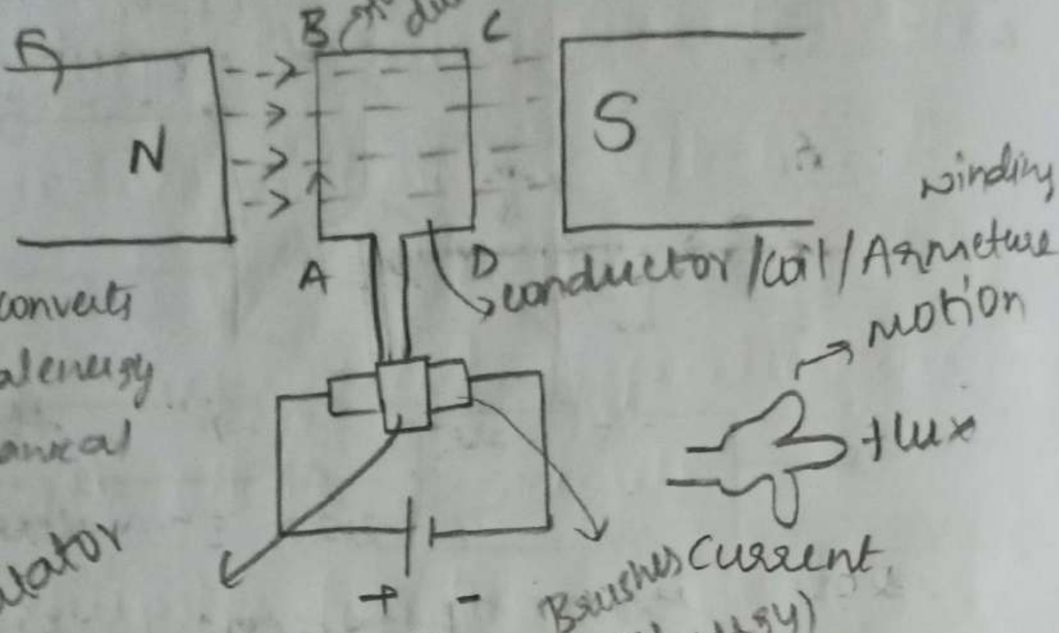
UNIT-II DC MACHINES

DC Motor:

Nature of supply is DC itself

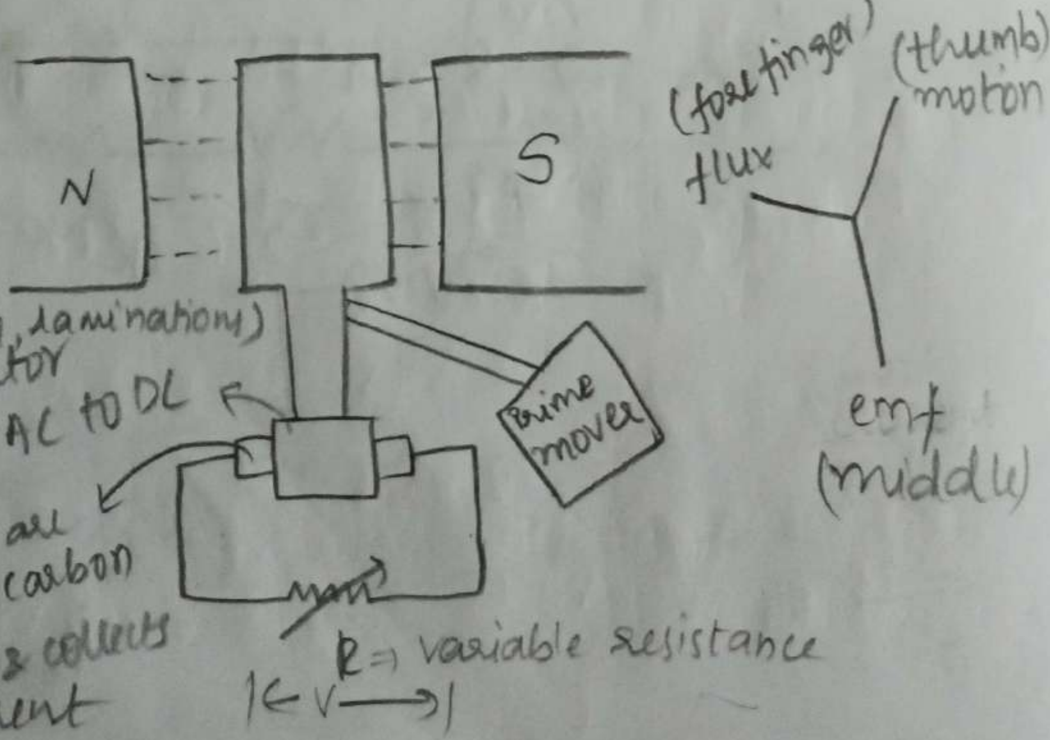


Motor converts electrical energy to mechanical energy

DC motor it converts electrical energy into mechanical energy ~~Prin~~

Principle: when a current carrying conductor is placed in a magnetic field it experiences mechanical force according to Fleming's left hand rule

