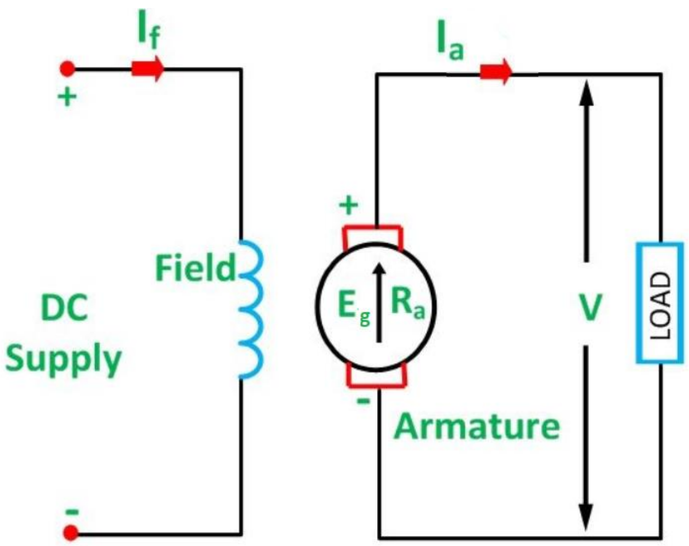
EEE363

Electrical Machines

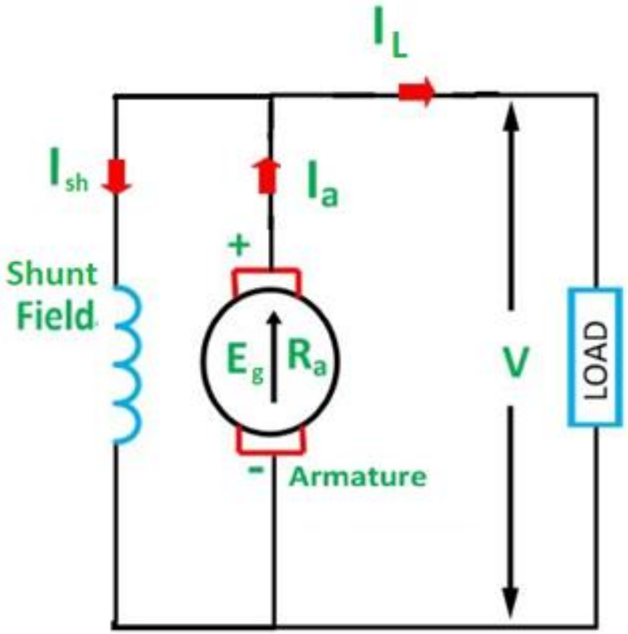
Lecture # 5

Dr Atiqur Rahman

Generated EMF



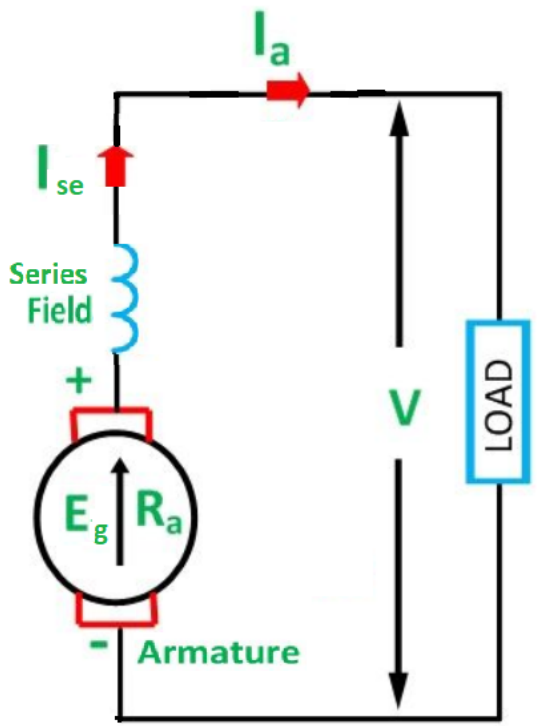
$$E_g = V + I_aR_a$$

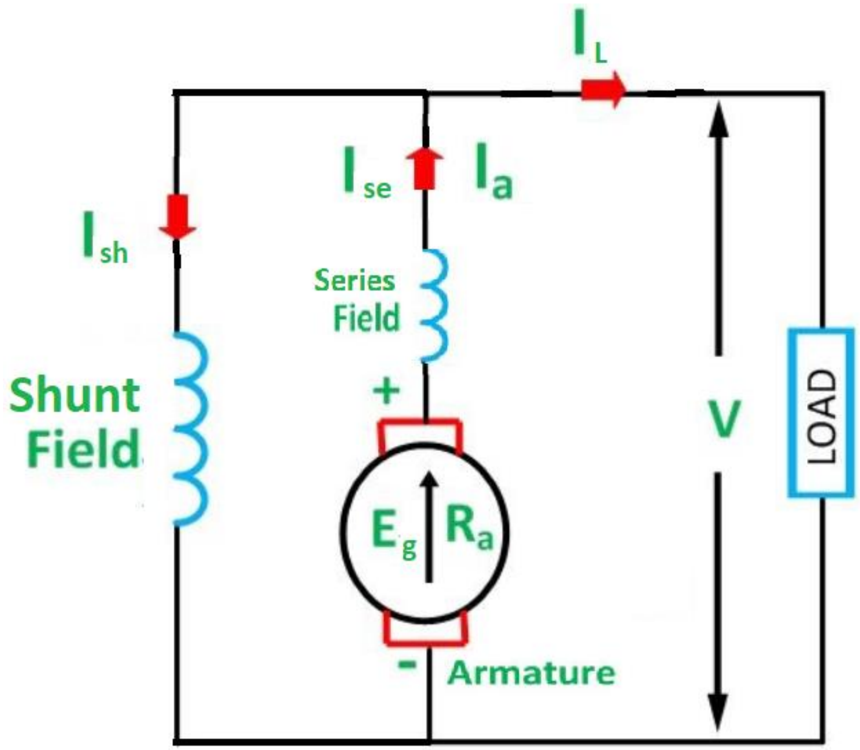


$$I_a = I_L + I_{sh}$$

$$E_g = V + I_aR_a$$

Generated EMF





$$I_a = I_L + I_{sh}$$

$$E_g = V + I_a R_a + I_a R_{se}$$

$$E_g = V + I_a R_a + I_a R_{se}$$

Mechanical losses

These losses are due to friction and windage

(i) Friction loss e.g., bearing friction, brush friction etc.

(ii) Windage loss i.e., air friction of rotating armature.

Iron losses and mechanical losses together are called stray losses

Constant and Variable Losses

(i) Constant losses

(a) iron losses (b) mechanical losses (c) shunt field losses

(ii) Variable losses

(a) Copper loss in armature winding
(b) Copper loss in series field winding

Condition for Maximum Efficiency

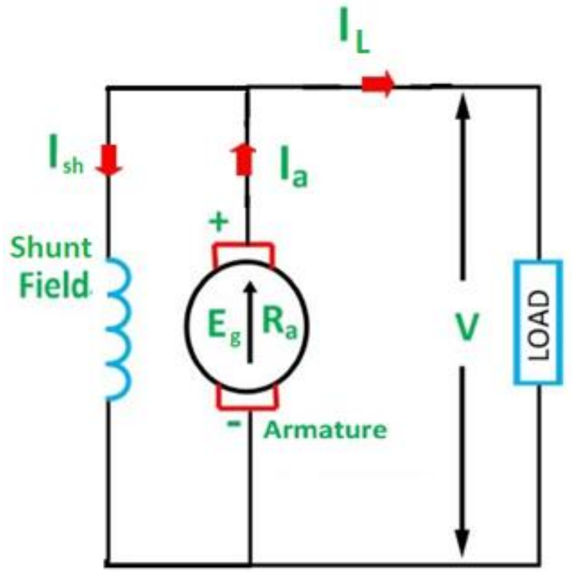
$$\text{Generator output} = V I_L$$

$$\text{Generator input} = \text{Output} + \text{Losses}$$

$$= V I_L + \text{Variable losses} + \text{Constant losses}$$

$$= VI_L + I_a^2 R_a + W_C$$

$$= VI_L + (I_L + I_{sh})^2 R_a + W_C$$



