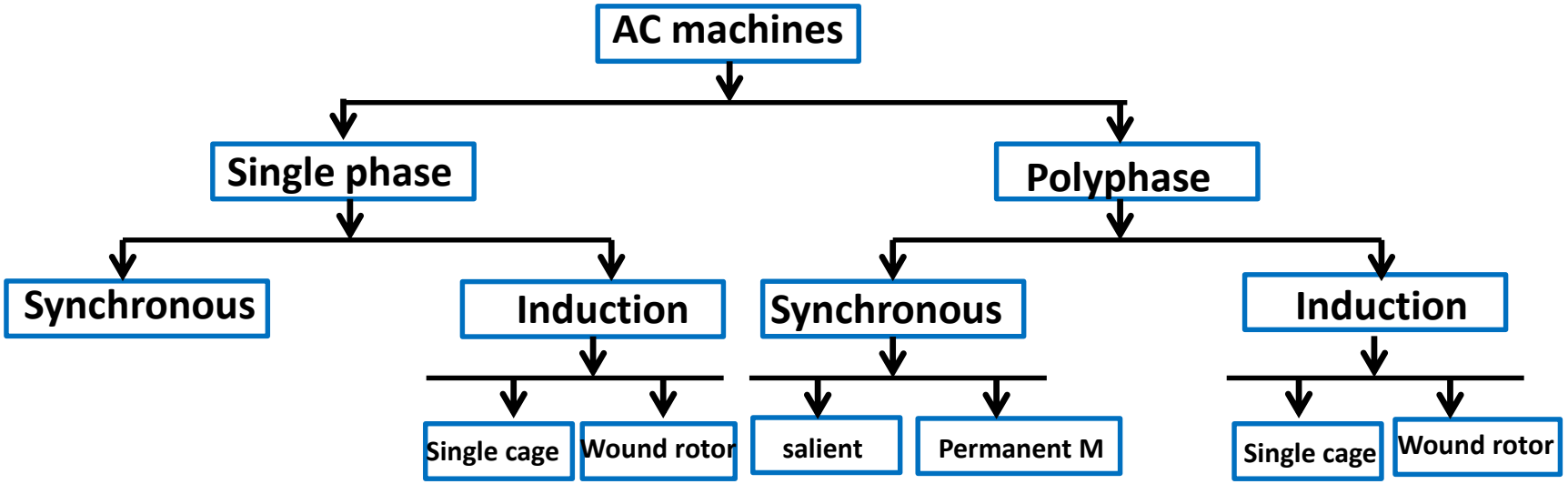
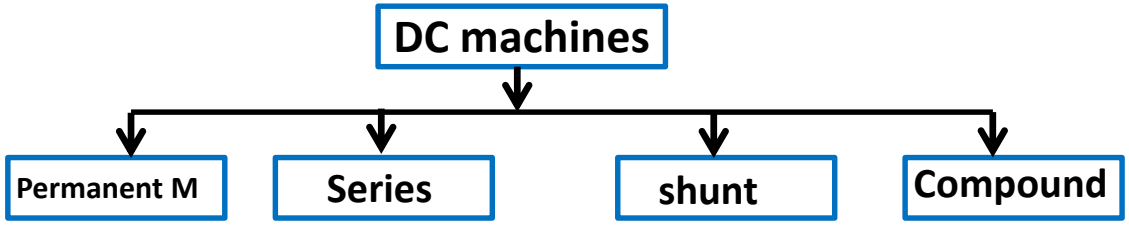
Classification of electrical machines