DC Generator:



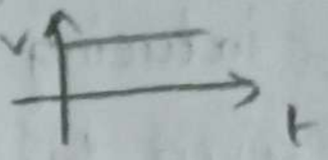
(made up of cast steel, laminations)

commutator changes AC to DC

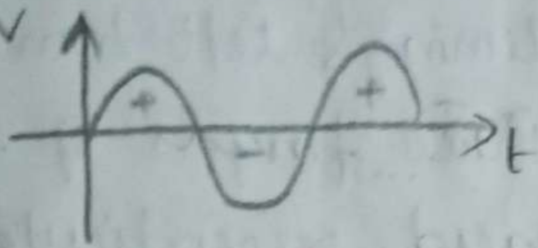
Brushes are made up of carbon material & collects current electric supply

AC / DC

DC → frequency = 0



AC



1ø, 3ø supplies will be there

↓ ↓

240V, 415V,
50Hz 50Hz

Indian standard frequency 50Hz

US standard frequency 60Hz

DC motor:

There are two fluxes produced in DC motor

1) Main field flux due to field winding

2) flux which is produced due to current flow in the conductor

Due to interaction b/w these two fluxes there is a twisting or turning force produced which is nothing but <u>torque</u>.

When torque is exerted on the coil it starts rotating and direction of inducing of current in dc motor is given by fleming's left hand rule where three fingers of left hand are placed perpendicular (90°) to each other & namely

thumb, forefinger, middle finger

where

thumb - Represents motion of the conductor

forefinger - Indicates the directⁿ of flux lines

middle finger - Represents direction of inducing of current in it

DC Generator:

Working principle of DC generator:

It is a rotating electrical machine

which works under the principle of electromagnetic induction here it is a two pole DC generator with a armature coil of ABCD sides placed in magnetic field which is rotating with external prime mover known as rotating conductor or coil. whenever a rotating conductor cuts magnetic field there is a relative speed b/w flux and conductor according to faraday's laws of electromagnetic induction. an emf gets induced in ABCD coil.

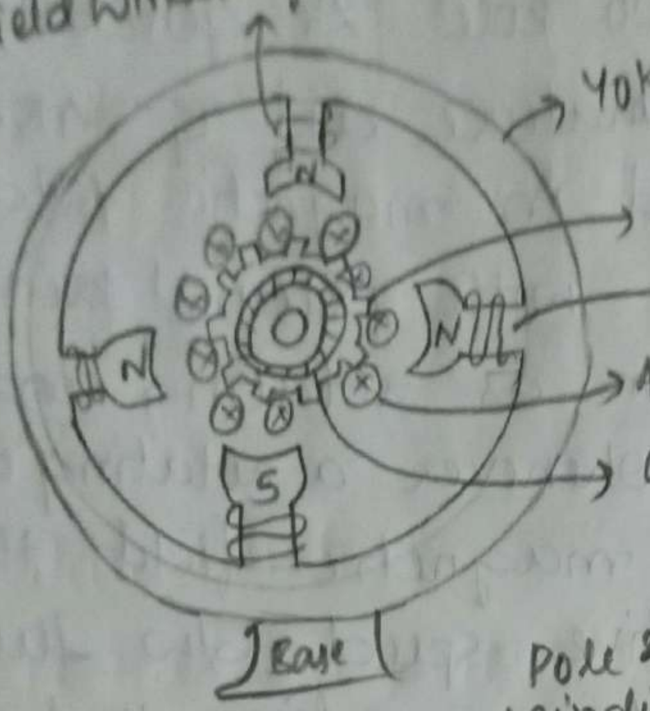
According to fleming's right hand rule :

fore finger - Indicates flux direction

Middle finger - Direction of induced emf

Thumb - Indicates motion of conductor !

Construction of DC generator:



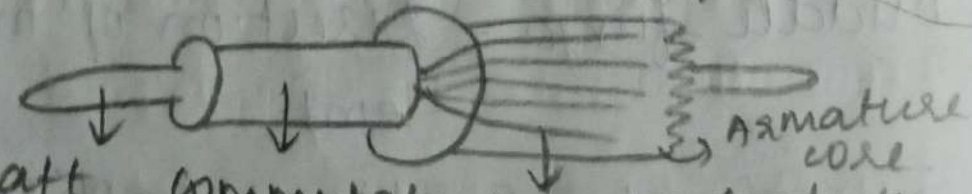
Pole & Armature winding provide required flux.

Purpose of pole is to hold the fieldwinding.

coil) conductor => Armature winding

Armature core => to hold Armature winding

Armature winding => made up of copper



Yoke: It provides Mechanical protect-ion to the entire machine made up of cast iron or cast steel

Field Winding & Pole:

Pole is made up of high permeable material which holds field winding and also provides magnetic flux in the machine.

Field winding is made up of copper material which supports to devolop magnetic flux.

Armature core:

Armature core is a cylindrical drum shaped structure punched into slots on peripherals to hold armature winding made up of silicon lami-nated steel.