$$I_a + I_L + I_{sh}$$

The shunt field current I_{sh} is generally small as compared to I_L and, therefore, can be neglected.

$$\text{Generator input} = VI_L + I_L^2 R_a + W_C$$

$$\eta = \frac{\text{output}}{\text{input}} = \frac{VI_L}{VI_L + I_L^2 R_a + W_C}$$

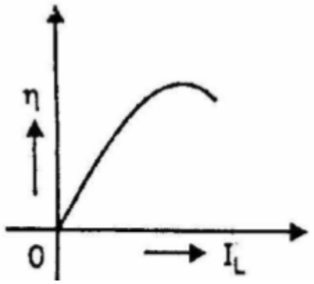
$$= \frac{1}{1 + \left(\frac{I_L R_a}{V} + \frac{W_C}{VI_L}\right)}$$

The efficiency will be maximum when the denominator of the expression is minimum

$$\frac{d}{dI_L}\left(\frac{I_L R_a}{V} + \frac{W_C}{VI_L}\right) = 0$$

$$\frac{R_a}{V} - \frac{W_C}{VI_L^2} = 0$$

$$\frac{R_a}{V} = \frac{W_C}{VI_L^2} \quad \text{or} \quad I_L^2 R_a = W_C$$



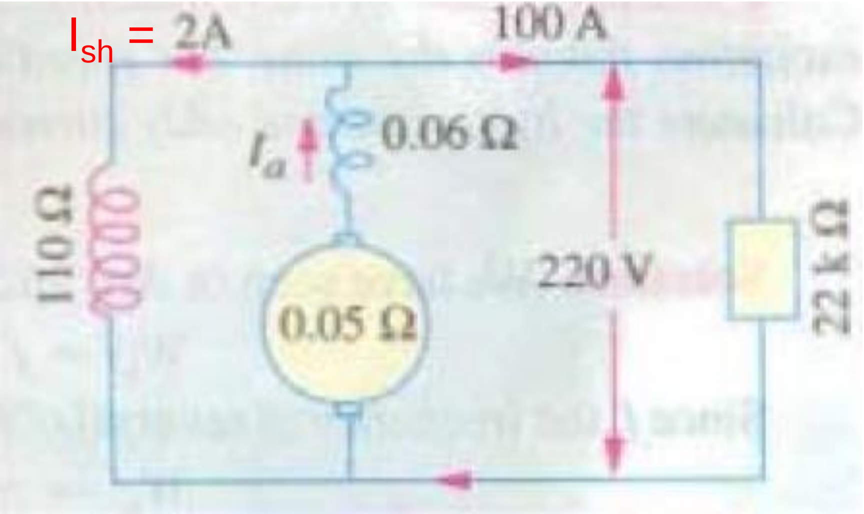
$$I_L = \sqrt{\frac{W_C}{R_a}}$$

Problem # 1

Example 26.26. *A long-shunt dynamo running at 1000 r.p.m. supplies 22 kW at a terminal voltage of 220 V. The resistances of armature, shunt field and the series field are 0.05, 110 and 0.06 Ω respectively. The overall efficiency at the above load is 88%. Find* (a) *Cu losses* (b) *iron and friction losses* (c) *the torque exerted by the prime mover.*

$$I_{sh} = 220/110 = 2 \text{ A}$$
$$I = 22{,}000/220 = 100 \text{ A},$$
$$I_a = 102 \text{ A}$$

