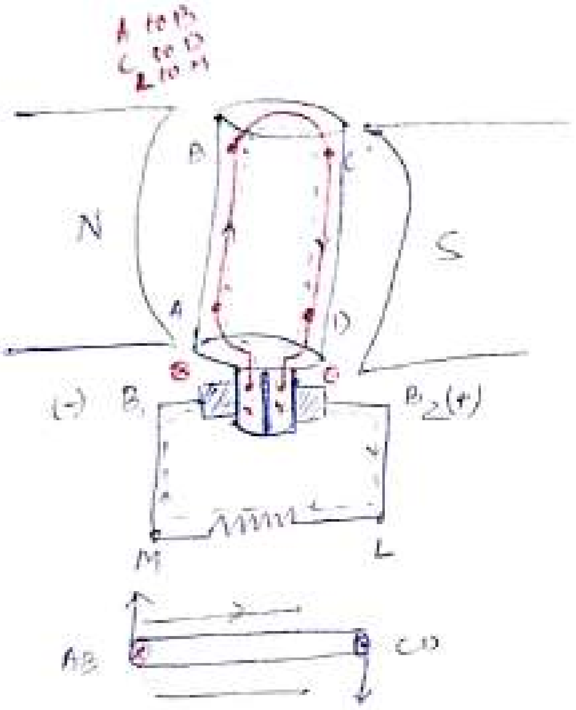
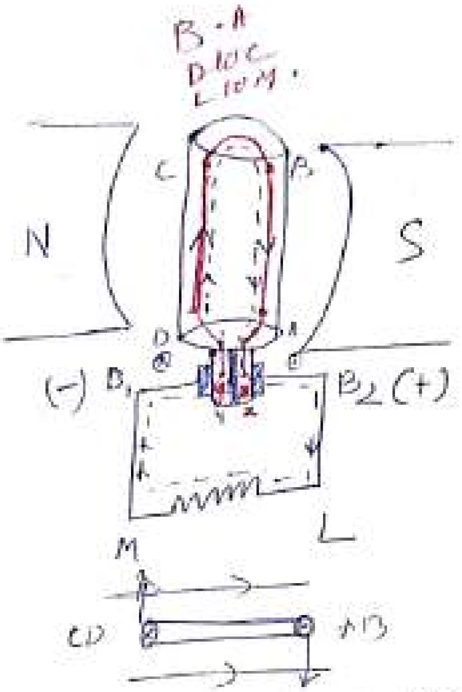
D·C MACHINES

D·C Generator = synchronous generator + commutator

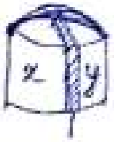
D·C Motor = synchronous motor + commutator





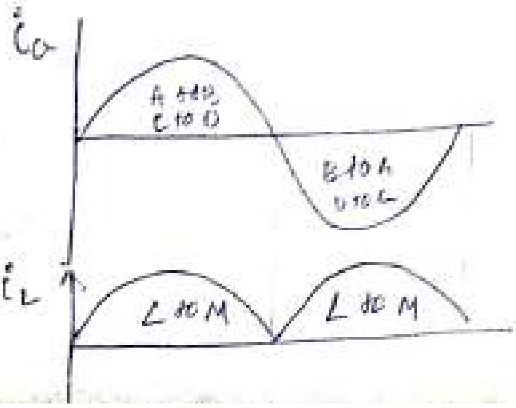
1.

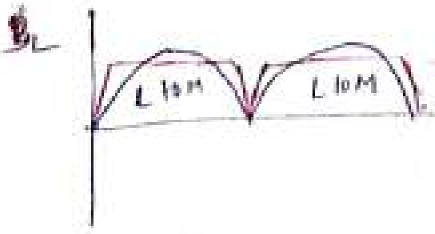
In ac generator induced emf inside of armature is a.c. in load also a.c. In dc generator ac is in armature conductor can be converted dc in load ckt by using the ~~[illegible]~~ split rings



mica insulation.

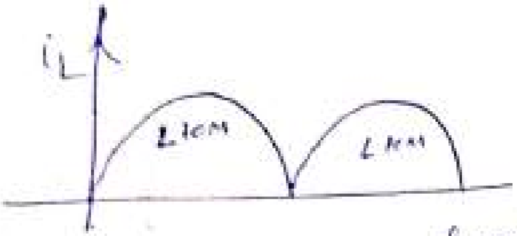
AB always connected to x (welded)
CD " " to y
But B_1 in fig 1 is connected to x, & fig two 2 it is connected to y



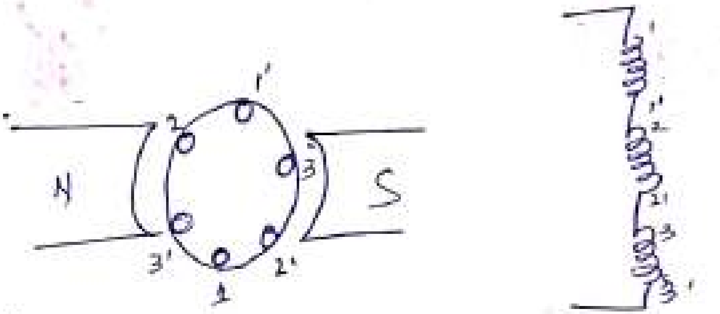


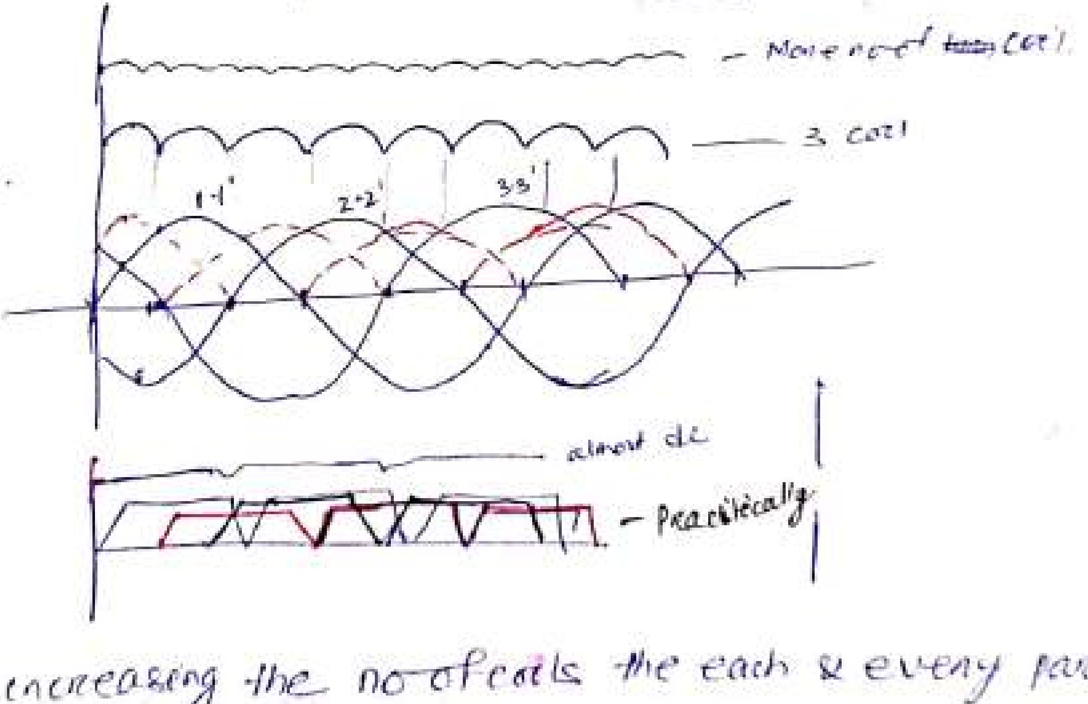
Practically E_L flat topped wave, E_L to i_L also flat topped means in E_L also i_L is almost constant so it's [illegible]

The commutator converts AC in the armature conductor to dc in load ckt therefore in dc generator the commutator behaves as mechanical rotating full wave rectifier.



By connecting more no of coil in series the o/p voltage can be improved.

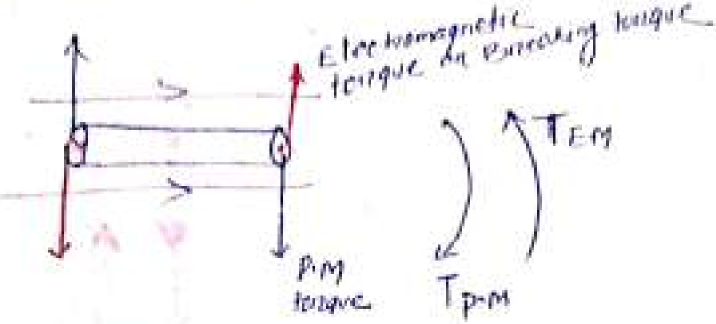




By increasing the no of coils the each & every parallel path connected in series the dc ripple in the generated voltage can be reduced.

In dc machine always salient poles are used & no chamfering is required, the flux distribution is flat topped wave, induced emf also flat topped wave.

No need to eliminate the harmonic such that more avg value of generated voltage.



$$P_m = T_{PM} \times \omega$$

$$P_{ele} = T_{em} \times \omega$$

$$T_{PM} = \frac{J\,d\omega}{dt} + B\cdot\omega + T_{em}$$

$$T_{P.M} = \underset{\text{Inertia torque}}{T_I} + \underset{\text{damping torque}}{T_B} + T_{em}$$

under steady state condition (i.e ω = constant) $T_I = 0$

so under steady state condition

$$T_{PM} = B\cdot\omega + T_{em}$$

$$\boxed{\omega = \frac{T_{P.M} - T_{e.m}}{B}}$$

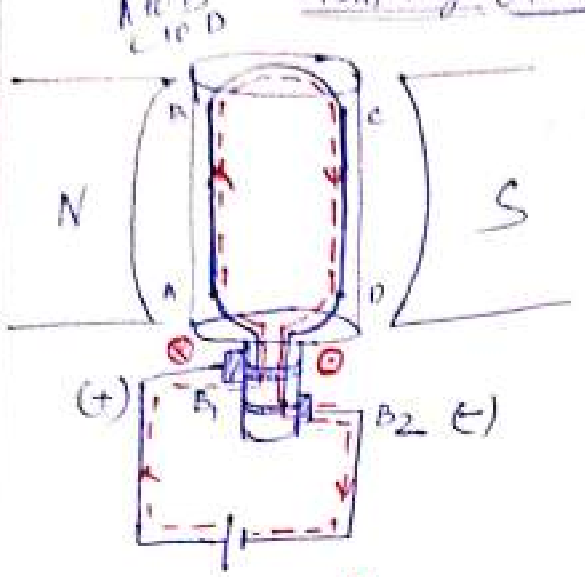
$T_{em} \propto \phi I_a$, when load increases I_a will increase

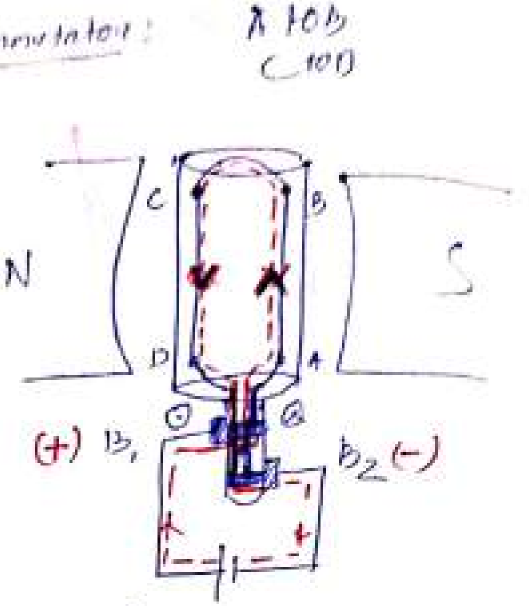
so $T_{e.m}$ will increases, so speed will decreases.

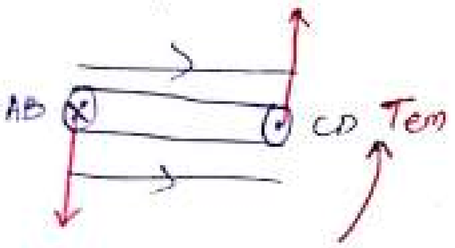
$f = \frac{PN}{120}$ f = frequency of induced emf in the armature winding

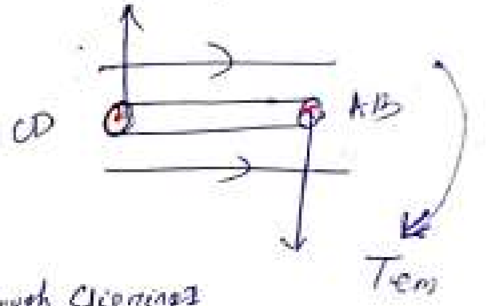
D·C MOTOR:- (Commutator action)

using slipring without commutator:









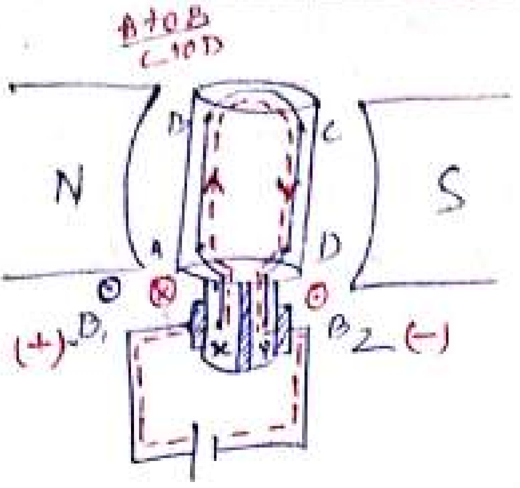
Here always B₁ connected to AB through Sliprings

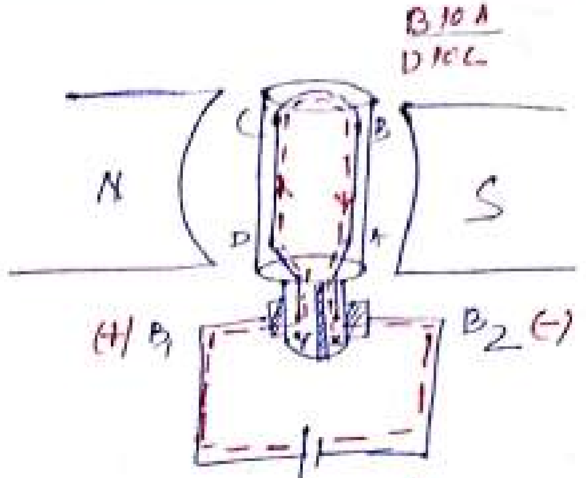
If the dc is directly given to the armature winding through the ~~wen~~ Slipring the avg torque is zero that means the rotor ~~would~~ would not rotate.

