A Review on Design Features and Torque of DC Motor

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Abstract

Direct current (DC) motors are electro-mechanical devices that convert electrical energy into mechanical motion. They are widely used in various applications due to their simplicity, reliability, and controllability. This abstract provides an overview of DC motors, including their basic principles of operation, types, and applications.

Introduction

DC motor is similar to dc generator; in fact the same machine can act as motor or generator. The only difference is that in a generator the EMF is greater than terminal voltage, whereas in motor the generated voltage EMF is less than terminal voltage. Thus the power flow is reversed, that is the motor converts electrical energy into mechanical energy. That is the reverse process of generator. DC motors are highly versatile machines. For example, dc motors are better suited fore many processes that demand a high degree of flexibility in the control of speed and torque. The dc motor can provided high starting torque as well as high decelerating torque for application requiring quick stop or reversals. DC motors are suited in speed control with over wide range is easily to achieve compare with others electromechanical.

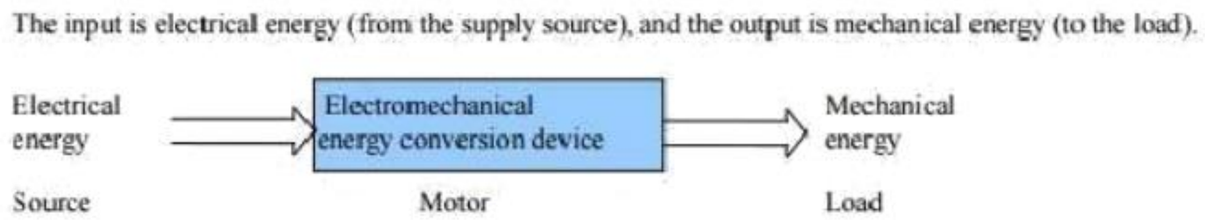


Fig 1.: Electromechnical Energy Conversion

DC Motor Basic Principles

(a) Energy Conversion

If electrical energy is supplied to a conductor lying perpendicular to a magnetic field, the interaction of current flowing in the conductor and the magnetic field will produce mechanical force (and therefore, mechanical energy).

(b) **Value of Mechanical Force**

There are two conditions which are necessary to produce a force on the conductor. The conductor must be carrying current, and must be within a magnetic field. When these two conditions exist, a force will be applied to the conductor, which will attempt to move the conductor in a direction perpendicular to the magnetic field. This is the basic theory by which all DC motors operate.

The force exerted upon the conductor can be expressed as follows.

$$F = B\ I\ L \text{ Newton } \ldots.(1)$$

where B is the density of the magnetic field,
L is the length of conductor,
and I the value of current flowing in the conductor.

The direction of motion can be found using Fleming's Left Hand Rule

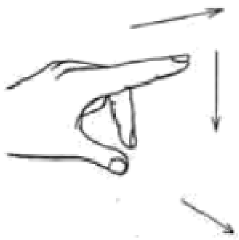


Fig 2: Fleming's Left Hand Rule

The first finger points in the direction of the magnetic field (first - field), which goes from the North pole to the South pole. The second finger points in the direction of the current in the wire (second - current). The thumb then points in the direction the wire is thrust or pushed while in the magnetic field (thumb - torque or thrust).

Principle of operation

Consider a coil in a magnetic field of flux density B . When the two ends of the coil are connected across a DC voltage source, current I flows through it. A force is exerted on the coil as a result of the interaction of magnetic field and electric current. The force on the two sides of the coil is such that the coil starts to move in the direction of force.

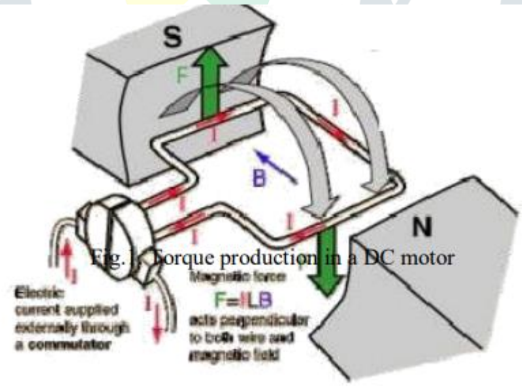


Fig 3: Torque production of dc motor

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. At /dt) as shown in different positions, the flux linked with it changes, which causes an emf to be induced (e = d figure 5. 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 emf.

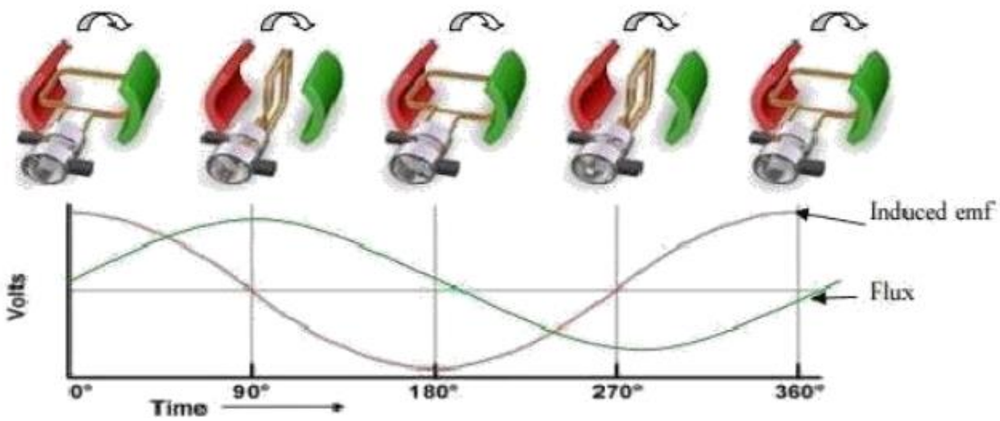


Fig.4: Induced voltage in the armature winding of DC motor

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. Construction DC motors consist of one set of coils, called armature winding, inside another set of coils or a set of permanent magnets, called the stator. Applying a voltage to the coils produces a torque in the armature, resulting in motion.