Commutator:

It is a mechanical rectifier used to convert pure AC to DC voltage. It is made up of Hard drawn copper.

Brushes: It is soft material

They are made up of carbon and used to collect current from rotating commutator.

Armature winding: Made up of copper.

① lap (It will be overlapped) 

② wave (↑V ↓I) 

At high current and low voltage

At high voltage & low current

Armature Winding:

It is a distributed winding as per the requirement it is classified into two types ① lap winding ② wave winding.

It is a main winding of the machine which supports to produce EMF and torque.

EMF eqn of a DC generator:

According to faraday law of EMF induction

$$E \alpha \frac{d\phi}{dt}$$

$$\boxed{E = N \frac{d\phi}{dt}}$$

$N = 1$

N = no of turns

E = Emf ~~conductor~~ Induced per conductor

change in $\phi = d\phi = \phi \times P$.

ϕ = flux

P = Poles (no of poles)

change in time. $dt = \frac{60}{N}$

$$E = \frac{d\phi}{dt} = \frac{\phi \times P}{\frac{60}{N}}$$

$$E = \frac{N\phi P}{60} \times \left(\frac{1}{A} \times Z\right)$$

A = no of llel paths.

Z = no of conductors

ϕ = flux

N = speed.

P = poles.

$$\boxed{E_g = \frac{\phi Z N P}{60 A}}$$

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$$\boxed{E_g = \frac{\phi Z N P}{60 A}}$$

E_g = EMF of induced for 'Z' no of ~~xo~~ conductors.

A = No of parallel paths.

P = Poles.

Z ~~A~~ = No of conductors.

N = Speed.

ϕ = flux.

lap $\boxed{A = P}$ ↑I V↓

$$\text{lap } E_g = \frac{\phi Z N \cancel{P}}{60 \cancel{A}} = \frac{\phi Z N}{60}.$$

$$\boxed{\text{lap } E_g = \frac{\phi Z N}{60}}$$

wave = $\boxed{A = 2}$ ↑V ↓I

$$\text{wave } E_g = \frac{\phi Z N P}{60 \times 2} = \frac{\phi Z N P}{120}$$

$$\boxed{\text{wave. } E_g = \frac{\phi Z N P}{120.}}$$

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1) A four pole generator having wave wound armature winding has 51 slots each slot consisting of 20 conductors determine the generated EMF in the machine when driven at 1500 RPM if flux per pole is 7milliwebers.

$P=4.$

flux units = Milli webers
= mWb.

$\phi = 7mWb. = 7\times10^{-3} = 0.007.$

$P = 4.$

$Z = 51\times20.$

$N = 1500.$ $A=2.$

$$E_g = \frac{\phi ZNP}{60A} = \frac{10^{-3}\times7\times51\times\cancel{20}\times1500\times4}{60\times\cancel{2}.}$$

$$= \frac{7\times51\times\cancel{18}\times\cancel{4}}{\cancel{60}.}$$

$E = 357V$

Q) A 4 pole DC generator has a lap wound armature with 792 conductors if flux per pole is 0.0121 weber determine the speed at which it should run to generate 240V

P=4.

P=A

ϕ = 0.0121

N=?

E=V=240.

$$E_g = \frac{\phi Z N P}{60A}.$$

$$240 = \frac{0.0121 \times 792 \times N \times \cancel{4}}{60}$$

$$N = \frac{240 \times 60}{121 \times 792 \times 10^{-4}}$$

$$= \frac{24 \times 6 \times 10^{6}}{121 \times 792}.$$

$$= \frac{144 \times 10^{6}}{95832}. = \cancel{15026} = 1502.6$$

1500 → Rated RPM. if load is there there would be around 1400.

8) A 6 pole DC generator have wave wound armature with 574 conductors and armature is rotating with a 1492 RPM determine flux per pole at which it should run to generate 220V

$\boxed{A22}$

P = 6
Z = 574
N = 1492
ϕ = ?
E = 220V

$$220 = \frac{6 \times 574 \times 1492 \times \phi}{60 \times 2}$$

$$\phi = \frac{220 \times 60 \times 2}{6 \times 574 \times 1492}$$

$$= \frac{26400}{5138448}$$

$$= 5.137 \times 10^{-3}$$

= 5.137 mWebers.

