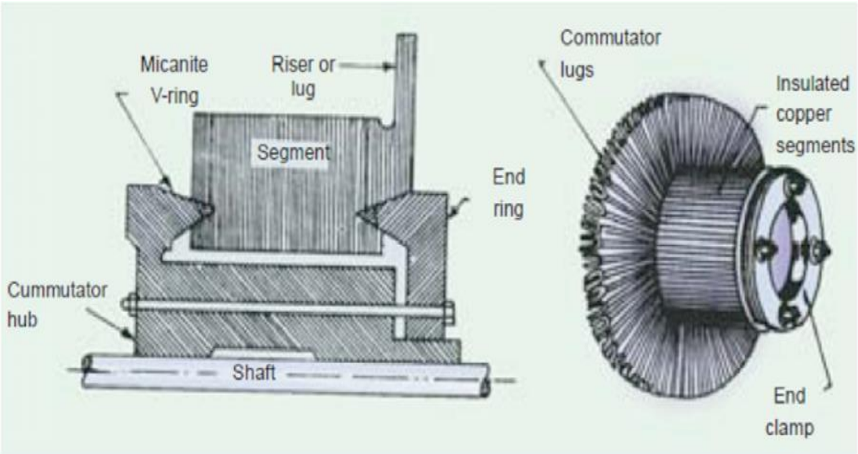

Fig.5.7: Commutator

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, 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. A flexible copper pigtail mounted at the top of the brush conveys current from the brushes to the holder. The number of brushes per spindle depends on the magnitude of the current to be collected from the commutator.

Because of their reliability, ball-bearings are frequently employed, though for heavy duties, roller bearings are preferable. The ball and rollers are generally packed in hard oil for quieter operation and for reduced bearing wear, sleeve bearings are used which are lubricated by ring oilers fed from oil reservoir in the bearing bracket.

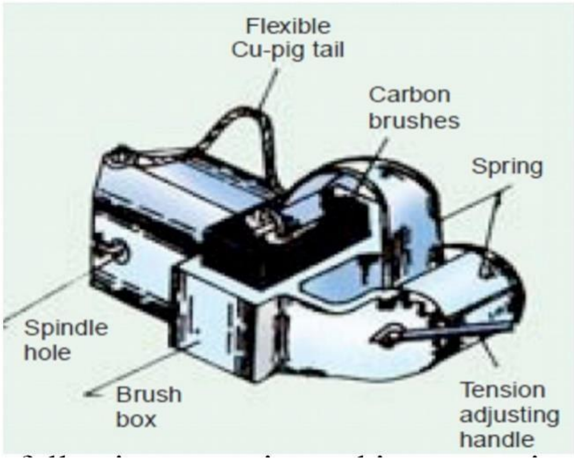

Fig.5.8: Brushes

TYPES OF A DC GENERATOR

DC generators can be classified in two main categories, viz;

(i) Separately excited and

(ii) Self-excited.

(i) **Separately excited**: In this type, field coils are energized from an independent external DC source.

(ii) **Self excited**: In this type, field coils are energized from the current produced by the generator itself. Initial e.m.f. generation is due to residual magnetism in field poles. The generated e.m.f. causes a part of current to flow in the field coils, thus strengthening the field flux and thereby increasing e.m.f. generation. Self excited dc generators can further be divided into three types -