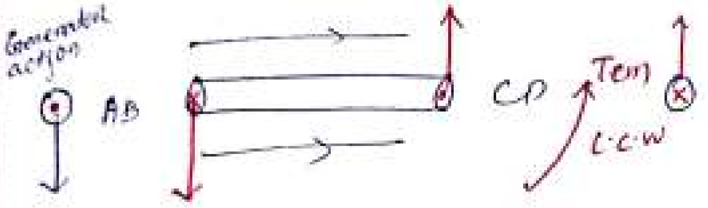
for production of unidirectional torque current in the conductor which existing under N pole must be ⊗ the current in conductor under S pole must be ⊙ for counter clockwise torque.

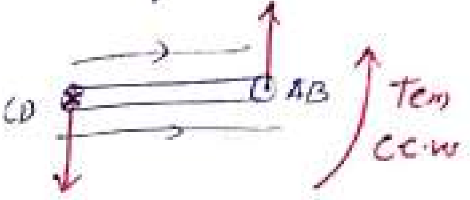
It means when the conductor AB existing under N pole the current must be ⊗ leaving, while it is under S pole current must be ⊙ i.e B→A. that means for every half of revolution the current must be reversed for production of unidirectional torque

This can be accomplish by replacing the Slip ring with split ring i.e commutator segment



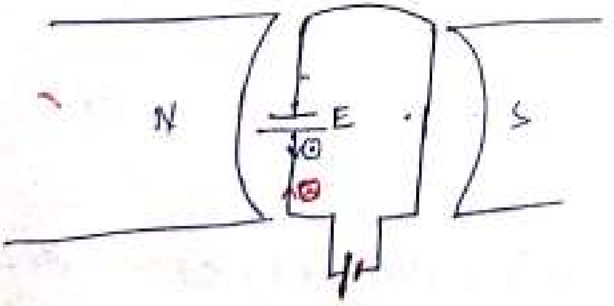






The commutator converts dc to ac in the armature conductor therefore commutator behaves as mechanical rotating inverter. Always ct in conductor under N pole is inward (x) & ~~ot~~ dot (·) under S pole always for c.c.w torque ∴ so unidirectional torque produced.

Due to generator action in motor:-



=

produced due to Net voltage (V - E)

As V > E

Sol = clean

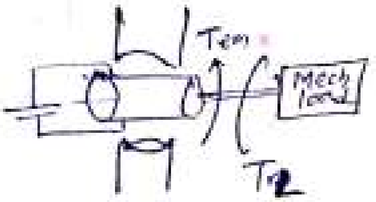
$$I_a = \frac{V - E_b}{R_a}$$

$$= \boxed{V = E_b + I_a R_a}$$

$P_e = V \times I_a$

$P_{mech} = E \times I_a$ (Electrical eq of mech power)

In motor also generator action takes place. due to motor action the armature rotates, armature conductor cut the flux & an emf is induced according to faraday's law. This induced emf is always in phase opposition with the supply voltage therefore it can be called as back emf. The supply voltage always being opposed by back emf. This back emf opposition converted to mechanical power according to energy conservation.



$$T_{em} = J\frac{d\omega}{dt} + B\cdot\omega + T_L$$

J → moment of inertia

B → viscous friction coefficient

under steady state condition $J\frac{d\omega}{dt} = 0$

$$T_{em} = B\cdot\omega + T_L$$

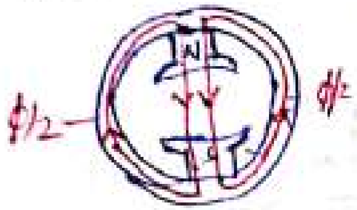
$$\boxed{\omega = \frac{T_{em} - T_L}{B}}$$

for a particular Tem if load increases speed decreases.

Construction of D.C Machine :-

1. Magnetic frame or Yoke
2. Field/pole core and pole shoe
3. Armature core
4. Armature winding
5. Commutator
6. Brushes.

Magnetic frame or YOKE

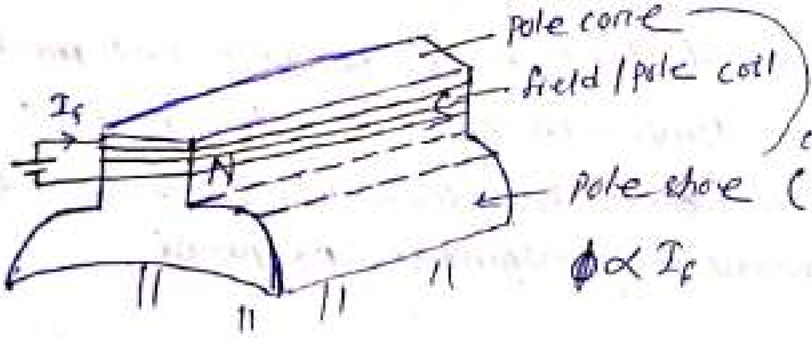


→ It is made with cast-iron for small m/c and cast steel for large m/c.

→ It acts as protecting cover for entire m/c. It gives the mechanical support to field poles

→ It provides the return path for magnetic ckt.

Pole core & pole shoe



$\phi \propto I_f$

Bothe pole core & pole shoe made with cast steel or Silicone steel laminatations are required for large m/c but for small m/c no laminations are required.

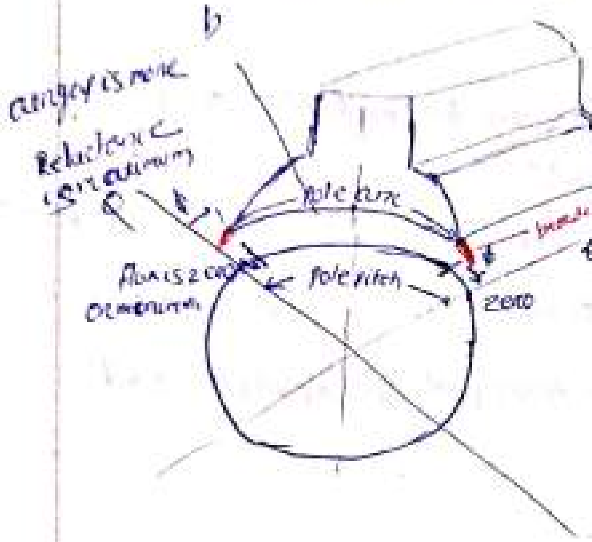
Functioning of pole core :- It accomodate the field winding, when the field winding is exccited it behaves as magnet & produces the flux.

Functioning of pole shoe :- ① Gives the mechanical support for field winding.

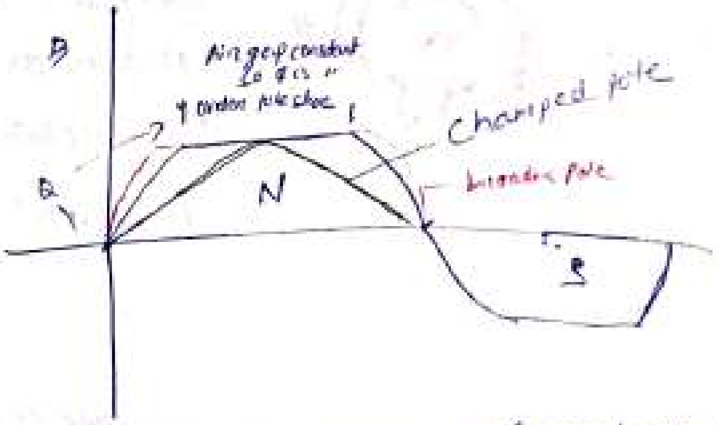
② It reduces the magnetic reluctance due to enlarged area.

③ It distribute the flux uniformly in the air gap.

Pole core is ~~lamminatted~~ lamminated. It is given dc ~~but~~ still it requires lamination bcoz it may be supplied from some power electronics device where supply is not pure dc.



* Flux distribution in dc m/c is a flat topped wave (or) trapizoidal wave

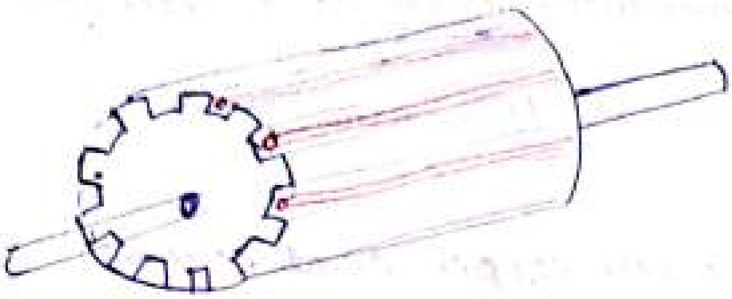


In flat topped avg value of flux is more so more emf ~~pret~~ induced in (generator) & more torque in case of motor produced. But in AC m/c flux wave required to be sinusoidal for sinusoidal emf but here it is not required, only magnitude required.

$$\frac{\text{Pole arc}}{\text{Pole pitch}} = .7$$

In dc m/c flat topped wave is prefered. bcoz more avg value of flux therefore more generated voltage, more torque. In dc m/c broader pole shoe are preferred such that avg value of flux increased. The pole shoe (pole arc) covers 70% of the pole pitch.

(c) Armature core:-



Armature core is made with Silicon steel & laminated to reduce the eddy current loss.

Functioning :-

① It houses the armature winding

② It provides low reluctance path to the magnetic ~~path~~ flux as it is made of good magnetic material.

Winding is normally double layer.

$\downarrow \phi_L = \frac{mmf}{Rel \uparrow}$ ← leakage flux is less

$\downarrow L = \frac{N\phi_L \downarrow}{\phi_l}$

$\downarrow$ Inductance is decrease

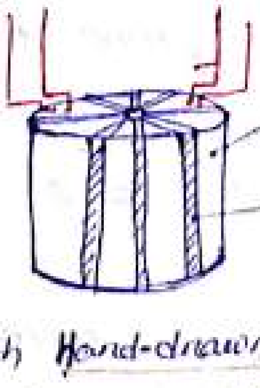
so reactance ~~is less~~ voltage $\downarrow e_L = \downarrow L \frac{di}{dt}$ is less

so commutation is improved.

Sometimes in large m/c slots are skewed to reduce the vibration.

Overall:- In dc m/c open slots are prefered ~~to~~ with this leakage flux is reduce, leakage inductance is reduce, reactance voltage is reduce hence commutation is improved. In dc m/c the armature slots are skewed to reduce the vibration.

Commutator :-



mica insulation of 0.5mm thickness → dielectric strength - (30-40)V

→ Commutator is made with Hard-drawn copper to reduce wear & tear.

→ No of commutator segments = no of coil.

Brushes :-

Function: To collect the current from armature conductor through the commutator segment in generator.

or

To give the current to armature conductor in the motor

⇒ Brushes are made with copper or ~~ch~~ carbon for small m/c (1kW) But they are made with Electrographite for normal rating even large m/c. (6 kW)

Made with - carbon graphite for large current low voltage

Carbon + more resistance - so commutation improved.

→ thermal stability.

→ polishing in nature → frictional is less.

Small rating - Interpole not

For small m/c carbon brushes are preferred over copper brush due to following advantage.

① Carbon has more resistance therefore it improve commutation.

② It has more thermal stability therefore can withstand even at high temp. i.e during sparking.

③ It is polishing in nature therefore less friction betn brush & commutator segment, hence life of commutator is more & frictional losses at brushes is reduce.

Dis advantage :-

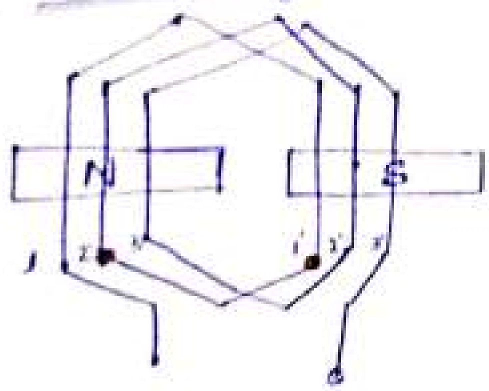
① The brush copper loss are more due to it's more resistance.