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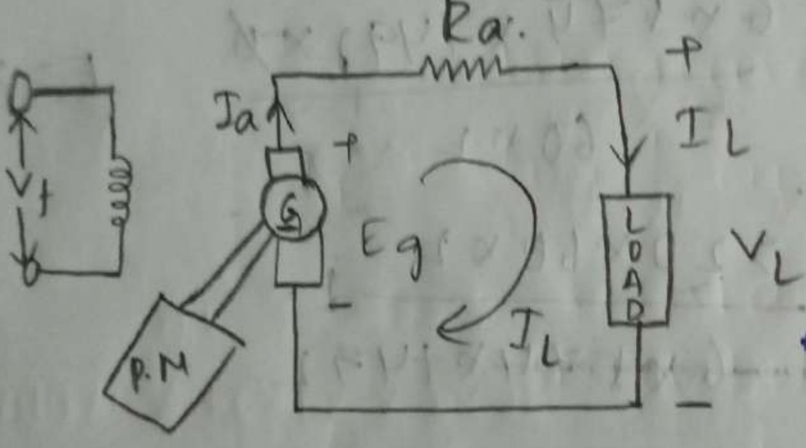
Types of DC Generator:

(i) sep. Excited

(ii) self excited — capable to work on its own

- (a) series
- (b) shunt
- (c) compound
  - (d) long shunt
  - (e) short shunt

(1) seperatly generated DC generators:



Apply KVL

$$-E_g + I_a R_a + V_L + B.C.D = 0.$$

B.C.D = Brushes contact Drop.

In problems If mentioned about BCD take that BCD value if not take

BCD = 2V in problems.

$$\boxed{E_g = I_a R_a + V_L + BCD}$$

armature generated power

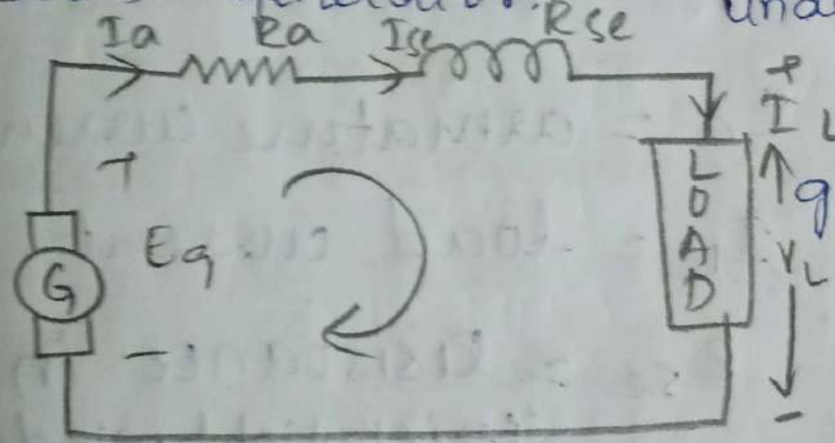
$$\boxed{P_g = E_g I_a}$$

Power ~~generated~~ by load.
consumed $\boxed{P_L = I_L V_L}$

$$\boxed{I_a = I_L}$$

(ii) Self ~~Gene~~ Excited:

(a) Series Generator: The field winding under self excited of DC generator



Apply KVL

$$-E_g + I_a R_a + I_{se} R_{se} + V_L + BCD = 0$$

$$E_g = I_a R_a + I_{se} R_{se} + V_L + BCD$$

$\boxed{P_g = E_g I_a}$. Power generated in armature.

$\boxed{P_L = V_L I_L}$ Power consumed by load.

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The field winding of DC generator connected in series with armature winding known as series generator.

I_{se} = current in series field winding

I_a = armature current.

I_L = load current.

R_{se} = Resistance in series field winding.

R_a = armature resistance

E_g = Generated voltage.

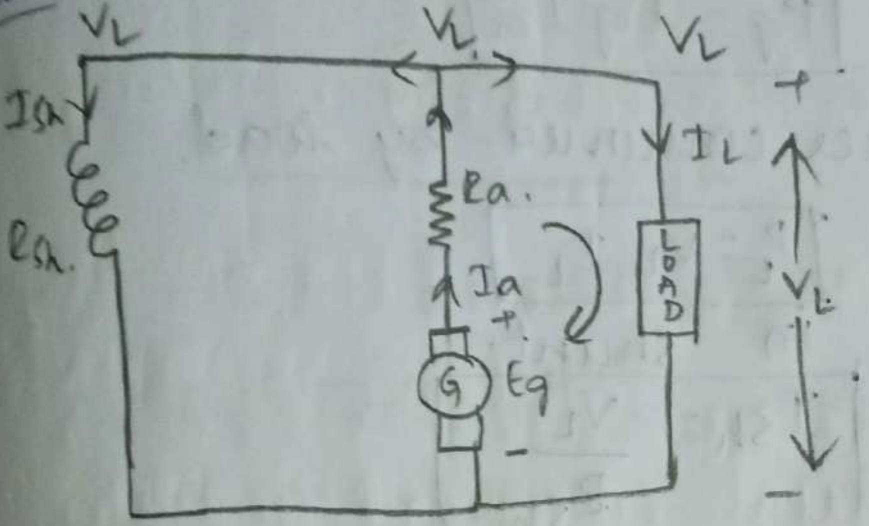
V_L = load voltage.

BCD = Brush contact drop.

separatly Generated:

we need to separatly provide external electrical energy to the stator get working flux on armature.

shunt Generator:



The field winding of the generator connected in parallel to armature known as shunt generator.

I_L = load current.

I_a = armature current.

E_g = generated EMF.

R_a = armature resistance.

R_{sh} = shunt field resistance.

