DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

VII Semester

AU3008 Sensors and Actuators

UNIT – 4 - AUTOMOTIVE ACTUATORS

4.2 Electrical Machines – DC Machines

- A DC machine is an electromechanical energy conversion device that comes in two types: the DC generator and the DC motor. **A DC generator converts mechanical power into DC electrical power, while a DC motor converts DC electrical power into mechanical power.** Although AC motors are commonly used in the industry for converting electrical power into mechanical power, DC motors are preferred in applications requiring a wide range of speeds and precise speed regulation, such as electric traction systems.
- The construction of DC motors and generators is nearly identical. However, generators are typically housed in protected environments, allowing for an open construction type. In contrast, motors often operate in environments exposed to dust and moisture, necessitating the use of enclosures such as dirt-proof or fireproof housings, depending on the specific requirements.
- While batteries are a significant source of DC electrical power, they can only supply a limited amount of power to machines, for applications that demand large quantities of DC power, such as electroplating and electrolysis, DC generators are utilized to meet these power needs.

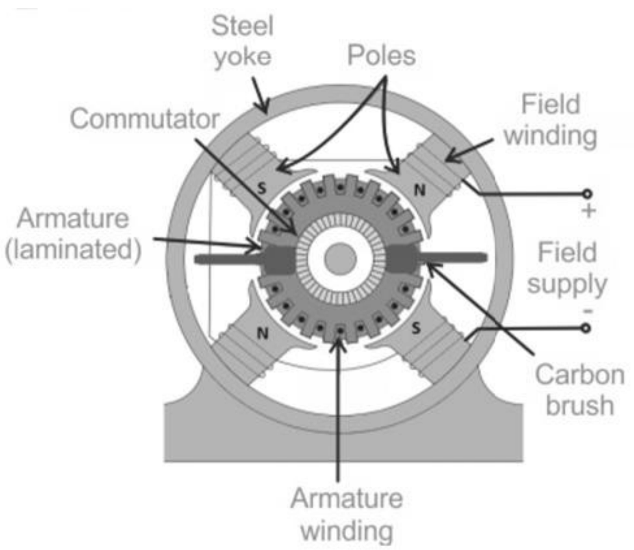
Construction of DC Machines:

- The construction of a DC machine involves key components like the yoke or frame, armature, field system, commutator, and brushes. The yoke acts as the external casing and houses other parts. The armature, made of conducting coils and core, is responsible for generating electromagnetic torque.
- The stationary field system comprising electromagnets produces a magnetic

field. A commutator and brushes are utilized for mechanical rectification of current between the rotating armature and external circuit. Proper construction ensures smooth and efficient energy conversion in a DC machine.

DC Motor:

- ❒ When a DC machine is designed to convert DC electrical energy into rotational mechanical energy, it is referred to as a DC motor. In the case of a DC motor, electrical energy is supplied to the machine through input terminals and mechanical energy is extracted from the shaft in the form of rotational motion.



DC Motor Parts:

DC Machine has the following main parts:

- ❒ Field System or Stator
- ❒ Armature
- ❒ Commutator
- ❒ Brushes

Field Coil or Stator:

As the name suggests, the field coil or stator is the non-moving or the stationary part of the DC motor around which coil is wounded and produce magnetic field

The stator consists of various parts:

- Yoke
- Pole Core
- Pole Body

- Shoe for the pole
- Field Winding
- End Plates

Yoke: The structure of a DC machine works to create the magnetic circuit between the poles.

Pole Core: Pole Core is usually of laminated iron or other magnetic material. Its function is to serve as a passage for the magnetic flux generated by the field winding.

Pole Body: Pole body works with the pole core. When an electric current passes through the field winding, a magnetic flux is established not only in the pole core but also around it. The poles and their bearings are known as the pole body.

Shoe: Shoe is a synonym for one of the brushes inside an electric motor. DC motors have brushes to make contact with the rotating armature, and typically they are sodded.

Field Winding: Field winding is on the pole core next to the stator. Field winding uses insulated copper wire. An insulated copper coil is wound round the pole core. If this coil on the pole core is excited with direct current, we get magnetic flux.

End Plates: End plates encapsulate the entire motor. They provide a casing for all of the internal parts--the armature, commutator and brushes as well sometimes also including field windings

Armature:

Armature is the rotating part of the motor which generates mechanical energy. Armature core has windings. The armature core is made of 0.3 to 0.5 mm thick high magnetic strength (silicon steel lamination) and a thin layer of varnish is applied on each sheet.

Commutator:

Commutators are used in DC appliances such as DC Motors and DC Generators. It periodically reverses the current between the armature and the circuit and produces steady torque

Brushes:

Brushes or often called Carbon Brushes are made up of graphite. In DC Motors, brushes supplies current to the winding of the armature.