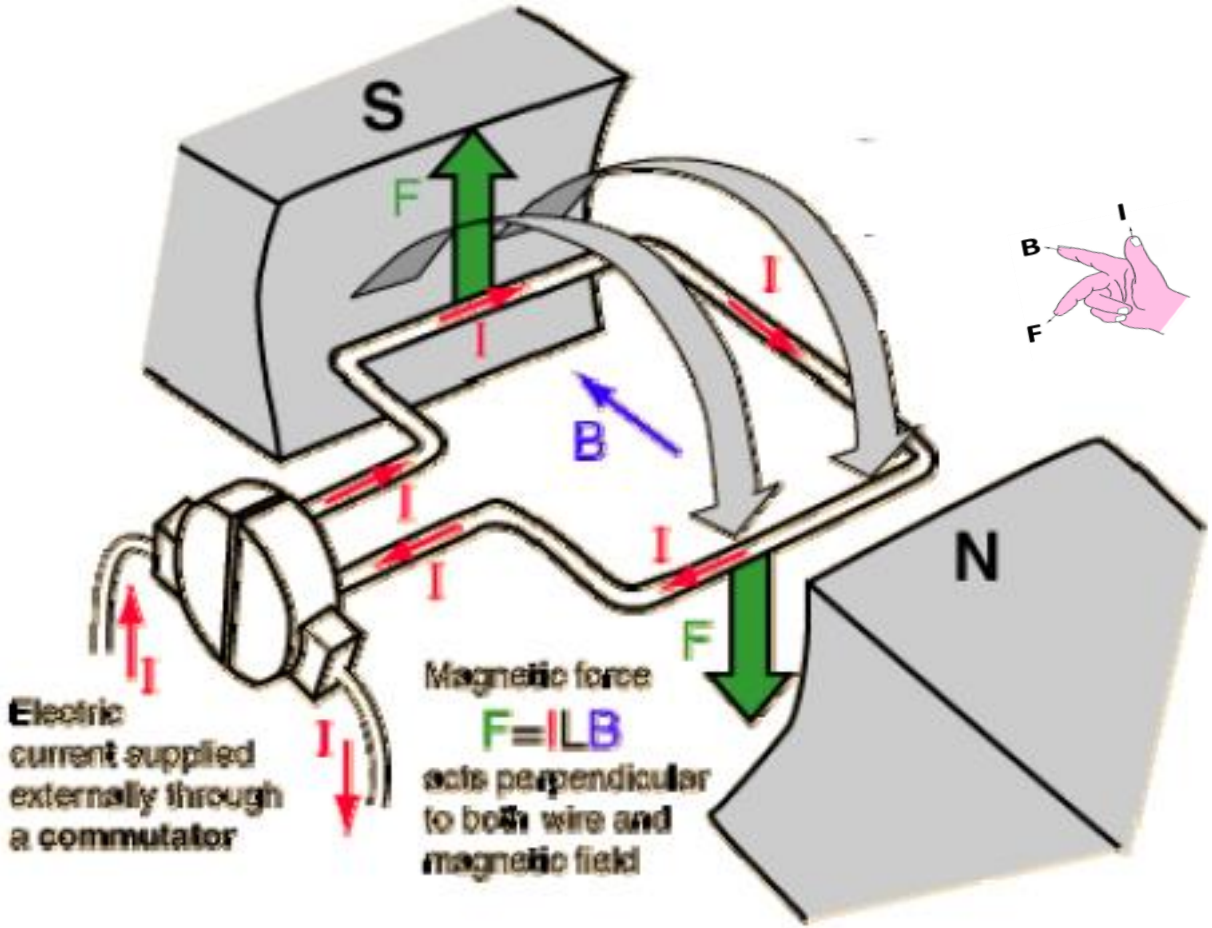


CHAPTER TWO

DC machines

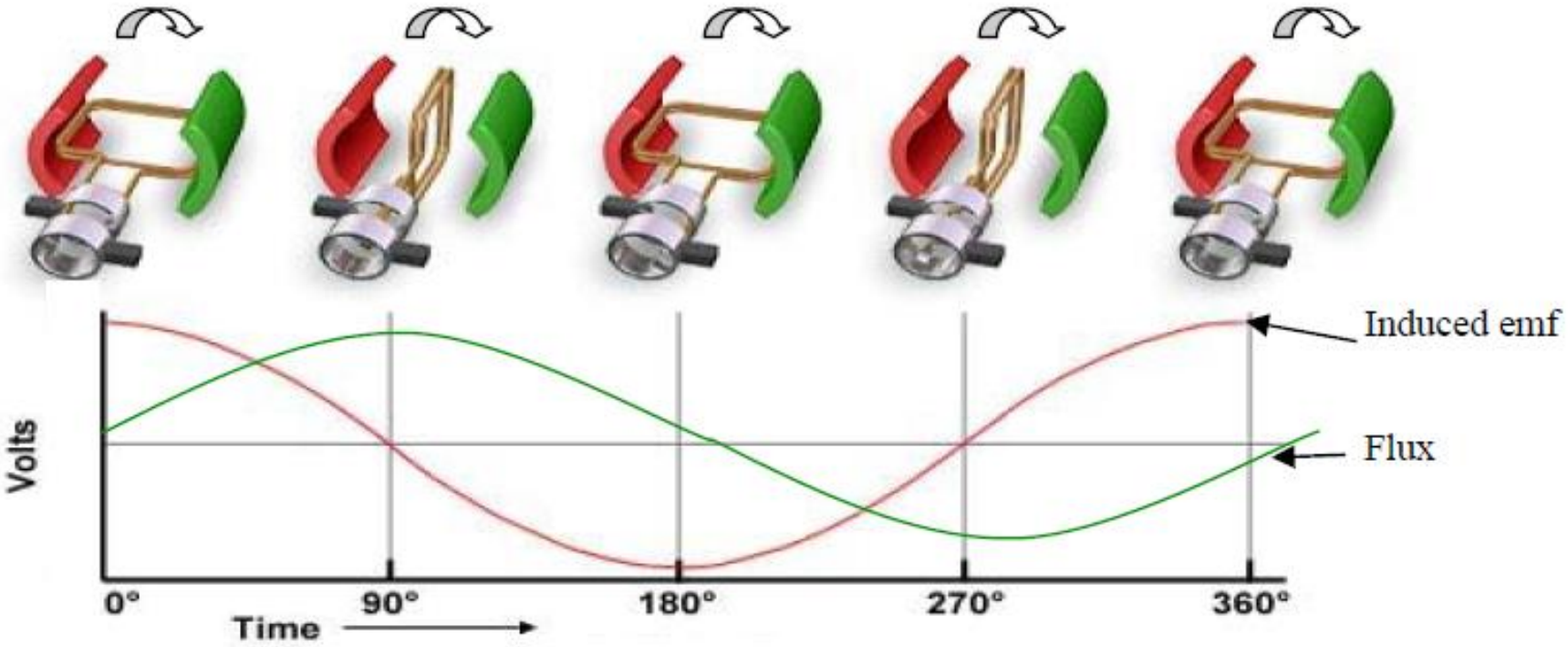
- ✓ Understand the basic principles of operation of a DC motor.
- ✓ Understand the operation and basic characteristics of simple DC motors.
- ✓ Compute electrical and mechanical quantities using the equivalent circuit.
- ✓ Study some applications of DC motors.
- ✓ Use motor nameplate data.

Production of induced force on a wire.