② Voltage drop is more 1 V per brush

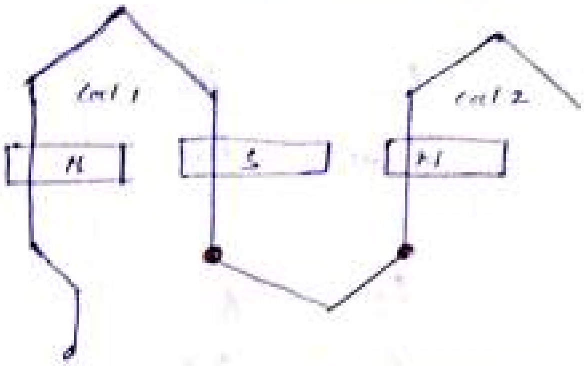
Armature winding :-

1. Lap winding
2. Wave winding

1. Lap winding



Wave winding



⇒ Finishing end of one coil is connected to begining of adjacent of other coil under one pole.

⇒ The no of parallel path in multiplex lap winding $A = m \times P$

$m \Rightarrow$ plex

$m = 1$ simplex winding

$m = 2$ duplex winding

$m = 3$ Triplex winding.

⇒ Generally in DC m/c simplex winding is more common therefore no of ll path

lap winding = $A = P$ $m = 1$

⇒ The finishing end of one coil is connected to the begining end of other coil under the adjacent simillar pole

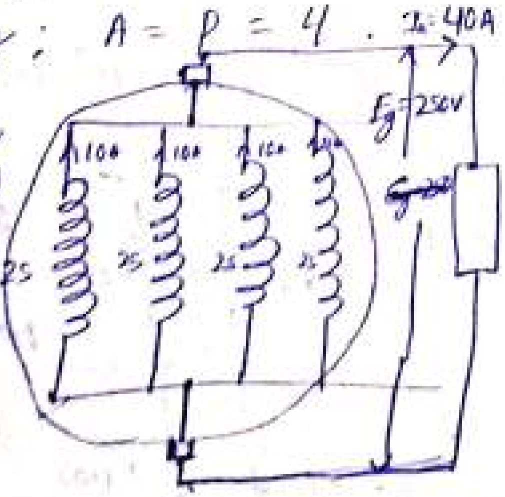
⇒ No of parallel ~~paral~~ path in multiplex wave winding $A = 2 \times m$

⇒ for wave wound m/c $A = 2$.

Ex A 4 ~~ople~~ pole dc m/c the no of conductor $Z = 100$ emf/cond = 10V

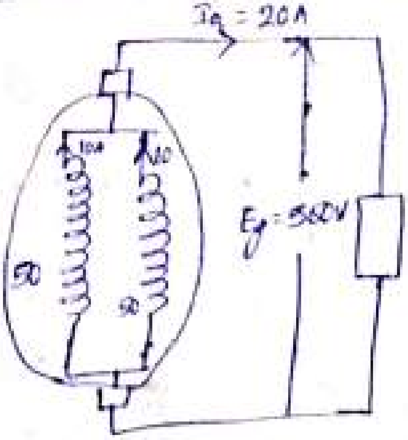
lap winding ; $A = P = 4$.

Current rating of winding is 10A range are selected like that.



$P = E_g \times I_a = 250 \times 40 = \underline{10\ kW}$

wave winding $A = 2$

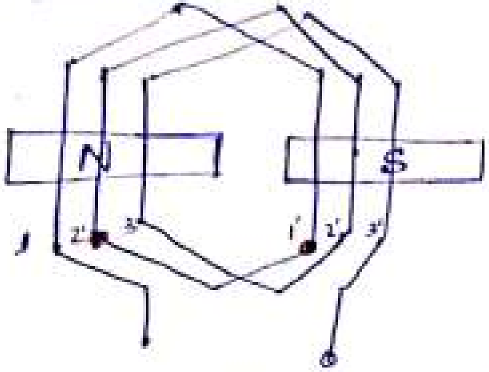


$P = E_g I_a = 500 \times 20 = \underline{10\ kW}$

Armature winding :-

1. Lap winding
2. Wave winding

1. Lap winding :-



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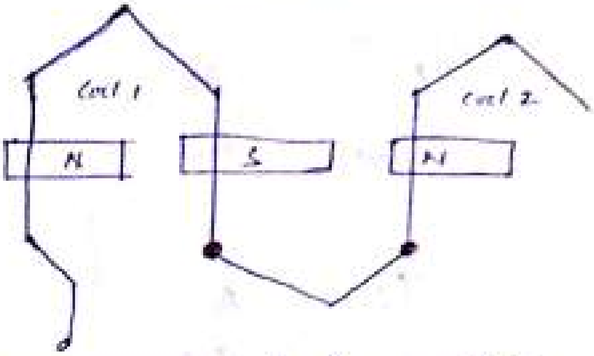
Wave winding



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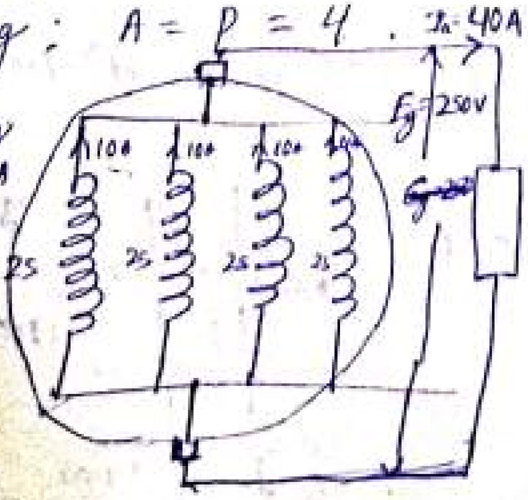
lap winding = $A = P$ $m = 1$

→ for wave wond m/c $A = 2$.

Ex A 4 pole dc m/c the no of conductor $Z = 100$ emf cond = 10 V

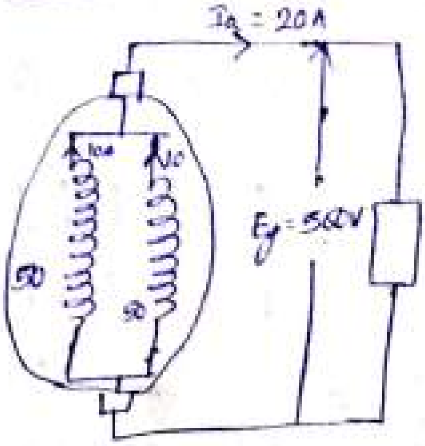
lap winding ; $A = P = 4$.

Current rating of winding is 10A they are selected like that.



$P = E_g \times I_a = 250 \times 40 = \underline{10\,kW}$

wave winding $A = 2$



$P = E_g I_a = 500 \times 20 = \underline{10\,kW}$

In both case power rating same.

lap
It is used for large current ratings
low voltage m/c

wave more no of conductor are [illegible]
It is used for large voltage
& low current m/c

$$\boxed{\begin{array}{c} \frac{E_L}{E_W} = \frac{A_W}{A_L} \\ \\ \frac{I_L}{I_W} = \frac{A_L}{A_W} \\ \\ P_L = P_W \end{array}}$$

Q. A six pole dc m/c the ratio of voltages for lap connection & wave connection respectively

[✓ a)] 1:3 b) 3:1 c) 1:1 d) 1:2

$$\frac{E_L}{E_W} = \frac{A_W}{A_L} = \frac{2}{6} = \frac{1}{3}$$

$$E_L : E_W = 1:3$$

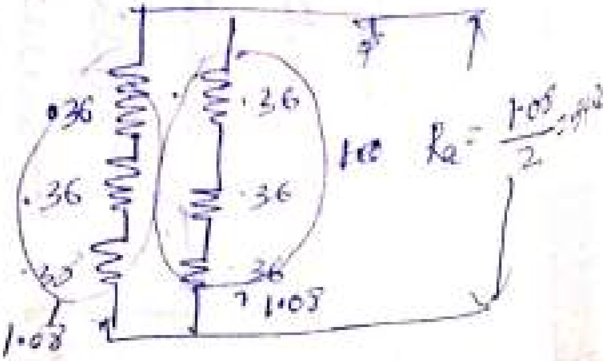
Q) A ~~est~~ lap connected 6 pole dc m/c has its armature resistance of 0.06 Ω if the m/c is reconnected for wave winding then the armature resistance is

a) 0.06 Ω b) 0.36 Ω [✓ c)] .54 Ω d) 1.08 Ω

& Ra = 0.06

$$R_a = \frac{R_P}{6} = 0.06$$

$$R_P = 0.06 \times 6 = .36$$

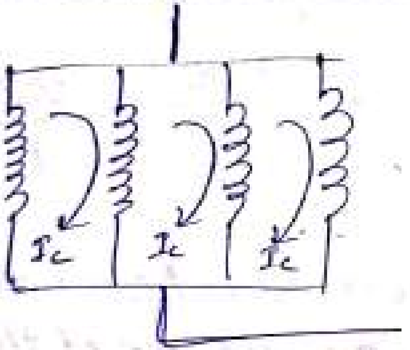


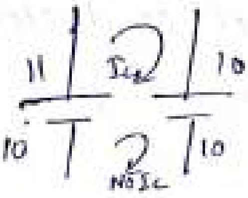
I.e. $R_a = \frac{1.08}{2} = .54\Omega$

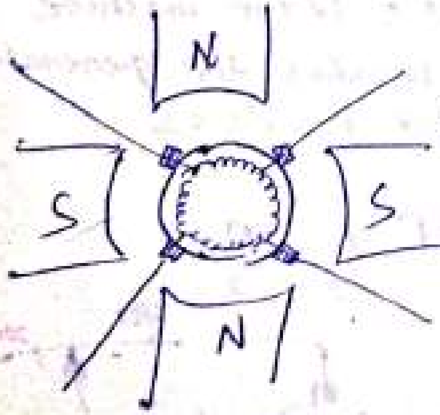
Lap winding is called complete winding. after the completion of the winding all the slots w are fillupad with armature winding no slot is left empty.

Wave winding is called incomplete winding bcoz after the completion of winding some slots are left empty. The empty slots are fillup with dummy coil for mechanical balance. There fore dummy coil exist only in the wave winding but not in lap winding. These dummy coils are although similar to other coil but they are short ckted & not electrically connected with the armature winding, they exist physically but no electrical participation.

lap winding **Circulating current :-**

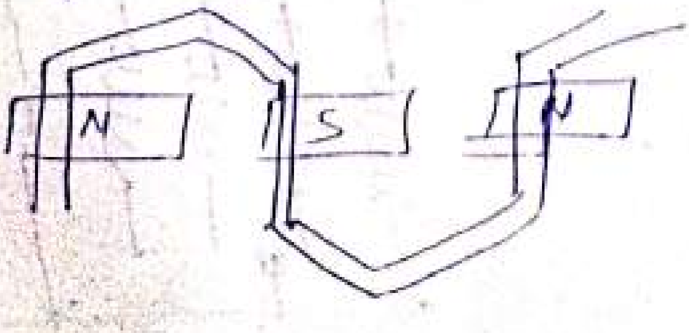






Here one parallel path under one pole.

If flux under each pole not same due to unequal airgap ~~due to any~~ for mechanical reason (for faulty assembly). The emf induced in Each parallel path is not same so may some circulating current exist.



Circulating currents are more in lap winding but no circulating current exist in wave winding. These circulating currents are due to flux unbalances i.e flux under each pole may not equal. therefore induced emf in each parallel path is differe, will result the circulating currents.

But in wave winding the two parallel path are placed under all the poles therefore both paths are equally affected hence no circulating current exist in wave winding.

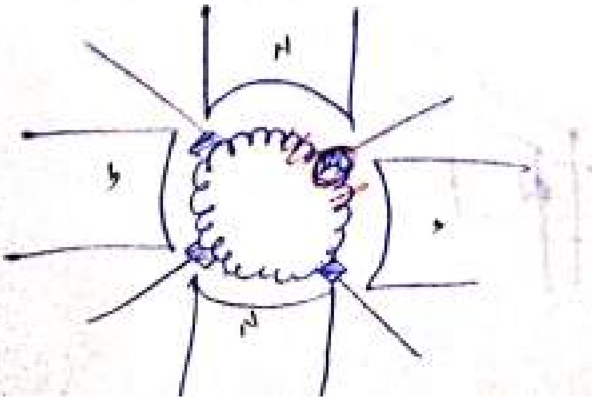
Circulating can be minimised by using the equiliser rings.

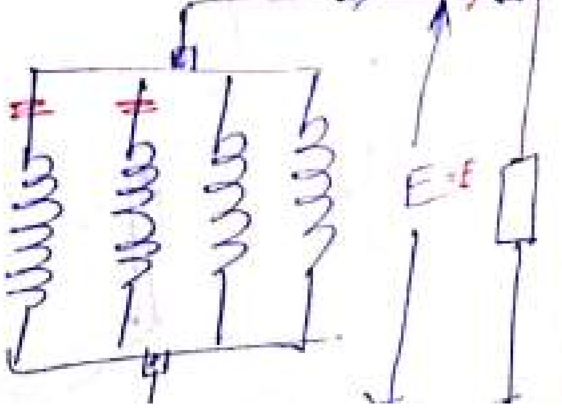
⇒ The maximum no of possible equiliser ring is ~~equal to~~

$$= \frac{\text{no of conductors}}{\text{pair of pole}} = \frac{Z}{\frac{P}{2}} = \frac{2Z}{P}$$

Q In a 4 pole lap connected dc ~~m/c~~ generator the induced emf is E volts, developed power is P watts, one of the brush is removed as it is burn out; If the machine continues to operate with remaining brushes the generated voltage (brush voltage) & developed power is

ⓐ E, P ⓑ $\frac{E}{2}$, P [✓ ⓒ E, $\frac{P}{2}$] ⓓ $\frac{E}{2}$, $\frac{P}{2}$





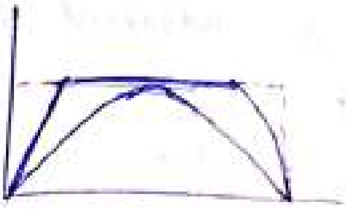
-: EMF EQUATION OF DC MACHINE :-

$$E = 4.44\, k_p k_d \phi f T$$

$= \sqrt{2}\pi\, k_p k_d \phi f T$ Rms value & for Sinusoidal flux distribution.