V_L = load voltage or terminal voltage

I_{sh} = shunt current.

Applying KVL

$-E_g + I_a R_a + V_L + BCD = 0$.

$$\boxed{E_g = I_a R_a + V_L + BCD}$$

Armature Current

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

Power generated by armature

$$\boxed{P_g = E_g I_a}$$

Power consumed by load.

$$\boxed{P_L = V_L I_L}$$

current in shunt.

$$\boxed{I_{sh} = \frac{V_L}{R_{sh}}}$$

crane weight lifting → compound generator

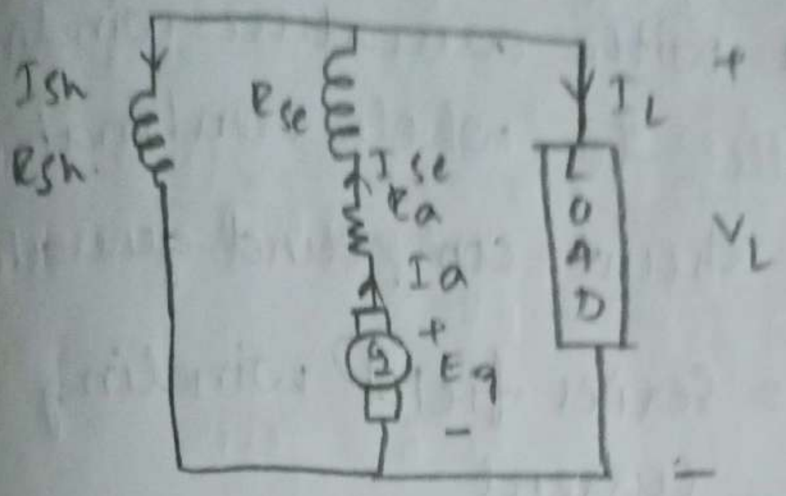
train → series generator → to produce more torque

mills → shunt generator → for constant speed

We use field winding in these series & shunt for flux.

(c) Compound:
↳ combination

① long shunt compound generator:



$$-E_g + I_a R_a + I_{se} R_{se} + V_L + BCD = 0.$$

$$E_g = I_a R_a + I_{se} R_{se} + V_L + BCD$$

current through armature and shunt are same

$$\boxed{I_a = I_{se}}$$

current is getting divided in I_{sh} & I_L

$$\boxed{I_a = I_{se} = I_{sh} + I_L}$$

Emf

$$\boxed{E_g = I_a R_a + I_{se} R_{se} + V_L + BCD.}$$

$$\boxed{E_g = I_a (R_a + R_{se}) + V_L + BCD}$$

Power generated by armature

~~$P_g = V$~~ $\boxed{P_g = E_g I_a} = E_g I_{se}$

$\boxed{P_L = V_L I_L}$

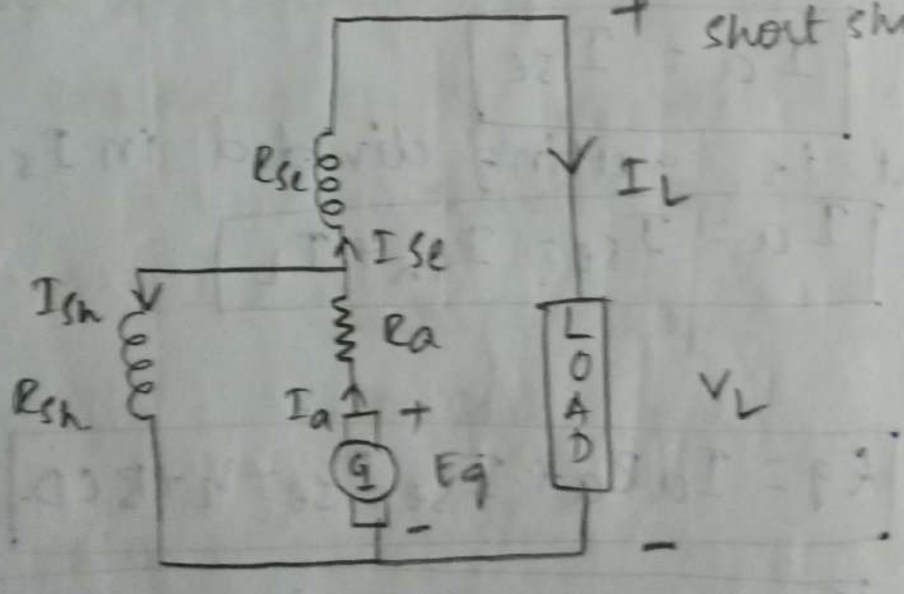
long shunt: The field winding in series with armature winding and parallel to whole combination is long shunt compound generator

I_{se} = Series field winding current.

R_{se} = series field winding resistance.