$$F = i.(l \times B)$$

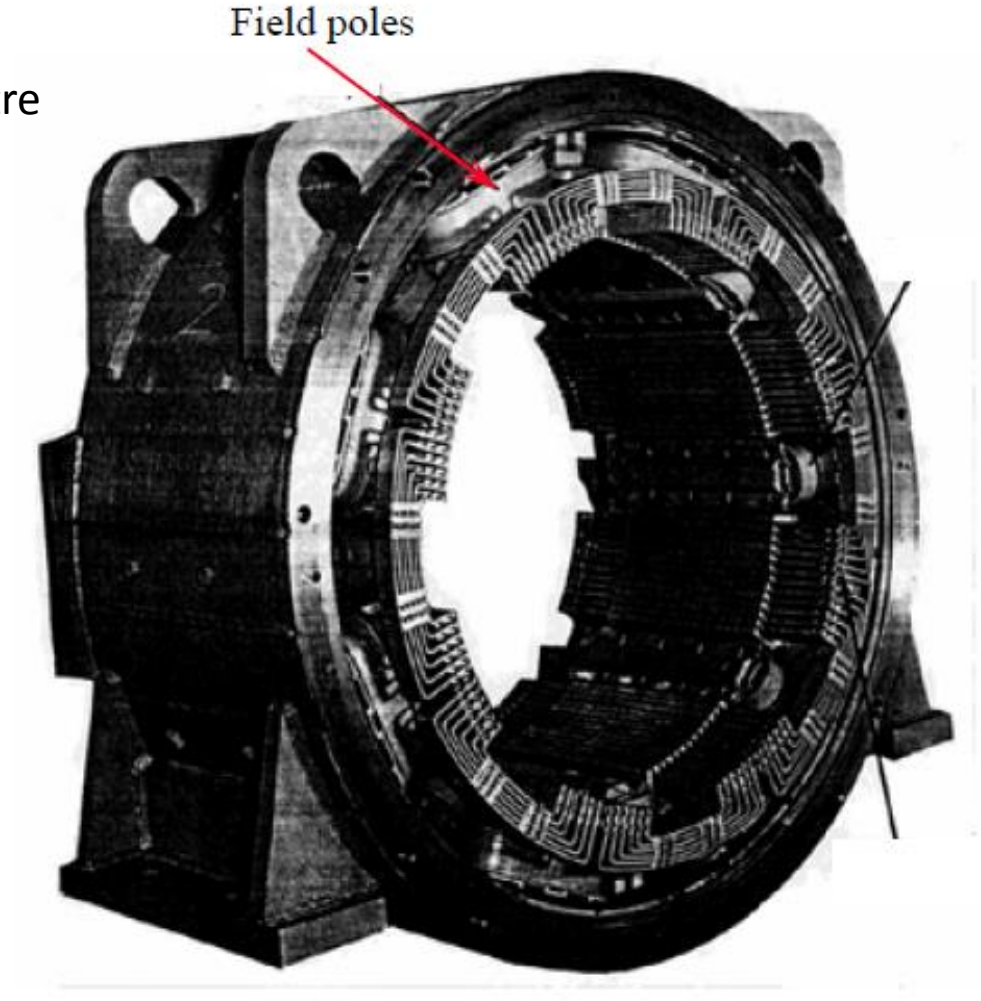
Induced voltage in the armature winding of DC motor