DC Motor Characteristics:

If length of conductor = L meter, field intensity = B weber per square meter (Bwb/m2) and current flowing in the conductor = i ampere, then the force experienced by the conductor will be F = iBL Newton.

$$F = B.L.I. \sin \theta$$

where,

***B =** flux density (in Tesla).*

***L =** length of conductor (in meters).*

***I =** current flowing in the conductor.*

***Sin θ =** angle between the conductor and magnetic lines of force.*

- ❒ EMF or the electromotive force is responsible for flow of current in the electrical appliances. EMF is not a force but the electric potential. In case of DC Motor, a back EMF is produced which counters the armature current. The direction of this back EMF is given by Lenz Law. The formula of back emf is given as

$$E_b = P\Phi NZ/60A$$

where,

***P** is Number of Poles*

***Φ** is Flux per pole*

***N** is Speed of motor in (RPM)*

***Z** is Number of conductors*

***A** is Number of parallel paths*

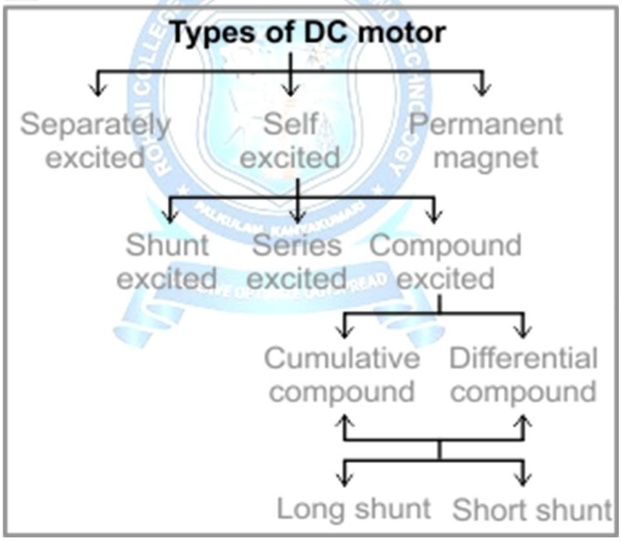
Working Principle:

- ❖ When current flows through the armature winding, it generates a magnetic field around it.
- ❖ This magnetic field interacts with the magnetic field of the stator (created by permanent magnets or field coils).
- ❖ The interaction between these magnetic fields generates a force (according to Fleming's Left-Hand Rule), causing the armature to rotate.

Types of DC Motors:

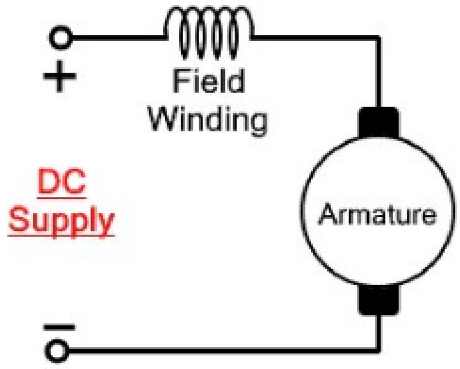
There are different types of DC motors, each with beneficial characteristics that are useful for specific applications.

- Permanent Magnet DC Motor (PMDC Motor)
- Separately-Excited DC Motor
- Self-Excited DC Motor
- Shunt Wound DC Motor
- Series Wound DC Motor
- Compound Wound DC Motor
- Short shunt DC Motor
- Long shunt DC Motor
- Differential Compound DC Motor



Series Wound DC Motor

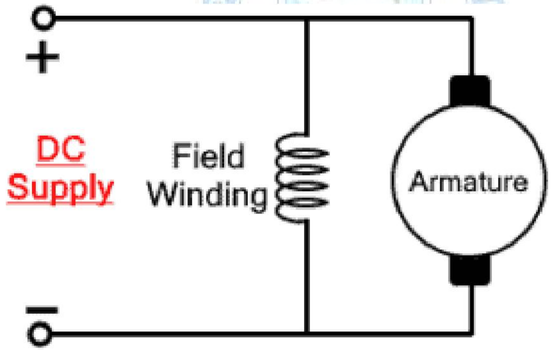
In series-wound DC motors, the field winding and the armature coil are connected in series to the power supply. This means the same current flows through the coil and armature. Since these types of motors can work both with DC and AC, they are also called universal motors. Series motors always rotate in the same direction, and their speed depends on the mechanical load.



Series Wound DC Motor

Shunt Wound DC Motor

In shunt-wound DC motors, the armature winding and field coil are connected in parallel to the power source. The parallel connection means that the current is split between the two components. A DC shunt motor has a constant speed that doesn't change with varying mechanical loads.

