Physical Structure & Configuration of DC Machines

Physical structure and configuration of DC Machines

Two-pole machine

Figure 1 depicts a two-pole machine in which the stator poles are constructed in such a way as to project closer to the rotor than to the stator structure. This type of construction is rather common, and poles constructed in this fashion are called ***salient poles***.

Note that the rotor could also be constructed to have salient poles.

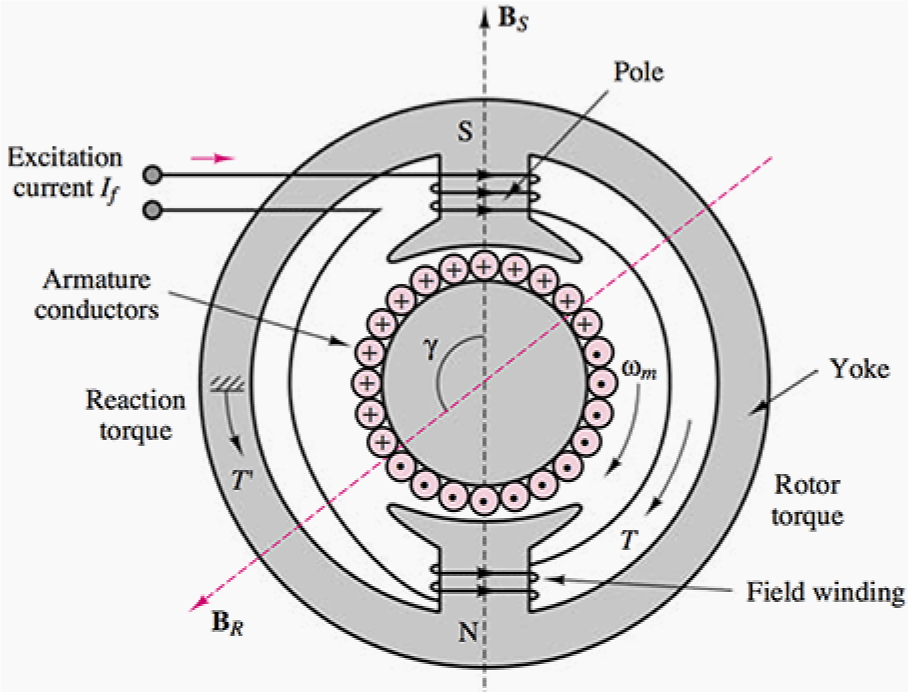


Figure 0 – Cross section of DC machine

Direct Current Motor (Rotor, Startor)

A representative **DC machine** was depicted in ***Figure 0*** above, with the magnetic poles clearly identified, for both the stator and the rotor.

Figure 1 is a photograph of the same type of machine. Note the salient pole construction of the stator and the slotted rotor. As previously stated, the torque developed by the machine is a consequence of the magnetic forces between stator and rotor poles.

This torque is maximum when the ***angle γ*** between the rotor and stator poles is ***90***◦.

Also, as you can see from the figure, in a DC machine the armature is usually on the rotor, and the field winding is on the stator.