Dc motor stator construction

Moteur lève vitre

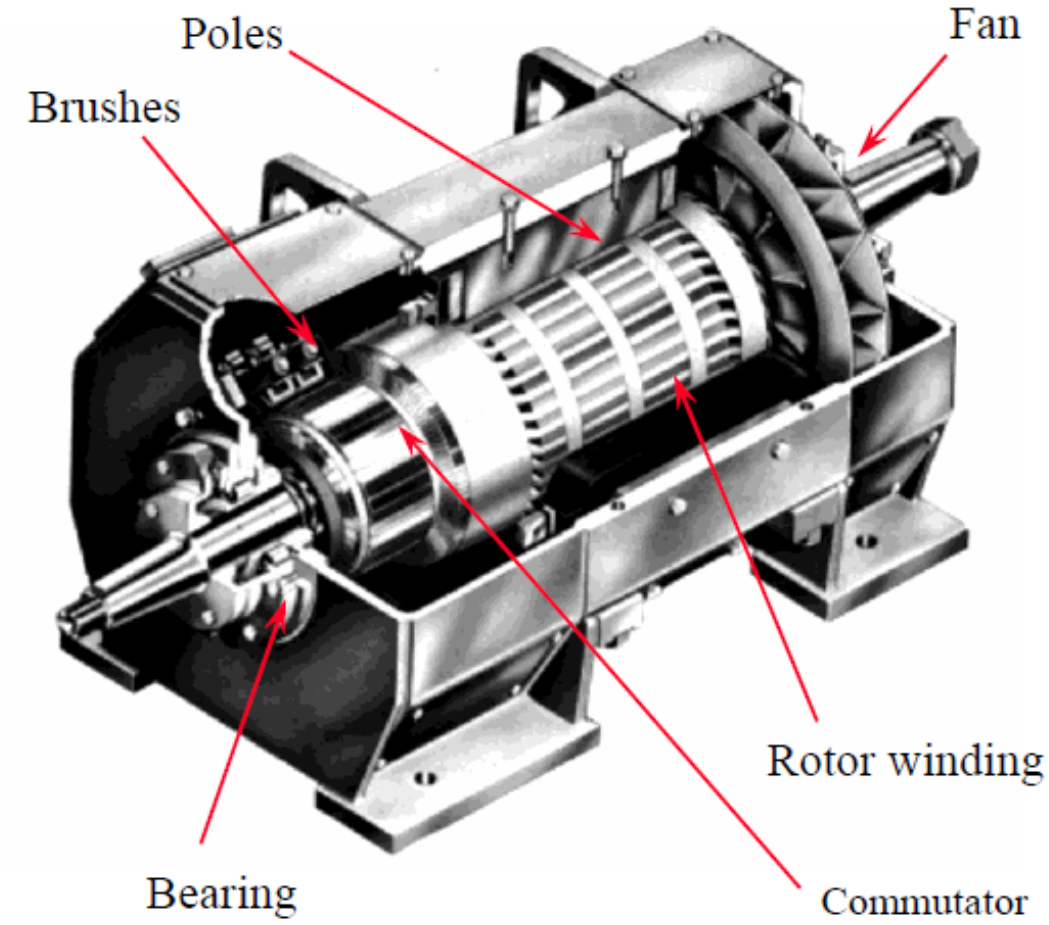
Moteur lève-vitre



Moteur universel

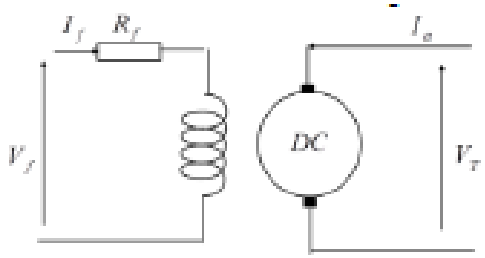
Moteur universel

DC motor rotor construction

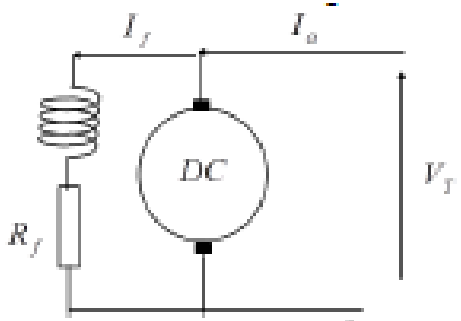


Classification of DC motors

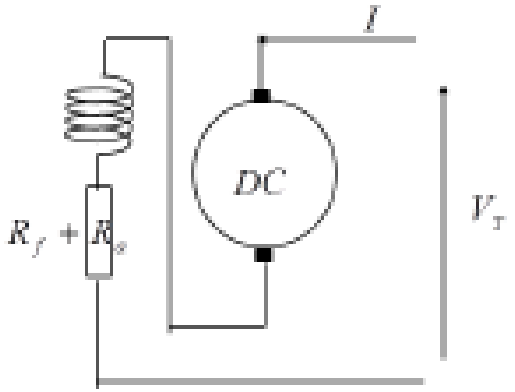
Separately excited: Field and armature are either connected separate