→ In dc m/c brushes collect the maximum value

∴ flux distribution is a flat topped wave



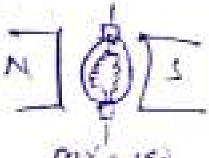
$E = E_{avg} = E_{max} = \sqrt{2} E_{rms} = \sqrt{2} \times \sqrt{2} \pi k_p k_d \phi f T$

$\Rightarrow E = 2\pi k_p k_d \phi f T$

In dc machine the armature winding is a full pitch winding $k_p = \underline{1}$

⇒ Armature winding is uniformly distributed ∴ emf polygon is a circle.

distribution factor : $k_d = \dfrac{\sin\frac{m\gamma}{2}}{\frac{m\gamma}{2} \times \frac{\pi}{180}}$



$m\gamma = 180$

⇒ phase spread due to each parallel path. $m\gamma = \pi$ rad $= 180^\circ$

$$k_d = \frac{\sin \pi/2}{\frac{\pi}{2} \times \frac{\pi}{18}} = \frac{\sin\frac{180}{2}}{\frac{180}{2} \times \frac{\pi}{180}} = \frac{1}{\frac{\pi}{2}} = \boxed{\frac{2}{\pi}}$$

$f = \dfrac{PN}{120}$

If Z → Total no of conductor

⇒ No of turns = $\boxed{\frac{Z}{2} = T}$

⇒ No of turns per parallel path $= \dfrac{\frac{Z}{2}}{A} = \dfrac{Z}{2A}$

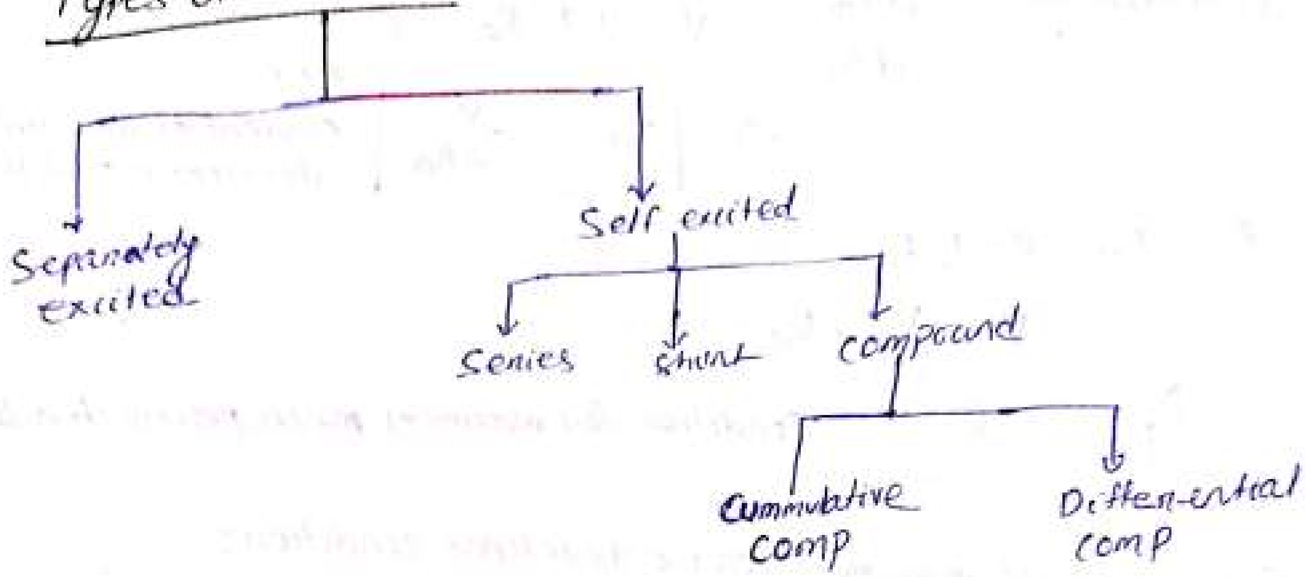
i.e turns per path $= \dfrac{Z}{2A}$

$$E_{path} = \cancel{2}\cancel{\pi} \times 1 \times \frac{2}{\pi} \times \phi \times \frac{PN}{120} \times \frac{Z}{2A}$$

$$E = \frac{\phi P N}{6} \times \frac{Z}{A} = \boxed{E = \frac{\phi Z N}{60} \frac{P}{A}}$$

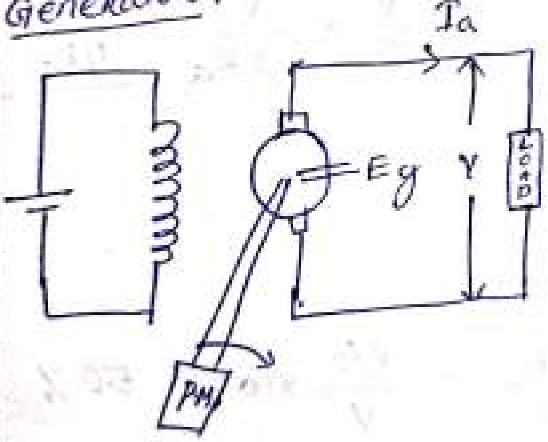
∴ $A = P$ – lap winding
$A = 2$ – wave winding.

Types of D.C M/C



Separately excited dc M/C

Generator :-



$E_g = V + I_a R_a + B \cdot D$

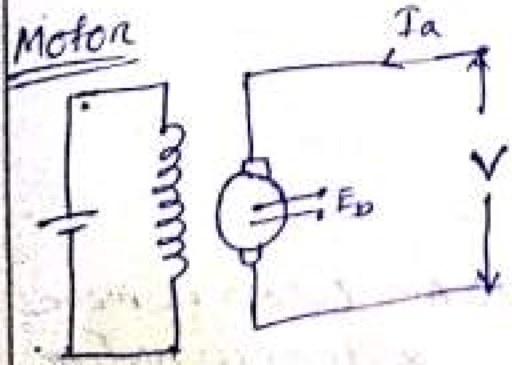
$E_g I_a = V I_a + I_a^2 R_a + B \cdot D \times I_a$

where $E_g I_a$ = gross electrical power develop

$V I_a$ = power output

$I_a^2 R_a$ = ~~curren losses~~ arm cu loss

Motor



$V = E_b + I_a R_a + B \cdot D$

$V I_a = E_b I_a + I_a^2 R_a + B \cdot D\, I_a$

where $V I_a$ = Electrical power input

$E_b I_a$ → Electrical equivalent of mech power develop.

$P_m = E_b I_a = V I_a - I_a^2 R_a - B \cdot D\, I_a$.

B·D can be neglected. so

$P_m = VI_a - I_a^2 R_a$

Condition for maximum mech power developed.

differentiating : $\frac{dP_m}{dI_a} = V - 2I_a R_a = 0$

***

$\Rightarrow \boxed{I_a = \frac{V}{2R_a}}$ current at maximum power developed condition

AS $E_b = V - I_a R_a$

$= V - \frac{V}{2R_a} \times R_a$

$\boxed{E_b = \frac{V}{2}}$ Condition for maximum mech power developed.

Efficiency at maximum power developed condition :-

Max mech power develop = $P_m(max) = E_b \times I_a$

$= \frac{V}{2} \times \frac{V}{2R_a} = \boxed{\frac{V^2}{4R_a}}$ ***

$\boxed{P_m(max) = \frac{V^2}{4R_a}}$ ***

Efficiency at P_m(max)

$\eta = \frac{P_m(max)}{P_{in}} = \frac{E_b I_a}{V I_a} = \frac{E_b}{V} = \frac{V/2}{V} \times 100 = 50\%$

$\boxed{\% \eta = 50\%}$ ***

why $\eta = 50\%$ only?

$V = 220\,V \quad R_a = 1\Omega$

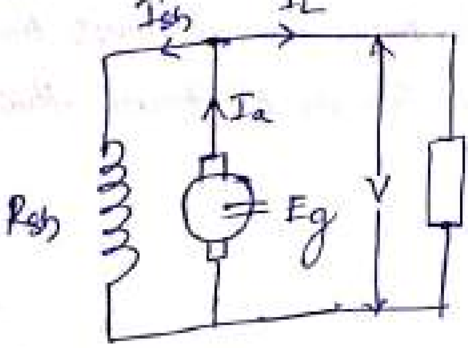
$I_a = \frac{V}{2R_a} = \frac{220}{2 \times 1} = 110\,A$ Cu loss is more & temp is high or heating of armature is high.

Note :-

At maximum power developed condition the efficiency is nearly 50%, therefore the m/c never be operated at maximum power developed condition because due to large heating effect the insulation may spoil. and armature winding may get damage. all the m/c generally design with better efficiency at rated power on load condition.

Self Excited :→

Shunt generator :-

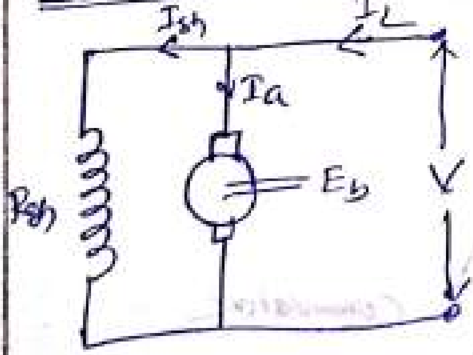


$$E_g = V + I_a R_a + B \cdot D$$

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

$$I_{sh} = \frac{V}{R_{sh}}$$

Shunt motor :-

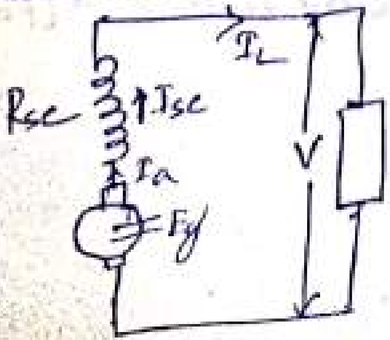


$$V = E_b + I_a R_a + B \cdot D$$

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

$$I_{sh} = \frac{V}{R_{sh}}$$

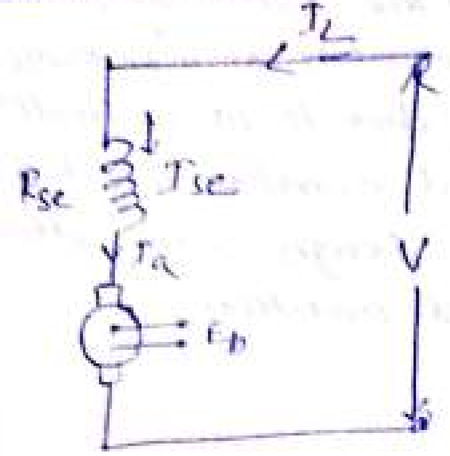
Series generator :-



$$E_g = V + I_a (R_a + R_{se}) + B \cdot D$$

$$I_a = I_{se} = I_L$$

Series motor :-



~~$V = E_b (R_a + R_s$~~

$V = E_b + I_a(R_a + R_{se}) + B.D$

$I_a = I_L = I_{se}$

$\phi = \frac{\uparrow AT \downarrow}{Rel} = \frac{MMF}{Rel}$

Armature winding area of cross section is less than series winding bcoz current rating is less (as parallel path is there)

Shunt field winding is made with more no of turns thin wires

series field winding is made with few no of turns thick wires.

$R_{sh} = 100 - 200\,\Omega$

$R_{se} = \cdot 1 - 1\,\Omega$

Area of x section :-

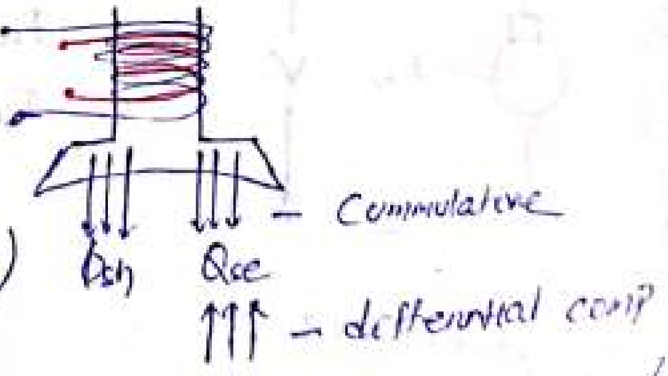
$\boxed{\text{Area of series} > \text{Area of arm} > \text{Area of shunt.}}$

Compound m/c

1. Cummulative comp
2. Differential comp

→ The series field flux (ϕ_{se}) aids the shunt field flux(ϕ_{sh})

$\phi = \phi_{se} + \phi_{sh}$.



→ The series field flux(ϕ_{se}) opposes the shunt field flux (ϕ_{sh})

$\therefore \phi = \phi_{sh} - \phi_{se}$

Cu loss is more in series winding as current is high. so it placed in outside to dissipate the heat.

If the series winding is same both flux will be additive.

If the winding terminal of series field changed the current direction changed so flux will oppose.

Flux in shunt field flux is more than series field flux.