(a) Series wound - field winding in series with armature winding

(b) Shunt wound - field winding in parallel with armature winding

(c) Compound wound - combination of series and shunt winding

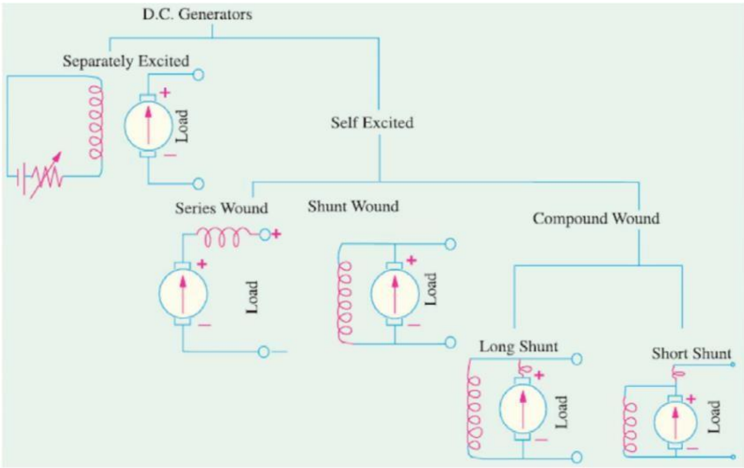

Fig.5.9: Separately excited & Self-excited D.C generators

D.C MOTORS

There is no difference between the construction of D.C motor and D.C. Generator. Motor is that machine which converts electrical energy to mechanical energy. The motor works on the principle that whenever a current carrying conductor is placed in a magnetic field, conductor tends to move.

D.C. MOTOR PRINCIPLE OF WORKING

An electromechanical energy conversion device will take electrical energy at the input and produces a mechanical energy at the output side. There are three electrical machines that are extensively used for this task: a DC motor, an induction or asynchronous motor and a synchronous motor.

Induction motor and synchronous motors are AC motors. In all the motors, the electrical energy is converted into mechanical when the magnetic flux linking a coil is changed.

An electric motor takes electrical energy as input and converts into mechanical energy.

When the electrical energy is applied to a conductor which is placed perpendicular to the direction of the magnetic field, the result of the interaction between the electric current flowing through the conductor and the magnetic field is a force. This force pushes the conductor in the direction perpendicular to both current and the magnetic field, hence, the force is mechanical in nature.

The value of the force can be calculated if the density of the magnetic field B, length of the conductor L and the current flowing in the conductor I are known.

The force exerted on the conductor is given by $F = B \times I \times L$ Newton's

The direction of the motion of the conductor can be determined with the help of Fleming's Left Hand Rule. Fleming's Left Hand Rule is applicable to all electric motors. The figure representing Fleming's Left Hand Rule is shown below.

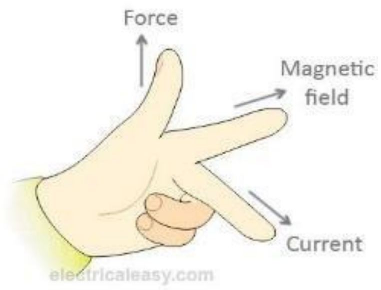

Fig.5.10: Fleming's Left Hand Rule

When a conductor which is carrying current is placed in a magnetic field, a force acts on theconductor that is perpendicular to both the directions of magnetic field and the current.

According to Fleming's Left Hand Rule, the left hand thumb represents the direction of the force, the index finger represents the direction of the magnetic field and the middle finger represents the direction of the current.

A DC motor consists of two sets of coils called armature winding and field winding. Field winding is used to produce the magnetic field. A set of permanent magnets can also be used for this purpose. If field windings are used, it is an electromagnet. The field winding is the fixed part of the motor or a stator. The armature winding is rotor part of the motor. The rotor is placed inside of stator. The rotor or the armature is connected to the external circuit through a mechanical commutator.

Generally, Ferro magnetic materials are used to make both stator and rotor which are separated by air gap. The coil windings inside the stator are made of series or parallel connections of number of coils. The Copper windings are generally employed for botharmature and field windings.
The principle of operation of a DC motor is explained below.

