Behavioral Objectives

By the end of this lecture, the student will be able to:

1. Define the concept and main components of **armature windings** in D.C. machines.
2. Explain the relationship between the **conductor, magnetic flux, and motion** in producing the induced e.m.f.
3. Calculate the **induced e.m.f.** in a conductor moving within a magnetic field.
4. Differentiate between a **full-pitched coil** and a **fractional-pitched coil** in terms of construction and performance.
5. Identify and describe **commutator pitch (YC)** and **coil pitch (YS)** and their effects on winding behavior.
6. Analyze how reducing coil pitch affects **generated voltage and copper consumption efficiency**

General Features OF D.C. Armature Windings

(i) A d.c. machine (generator or motor) generally employs windings distributed in slots over the circumference of the armature core. Each conductor lies at right angles to the magnetic flux and to the direction of its movement Therefore, the induced e.m.f. in the conductor is given by;

$e = B\, l\, v$ volts

where B = magnetic flux density in Web/m2

l = length of the conductor in meters

v = velocity (in m/s) of the conductor

A straight conductor of length l=0.20 mm ,moves at right angles to a uniform magnetic field of flux density B=0.5 mwb / $m^2$with a velocity of v=3.0 m/s Find the induced e.m.f in the conductor?

(ii) The armature conductors are connected to form coils. The basic component of all types of armature windings is the armature coil. Fig. (1.13) (i) shows a single-turn coil. It has two conductors or coil sides connected at the back of the armature. Fig. 1.13 (ii) shows a 4-turn coil which has 8 conductors or coil sides.

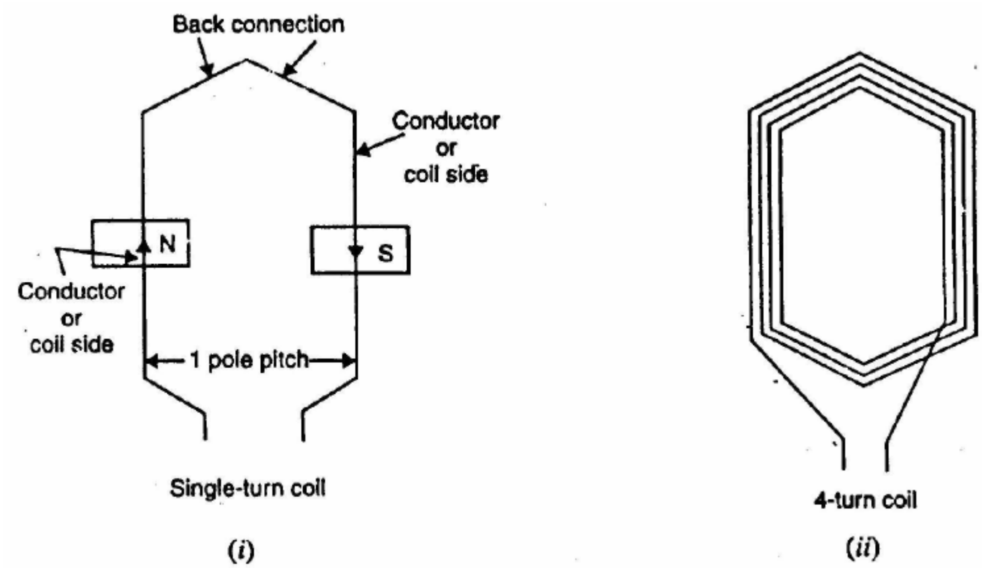

Fig. (1.13)

The coil sides of a coil are placed a pole span apart i.e., one coil side of the coil is under N-pole and the other coil side is under the next S-pole at the corresponding position as shown in Fig. 1.13 (i). Consequently the e.m.f.s of the coil sides add together. If the e.m.f. induced in one conductor is 2.5 volts, then the e.m.f. of a single-turn coil will be = 2 ´ 2.5 = 5 volts. For the same flux and speed, the e.m.f. of a 4-turn coil will be = 8 ´ 2.5 = 20 V.

(iii) Most of d.c. armature windings are double layer windings i.e., there are two coil sides per slot as shown in Fig. (1.14). One coil side of a coil lies at the top of a slot and the other

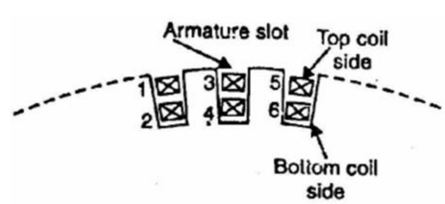

Fig. (1.14)

coil side lies at the bottom of some
other slot. The coil ends will then lie
side by side. In two-layer winding, it is desirable to number the coil sides rather than the slots. The coil sides are numbered as indicated in Fig. (1.14). The coil sides at the top of slots are given odd numbers and those at the bottom are given even numbers. The coil sides are numbered in order round the armature.