Based on degree of compounding, the cummulative comp is classified as

1. over compound = [illegible]
2. under compound
3. Flat compound
   OR
   level compound.

over compound = series field mmf > shunt field mmf

$= AT_{se} > AT_{sh}$

under comp = series field mmf < shunt field mmf

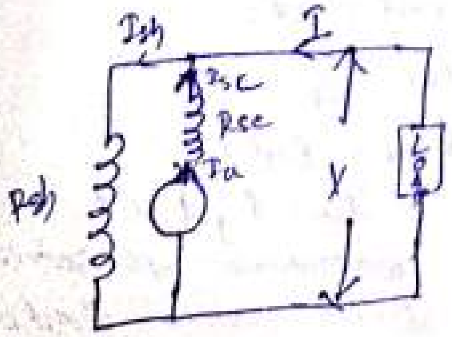
$= AT_{se} < AT_{sh}$

flat comp = series field mmf = shunt field mmf

$= AT_{se} = AT_{sh}$.

⇒ Based on the connection two types of compound m/c

① long shunt
② short shunt

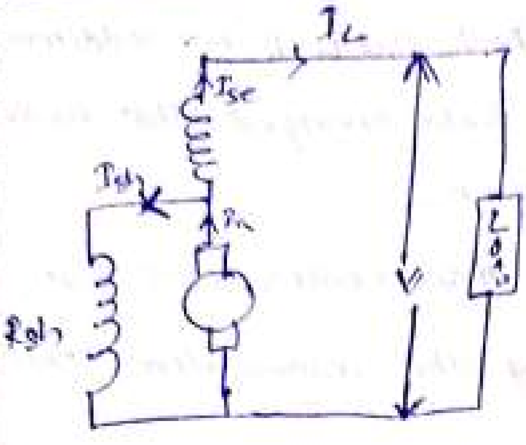


$$E_g = V + I_a(R_a + R_{se}) + B.D$$

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

$$I_{sh} = \frac{V}{R_{sh}}.$$

Short shunt :-



$$E_g = V + I_a R_a + I_{se} R_{se} + B \cdot D$$

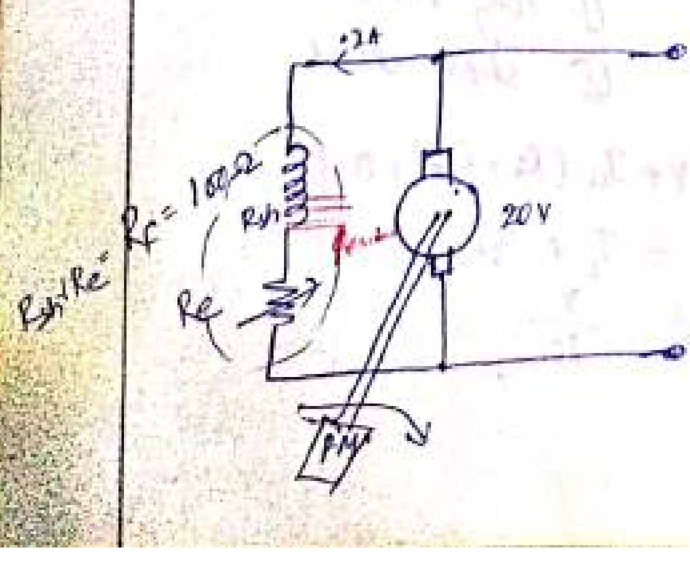
$$I_a = I_L + I_{sh}$$

$$I_{sh} = \frac{V + I_L R_{se}}{R_{sh}} = \frac{E_g - I_a R_a - BD}{R_{sh}}$$

In long-shunt flux in series m/c is more than short shunt.
% regulation of ~~sh~~ long shunt is more for same terminal voltage as flux in it more due to its ~~h~~ high ct in series field so more emf produced.

Note :- The generated voltage for long shunt connection is little more than the short shunt connection, therefore same terminal voltage the voltage regulation is little more for long shunt connection bcoz series field winding carry the entire armature ct. whereas in short shunt the series field wind carry the load current.

Voltage build up in self excited generator :-



$\phi_{residual} \rightarrow emf = 20V$

$I_{sh} = \frac{20}{100} = \cdot 2A$

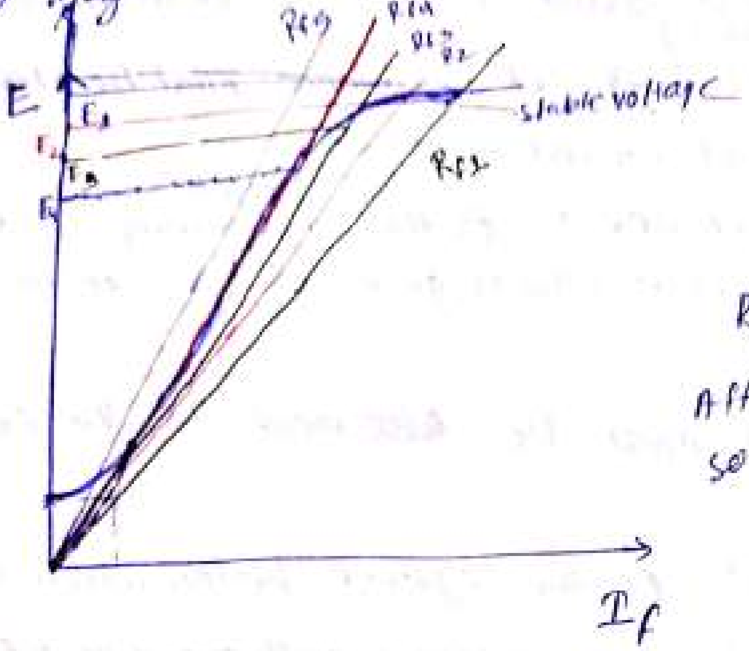
$\phi = \phi_{res} + \phi_{\cdot 2A}$. Emf ↑ .

$I_{sh} = \uparrow$, ϕ st ↑

will continue . upto saturation so flux constant . Emf constant

Soft magnetic material
hard " " → Highly Relativity → Residual magnetismis more.
Ex- Cobalt steel, coball vanadium etc

Soft magnetic material → cast iron, cast steel, silicon steel.



$R_f = \frac{E}{I_f} = \frac{Y}{X} = \text{Slop} = m$

$R_5 > R_4 > R_{f3} > R_{f2} > R_{f1}$

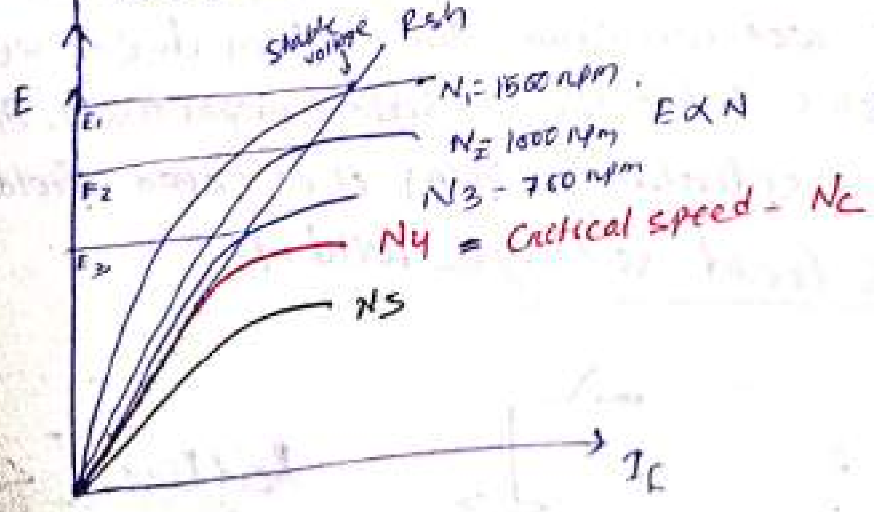
After R_{f4} NO voltage buildUP

so R_{f4} = Critical resistance R_c

Condition:-

① ~~A~~ Residual flux must be there

② ~~armature~~ field terminal are properly connected, otherwise the residual flux & ~~Rot~~ flux of induced current the residual flux will reduced



$E \propto N$

$N_1 > N_2 > N_3$ ----.

Condition for build voltage:-

① There must be residual magnetisim in field pole

② The field terminals must be properly connected to armature terminals such that flux produced by the field current should adds to the residual flux (cumulative action take place)

③ The total field ckt resistance must be less than the critical resistance

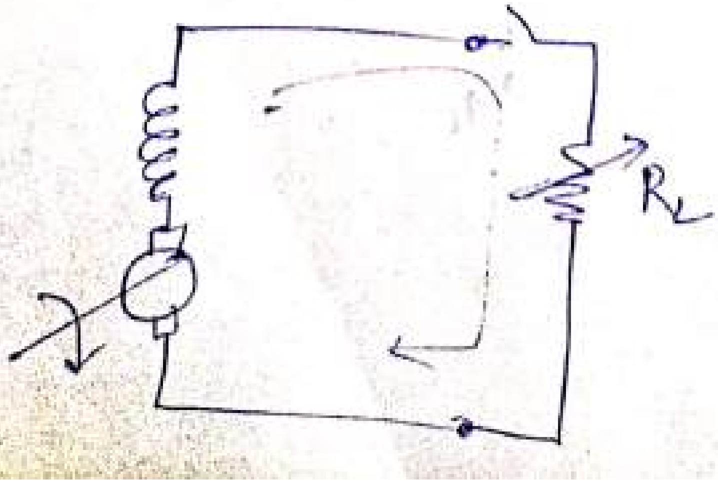
<u>Critical resistance</u>:- is the ~~maximum~~ total field ckt resistance above which generator fails to build up it's voltage.

④ The speed must be ~~less~~ more than the critical speed.

<u>Critical speed</u>:- is the speed below which the generator fails to build up it's voltage with out any external resistance in the field ckt. i.e only field winding resistance.

<u>Field Flashing</u>:- If the field terminals are not properly connected the residual magnetisim may be lost. Therefore to reestablise the residual magnetisim the field terminals are separated & excited with a low voltage wait for some time. then due to retentivity property the field poles holds the residual magnetisim. The process of reestablising the residual magnetisim it is called field flashing.

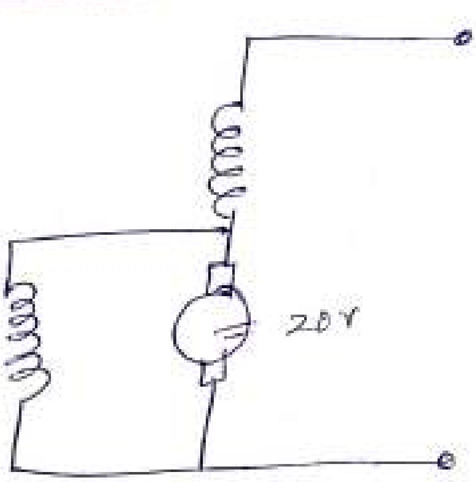
Series field voltage build up

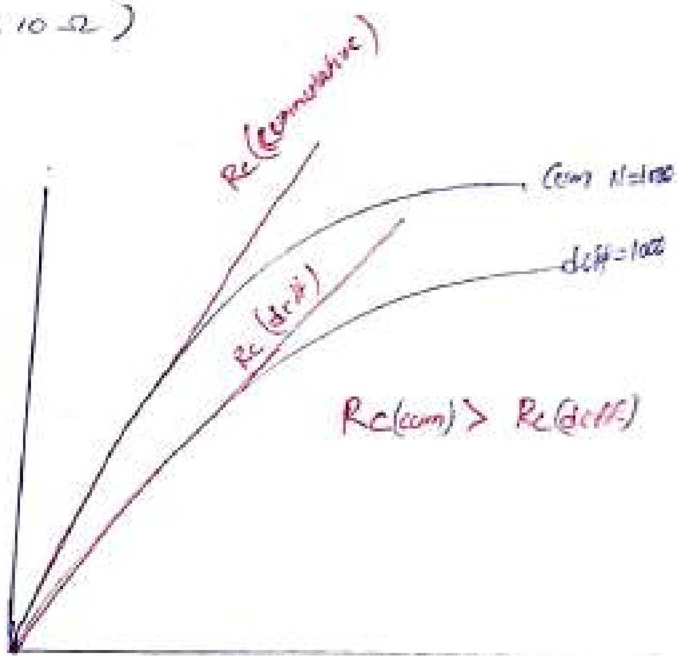


$R_a + R_{se} + R_L < R_c$

- Series generator will not build up any voltage under no load condition.
- The voltage under no load condition is only small voltage due to residual magnetism.
- For the build up of the voltage to be take place the series Generator must be loaded with some load such that the total field ckt resistance must be less than critical field resistance (ordinarily some 10 Ω)

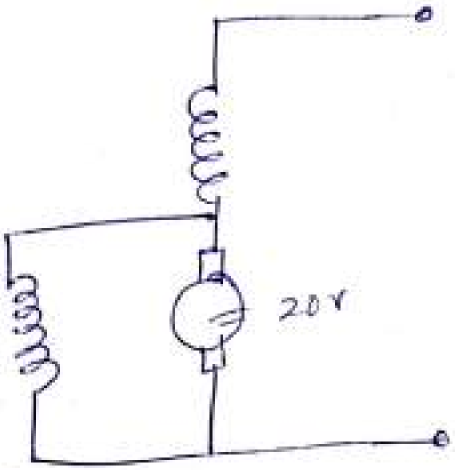
Compound generator :-

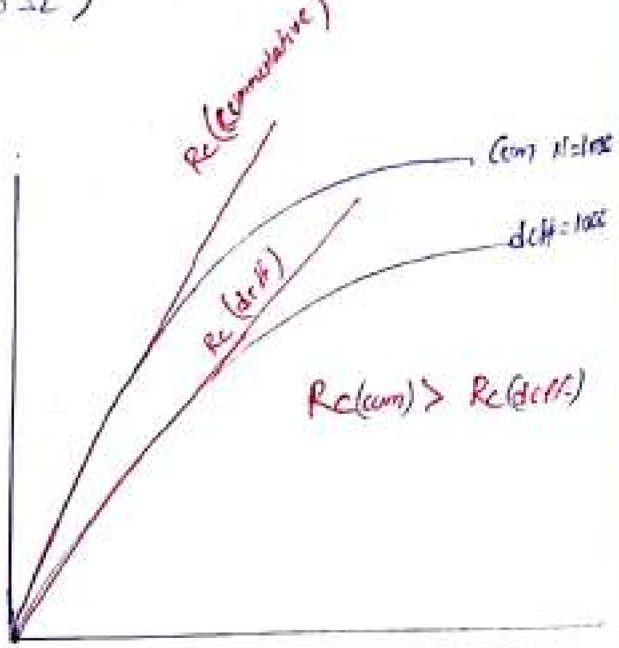




- Series generator will not build up any voltage under no load condition.
- The voltage under no load condition is only small voltage due to residual magnetism.
- For the build up of the voltage to be take place the series Generator must be loaded with some load such that the total field ckt resistance must be less than critical field resistance (order of some 10 Ω)

Compound generator :-





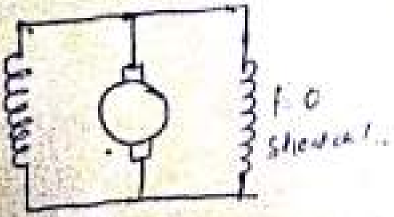
Armature Reaction:-

The effect of armature flux (ϕ_a) on main field flux ϕ_m is called the armature reaction. It depends magnitude of load.