Short shunt compound generator:

Application for short shunt

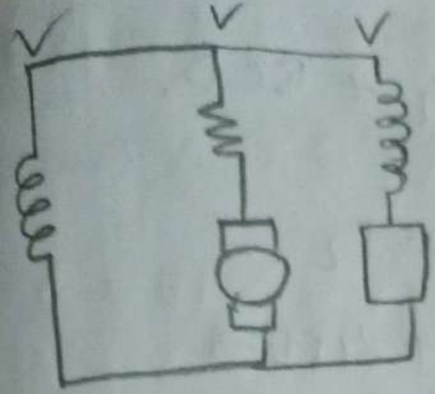


$$-E_g + I_a R_a + I_{se} R_{se} + V_L + BCD = 0$$

$$I_{sh} R_{sh} = I_{se} R_{se} + V_L$$

$$\boxed{I_{sh} = \frac{I_{se} R_{se} + V_L}{R_{sh}}}$$

32



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

$\boxed{I_{se} = I_L}$

$\boxed{P_g = E_g I_g}$

$\boxed{P = V_L I_L}$

Q) A shunt generator delivers 450A at 230V the resistance of shunt field and armature resistance are 50 Ω and 0.03 Ω respectively calculate the generate emf.

I_L $I_{sh} = 450$ A. $I = 450A$

$V_{sh} = 230$ V

~~$R_a = 50\ \Omega$~~ $R_{sh} = 50\ \Omega$

$R_a = 0.03\ \Omega$.

V_{sh}

$I_L = 450A$, $V_L = 230$ V.

$R_{sh} = 50\ \Omega$ $R_a = 0.03\ \Omega$.

$E_g = I_a R_a + V_L + BCD.$

$I_a = I_{sh} + I_L$

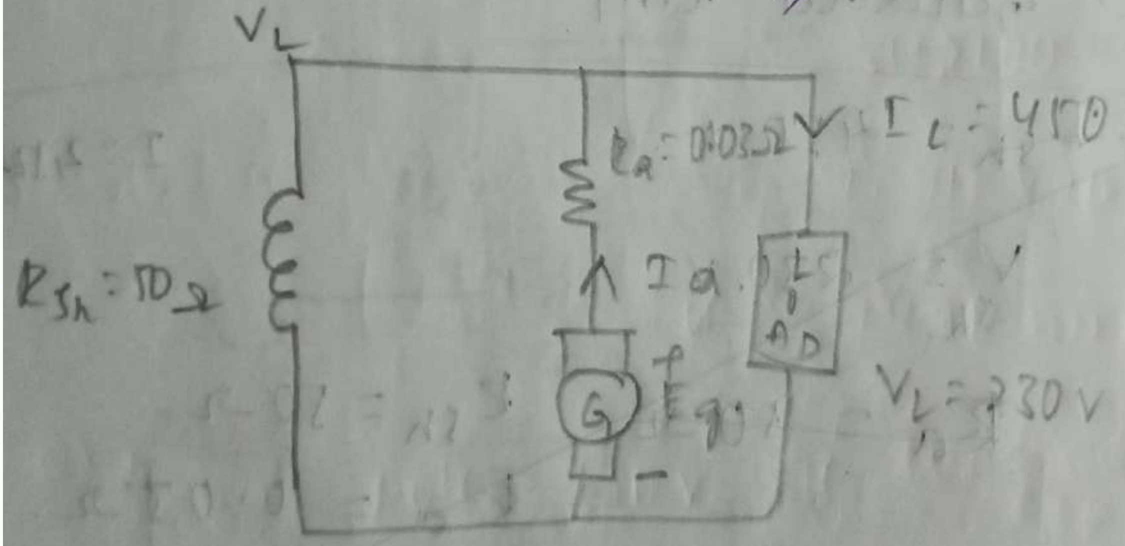
$= \frac{230}{50} + 450 A.$

$= 4.6 + 450.$

$= 454.6$

$E_g = (454.6)(0.03) + 230 + 2$

$= 245.638 V$



Q) A ~~8V~~ 8 pole DC generator with 778 wave connected armature running at 500 RPM supplies a load of 12.5 Ω resistance

P = 8

N = 500 A = 2

$R_L = 12.5$ terminal Voltage is 250V

calculate 1) Armature current

2) Generated EMF

3) Flux per pole

Assume armature resistance is 0.24Ω and shunt field resistance is 250Ω.

Armature current.

$R_{sh} = 250\Omega$

$I_a = I_{sh} + I_L$.

V_L. $R_{sh} = 250\Omega$

$I_a = \frac{V_L}{R_a}$

$R_a = 0.24\Omega$

$Z = 778$

$= \frac{250}{0.24} + \frac{250}{12.5}$

$= 1041$

$I = 213$

$\frac{V_L}{R_{sh}}$

$I_L = \frac{V_L}{R_L} = \frac{250}{12.5} = 20A$.

$= \frac{V}{R_{sh}} = \frac{250}{250} = 1A$.

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$I_a = 21A$.

$E_g = I_aR_a + V_t + BCD$

$= (21)(0.24) + 250 + 2$.

$E_g = 257.04\ V$.

$\phi = \quad E = \dfrac{\phi Z N P}{60A}$.