As discussed above, each coil has one side at the top of a slot and the other side at the bottom of another slot; the coil sides are nearly a pole pitch apart.
In connecting the coils, it is ensured that top coil side is joined to the bottom coil side and vice-versa. This is illustrated in Fig. (1.15). The coil side 1 at the top of a slot is joined to coil side 10 at the bottom of another slot about a pole pitch apart. The coil side 12 at the bottom of a slot is joined to coil side 3 at the top of another slot. How coils are connected at the back of the armature and at the front (commutator end) will be discussed in later sections. It may be noted that as far as connecting the coils is concerned, the number of turns per coil is immaterial. For simplicity, then, the coils in winding diagrams will be represented as having only one turn (i.e., two conductors).

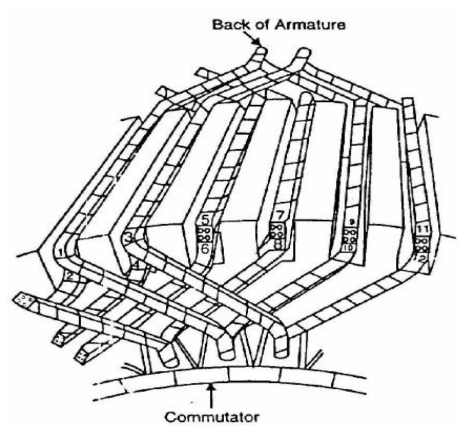

Fig. (1.15)

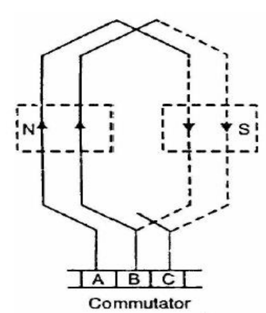

Fig. (1.16)

(iv) The coil sides are connected through commutator segments in such a manner as to form a series-parallel system; a number of conductors are connected in series so as to increase the voltage and two or more such series-connected paths in parallel to share the current. Fig. (1.16) shows how the two coils connected through commutator segments (A, R, C etc) have their e.m.f.s added together. If voltage induced in each conductor is 2- 5 V, then voltage between segments A and C = 4 ´ 2.5 = 10 V. It may be noted here that in the conventional way of representing a developed armature winding, full lines represent top coil sides (i.e., coil sides lying at the top of a slot) and dotted lines represent the bottom coil sides (i.e., coil sides lying at the bottom of a slot).

(v) The d.c. armature winding is a closed circuit winding. In such a winding, if one starts at some point in the winding and traces through the winding, one will come back to the starting point without passing through any external connection. D.C. armature windings must be of the closed type in order to provide for the commutation of the coils.

1.6 Commutator Pitch (YC)

The commutator pitch is the number of commutator segments spanned by each coil of the winding. It is denoted by YC. In Fig. (1.17), one side of the coil is connected to commutator segment 1 and the other side connected to commutator segment 2. Therefore, the number of commutator segments spanned by the coil is 1 i.e., YC = 1. In Fig. (1.18), one side of the coil is connected to commutator segment 1 and the other side to commutator segment 8. Therefore, the number of commutator segments spanned by the coil = 8 - 1 = 7 segments i.e., YC = 7. The commutator pitch of a winding is always a whole number. Since each coil has two ends and as two coil connections are joined at each commutator segment,

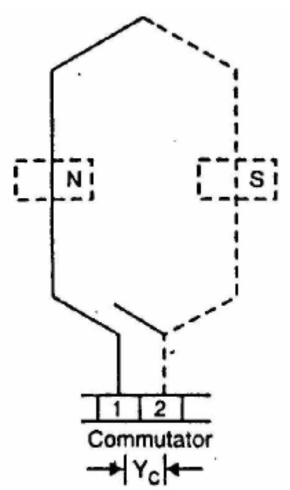

Fig. (1.17)

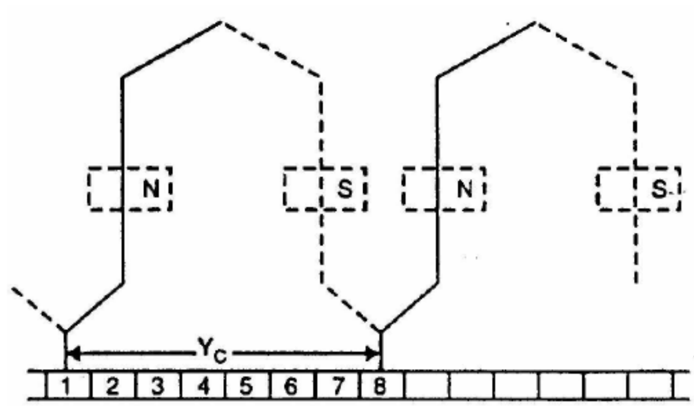

Fig. (1.18)

Number of coils = Number of commutator segments For example, if an armature has 30 conductors, the number of coils will be 30/2 = 15. Therefore, number of commutator segments is also 15. Note that commutator pitch is the most important factor in determining the type of d.c. armature winding.