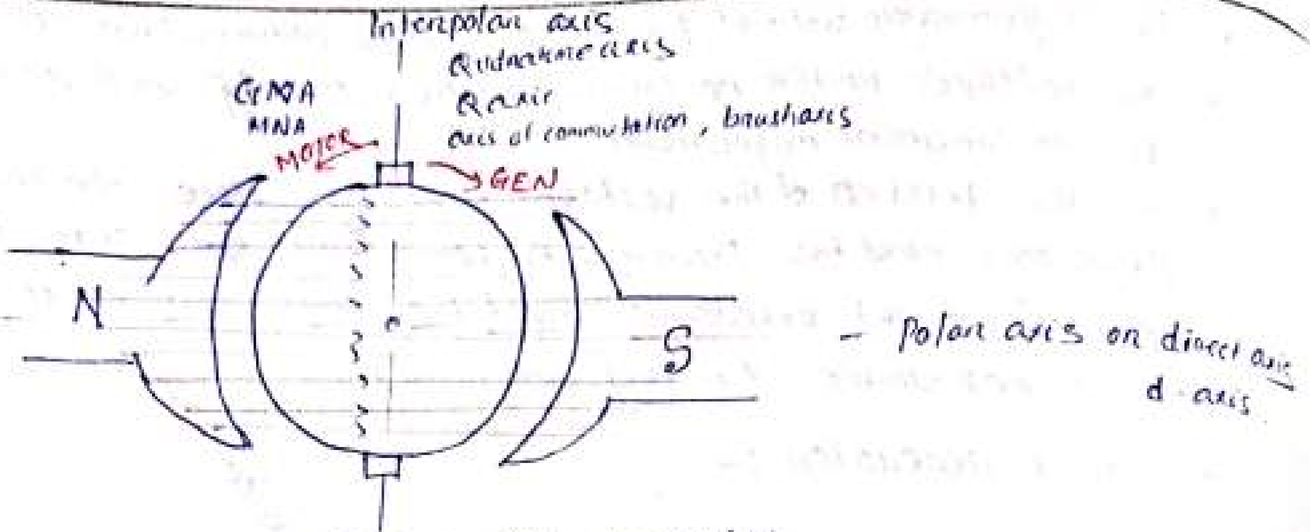
There are two effect :-

1) Cross magnetisation – dissortion of air gap Flux
Sparking at the brush

2) Demagnetisation – Net Reduction of Flux
SO Reduction in E, V, & Tem



IN AC M/C it depends on load & p.f.
There three effect
① demagnetisation.
② Cross magnetisation
③ magnetisation.



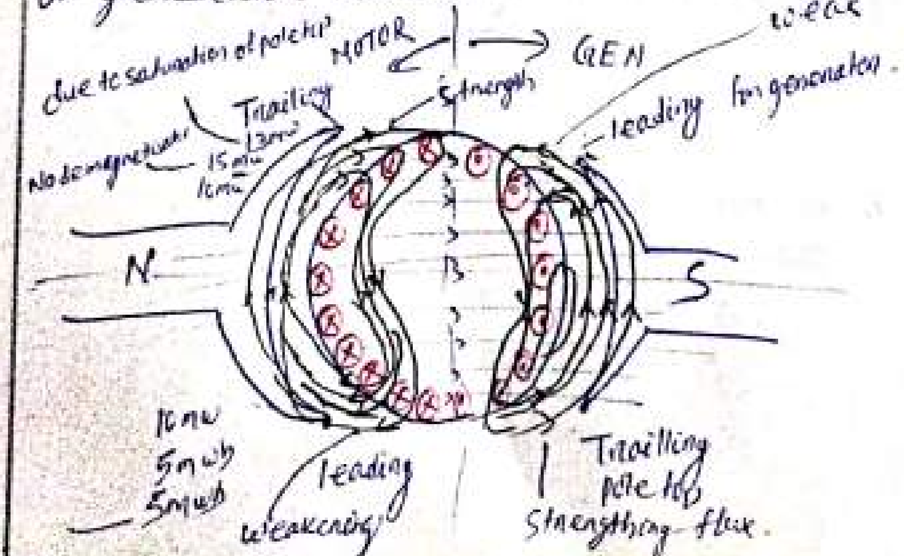
Main field ~~axis~~ flux distribution.

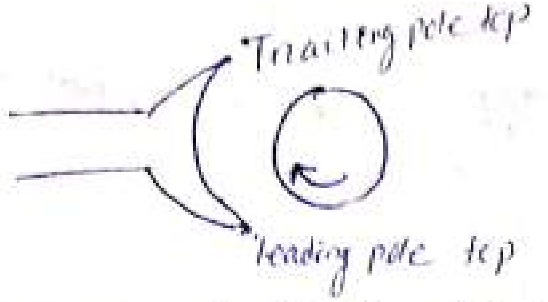
MNA :- Main pole will produce an opposite Pole on the rotor. rotor pole strength is Maximum at polar axis & gradually decreases towards the brush axis so pole strength at brush axis is zero. (neutral). so called magnetically Neutral axis.

GNA : Geometrical Neutral axis :. is the axis which is perpendicular to the main field flux or direct axis GNA can also be called as brush axis and axis of commutation. bcoz brushes are always placed along GNA, and commutation process takes place along the

GNA :

MNA : Magnetically neutral axis :- is the axis which is always perpendicular to the airgap flux. under No load condition MNA will align with the GNA. But under loaded condition MNA will shift in the direction of generator rotation.

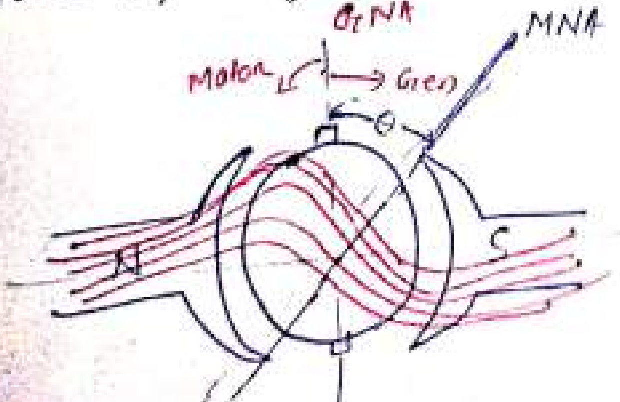




flux at leading pole tip flux decreasing (weak) & flux at ~~leadi~~ trailling pole tip increase (strengthening). This non uniform flux destribution take place is called cross magnetisation.

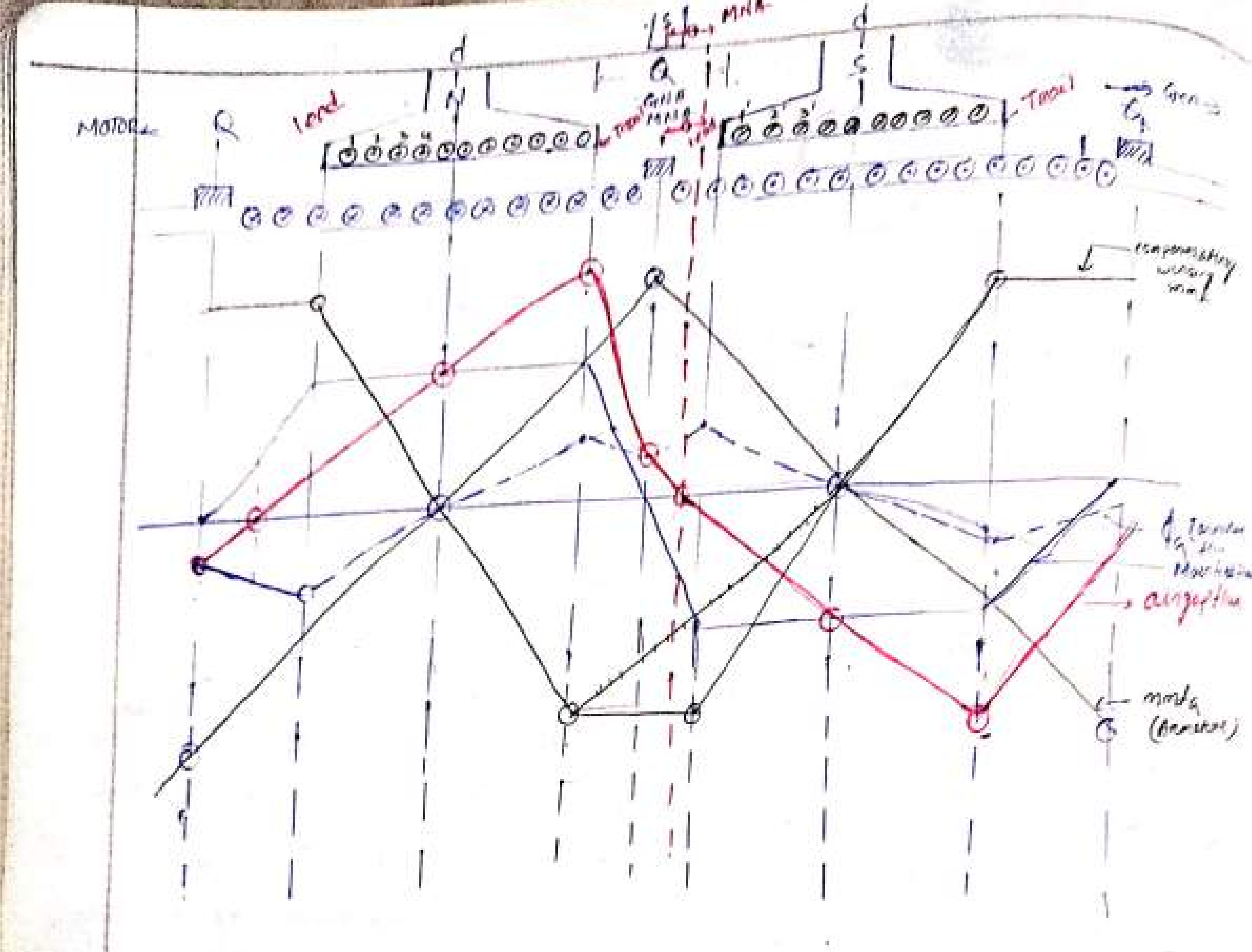
Due to effect of armature reaction strengthening effect takes place at trailling pole tip, weakening effect take place at leading pole tip. If strengthening effect is equal to weakening effect the avg value of flux under each pole is same, therefore no demagnetising effect of armature reaction. But saturation takes place at trailing pole tip, therefore strengthening effect is always less than weakening effect. Therefore net flux under each pole reduce which is said to be demagnetising effect of armature reaction.

