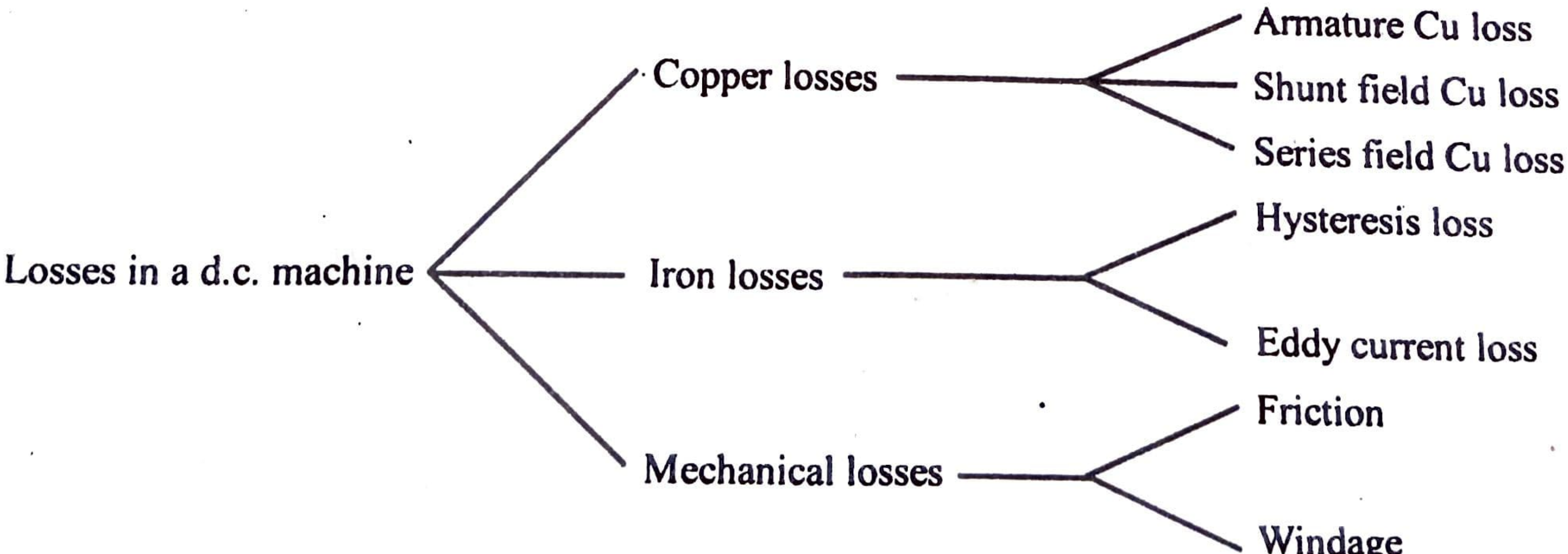
2.27 LOSSES IN A D.C. MACHINE

The losses in a d.c. machine (generator or motor) may be divided into three classes *viz* (*i*) copper losses (*ii*) iron or core losses and (*iii*) mechanical losses. All these losses appear as heat and thus raise the temperature of the machine. They also lower the efficiency of the machine.



1. **Copper losses.** These losses occur due to currents in the various windings of the machine.

(*i*) Armature copper loss $= I_a^2 R_a$

(*ii*) Shunt field copper loss $= I_{sh}^2 R_{sh}$

(*iii*) Series field copper loss $= I_{se}^2 R_{se}$

Copper losses also occur in interpole field winding and compensating field winding and must be accounted for if required. As we shall see, these windings are connected in series with armature of the d.c. machine and, therefore, carry armature current (I_a).

Note. There is also brush contact loss due to brush contact resistance (*i.e.*, resistance between the surface of brush and surface of commutator). This loss is generally included in armature copper loss.

2. Iron or Core losses. These losses occur in the armature of a d.c. machine and are due to the rotation of armature in the magnetic field of the poles. They are of two types *viz.*, (*i*) hysteresis loss (*ii*) eddy current loss.

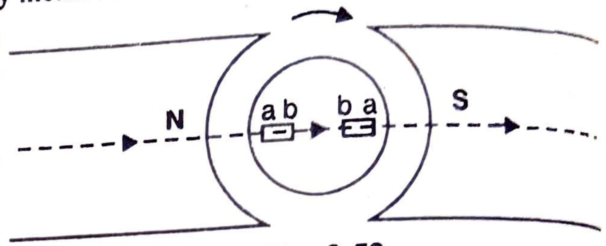


Fig. 2.53

(*i*) **Hysteresis loss.** Hysteresis loss occurs in the armature of the d.c. machine since any given part of the armature is subjected to magnetic field reversals as it passes under successive poles. Fig. 2.53 shows an armature rotating in two-pole machine. Consider a small piece *ab* of the armature. When the piece *ab* is under *N*-pole, the magnetic lines pass from *a* to *b*. Half a revolution later, the same piece of iron is under *S*-pole and magnetic lines pass from *b* to *a* so that magnetism in the iron is reversed. In order to reverse continuously the molecular magnets in the armature core, some amount of power has to be spent which is called hysteresis loss. It is given by **Steinmetz** formula. This formula is

Hysteresis loss, $P_h = \eta B_{max}^{1.6} f V$ watts

where B_{max} = Maximum flux density in armature

f = Frequency of magnetic reversals

$= NP/120$ where N is in r.p.m.