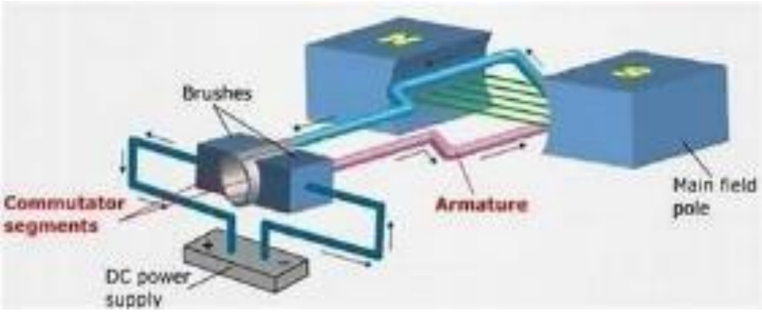

Fig.5.11: Torque production in a DC motor

In an actual DC motor, several such coils are wound on the rotor, all of which experience force, resulting in rotation. The greater the current in the wire, or the greater the magnetic field, the faster the wire moves because of the greater force created.

At the same time this torque is being produced, the conductors are moving in a magnetic field as shown indifferent positions, the flux linked with it changes, which causes an e.m.f. to be induced. This voltage is in opposition to the voltage that causes current flow through the conductor and is referred to as a counter-voltage or back e.m.f.

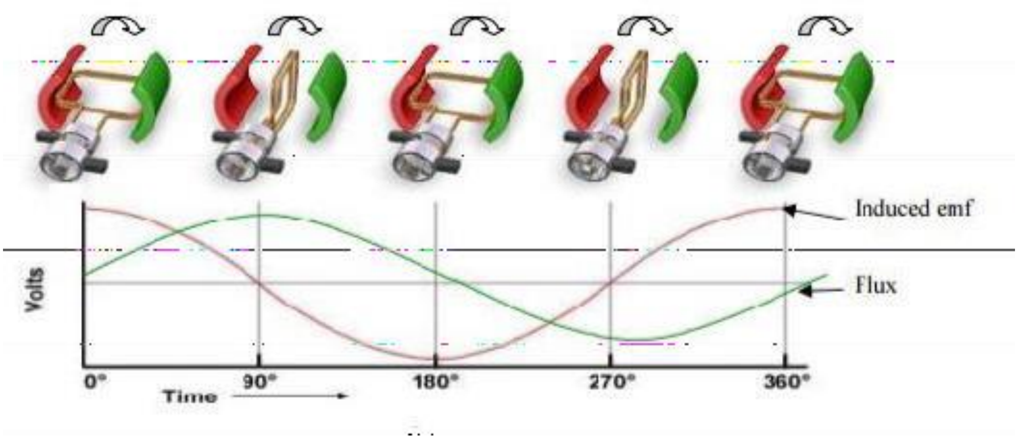

Fig.5.12: Induced voltage in the armature winding of DC motor

The value of current flowing through the armature is dependent upon the difference between the applied voltage and this counter-voltage. The current due to this counter-voltage tends to oppose the very cause for its production according to Lenz's law. It results in the rotor slowing down. Eventually, the rotor slows just enough so that the force created by the magnetic field (F= Bil) equals the load force applied on the shaft. Then the system moves at constant velocity.

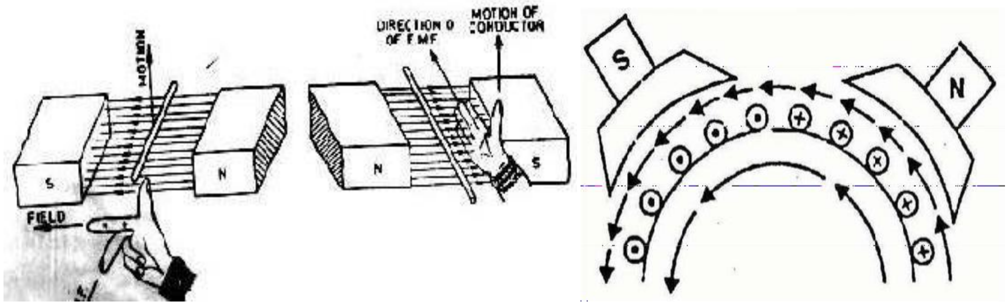

Fig.5.13: Electromagnetic Induction

If a current carrying conductor placed in a magnetic field, it experiences a force due to the magnetic field. On the other hand, if a conductor moved in a magnetic field, an e.m.f. gets induced across the conductor (Faraday's law of electromagnetic induction).