Drop in series field winding = $102 \times 0.06 = 6.12$ V



(a)
$$I_a^2 R_a = 102^2 \times 0.05 = 520.2 \text{ W}$$
$$\text{Series field loss} = 102^2 \times 0.06 = 624.3 \text{ W}$$
$$\text{Shunt field loss} = 4 \times 110 = 440 \text{ W}$$
$$\text{Total Cu losses} = 520.2 + 624.3 + 440 = \mathbf{1584.5 \text{ W}}$$

(b)
$$\text{Output} = 22{,}000 \text{ W} ; \text{Input} = 22{,}000/0.88 = 25{,}000 \text{ W}$$
$$\therefore \quad \text{Total losses} = 25{,}000 - 22{,}000 = 3{,}000 \text{ W}$$
$$\therefore \quad \text{Iron and friction losses} = 3{,}000 - 1{,}584.5 = \mathbf{1{,}415.5 \text{ W}}$$

(c)
$$T \times \frac{2\pi N}{60} = 25{,}000$$
$$T = \frac{25{,}000 \times 60}{1{,}000 \times 6.284} = \mathbf{238.74 \text{ N-m}}$$

Problem # 2

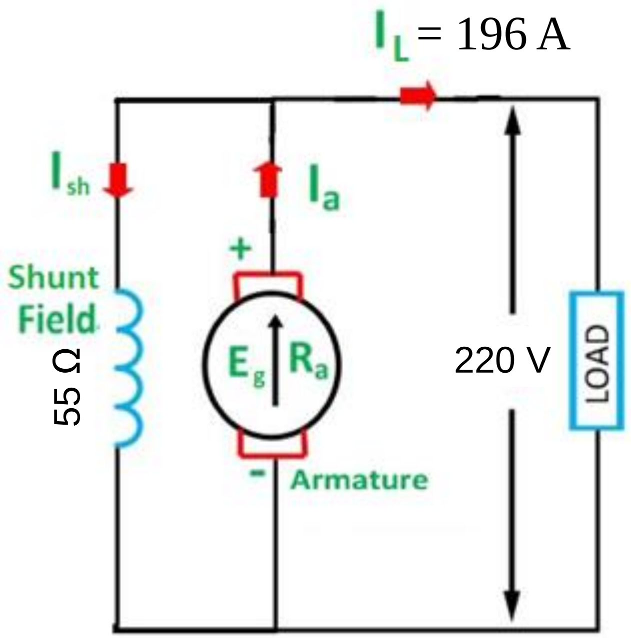
A shunt generator has a full load current of 196A at 220V. The stray losses are 720W and the shunt field coil resistance is 55 Ω. It has a FL (full load) efficiency of 88%. Find i) Armature resistance ii) current corresponding to maximum efficiency.

Total loss = Stray loss + Cu loss

Cu loss = Armature Cu loss + shunt field loss

I_{sh} = 220/55 =4 A

I_a = 196 + 4 = 200 A



Armature Reaction

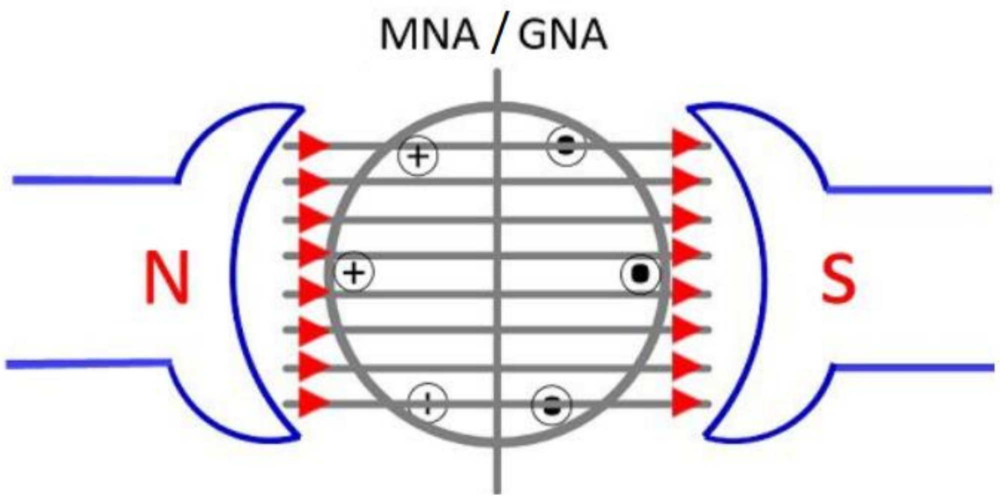
- ✓ The effect of magnetic field set up by the armature current on the distribution of main pole flux.