$257.04 = \dfrac{\phi \times 7.78 \times 8 \times 500}{120}$.

$\phi = \dfrac{30844.8}{3112000}$

$= 9.911 \times 10^{-3}$

$\phi = 9.91\ mWb$.

Q) A 4 pole 250V DC long shunt compound generator supplies a load of 10kW at the rated voltage. the armature, series ~~A~~ field and shunt field resistances are 0.1, 0.15, 250 Ω respectively the armature is lap connected

$P = 4$

$N = ?$

$P_2 = 10 kW$

$\phi = 50 mwb$

$A = P.$

$Z = 50 \times 6$

with 50 slots each slot containing 6 conductors if the flux per pole is 50 mWb. calculate N

$R_a = 0.1 \Omega$

$V_L = 250V.$

$R_{se} = 0.15 \Omega.$

$R_{sh} = 250 \Omega$

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

$E = I_a R_a + I_{se} R_{se} + V_L + BCD.$

$\cancel{I_a = \frac{250}{0.1} = 2500 A.}$

$I_{se} = \frac{V_L}{R_{se}} = \frac{250}{0.15} = 1666.66$

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$$E_g = \frac{\phi Z N P}{60 A}$$

$$E_g = I_a R_a + I_{se} R_{se} + V_L + BCD$$

$$I_a = I_{se}$$

$$= I_a (R_a + R_{se}) + V_L + BCD$$

$P_L = 10 kW = V_L I_L$

$$I_L = \frac{P_L}{V_L} = \frac{10 \times 10^3}{250}$$

$$= 40 A$$

$$I_{sh} = \frac{V}{R_{sh}} = \frac{250}{250} = 1 A$$

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

$I_a = 1 + 40 = 41 A.$

$E_g = 41(0.1 + 0.15) + 250 + 2$

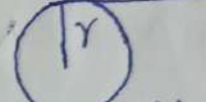
$= 262.25 V.$

$$262 = \frac{50 \times 10^{-3} \times 300 \times N \times \cancel{P}}{60 \times \cancel{P}}$$

$\therefore N = 1049 rpm //$

Torque eqn of a DC motor:

Torque is defined as twisting/



pully.

turning ~~force or of~~ movement of force and it is given by product of force and radius.

Let us consider a pully of radius r acted upon circumferen-tial force newton's which causes it to rotate at 'N' rpm

$T = F \times r$ $\left(\because P = \frac{W}{t}\right)$

$W = F \times D$

where D = Distance travelled in 1 revolution.

Work done to complete 1 revolution

$W = F \times D$

$= F \times 2\pi r.$

time taken complete 1 revolution.

N - rpm.

N rev — 60 sec.

rev — ? $\Rightarrow \frac{60}{N}$.

$t = \frac{60}{N}$.

$P = \frac{W}{t} = \frac{F \times D}{\frac{60}{N}}$

$P = \frac{F \times 2\pi r}{60/N}$

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$$= F \times r \times \frac{2\pi N}{60}$$

$$\boxed{P = T \times \omega}$$

$$\omega = \frac{2\pi N}{60} \Rightarrow \text{Angular velocity}$$

$$V \times I$$

$$P = E_b \times I_a$$

$$E_b I_a = T \times \omega$$

$$E_b = \frac{T \times \omega}{I_a}$$

$$\frac{\phi Z \cancel{N} P}{\cancel{60} A} = \frac{T_a \times 2\pi \cancel{N}}{\cancel{60} I_a}$$

$$\boxed{T_a = \frac{\phi Z P \times I_a}{2\pi \times A}} \quad N\text{-}m$$

Units of torque are 'N-m'.

where ϕ = flux

Z = speed

P = pole

I_a = armature current

A = No of ||el paths.

Q) calculate the value of Torque established by the armature of a 4 pole motor having 774 conductors. 2 paths in ||el 24 mwb flux per pole when I_a is 50 A.

$P = 4 \quad Z = 774$

$A = 2 \quad \phi = 24 mWb$

$I_a = 50 A.$

$$T_a = \frac{4 \times 24 \times 774 \times 50 \times 10^{-3}}{2 \times 3.14 \times 2.}$$

$$= \frac{4 \times 9288 \times 10^{-1}}{12.56.} = 295.718 \text{ N.m.}$$

295.796. (or)

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8) Determine the value of T in N-m developed by armature of 6 pole wave wound motor having 492 conductors and has an armature current of 40A find out Eg?

$P = 6$ $A = 2$ $Z = 492$

$\phi = 30 \times 10^{-3}$ $I_a = 40.$

$$E_g = \frac{\cancel{6} \times 30 \times 10^{-3} \times 40 \times 492}{\cancel{60}_{10} \times 2}$$

$$= \frac{3542.4}{60 \times 2} = 29.52.$$

$$= \frac{\overset{15}{\cancel{30}} \times \cancel{40} \times 492 \times 10^{-2}}{\cancel{20}}$$

$= 15 \times 492 \times 10^{-2}$

$= 282.0392$

Q) A 250V dc motor runs at 1500 rpm and takes Ia of 50 A back emf of DC motor is 240 V obtain Torque developed in motor.