John Ambrose Fleming introduced two rules to determine the direction of motion (in motors) or the direction of induced current (in generators). The rules are called as **Fleming's left hand rule** (for motors) and **Fleming's right hand rule** (forgenerators).

PARTS OF THE D.C. MOTOR

The Parts of the motor are :

1. Bearing,
2. Field pole and housing
3. Armature
4. Brushes and Commutator

1. Bearing

Bearings are used at each end of the motor to mount the rotating assemblyto the fixed housing and to provide minimal friction between the assembly and the housing.

2. Field pole and housing

* The housing for the field pole consists of a drum. Mounted onto the drum's internal surface are magnets that provide one of the two primarymagnetic fields of the motor.
* These magnets are either the permanent type or electromagnets with wire wound around iron cores.
* The drum is made of steel, which magnetic flux lines pass through easily. The steel enables the magnetic fields to be strong.

3. Armature

The armature rotates inside the fixed motor housing.

* The armature consists of a cylindrical core made of sheet-steel laminations that are attached to the shaft.

* The outer surface of the core has slots where armature loops are placed.

* The ends of the armature loops are soldered to the commutator that also mounts on the shaft.

* A fan with blades keeps the motor cool, as the armature spins, by blowing outside air over the parts inside the housing.

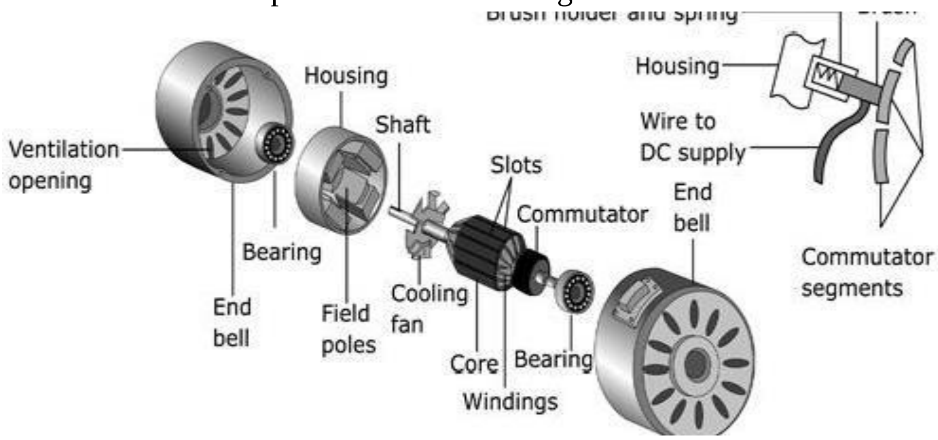

Fig.5.14: Parts of the motor

4. Brushes and Commutator

* To produce a magnetic field, direct current passes through the armature's loops of wire.

* Brushes are fixed conductive metal pieces. Tension springs press the brushes onto the surface of the rotating armature's commutator segments.

* As the brushes ride on the rotating surface of the commutator segments, they provide the electrical connection between the DC power source and the armature's wire loops.

