# ELEC0431 : Exercise session 9

# DC machine

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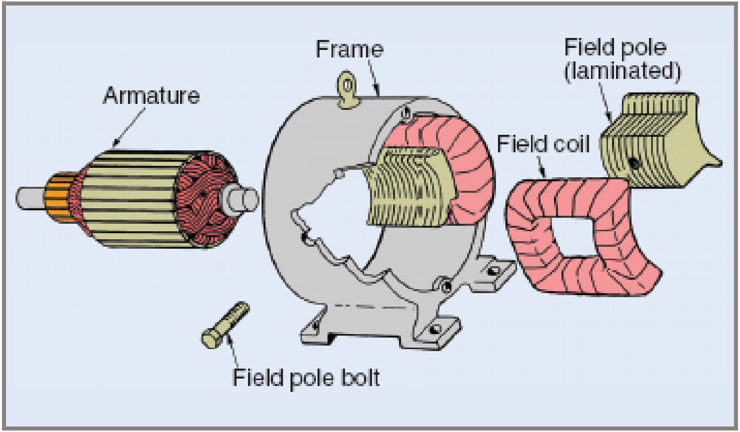
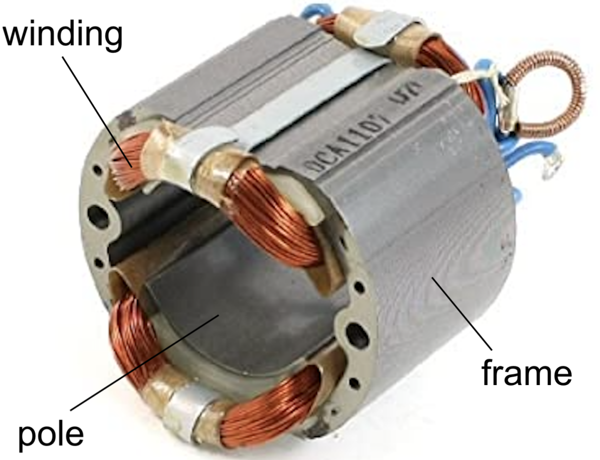
# DC machines - Main parts

- Inductor (stator)
- Armature (rotor)
- Collector (commutator) and brushes



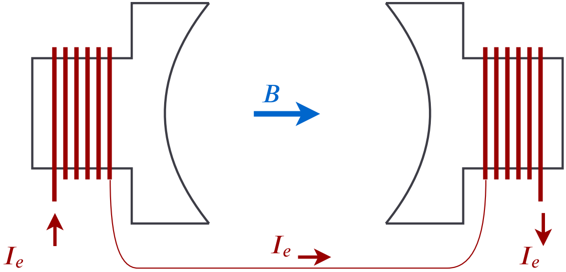
# DC machines - Main parts

- Inductor (stator)



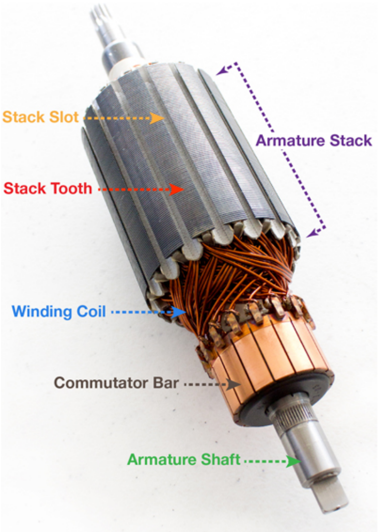
- Inductor (stator)

The inductor can be made of permanent magnets or electromagnets. In the case of electromagnets, the stator winding is crossed by a DC current : the excitation current $I_e$.



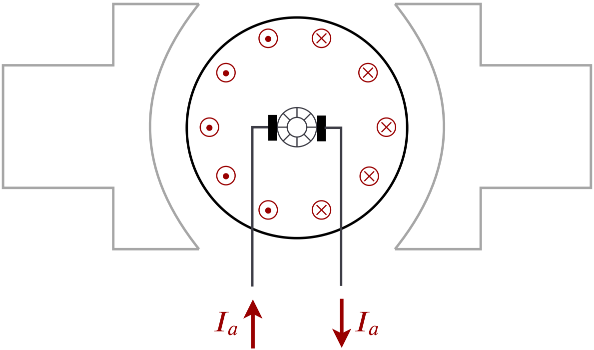

The excitation current, $I_e$, allows to create the inductor magnetic field $B$ seen by the rotor of the machine.