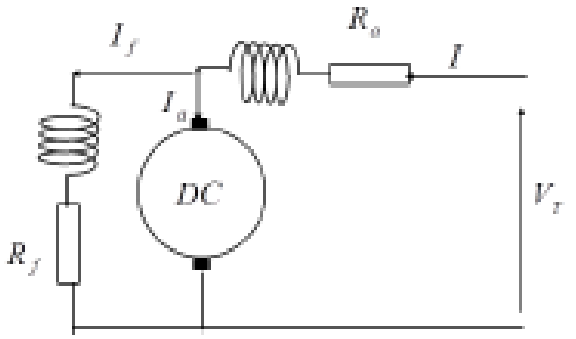
Shunt excited: Field and armature are either connected in parallel



Series excited: Field and armature are either connected in series



Compound excited: Has both shunt and series field so it combines features of series and shunt motors.

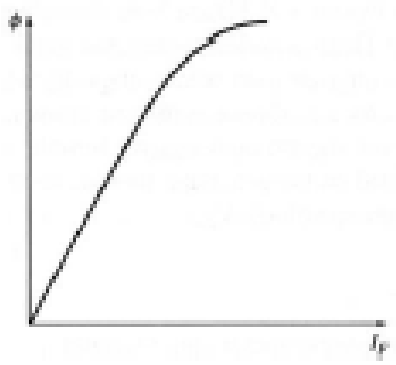


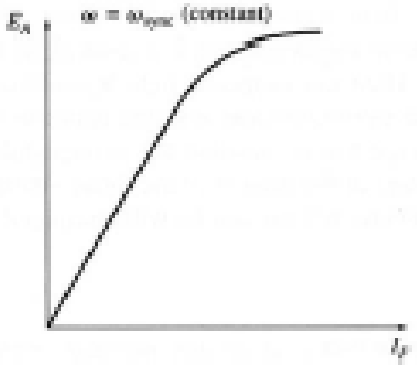
DC Generator Fundamentals

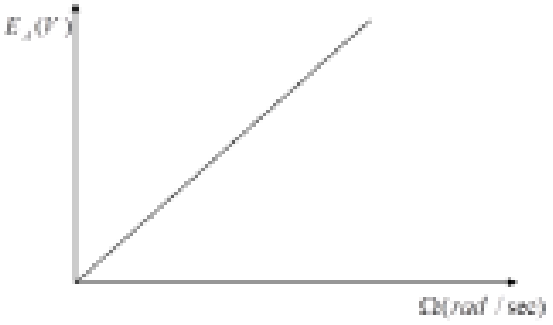
The voltage out of the armature of a DC generator is: $E_A = k_1 \times \phi \times \Omega$

: if the iron core is not saturated: $\phi = k_2 I_F$

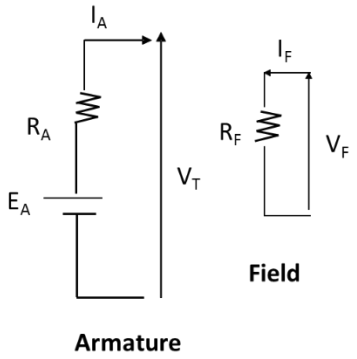
Hence $E_A = k_1 k_2 I_F \Omega = k_\phi \Omega$