FLEMING'S LEFT HAND RULE

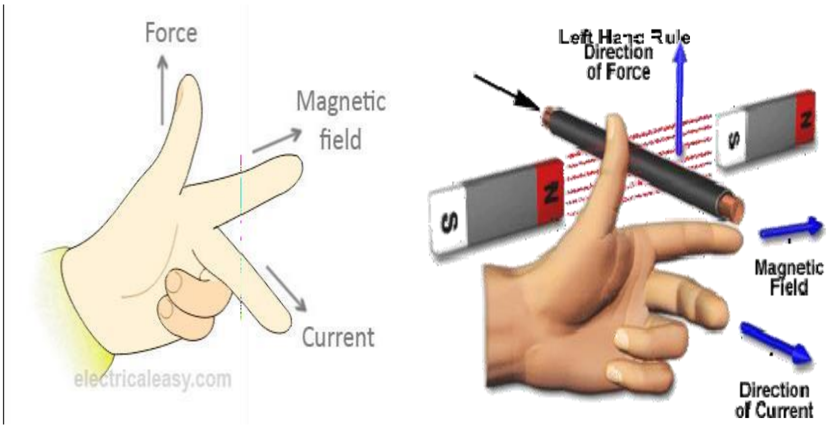

Fig.5.15: Fleming's Left Hand Rule

Whenever a current carrying conductor is placed in a magnetic field, the conductor experiences a force which is perpendicular to both the magnetic field and the direction of current. According to **Fleming's left hand rule**, if the thumb, fore-finger and middle finger of the left hand are stretched to be perpendicular to each other as shown in the illustration at left, and if the fore finger represents the direction of magnetic field, the middle finger represents the direction of current, then the thumb represents the direction of force. Fleming's left hand rule is applicable for motors.

How to remember Fleming's left hand rule?

Method 1: Relate the thumb with thrust, fore finger with field and center-finger with current as explained below.

- The **Th**umb represents the direction of **Th**rust on the conductor (force on the conductor).
- The **F**ore finger represents the direction of the magnetic **F**ield.
- The **C**enter finger (middle finger) the direction of the **C**urrent.

Method 2: Relate the **Fleming's left-hand rule** with **FBI** (. Here, F for Force, B is the symbol of magnetic flux density and I is the symbol of Current. Attribute these letters F,B,I to the thumb, first finger and middle finger respectively.

FLEMING'S RIGHT HAND RULE:

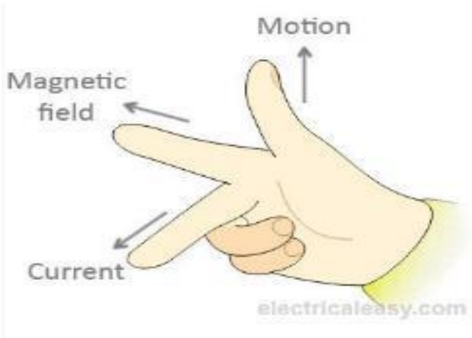

Fig.5.16: Fleming's Right Hand Rule

Fleming's right hand rule is applicable for electrical generators. As per Faraday's law of electromagnetic induction, whenever a conductor is forcefully moved in an electromagnetic field, an e.m.f. gets induced across the conductor. If the conductor is provided a closed path, then the induced e.m.f. causes a current to flow.

According to the **Fleming's right hand rule**, the thumb, fore finger and middle finger of the right hand are stretched to be perpendicular to each other as shown in the illustration at right, and if the thumb represents the direction of the movement of conductor, fore-finger represents direction of the magnetic field, then the middle finger represents direction of the induced current.

ALTERNATOR

It is a machine that converts the input mechanical power into an output alternating electrical energy. It works just like a generator. Hence, it is also called as AC generator.

CONSTRUCTION

It consists of a Yoke, pole core, stator, rotor, armature, slip rings, bearings, and fan. The yoke is the outer portion of it is used as a protecting cote for the machine. It protects against the environmental conditions such that the inner parts do not get damaged. It also gives mechanical support to the machine as well. Pole core is consists of pole shoe that gives support for the windings to rest on the pole shoe. The entire winding and pole shoe are considered as the pole core. The stator is the stationary part on which armature winding is wound. The rotor is the rotating part of the machine on which the field winding is wound. The clear view of the machine is shown in the figure below.