1.7 Pole-Pitch

It is the distance measured in terms of number of armature slots (or armature conductors) per pole. Thus if a 4-pole generator has 16 coils, then number of slots = 16.

$$\therefore \quad \text{Pole pitch} = \frac{16}{4} = 4 \text{ slots}$$

$$\text{Also} \quad \text{Pole pitch} = \frac{\text{No. of conductors}}{\text{No. of poles}} = \frac{16 \times 2}{4} = 8 \text{ conductors}$$

1.8 Coil Span or Coil Pitch (YS)

It is the distance measured in terms of the number of armature slots (or armature conductors) spanned by a coil. Thus if the coil span is 9 slots, it means one side of the coil is in slot 1 and the other side in slot 10.

1.9 Full-Pitched Coil

If the coil-span or coil pitch is equal to pole pitch, it is called full-pitched coil (See Fig. 1.19). In this case, the e.m.f.s in the coil sides are additive and have a phase difference of 0°. Therefore, e.m.f. induced in the coil is maximum. If e.m.f. = induced in one coil side is 2-5 V, then e.m.f. across the coil terminals = 2 ´ 2.5 = 5 V. Therefore, coil span should always be one pole pitch unless there is a good reason for making it shorter.

Fractional pitched coil. If the coil span or coil pitch is less than the pole pitch, then it is called fractional pitched coil (See Fig. 1.20). In this case, the phase difference between the e.m.f.s in the two coil sides will not be zero so that the e.m.f. of the coil will be less compared to full-pitched coil. Fractional pitch winding requires less copper but if the pitch is too small, an appreciable reduction in the generated e.m.f. results.

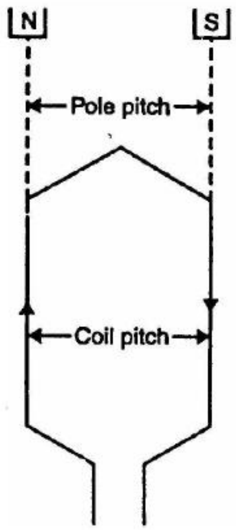

Fig. (1.19)

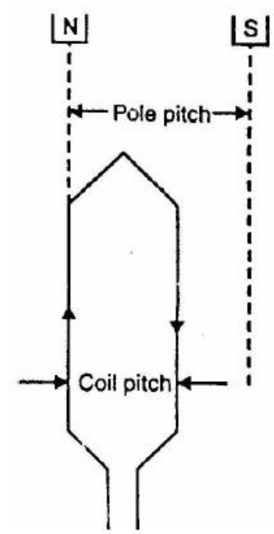

Fig. (1.20)

<u>Conclusion</u>

- The armature of a D.C. machine (generator or motor) consists of **conductors distributed in slots** around the armature core. Each conductor cuts the magnetic flux lines at right angles, producing an induced e.m.f.
- The conductors are connected to form **coils**, and most D.C. armatures use **double-layer windings**, where one coil side lies at the top of a slot and the other at the bottom of another.
- The **commutator pitch (YC)** represents the number of commutator segments spanned by each coil and is crucial in determining the winding type.
- The **pole pitch** and **coil pitch (YS)** are measured in terms of the number of armature slots or conductors per pole.
- A **full-pitched coil** has a span equal to one pole pitch, producing maximum induced e.m.f. since both coil sides are in phase.
- A **fractional-pitched coil** has a span less than one pole pitch, resulting in a slightly reduced e.m.f. but saving copper and improving mechanical compactness.
- Effective design requires balancing **electrical efficiency** with **economic considerations**

Question

1-

A straight conductor of length $l = 0.20\,m$ moves at right angles to a uniform magnetic field of flux density $B = 0.5\,Wb/m^2$ with a velocity $v = 3\,m/s$.
Find the induced e.m.f. in the conductor.

2-

If an armature has 30 conductors, determine the number of coils and commutator segments.

3-

If the induced e.m.f. in each conductor is $2.5\,V$, find the total e.m.f. in a 4-turn coil.

4-

Explain the difference between a **full-pitched coil** and a **fractional-pitched coil** in terms of induced voltage and copper usage