- ✓ It has two effects :

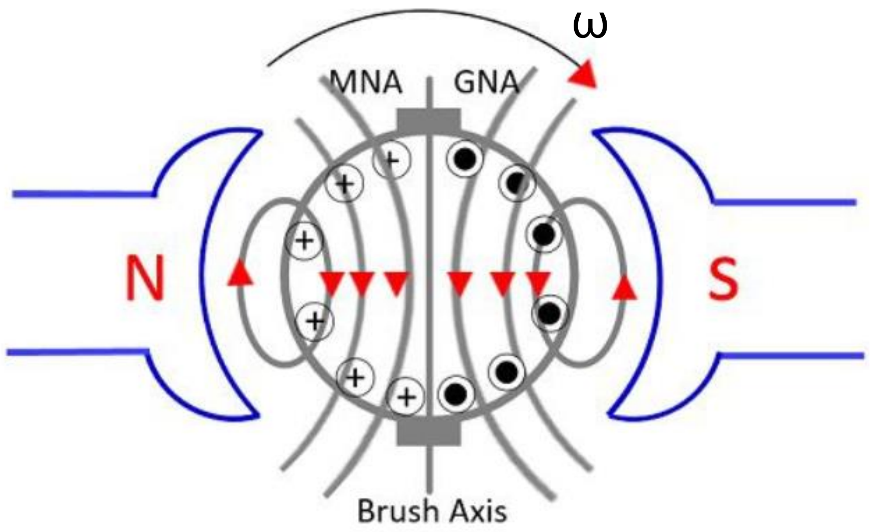
  i. It demagnetises or weakens the main flux

  ii. It cross-magnetizes or distorts the flux

Geometric Neutral Axis (GNA)
&
Magnetic Neutral Axis (MNA)