The demagnetising effect is due to saturation at traling pole tips in generator (in leading pole tip in motor)

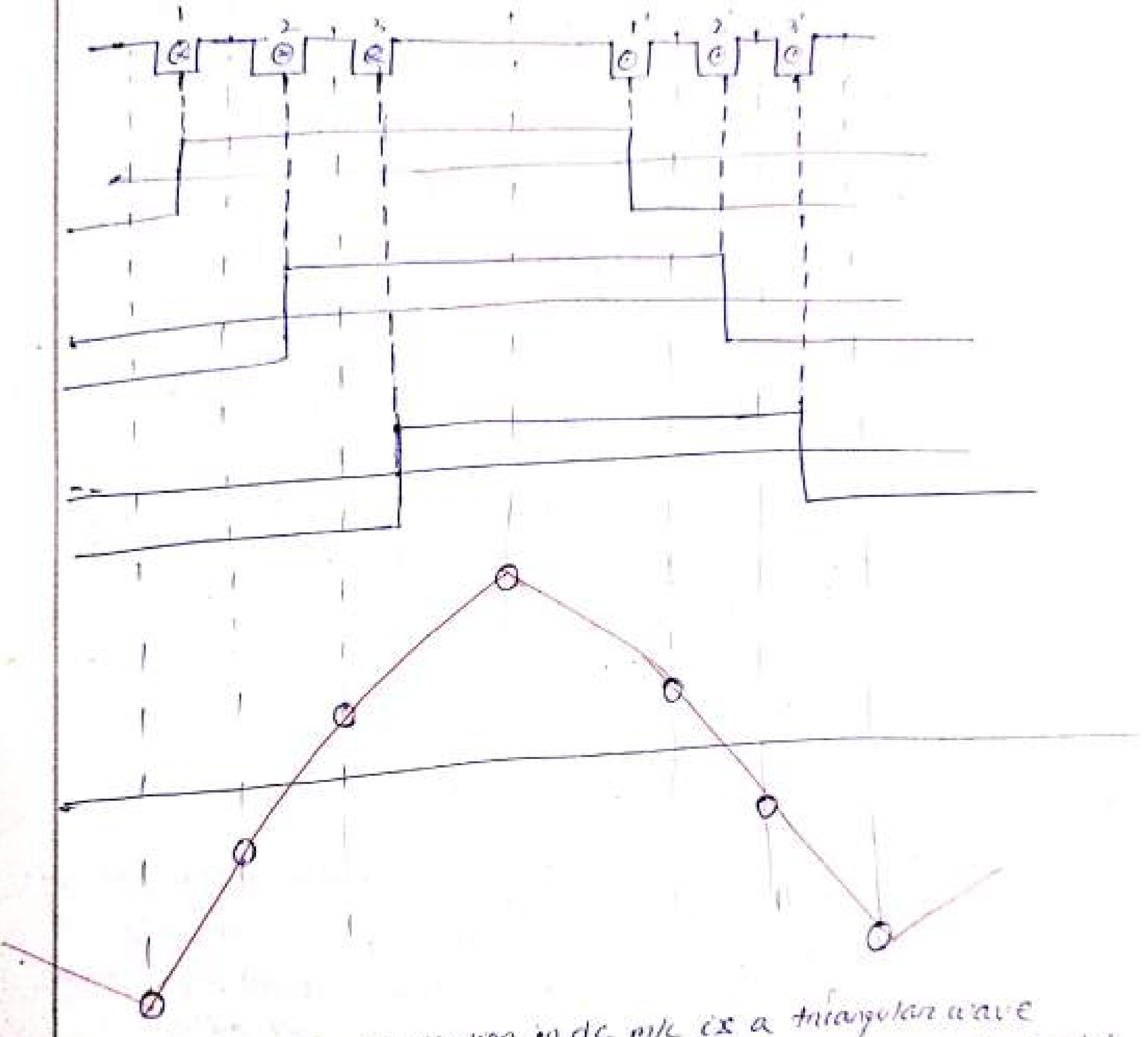


MNA will ~~s~~shift in the direction of generator rotation. or in the opposite direction on that of motor rotation.

=) Amount of shift 'θ' depends on the magnitude of load.


MOTOR
load
N
S
MNA
GNA
Total
Gen
compensating winding mmf
mmf (armature)
airgap flux

→ The main field flux ϕ_m distribution in the airgap is a flat topped wave (or) Trapezoidal wave.



⇒ Armature mmf distribution in dc m/c is a triangular wave. But in A C m/c the armature mmf distribution is a sinusoidal.

$\phi_a = \frac{\text{armature mmf}}{\text{rel}}$ - at q axis.

Reluctance is dominant even mmf maximum but flux is minimum. (at q axis)

⇒ Armature flux distribution is a saddle shaped wave

⇒ $\phi_r = \phi_m + \phi_a$

⇒ The air gap flux distribution is a peaky wave.

Cross magnetising effect of armature reaction:-

1) MNA will shift in the direction of generator rotation. or in the opposite direction that of motor rotation.

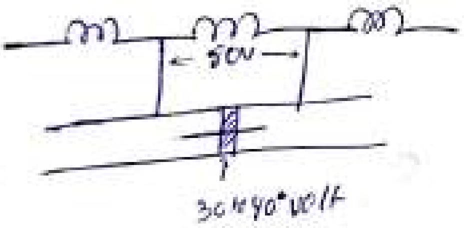
2) Iron losses are increases.

$W_h \propto B_{max}^{1.6}$ $W_e \propto B_{max}^2$ (As B max increases)

so efficiency will decrease.

3) Due to the presence of flux along the brush axis an emf is induced in the coil which is going under commutation process hence causes delayed commutation. Therefore sparking at the brushes.

With only main field flux, flux along brush axes is zero so easily current reversal take place as there is no emf at brush axis.

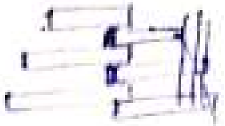


4) The coils which are placed under the trailing pole tips cuts the maximum value of airgap flux therefore induced emf is maximum. If this induced emf is beyond a particular value mica insulation fails. There for short ckt bet adjecent commutator segment. therefore sparking takes place.

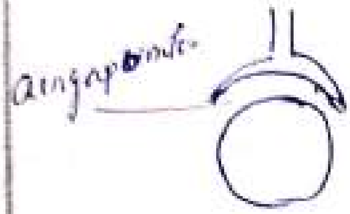
This process may take place to entire commutator.

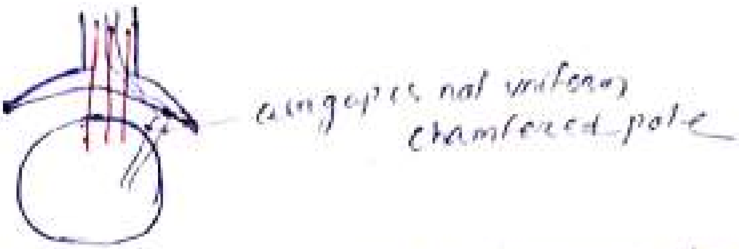
:Remedies for cross magnetising effect of Armature Reaction :-

1. By using high Reluctance pole tips.



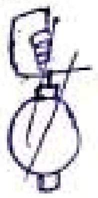
2. By chamfering the salient pole

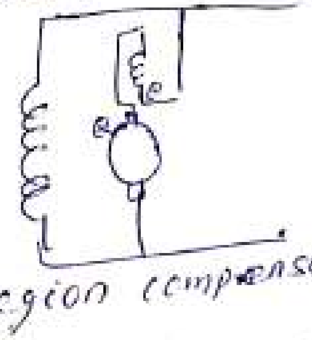




In ac m/c chamfering is $\propto \frac{1}{\cos\theta}$ i.e at 60° airgap is doubled.

3. The effect of armature reaction (CME) under the polar region can be reduced by using the compensating winding.
The componesating winding placed under the pole shoe connected in series with armature circuit.





under polar region compensating mmf neutralise the armature mmf only.

④ By using the interpoles the effect of CME under the interpolar region can be reduce

→ The polarity of the interpole is same as that of main field ~~flux~~ pole AHEAD in the direction of GENERATOR rotation.

⇒ The polarity of interpole is same as that of main field pole BEHIND in the direction of MOTOR rotation.

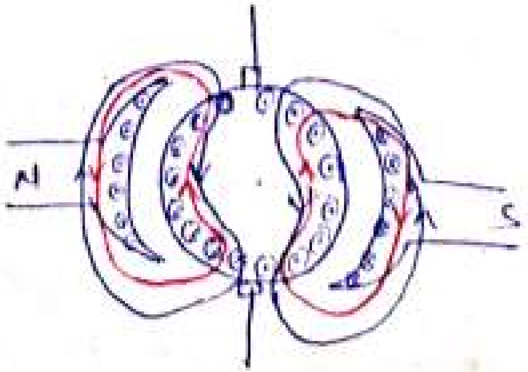
5) By shifting the brushes in the direction of generator rotation the effect of cml can be reduced.

$E_g \downarrow$ $V \downarrow$ $T \downarrow$ $N \uparrow$ $N \propto \frac{1}{\phi}$ $T \propto \phi$

If the brushes are shifted in the direction of generator rotation the average value of flux under each pole is reduces be E_g decreases, V decreases in generator & torque decreases speed increases in the case motor.

→ If the brushes are shifted in the direction of motor rotation (which is in opposite direction of generator rotation) The avg value of flux under each pole is increases therefore generated voltage increases in generator and torque increases speed decreases in case of motor.

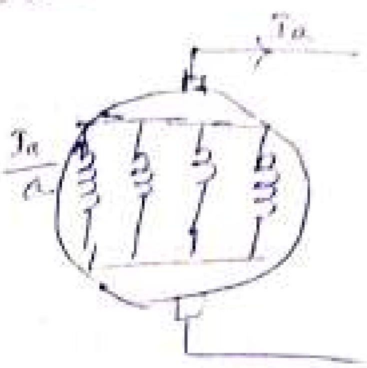
Compensating windings are used only for large machine which are subjected with variable load. If the load is varying the armature current also varies due to which a statically emf induced in armature coil. If this statically emf adds to the generated voltage net voltage is increased in the coil. If the voltage increase beyond a particular value the mica insulation fails therefore short ckt b/w commutator segment, therefore sparking at brush. This effect can be minimised compensating winding.



Statically induced emf due to change in load.

$$e = L\frac{di}{dt} = \frac{N d\phi}{dt}$$
$$= 0$$

No of compensating winding Amp turn/pole AT/pole



Total AT = $\frac{Z}{2} \cdot \frac{I_a}{A} \times \frac{1}{P}$ =

Amp turns per pole = $\frac{Z I_a}{2AP}$

So AT_{cw}/pole = $\frac{Z I_a}{2AP} \times \frac{\text{pole arc}}{\text{pole pitch}}$

$= \frac{Z I_a}{2AP} \times 0.7$ A.T

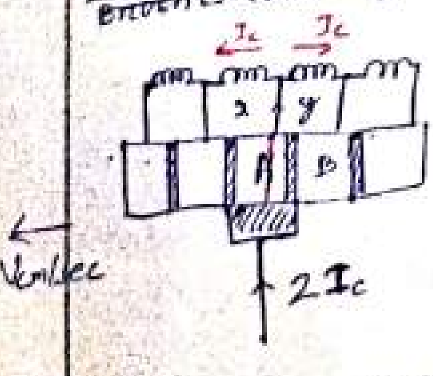
No of compensating winding turn = $\frac{AT_{cw}/\text{pole}}{I_a}$

$$= \boxed{\frac{Z}{2AP} \times 0.7}$$

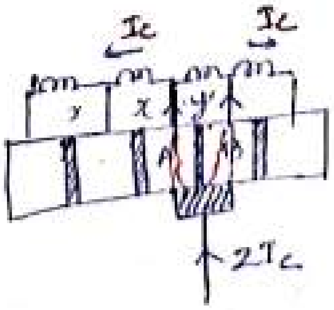
:Commutation:

The process of reversal of current in a short ckted armature coil through the commutator segments & brushes.

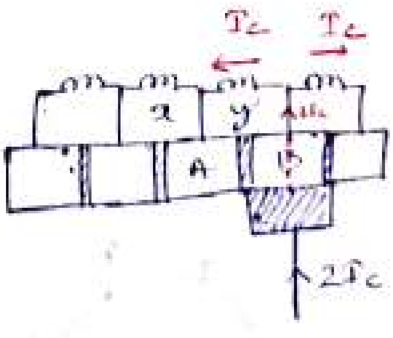
For motoring mode:-
~~Brushes completely~~



Brush is completely contact with brush commutator segment 'A'



The brush equally contact with seg A & B



The brush is completely contact with seg B.

The time taken to pass one commutator segment is known as commutation time

W_b :- Width of brush 'm'

W_c :- width of commutator segment in 'm'

W_m :- width of mica insulation in 'm'

V_c :- Velocity of commutator in m/sec

T_c :- commutation period in sec.

T_c → is the time required for the commutator to advance a distance of one commutator segment.

$\boxed{T_c := \frac{W_c}{V_c}} = \boxed{\frac{W_b - W_m}{V_c}}$ As $\boxed{W_b = W_c + W_m}$

$\boxed{T_c \leq 2 \text{ msec}}$

In position - 1

Current in the coil y + I_c

current in the coil x = $-I_c$

clockwise current = +ve

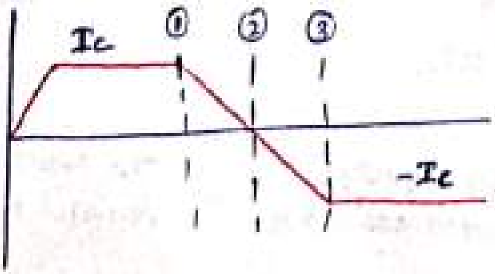
counter clockwise " = -ve

In position - 2 :-

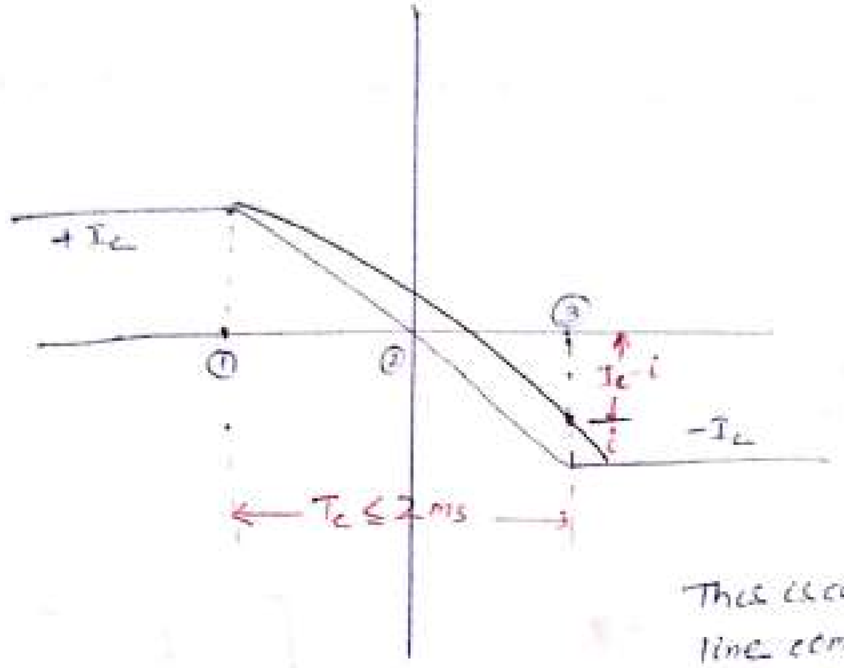
current in the coil y = 0

In position - 3 :-

Current in the coil y = $-I_c$



just after position 1 & upto just before position 3 coil 'y' is short circuited.