DC motor parts

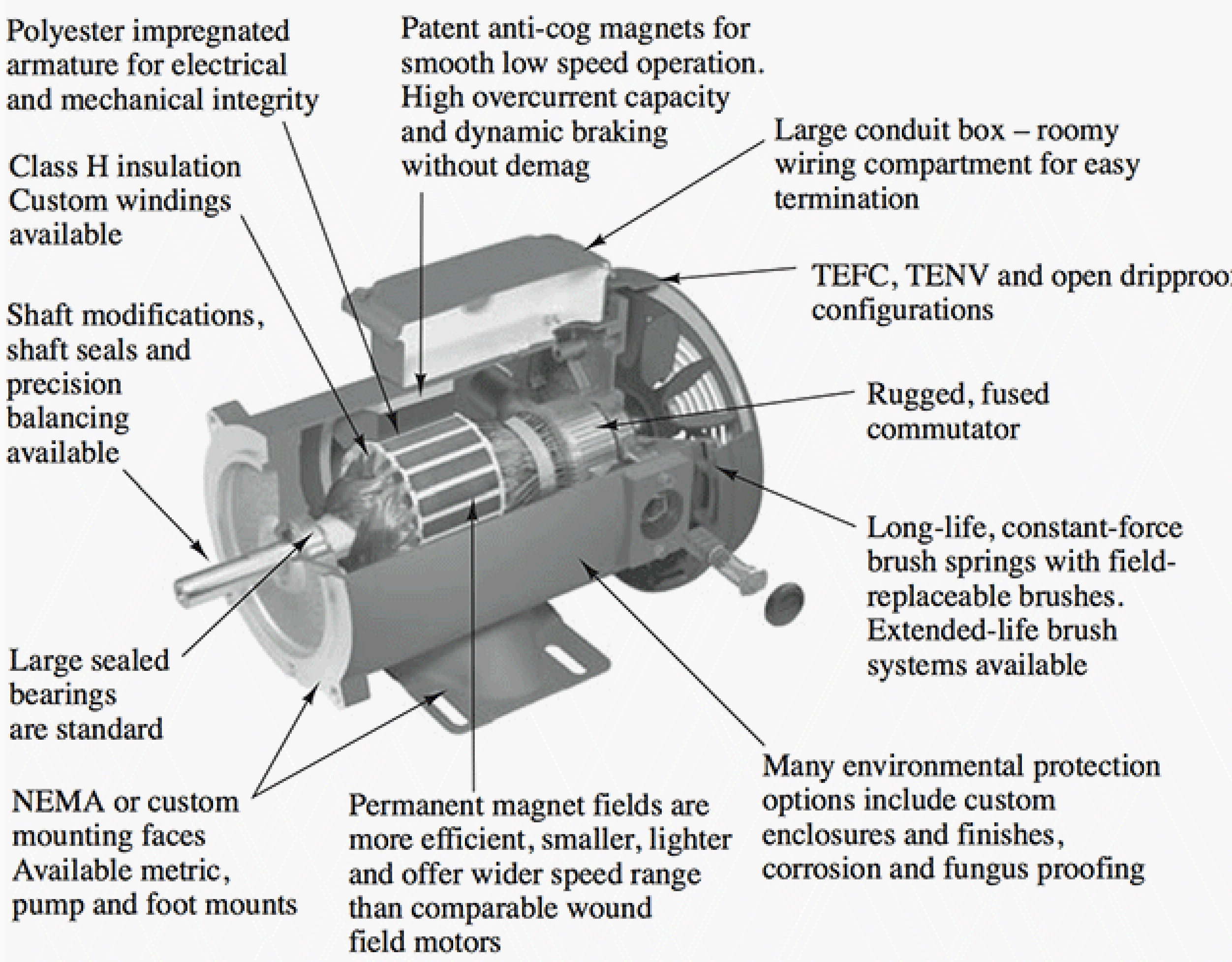


Figure 1 – DC machine

To keep this torque angle constant as the rotor spins on its shaft, a mechanical switch, called a**commutator**, is configured so the current distribution in the rotor winding remains constant, and therefore the rotor poles are consistently at 90◦ with respect to the fixed stator poles.

In a DC machine, ***the magnetizing current is DC***, so that there is no spatial alternation of the stator poles due to time-varying currents.

To understand the operation of the commutator, consider the simplified diagram of ***Figure 4***. In the figure, the brushes are fixed, and the rotor revolves at an ***angular velocity*** $\boldsymbol{\omega_m}$; the instantaneous position of the rotor is given by the expression: $\boldsymbol{\theta = \omega_m t - \gamma}$.
The commutator is fixed to the rotor and is made up in this example of six segments that are made of electrically conducting material but are insulated from one another. Further, the rotor windings

are configured so that they form six coils, connected to the commutator segments as shown in ***Figure 4***.

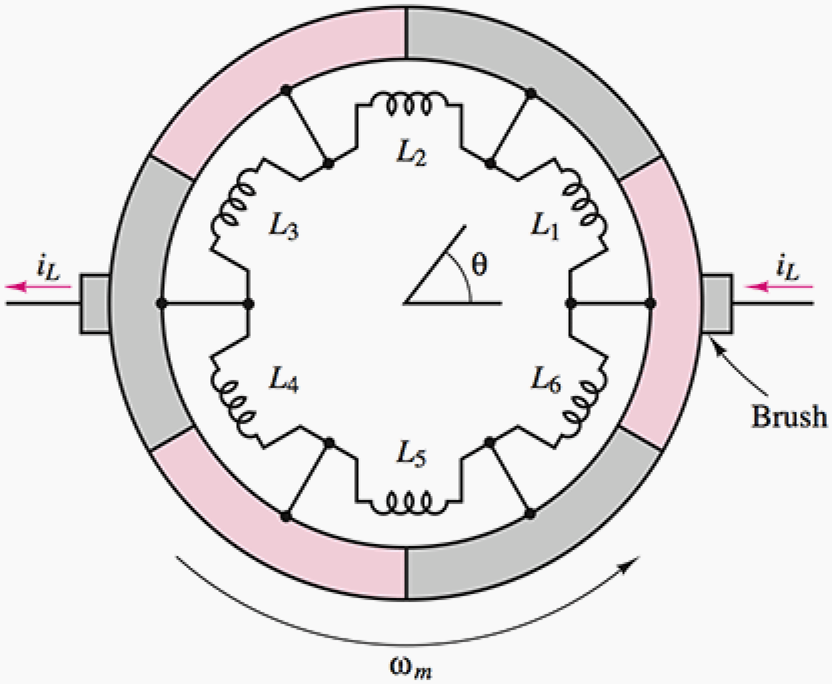


Figure 4 – Rotor winding and commutator

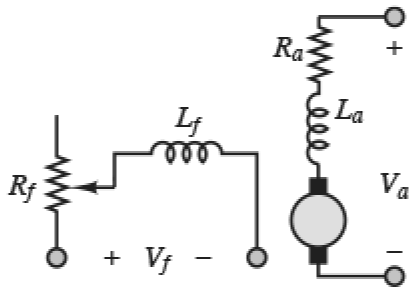
As the commutator rotates counterclockwise, the rotor magnetic field rotates with it ***up to θ = 30***◦. At that point, the direction of the current changes in coils L3 and L6 as the brushes make contact with the next segment.