Stator

The stator is the stationary outside part of a motor. The stator of a permanent magnet dc motor is composed of two or more permanent magnet pole pieces. The magnetic field can alternatively be created by an electromagnet. In this case, a DC coil (field winding) is wound around a magnetic material that forms part of the stator.

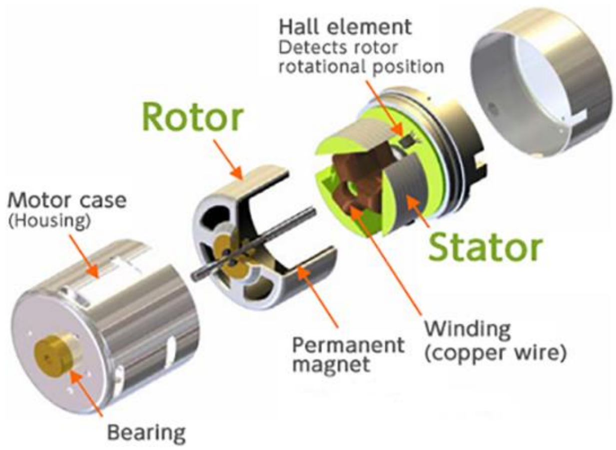


Fig.5: DC Motor Stator

Rotor

The rotor is the inner part which rotates. The rotor is composed of windings (called armature windings) which are connected to the external circuit through a mechanical commutator. Both stator and rotor are made of ferromagnetic materials. The two are separated by air-gap.

Fig.6: Rotor

Winding :
A winding is made up of series or parallel connection of coils.
Armature winding - The winding through which the voltage is applied or induced.
Field winding - The winding through which a current is passed to produce flux (for the electromagnet) Windings are usually made of copper.

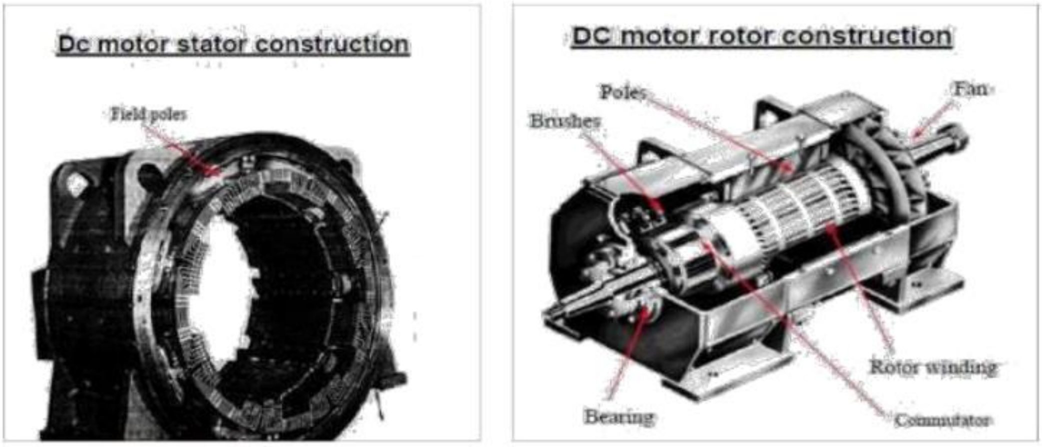
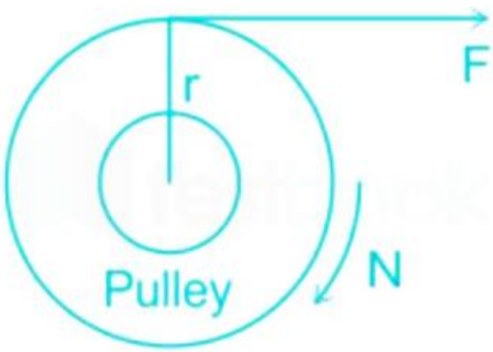


Fig.7: Winding

Torque of D.C. Motor:

Torque is meant the turning or twisting moment of a force about an axis.
Torque is the turning moment of a force about an axis and is measured by the product of force (F) and radius (r) at a right angle to which the force acts i.e.
D.C. Motors
In a DC Motor, each conductor is acted upon by a circumferential force F at a distance r, the radius of
the armature as shown below.



Let

P=Number of poles

r=Radius of the armature

l=Effective length of each conductor

Z=Total number of armature conductors

A=Number of parallel paths

i=Current in each conductor

B=Magnetic flux density

φ=Flux per pole

Therefore,

Force on each conductor, F=Bil

Torque developed by one condcutor=F×r

$\therefore$Total armature torque ,τ_a=Z×(F×r)=ZBilr

Since

Current in each conductor, i=I_aA

Magnetic flux density, B=φa

where

a = cross−sectional area of flux path at radius r=2πrlP

$$\tau_a = (PZ/2\pi A)\ \varphi\ I_a\ \text{Nm}\ldots(2)$$

The expression in the equation (2) is known as the *armature torque of DC motor*.

For a given DC motor, the (PZ/2πA) is a constant. Hence,

$$T_a \propto \varphi\ I_a\ldots(3)$$

Therefore, the armature torque developed in a DC motor is directly proportional to the flux per pole and the armature current.

Conclusion

In conclusion, DC motors play a vital role in modern technology and automation, offering a versatile and reliable means of converting electrical energy into mechanical motion.

Their applications span across a wide range of industries, and ongoing advancements in motor technology continue to improve their efficiency and performance.

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