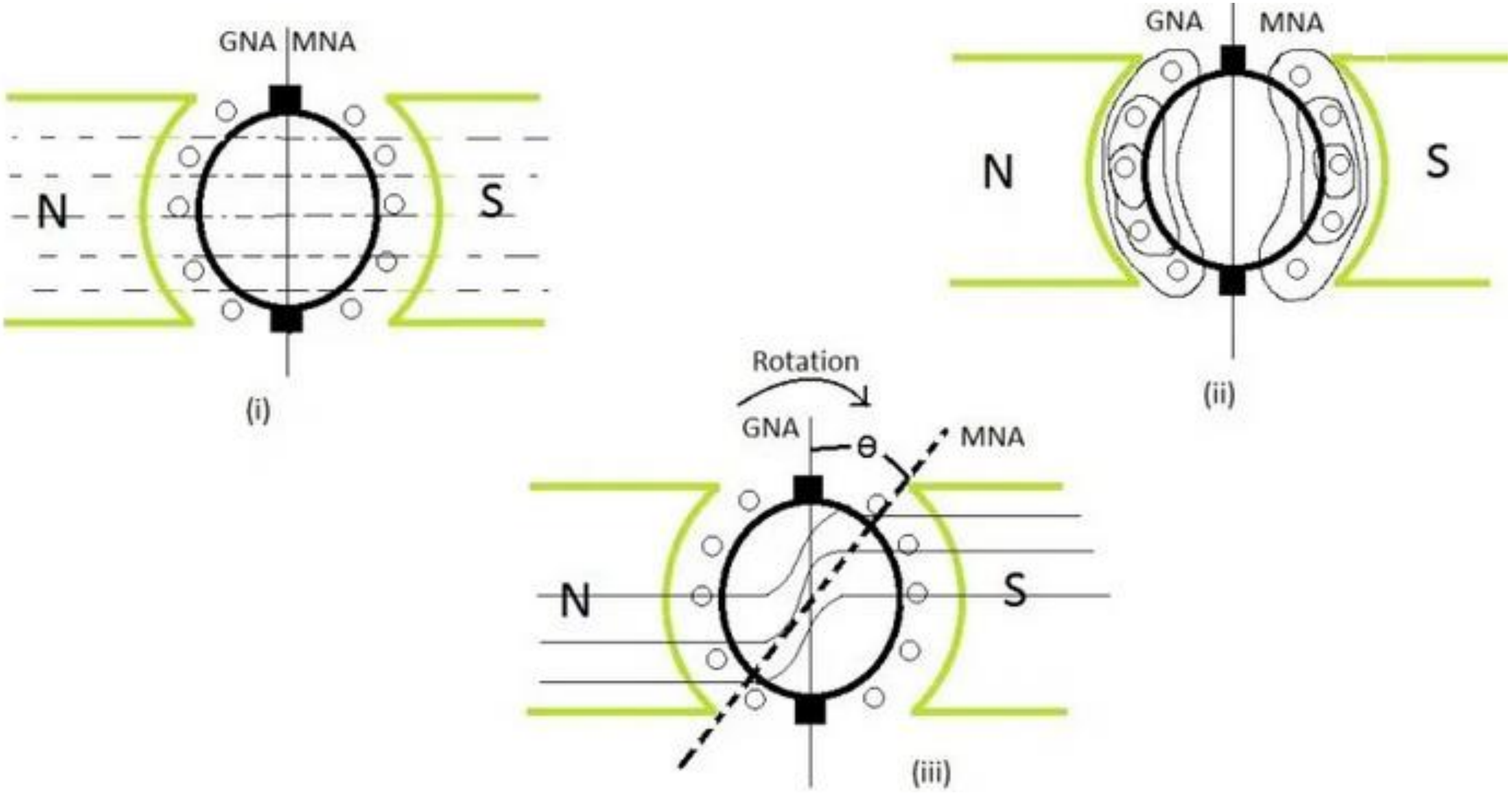


Flux due to poles only

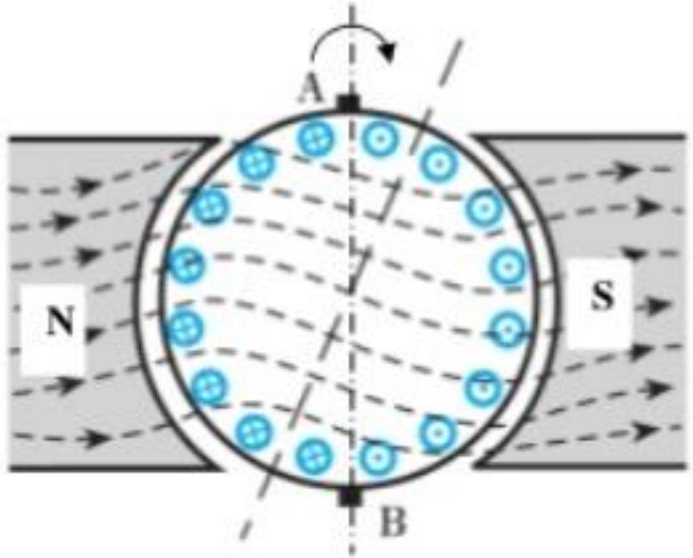


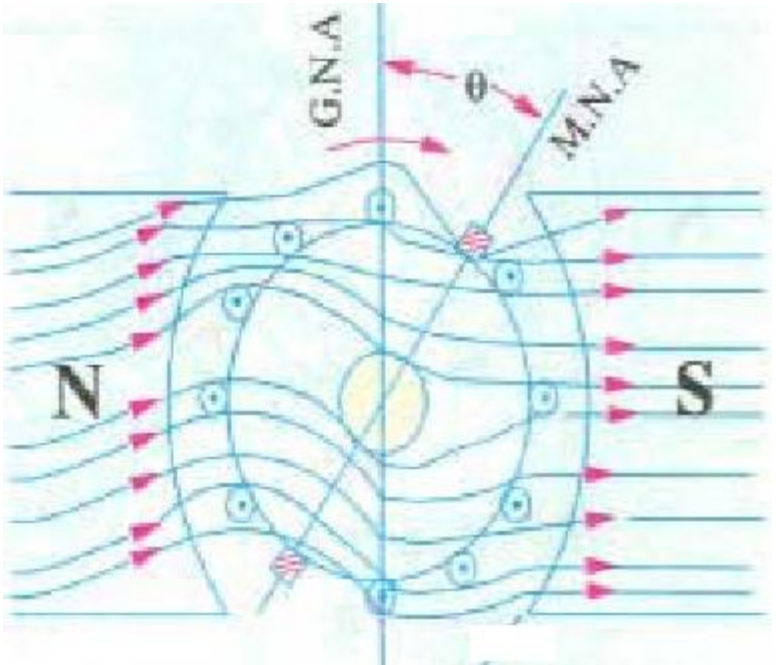
Flux due to armature current only

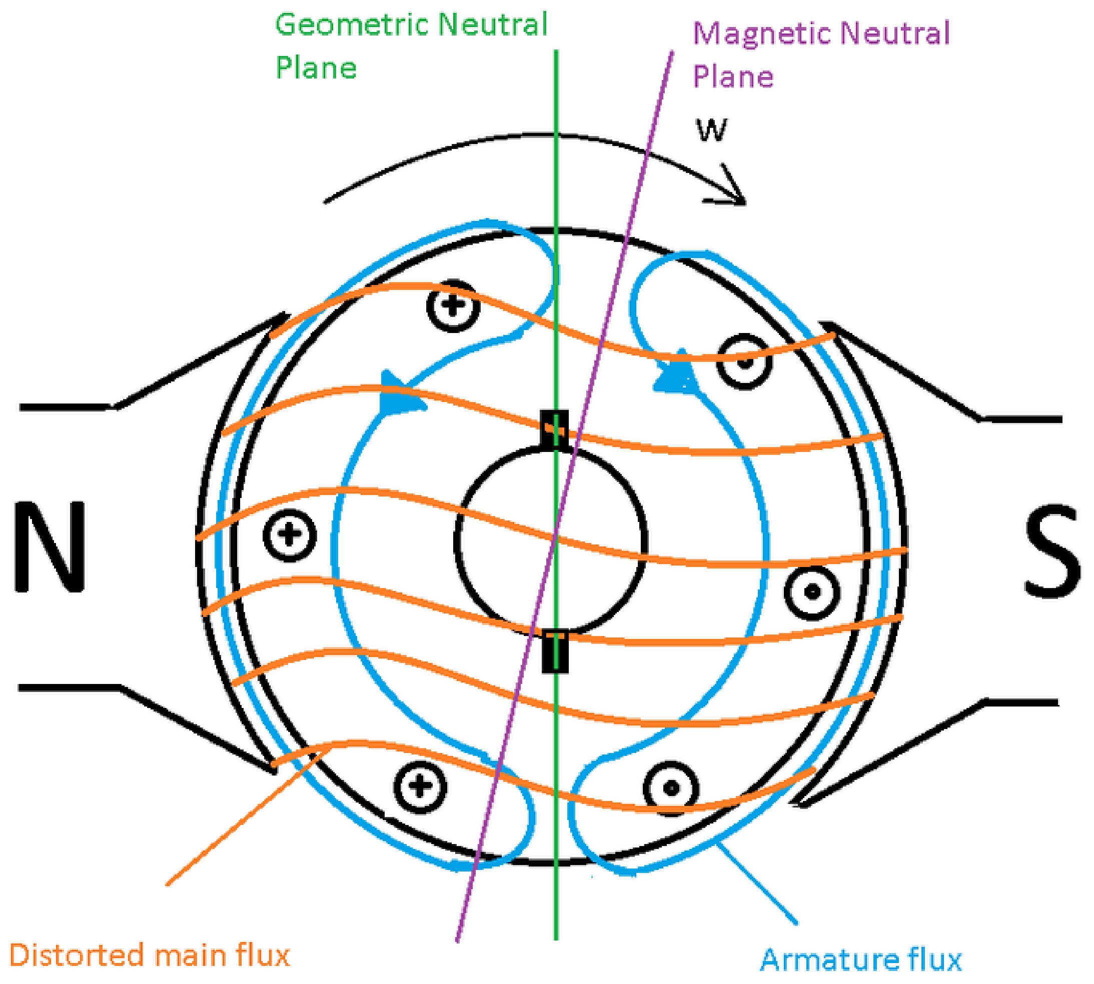
Armature Reaction



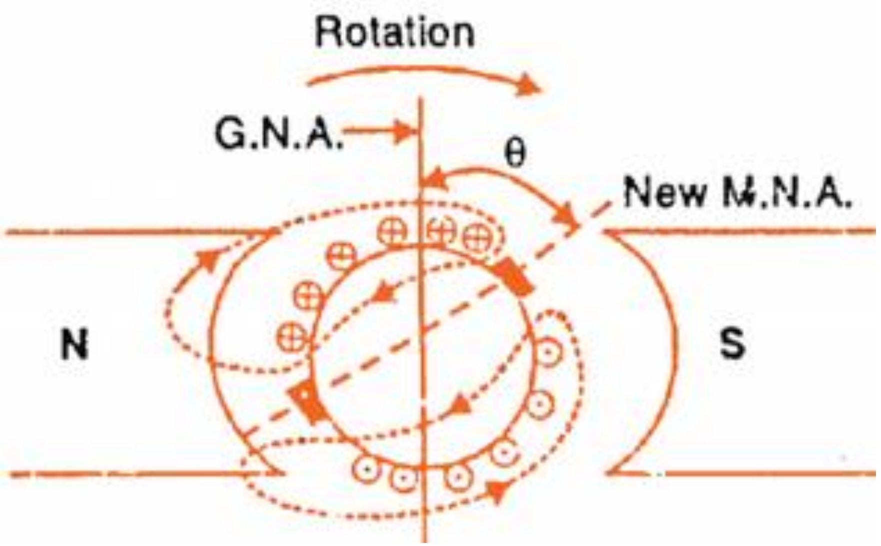