V = Volume of armature in m^3

η = Steinmetz hysteresis co-efficient

In order to reduce this loss in a d.c. machine, armature core is made of such materials which have a low value of steinmetz hysteresis co-efficient *e.g.*, silicon steel.

(*ii*) **Eddy current loss.** In addition to the voltages induced in the armature conductors, there are also voltages induced in the armature core. These voltages produce circulating currents in the armature core as shown in Fig. 2.54. These are called *eddy currents* and power loss due to their flow is called eddy current loss. The eddy current loss appears as heat which raises the temperature of the machine and lowers its efficiency.

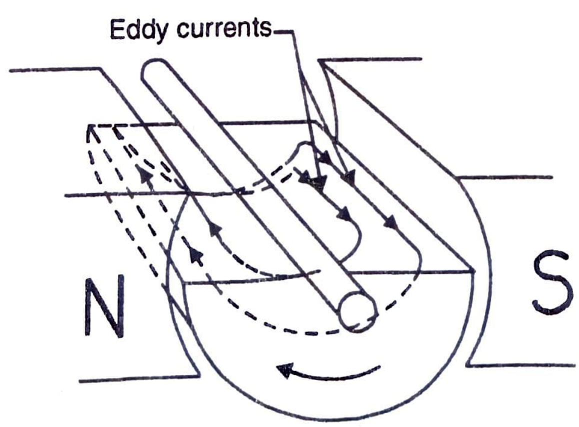


Fig. 2.54

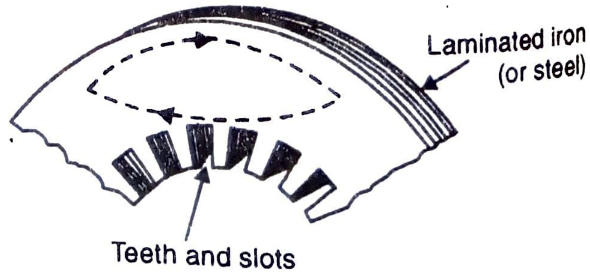


Fig. 2.55

If a continuous solid iron core is used, the resistance to eddy current path will be small due to large cross-sectional area of the core. Consequently, the magnitude of eddy current and hence eddy current loss* will be large. The magnitude of eddy current can be reduced by making core resistance as high as practical. The core resistance can be greatly increased by constructing the core of thin, round iron sheets called *laminations* [See Fig. 2.55]. The laminations are insulated from each other with a coating of varnish. The insulating coating has a high resistance, so very little current flows from one lamination to the other. Also, because each lamination is very thin, the resistance to current flowing through the width of a lamination is also quite large. Thus laminating a core increases the core resistance which decreases the eddy current and hence the eddy current loss.

Eddy current loss, $P_e = K_e B_{max}^2 f^2 t^2 V$ watts

where K_e = Constant depending upon the electrical resistance of core and system of units used

B_{max} = Maximum flux density in Wb/m^2

f = Frequency of magnetic reversals in Hz

t = Thickness of lamination in m

V = Volume of core in m^3

It may be noted that eddy current loss depends upon the square of lamination thickness. For this reason, lamination thickness should be kept as small as possible.

3. **Mechanical losses.** These losses are due to friction and windage.

(*i*) friction loss *e.g.*, bearing friction, brush friction etc.

(*ii*) windage loss *i.e.*, air friction of rotating armature.

These losses depend upon the speed of the machine. But for a given speed, they are practically constant.

Note. Iron losses and mechanical losses together are called **rotational losses.**

2.28 CONSTANT AND VARIABLE LOSSES

The losses in a d.c. generator (or d.c. motor) may be sub-divided into (*i*) constant losses (*ii*) variable losses.

(*i*) **Constant losses.** Those losses in a d.c. generator which remain constant at all loads are known as *constant losses*. The constant losses in a d.c. generator are :

(*a*) iron losses, (*b*) mechanical losses, (*c*) shunt field losses

(*ii*) **Variable losses.** Those losses in a d.c. generator which vary with load are called *variable losses*. The variable losses in a d.c. generator are :

(*a*) Copper loss in armature winding ($I_a^2 R_a$)

(*b*) Copper loss in series field winding ($I_{se}^2 R_{se}$)

Total losses = Constant losses + Variable losses

Note. Field Cu loss is constant for shunt and compound generators.