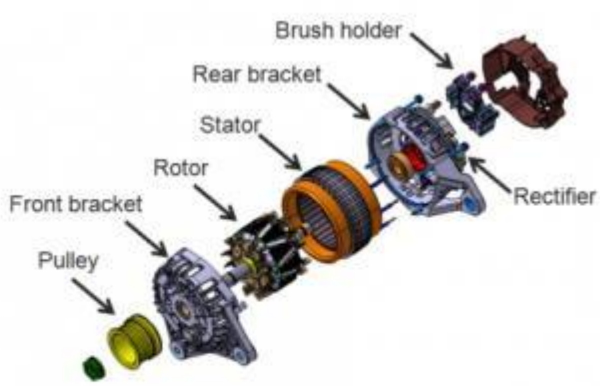

Fig.7.17: Parts of Alternator

PARTS OF THE MACHINE

The armature core consists of armature windings, slip rings, and brushes. The armature develops armature current when the coil cuts the magnetic flux such that an armature flux is also developed. The slips rings are responsible for the smoother operation between the brushes in order to avoid twisting of the winding. The brushes are used for the collection of current from the slip rings. The bearings are employed for the operation to be performed smoother. A fan is employed is to exhaust the heat that is generated during the running conditions.

WORKING

It works on the principle of faradays law of electromagnetic Induction. Any rotating machine when rotated in the magnetic flux works according to this principle.

The working of this machine is similar to that of an AC generator. The working figure of an AC generator is shown in the figure below.

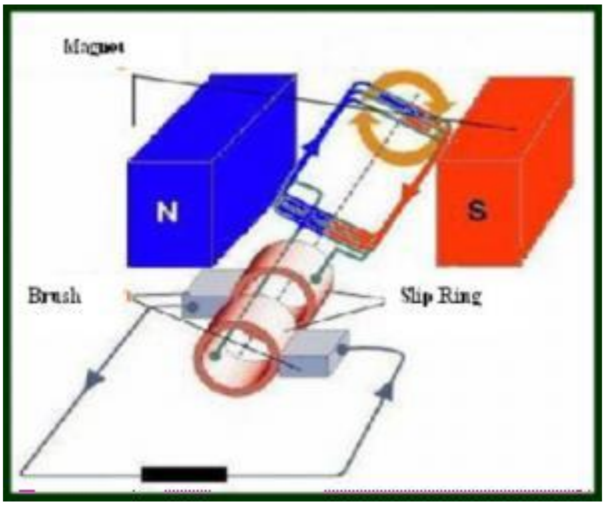

Fig.5.18: Working of A.C Generator

WORKING PRINCIPLE OF THE AC GENERATOR

Armature winding is a collection of coils placed in the magnetic field. The coil when rotated in the magnetic field by a prime mover, it cuts the magnetic lines of forces thus, generating an induced emf. This generated induced emf is according to the principle of faradays law of electromagnetic Induction. The induced emf develops current to flow in the armature winding. The direction of the armature current is found by using the Flemings right-hand rule.

The induced emf will be zero when the coil is in the alignment of magnets and is maximum when the coil is perpendicular. As the coil is rotated the current changes continuously which can be observed in a galvanometer. The current is passed through the slip rings and then to the brushes. The slip rings are used for the smoother operation of the machine and brushes are used to collect the current from the slip rings and deliver to the load.

TROUBLE SHOOTING OF MOTOR

a. **A Motor Fails to Start.** The possible reasons are as follows:
   i The supply is off

   ii The brushes are not making good contact with the commutator iii The connecting cable is broken or the connection are open.

   iii The starter coil is open-circuited.

   iv The armature or field windings are open-circuited

b. **As the Motor is started, the fuse burns out.**
   i The capacity of the fuse is small as compared to the load.

   ii The motor is over loaded

   iii The cable is short -circuited or earthed. iv The starting resistance is short-circuited

c. Heavy Sparking at the commutator

i The brushes are not in the neutral axis
ii The polarities of the interpoles are wrong
iii Armature wires are broken
iv There are small pits on the commutator segments
v The connections of armature windings at the commutator are loose
vi The commutator is dirty
vii The brushes are loose
viii The motor is over loaded
ix The pressure at the brushes is not proper

Short Answer Questions

1. Write the main difference between generator and motor.
2. Write the classification of D.C generator.
3. Write the parts of D.C motor.
4. Write Fleming's Right hand rule.

Long Answer Questions

1. Explain working principle of D.C generator with sketch.
2. Explain the parts of D.C generator with sketch.
3. Explain the working principle of D.C motor.
4. Explain the construction and working of alternator with sketch.