Resultant Flux

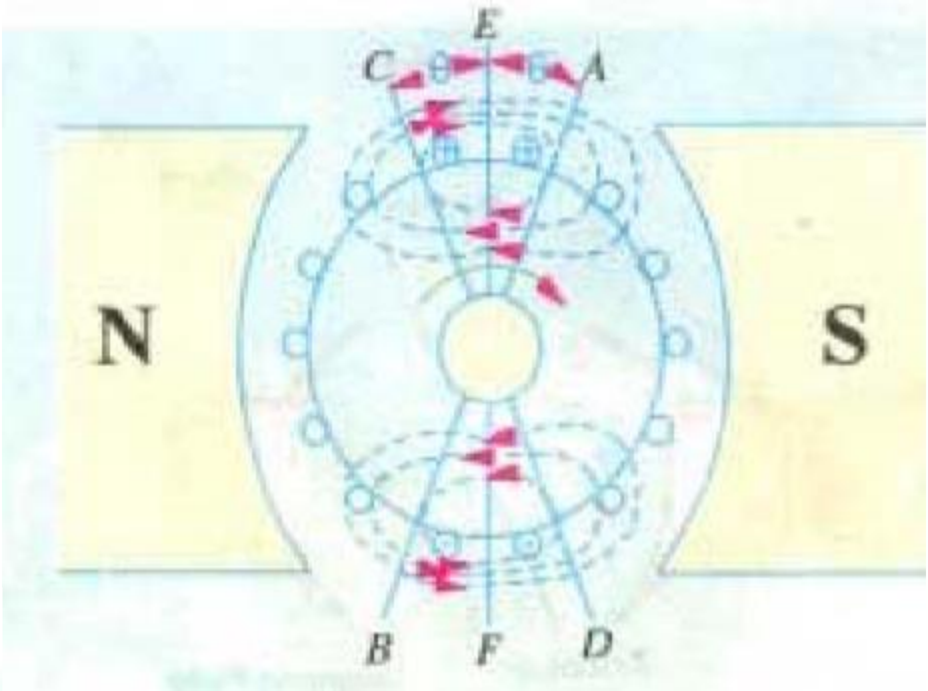


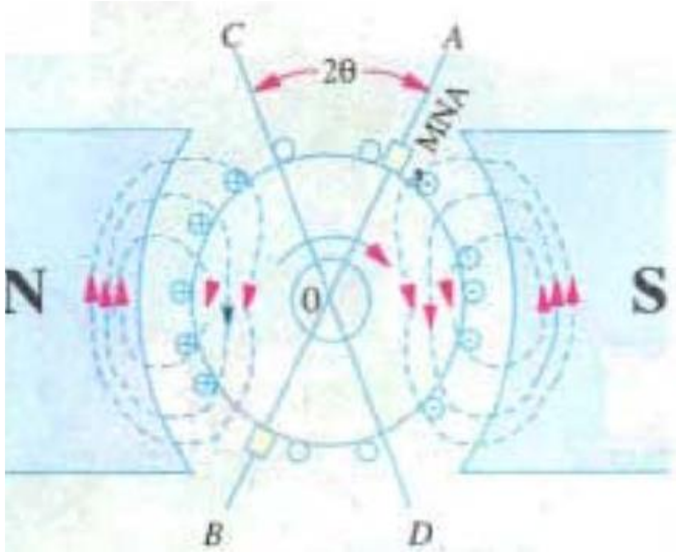




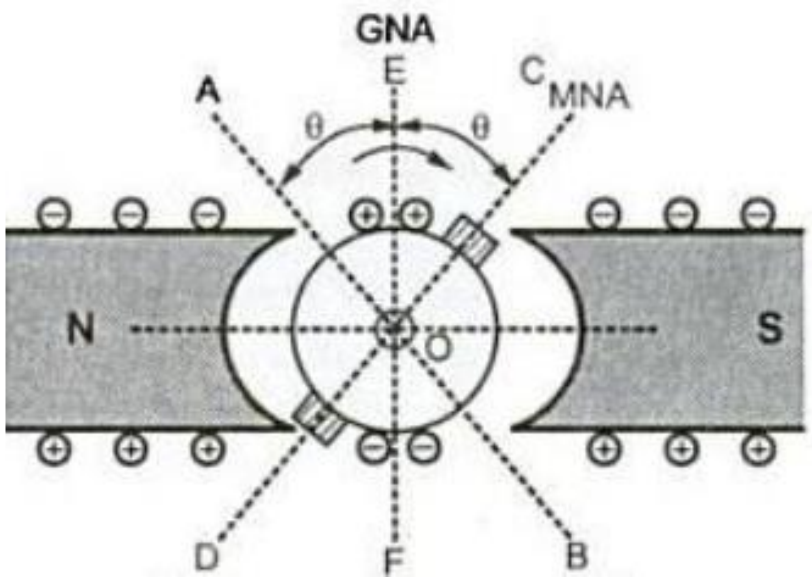
Demagnetizing & Cross-magnetizing conductors

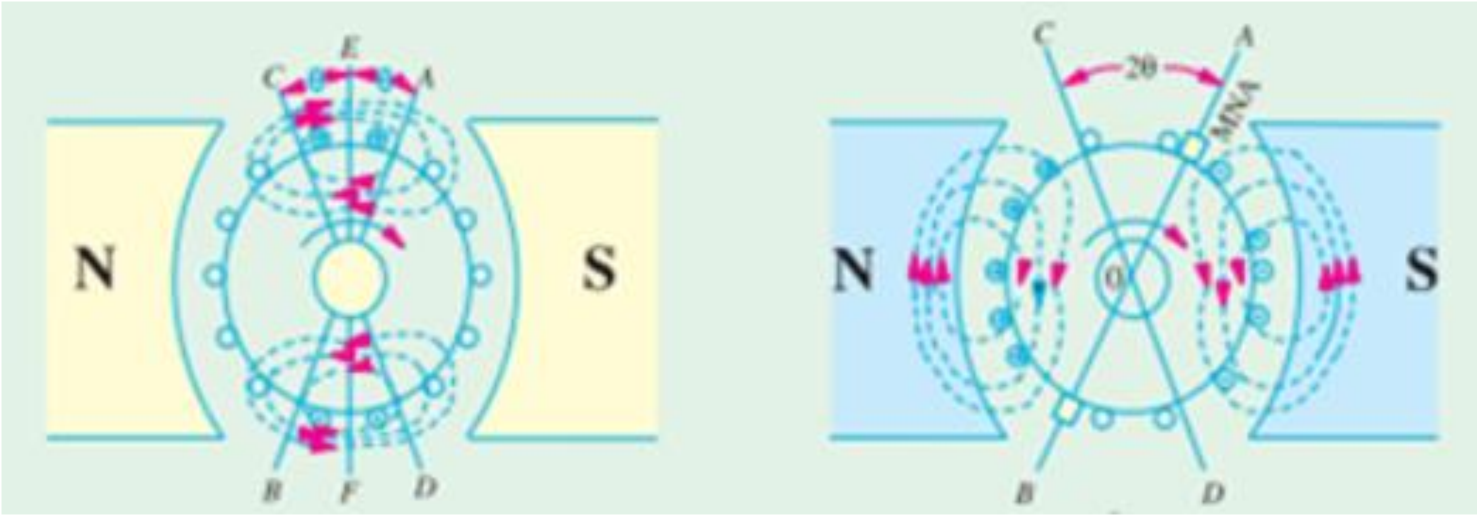






Demagnetizing & Cross-magnetizing conductors





Demagnetizing Effect

Let

Z = Total number of armature conductors

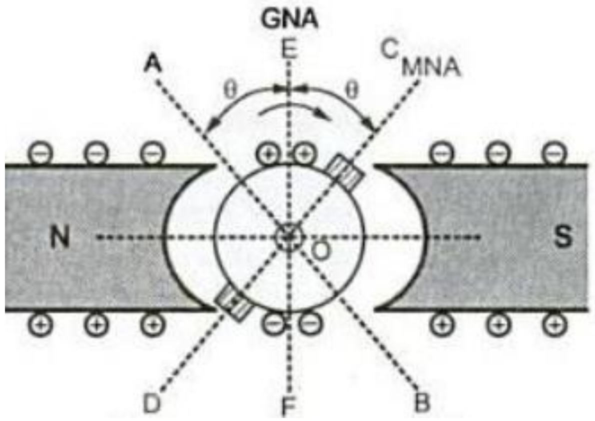
P = Number of poles

I = Armature conductor current in Amperes

= $I_a/2$ for simplex wave winding

= I_a/P for simplex lap winding

θ_m = Forward lead of brush in mechanical degrees.