- Armature (rotor)



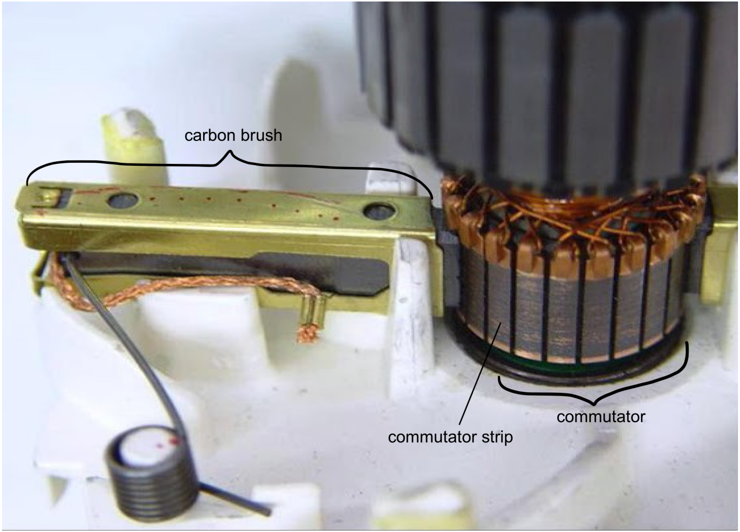
- Armature (rotor)

The windings of the rotor (armature) are crossed by a DC current : the armature current, $I_a$.



# DC machines - Main parts

- Collector (commutator) and brushes



# DC machines - Main parts

- Collector (commutator) and brushes

The collector is a set of copper strips connected to the extremities of the armature windings.

The brushes, generally made of carbon, are located on the stator and rub the collector.

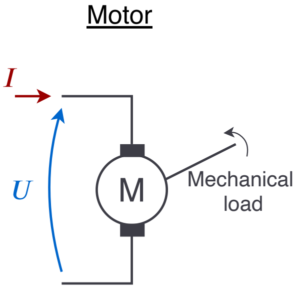
The collector and brushes allow the current to circulate in the armature.

Due to their irregular contact, the brushes and the collector are the parts that are the most prone to wear.

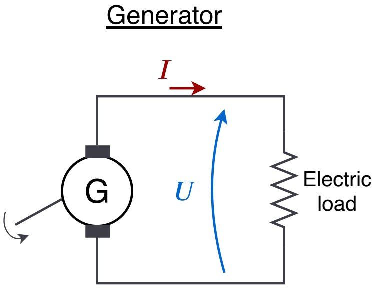
Brushes contacts create sparks and therefore need aeration. Therefore, the DC motor can not be hermetically sealed.

# DC motors and generators

The DC machines are reversible. They can convert electrical energy into mechanical and conversely.




"Converts electric power to mechanical"




"Converts mechanical power to electric"

The electromotive force can be expressed as

$$\boxed{E = k_E\ \dot{\theta}\ \Phi_v} \tag{1}$$

and the electromagnetic torque can be expressed as

$$\boxed{C = k_E\ \Phi_v\ I_a} \tag{2}$$

with the assumption that the armature reaction and non linearity of the magnetic material are neglected.

## Electromotive force

The electromotive force $E$ is proportionnal to the magnetic flux $\Phi_v$ which is generated by the excitation current $I_e$.

The flux $\Phi_v(I_e)$ is non linear with an hysteresis cycle due to the ferromagnetic materials used.