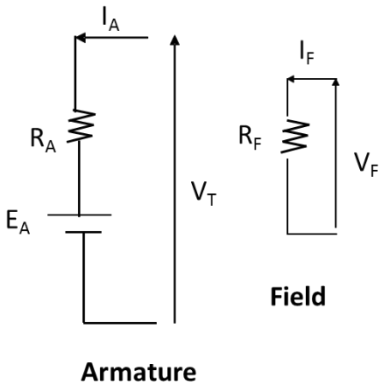
DC Generator Equivalent circuit



Voltage equation:

$$E_a = V_T + R_A I_A \qquad V_F = R_F \times I_F$$

DC Motor Equivalent circuit



Voltage equation:

$$V_T = E_A + R_A I_A \qquad V_F = R_F \times I_F$$

The relationship between the induced EMF and torque

$$E = Blv$$
$$T = Bli r$$

$$\frac{E_A}{T_{dev}} = \frac{Blv}{Bli r} = \frac{v}{i \times r} = \frac{\Omega \times r}{i \times r} = \frac{\Omega}{I_A}$$

$$E_{em} I_A = T_{dev} \Omega$$

$$T_{dev} = \frac{E_A \times I_A}{\Omega} = \frac{k_1 \phi \Omega I_A}{\Omega} = k_1 \phi I_A = k_\phi I_A$$

The power flow and losses in DC machines

$$P_{out} = P_{in} - \sum losses$$

$\sum losses$ = Copper losses (armature and field) + Core losses (both core) + Mechanical losses

Efficiency

Total electrical input power $P_{in} = V_T I_A + V_F I_F$

Power absorbed by the field winding is in turn converted to heat and is given by:

$$P_f = R_F I_F^2 = R_F \left(\frac{V_F}{R_F} \right)^2 = \frac{V_F^2}{R_F}$$

Some power is lost in the resistance of the armature winding, and can be calculated as:

$$p_A = R_A I_A^2$$

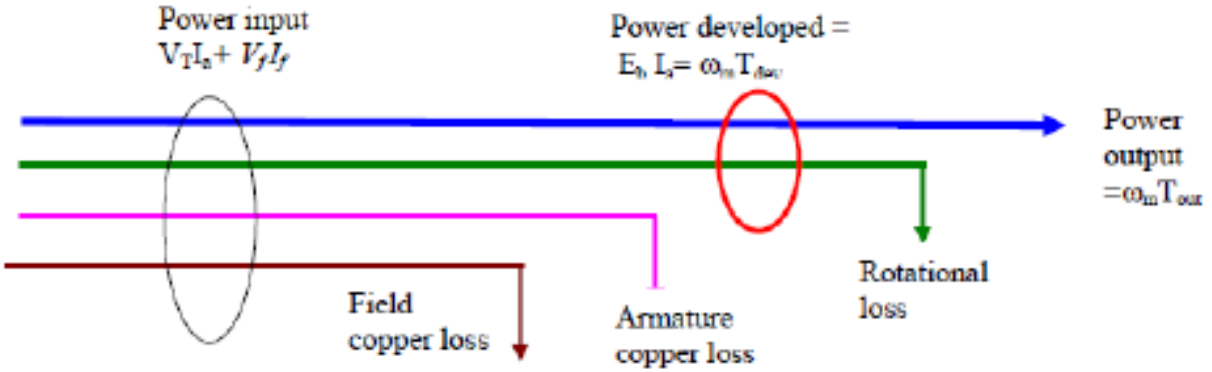
$$\sum copperloss = \text{Field loss} + \text{armature loss}$$

$$P_{dev} = P_{in} - \sum copperloss$$

$$P_{dev} = E_A I_A = T_{dev}\,\Omega$$

$$P_{out} = P_{dev} - p_{rot}$$

The power flow diagram

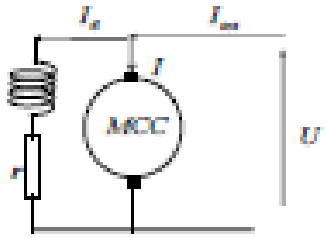


The efficiency of the DC motor can be calculated as:

$$\eta = \frac{P_{out}}{P_{.}} \times 100\%$$

$$\eta = \frac{P_{out}}{P_{out} + P_A + P_F + P_{rot}}$$

Exercise1. A DC shunt motor runs at no load speed 1140 rpm. At full load, armature reaction weakens the main flux by 5% whereas the armature circuit voltage drops by 10%. Calculate the motor full load speed N_2 in rpm.