This is called linear or straight line commutation or ideal commutation.

⇒ If the current reversal take place before commutation period is called over commutation.

⇒ If the current reversal take place after commutation period is called nonlinear or delayed commutation.

⇒ Normally commutation is under commutation.

Linear commutation:- If the current reversal takeplace exact betn the commutation period it said to be linear, ideal straight line commutation.

Over commutation:- If the time required for current reversal less than commulation period ie the commutation process take place before commutation period that said to be over commulation.

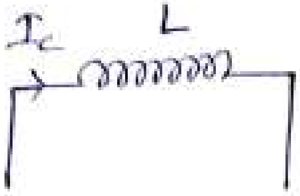
Under commutation:- If the current reversal take place after the commutation period then it said to be under commutation or delayed commutation.

Practically commutation is delayed commutation.

Causes for delayed commutation:

1. Reactance voltage
2. Cross magnetising effect of Armature reaction.

Reactance voltage:-



$$e_r = L\frac{di}{dt} = L\,\frac{+I_c-(-I_c)}{T_c} = \boxed{\frac{2LI_c}{T_c} = e_r}$$

e_r ↓ statically induced emf in short ckt coil under commutation.

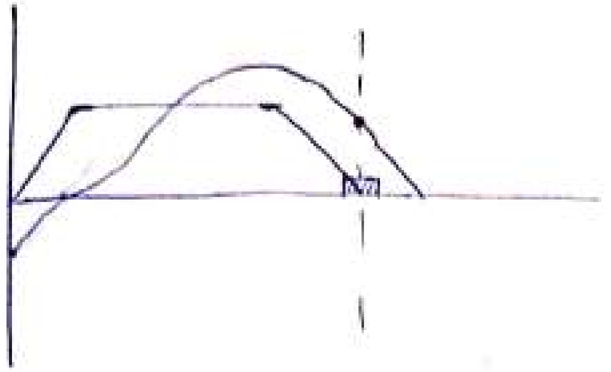
Effect → Reactance voltage

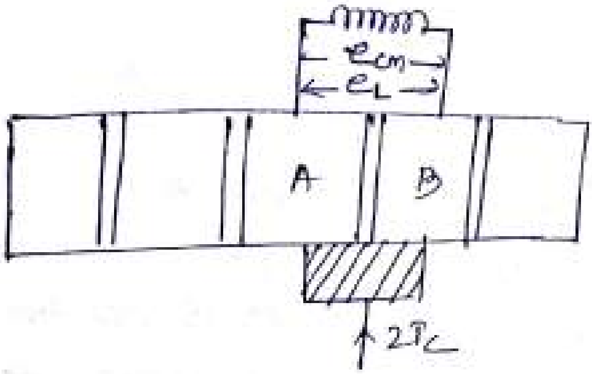
cause → current reversal.

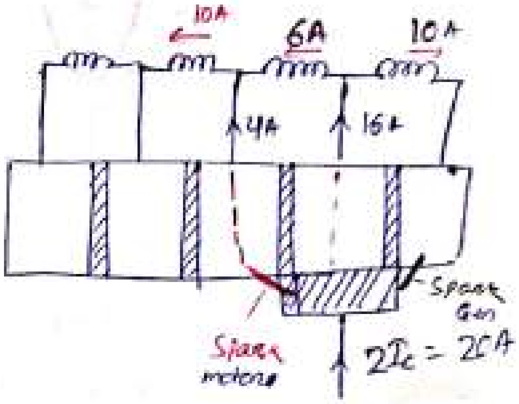
According to Lenz's law effect will oppose the cause.

The current is changing from $+I_c$ to $-I_c$ during the commutation period, the armature coil will have self inductance. Due to which a statically emf is induced in the coil which is going under commutation process. This induced emf is called reactance voltage, which will always opposes the current reversal according to Lenz's law. ie the effect always opposes the cause producing it. Therefore the current reversal always being opposes by reactance voltage hence causes delayed commutation.

Cross magnetising effect:-







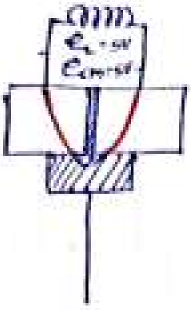
Due to the effect of cross magnetisine effect of armature reaction. some flux will be exist along the brush axis, the coil which is going under commutation cuts this flux there fore a dynamically emf is induced. This induced emf will maintain the current in same direction hence causes the delayed commutation.

At the end of the commutation period the total current is not reverse some current called residual current still to be reverse. This residual current jumps into the adjacent commutator segment in the form of spark. This residual current ionises the air bet brush and commutator & brush, ionised air behave as a good conductor through which current jumps to sem 'A'. the spark will take place at trailling ~~po~~ tip both in motor & generator.

Commutation methods:- (improvement method)

1. Voltage commutation (emf commutation) → By using interpole / commutating pole / compoles
2. Resistance commutation

Resistance commutation:-



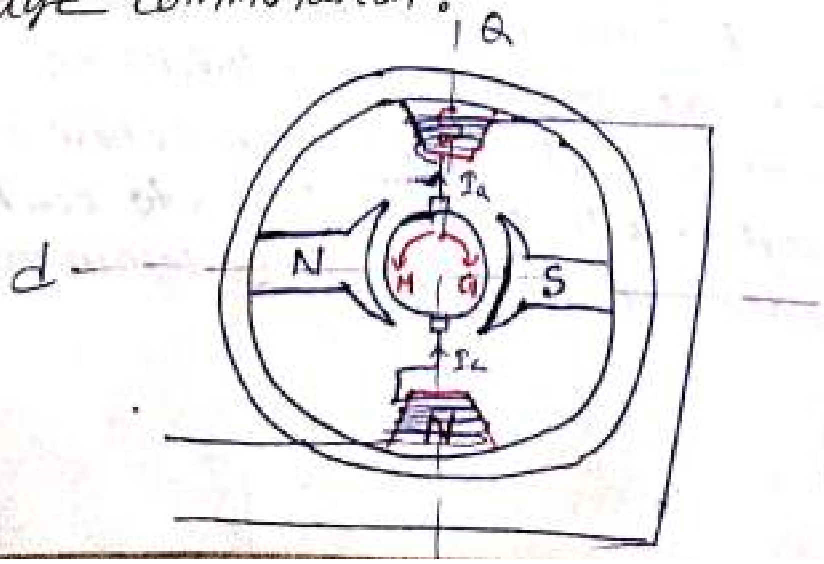
$$\uparrow \tau = \frac{L}{R \downarrow}$$

This is used in small m/c.

If the voltage drop across brush resistance is large sufficient that of reactance voltage, cross magnetising effect of A.R. the commutation process can be improved therefore by using high resistance brushes commutation process can be improved. since this brush resistance is in series with the coil which is going under commutation. therefore time constant is reduced, hence current reversal speeded up.

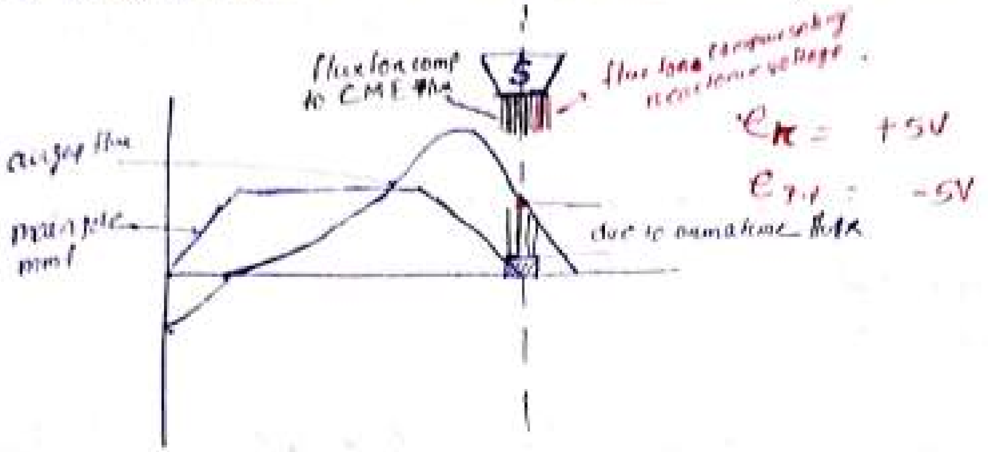
This method is used for only small machine for less than 1kW rating.

Voltage commutation:-



⇒ Interpoles are tapering shape

→ With broad base to reduce leakage reactance.



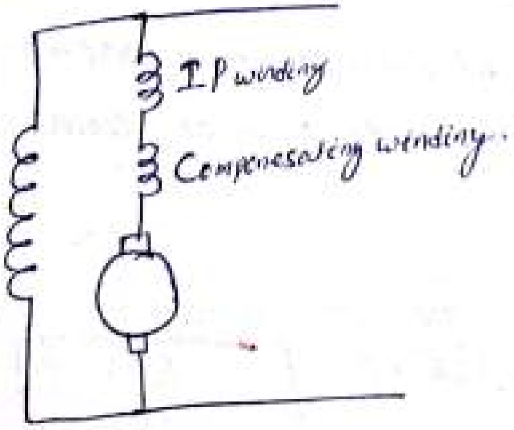
⇒ The mmf due to interpole is 1.2 to 1.3 times that of armature mmf

Interpoles are placed always along interpolar axis it will nullify the cross magnetising flux due to cmf and also produce the additional flux due to which the dynamically emf is induced which will nullify the reactance voltage.

The no of interpole is equal to no of main field pole for normal rating and large machine. But for small machine the no of interpole is equals to half of main field poles.

The interpole winding is connected in series with the armature for automatic neutralization i.e the effect will be equal and opposite.

The airgap under interpole is more compared with main field pole airgap to avoid saturation.



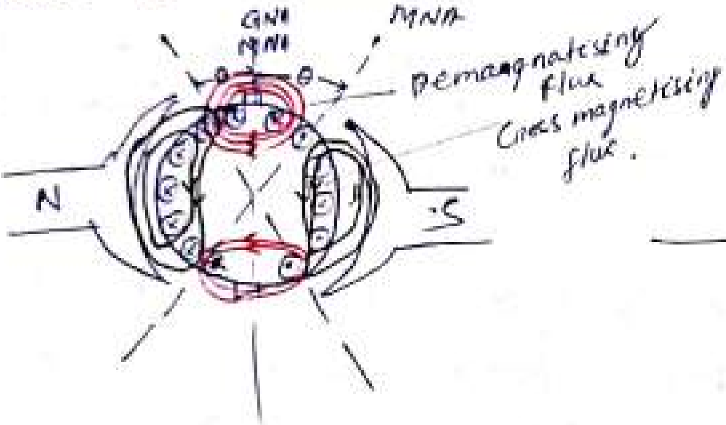
The size of interpole winding conductor is more in compared to armature winding conductor. Bcoz interpole winding conductor will carry the armature current. The conductor in armature current carry $\frac{I_a}{A}$ amount of full armature current current

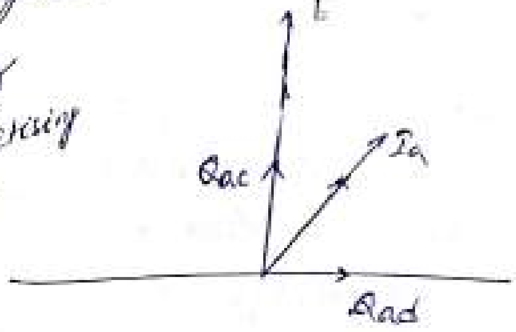
⇒ By using compenesating winding effect of cmc under the polar region is reduce. thereby commutation process improved but compenesating winding is used for large m/c which is subjected to large current. variable load.

⇒ By shifting the brush in the direction of generator rotation or opposite direction of motor rotation. so commutation process is improved.

Demagnetising Amp turns per pole i.e $AT_d/\text{pole} = \frac{ZI_a}{2AP} \times \frac{2\theta}{180}$

where θ = is in electrical degree.





Total AT/pole $= \frac{Z}{2} \times \frac{I_a}{A} \times \frac{1}{P} = \boxed{\frac{ZI_a}{2AP}}$

demagnetising AT/pole is $\boxed{AT_d/\text{pole} = \frac{ZI_a}{2AP} \times \frac{2\theta}{180}}$

$$\boxed{\theta_e = \frac{P}{2}\theta_m}$$

The demagnetising effect of armature reaction can be compenesated by placing the extra no of turns in the main field poles.

The extra no of turns to compensate demagnetising effect of armature reaction is equal to $= \boxed{\frac{AT_d}{I_f}}$

Where $I_f = I_{sh}$ in shunt m/c

$I_f = I_a$ in series m/c

Cross magnetising Amp turns/pole

$$= AT_c/\text{pole} = \frac{ZI_a}{2AP} - \frac{ZI_a}{2AP} \times \frac{2\theta}{180}$$

$$\boxed{AT_c/\text{pole} = \frac{ZI_a}{2AP}\left[1 - \frac{2\theta}{180}\right]}$$