Moreover, the flux seen by the rotor is also reduced by the armature reaction, such that the electromotive force is reduced

$$E = k_E \, \dot{\theta} \, \left( \Phi_v(I_e) - \underbrace{\Delta\Phi(I_a)}_{\text{armature reaction}} \right) \tag{3}$$

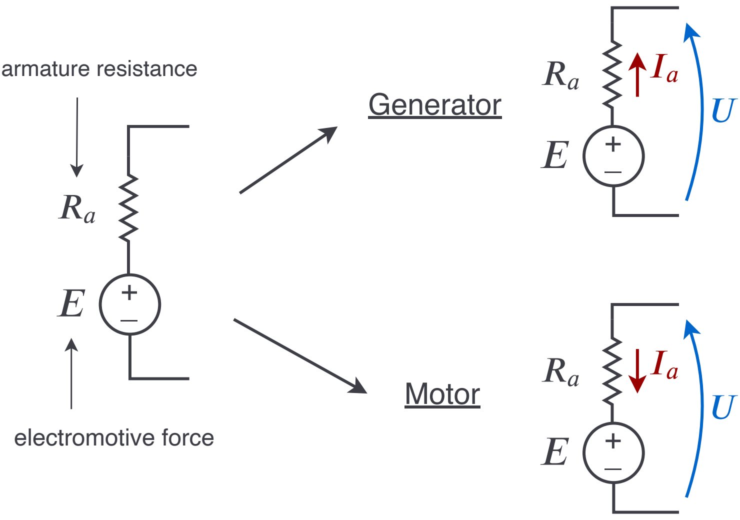
In practice, the electromotive force and torque depend on both the excitation current and the armature current.

$$E = k_E \, \dot{\theta} \, \Phi_v(I_e, I_a) \tag{4}$$

$$C = k_E \, I_a \, \Phi_v(I_e, I_a) \tag{5}$$

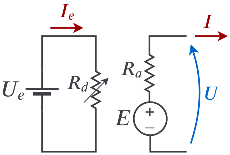
# Armature equivalent circuit

The equivalent circuit of the armature can be represented as



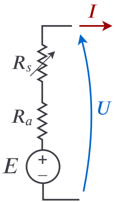
# The different types of excitation (generators)

Independent



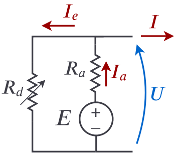

$I = I_a$

Series



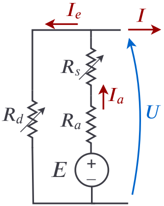

$I = I_a = I_e$

Shunt




$I_a = I_e + I$

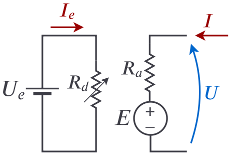
Compound




$I_a = I_e + I$

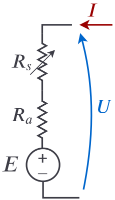
# The different types of excitation (motors)

Independent



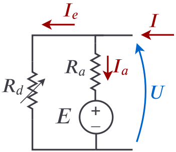

$I = I_a$

Series



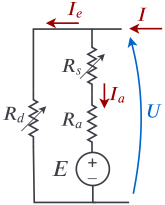

$I = I_a = I_e$

Shunt




$I = I_e + I_a$

Compound




$I = I_e + I_a$

## DC motors and risks of runaway

The main risks of runaway occur in two particular configurations :

- The independent excitation motor with the excitation circuit that is opened.
- The series excitation motor at light load.

In both cases, the speed of the machine can increase very quickly and very high. Such situations must absolutely be avoided as they can be harmfull and can cause damage to the equipment.

# DC motors applications

The DC motor are less widespread due to the use of asynchronous motor (robust and cheap) that are easier to drive nowadays with VFD (Variable Frequency Drive). However, DC motor are still used for low power applications (such as toys or home appliances) or high power applications as described below.

| Excitation Type | Characteristics |
|---|---|
| Series | High starting torque |
| Shunt | Constant speed, non severe starting conditions |
| Compound | Higher starting torque and fairly constant speed |

| Excit. | Applications |
|---|---|
| Series | Traction system, cranes, vaccum cleaner, sewing machine, etc. |
| Shunt | Centrifugal pumps, fans, conveyors, spinning machines, etc. |
| Comp. | Presses, shears, conveyors, elevators, heavy planners, etc. |

# Exercises