Answer:

$$E_{A1} = k_1\phi_1\Omega_1 \rightarrow k_1 = \frac{E_{A1}}{\phi_1\Omega_1}$$

$$E_{A2} = k_1\phi_2\Omega_2 \rightarrow k_1 = \frac{E_{A2}}{\phi_2\Omega_2}$$

$$\Omega_1 = \frac{2\pi N_1}{60}; \Omega_2 = \frac{2\pi N_2}{60} \rightarrow \frac{\Omega_2}{\Omega_1} = \frac{N_2}{N_1}$$

$$\phi_2 = 0{,}95\phi_1$$

$$E_{A2} = 0{,}9E_{A1}$$

$$\frac{E_{A1}}{\phi_1 N_1} = \frac{E_{A2}}{\phi_2 N_2}$$

$$\frac{E_{A1}}{\phi_1 N_1} = \frac{0{,}9E_{A1}}{0{,}95\phi_1 N_2} \qquad \frac{1}{N_1} = \frac{0{,}9}{0{,}95N_2} \qquad N_2 = \frac{0{,}9N_1}{0{,}95} = 1080rpm$$

Exercise2

A DC machine has a flux per pole of 30 10^{-3} Wb. The DC machine runs at 1050 rpm and it delivers a rated armature current of 225 A to a load connected to its terminals, the machine constant $K_1 = 85, 21$.
Calculate:
A) Generated voltage, E_A
B) Torque developed T_{dev}.
C) Power developed by the machine P_{dev}.

Solution

A) Generated voltage, E_A

$$E_G = k_1 \times \phi \times \Omega$$

$$\Omega = \frac{2\pi N}{60} = \frac{2\pi \times 1050}{60} = 109{,}96 rad/\sec$$

$$E_A = k_1 \times \phi \times \Omega = 85{,}21 \times 0{,}03 \times 109{,}96 = 281V$$

B) Torque developed T_{dev}.

$$T_{dev} = k_1 \times \phi \times I_A = 85{,}21 \times 0{,}03 \times 225 = 575{,}16 Nm$$

C) Power developed by the machine P_{dev}.

$$P_{dev} = E_A . I_A = 281 \times 225 = 63{,}22 kW$$

Review

1. A commutator in a DC machine
   a) Reduces power loss in armature
   b) Reduces power loss in circuit
   c) **Converts the induce AC armature voltage into direct voltage**
   d) It is not necessary

2. The DC series motor should always be started with load because
   e) **At no load, it will rotate at dangerously high speed**
   f) It will fail to start
   g) It will not develop high starting torque
   h) All are true

3. In a DC series motor the developed torque is proportional to:
   a) I_A
   b) I_A^2
   c) $\frac{1}{I_A}$
   d) $\frac{1}{I_A^2}$

4. In a DC machine, the armature mmf is:
   a) Stationary with respect to armature
   b) Rotating with respect to field
   c) **Stationary with respect to field**
   d) Rotating with respect to brushes

5. The torque, in a……is proportional to the square of armature current
   a) DC shunt motor
   b) Stepper motor
   c) Two phase servomotor
   d) **DC series motor**

Exercise 1 Fill in the blanks

1. Coils with several turns are placed in the _____.
2. The distance between the two legs of the coil is about _____.
3. The coils are connected _____ through the commutator segments.
4. The ends of each coil are connected to a _____ segment.
5. The commutator consists of insulated _____ segments mounted on an insulated tube.
6. Two brushes are pressed to the commutator to permit _____.
7. The brushes are placed in the _____, where the magnetic field is close to zero, to reduce arcing.

Answer

1. Slots.
2. 180 electric degrees.
3. in series
4. Commutator.
5. Copper
6. Current flow.
7. Neutral zone


The End