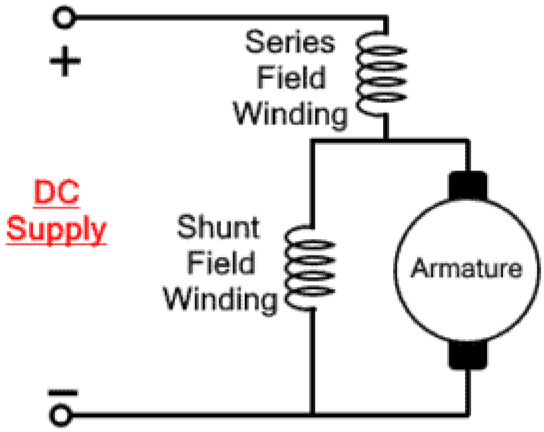


Compound Wound DC Motor

Compound DC motors use both shunt and series field windings. The armature winding is in series, while the field coils can be shunt or series. These motors are further divided into the short shunt and long shunt and cumulative and differential motors.

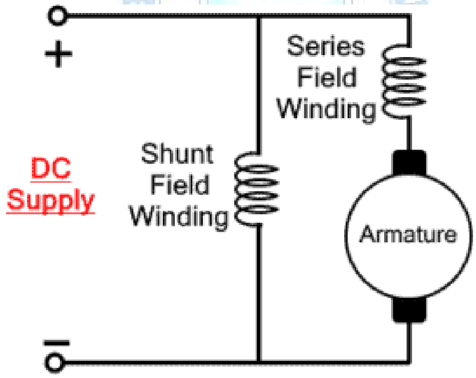
Short Shunt Compound DC Motor

In a short shunt DC motor, the shunt field winding is parallel to the armature winding; however, it is not parallel to the series field winding



Long Shunt Compound DC Motor

In a long shunt dc motor, the shunt field winding is parallel to both the armature and the series field winding.



Cumulative Compound Excited DC Motor

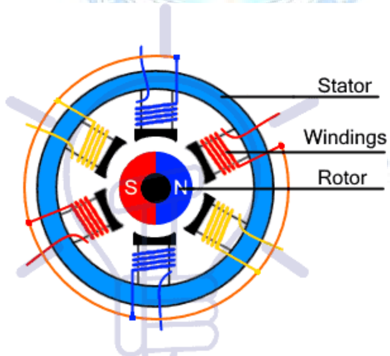
A **Cumulative Compound DC Motor** is a type of DC motor with both series and shunt field windings that work together to provide a combination of high starting torque (from the series winding) and stable speed control (from the shunt winding). This makes cumulative compound DC motors versatile and suited for applications requiring both power and control.

Differentially Compounded DC Motor

A **Differential Compound DC Motor** is a type of DC motor that has both series and shunt field windings, similar to a cumulative compound motor. However, in this case, the magnetic fields created by these two windings oppose each other instead of working together. This configuration affects the motor's characteristics, making it suitable for specific applications that require a particular type of speed and torque behaviour.

Brushless DC Electric Motor (BLDC):

- **Stator**: The stationary part, typically made of several coils (windings) arranged around the rotor, creating a series of electromagnets.
- **Rotor**: The rotating part of the motor, which consists of permanent magnets instead of coils.
- **Electronic Controller**: A crucial part of the BLDC motor that replaces the function of brushes and the commutator. It's responsible for switching current direction in the stator windings.



Brushless DC Motor

- **Magnetic Interaction**: The BLDC motor operates based on the interaction between the magnetic field of the rotor (permanent magnets) and the magnetic field generated by the stator windings.
- **Current Commutation**: The electronic controller alternates the current in the stator windings, creating a rotating magnetic field. This rotating field interacts with the magnetic field of the rotor, causing it to follow and rotate.

Applications of DC Motors

DC motors are widely used in various applications that require precise control, smoothspeed regulation, or high starting torque. Here are some key applications across different types of DC motors:

1. Series DC Motors

- Electric Trains:
- Cranes and Hoists:
- Electric Vehicles (EVs)

2. Shunt DC Motors

- Lathes, Drills, and Milling Machines
- Fans and Blowers:
- Conveyor Belts

3. Compound DC Motors (Combination of Series and Shunt)

- Rolling Mills and Presses
- Elevators and Lifts
- Heavy Machine Tools

4. Permanent Magnet DC (PMDC) Motors

- Automobile Applications
- Home Appliances
- Toys and Robotics

5. Brushless DC (BLDC) Motors

- Drones and RC Vehicles
- Electric and Hybrid Vehicles
- Computer Cooling Fans
- Home Appliances

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