Now the direction of the magnetic field is ***−30***◦. As the commutator continues to rotate, the direction of the rotor field will again change from −30◦ to +30◦, and it will switch again when the brushes switch to the next pair of segments. In this machine, then, the torque angle γ is not always 90◦, but can vary by as much as ±30◦; the actual torque produced by the machine would fluctuate by ***as much as ±14 percent***, since the torque is proportional to ***sin γ***.

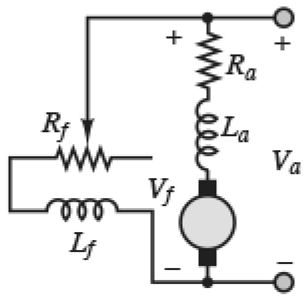
As the number of segments increases, the **torque fluctuation** produced by the commutation is greatly reduced. In a practical machine, for example, one might have as many as 60 segments, and the variation of γ from 90◦ would be only ±3◦, with a torque fluctuation of less than 1 percent.

Thus, the DC machine can produce a nearly constant torque (as a motor) or voltage (as a generator).

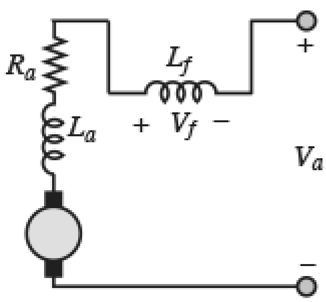
Configuration of DC Machines



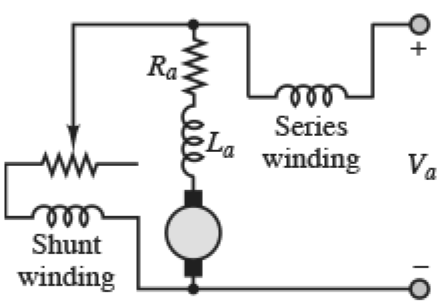
(a) Separately excited



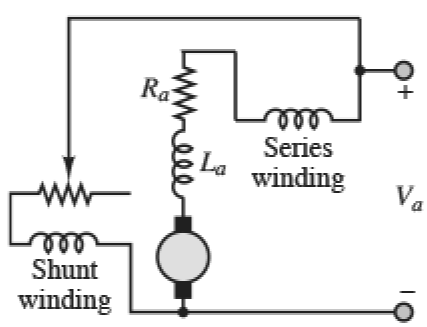
(b) Shunt-connected



(c) Series-connected



(d) Short-shunt compound
connection



(e) Long-shunt compound
connection

Figure 5 – Configuration of DC Machines

In DC machines, the field excitation that provides the magnetizing current is occasionally provided by an external source, in which case the machine is said to be separately excited [***Figure 5 (a)***]. More often, the field excitation is derived from the armature voltage, and the machine is said to be self-excited.
The latter configuration does not require the use of a separate source for the field excitation and is therefore frequently preferred. If a machine is in the separately excited configuration, an additional source ***Vf*** is required. In the self-excited case, one method used to provide the field excitation is to connect the field in parallel with the armature; since the field winding typically has significantly higher resistance than the armature circuit (*remember that it is the armature that carries the load current*), this will not draw excessive current from the armature.
Further, a series resistor can be added to the field circuit to provide the means for adjusting the field current independent of the armature voltage. This configuration is called a ***shunt-connected machine and is depicted in Figure 5 (b)***.
Another method for self-exciting a DC machine consists of connecting the field in series with the armature, leading to the series-connected machine, depicted in ***Figure 5 (c)***; in this case, the field winding will support the entire armature current, and thus the field coil must have low resistance (*and therefore relatively few turns*).
This configuration is rarely used for generators, since the generated voltage and the load voltage must always differ by the voltage drop across the field coil, which varies with the load current.
Thus, a series generator would have poor (large) regulation.
However, series-connected motors are commonly used in applications not more than about 1 kW output, or if we are talking about bigger motors – they are used for electric locomotives.

The third type of DC machine is the compound-connected machine, which consists of a combination of the shunt and series configurations. ***Figure 5 (d) and (e)*** shows the two types of connections, called the short shunt and the long shunt, respectively.
Each of these configurations may be connected so that the series part of the field adds to the***shunt part*** (*cumulative compounding*) or so that it ***subtracts*** (*differential compounding*).

REFERENCE:

*Fundamentals of electrical engineering by Giorgio Rizzoni, The Ohio State University (**purchase paperback from Amazon**)*

Source:

http://electrical-engineering-portal.com/physical-structure-configuration-of-dc-machines