Total number of armature conductors lying in angles AOC and BOD $= \frac{4\theta_m}{360} \times Z$

Since two conductors from one turn, **Total number of turns in these angles** $= \frac{1}{2} \cdot \frac{4\theta_m}{360} \times Z = \frac{2\theta_m}{360} \times Z$

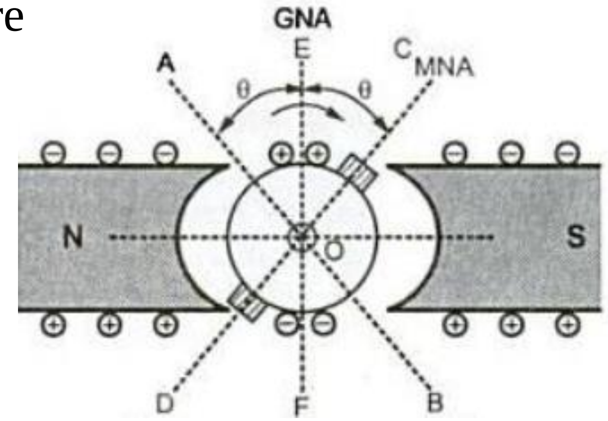
$$\text{Demagnetising amp-turns} = \frac{2\theta_m}{360} \times IZ$$

$$\text{Demagnetising amp-turns / pole} = \frac{\theta_m}{360} \times IZ$$

$$\boxed{AT_d \text{ per pole} = ZI \times \frac{\theta_m}{360}}$$

Cross-magnetizing Effect

The conductor which are responsible for cross magnetizing ampere turns are lying between the angles AOD and BOC, as shown in the Fig.



Total armature-conductors / pole = Z/P

$$\text{Demagnetising conductors / pole} = Z = \frac{2\theta_m}{360}$$

$$\text{Cross magnetising conductors/pole} = \frac{Z}{P} - Z\frac{2\theta_m}{360} = Z\left[\frac{1}{P} - \frac{2\theta_m}{360}\right]$$

$$\text{Cross magnetising amp-conductors / pole} = ZI\left[\frac{1}{P} - \frac{2\theta_m}{360}\right]$$

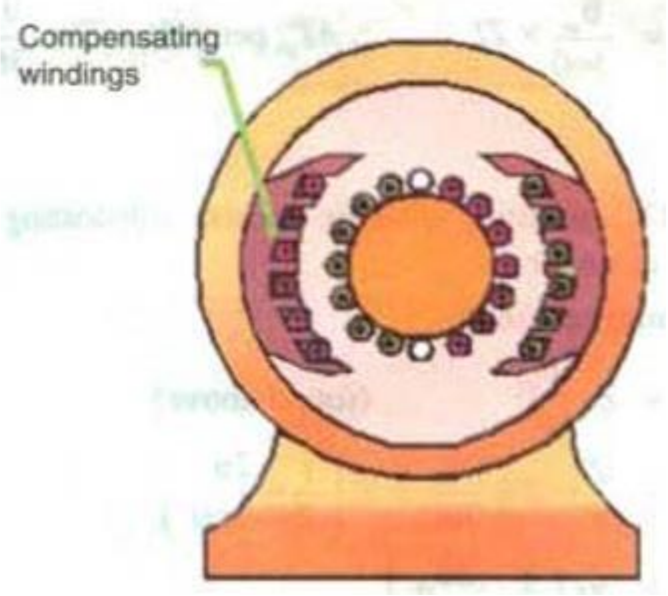
Since two conductors from one turn,

$$\text{Cross magnetising amp-turns / pole} = \frac{1}{2} \cdot ZI\left[\frac{1}{P} - \frac{2\theta_m}{360}\right] = ZI\left[\frac{1}{2P} - \frac{\theta_m}{360}\right]$$

$$\boxed{AT_c \text{ per pole} = ZI\left[\frac{1}{2P} - \frac{\theta_m}{360}\right]}$$

Remedy for De/Cross-Magnetizing Effect

- ✓ Demagnetizing effect ⇒ Additional field turns
- ✓ Cross-Magnetizing effect ⇒ Compensating winding



Compensating winding

Compensating Winding (CW)

- Windings are embedded in slots in the pole shoe and are connected in series with the armature.
- Used for large DC machines which are subject to large fluctuations in load.
- In the absence of compensating winding, the flux will be shifting forward and backward with every change in load.
- This change in flux causes statically induced emf in armature coil and thus result in sparking between commutator segments.

Problem # 3

A 4-pole generator has a wave-wound armature with 722 conductors, and it delivers 100 A on full load. If the brush lead is 8°, calculate the armature demagnetising and cross-magnetising ampere turns per pole.

$$I = I_a/2 = 100/2 = 50\text{A};\ Z = 722;\ \theta_m = 8^\circ$$

$$\text{AT}_d/\text{ pole} = ZI.\frac{\theta_m}{360} = 722 \times 50 \times \frac{8}{360} = 802$$

$$\text{AT}_c/\text{ pole} = ZI.\left(\frac{1}{2P} - \frac{\theta_m}{360}\right)$$

$$= 722 \times 50\left(\frac{1}{2 \times 4} - \frac{8}{360}\right) = 3718$$

Problem # 4

A 4-pole generator supplies a current of 143 A. It has 492 armature conductors (a) wave-wound (b) lap-wound. When delivering full load, the brushes are given an actual lead of 10°. Calculate the demagnetising amp-turns/pole. This field winding is shunt connected and takes 10 A. Find the number of extra shunt field turns necessary to neutralize this demagnetisation.

$$Z = 492\ ;\ \theta_m = 10°\ ;\ AT_d/\text{pole} = Z I \times \frac{\theta_m}{360}$$

$$I_a = 143 + 10 = 153\text{ A}\ ;\ I = 153/2 \quad \text{(wave winding)}$$

$$= 153/4 \quad \text{(Lap winding)}$$

(a) $\therefore AT_d/\text{pole} = 492 \times \frac{153}{2} \times \frac{10}{360} =$ **1046 AT**

Extra shunt field turns = 1046/10 = **105 (approx.)**

(b) $AT_d/\text{pole} = 492 \times \frac{153}{2} \times \frac{10}{360} =$ **523**

Extra shunt field turns = 523/10 = **52 (approx.)**