V_L ~~Eg~~ $= 250$

$N = 1500\,rpm$

$I_a = 50\,A$

$E_b = 240\,V$

$E_g = \dfrac{\phi Z N P}{60 A}$

$W = \dfrac{2\pi N}{60}$

$E_b = \dfrac{T \times W}{I_a}$

$\dfrac{9420}{60}$

$240 = \dfrac{157 \times T}{50}$

$W = 157$

$\dfrac{12000}{157} = T$

$T = 76.433\,N\text{-}m$

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8) A 250V 4 pole wave wound dc series generator delivers a current of 180A take $R_{a} = 0.75\Omega$ and $R_{se} = 0.15\Omega$ calculate Emf generated & I_a of generator.

$P = 4 \quad A = 2$

$I_{La} = 180$ $\quad R_a = 0.75\Omega$

$\cancel{E_g = 250V}$

$R_{se} = 0.15\Omega$ $\quad V_L = 250V$

$I_a = I_{se} = I_L$

$\cancel{I_a = \frac{E_g}{R_a} = \frac{250}{0.75}}$

$\cancel{I_a = 333.3}$

$E_g = I_a R_a + I_{se} R_{se} + V_L + BCD$

$= (180)(0.75) + (180)(0.15) + 250 + 2$

$= 135 + 27 + 252$

$= 414 V$

Types of DC Motors:

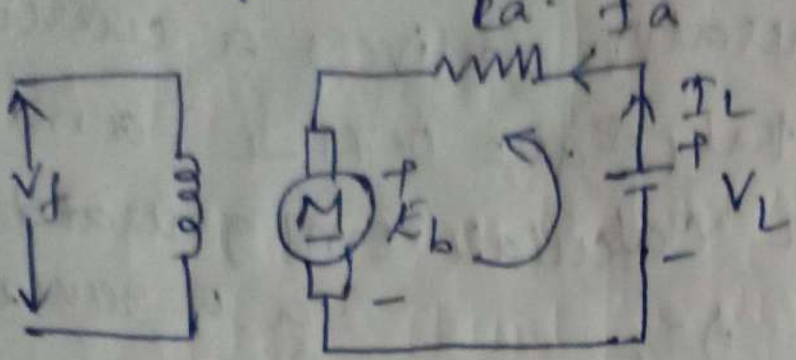
① Sep. Excited DC Motors

② Self excited DC motors

ⓐ DC series ⓑ shunt ⓒ compound

(i) long shunt compound motor (ii) short shunt

① Seperatly excited DC motor :



$\boxed{I_L = I_a}$

Applying KVL

$-V + I_a R_a + E_b = 0.$

$$\boxed{E_b = V - I_a R_a \mp BCD}$$

Power generated across source.

$$\boxed{P_s = V_L I_L}$$

Mechanical Power generated by motor/armature

$$\boxed{P_m = E_b I_a}$$

→ Whenever excitation to the field winding is provided by some external source is called separatly excited DC motor.

V_L = line voltage.

I_L = line current

I_a = Armature current

R_a = armature resistance.

V_f = V field excitation.

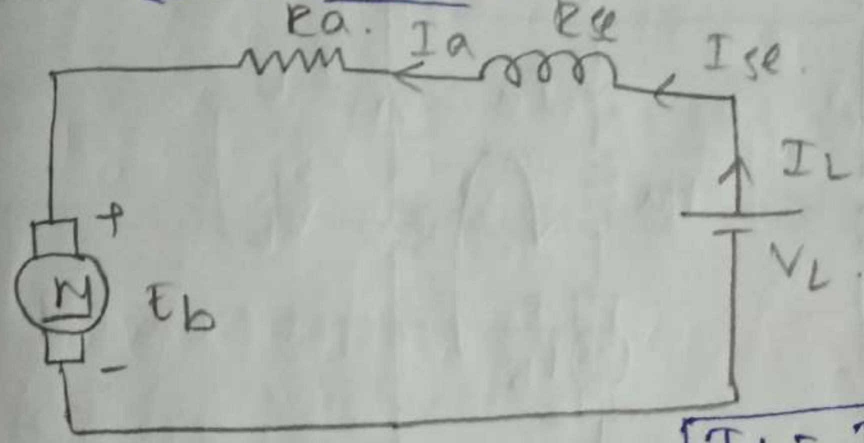
P_s = Source power.

E_b = back emf.

P_m = Mechanical power generated by armature.

2) Self-Excited DC motors:

a) DC series motor:



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

Applying KVL

$$-V_L + I_{se}R_{se} + I_aR_a + E_b = 0$$

$$\boxed{\cancel{V_L = I_{se}R_{se} + I_aR_a + E_b} + BCD}$$

$$-V_L + I_a(R_a + R_{se}) + E_b = 0$$

$$\boxed{E_b = V - I_a(R_a + R_{se}) - BCD}$$

Source Power

$$\boxed{P_s = V_L I_L}$$

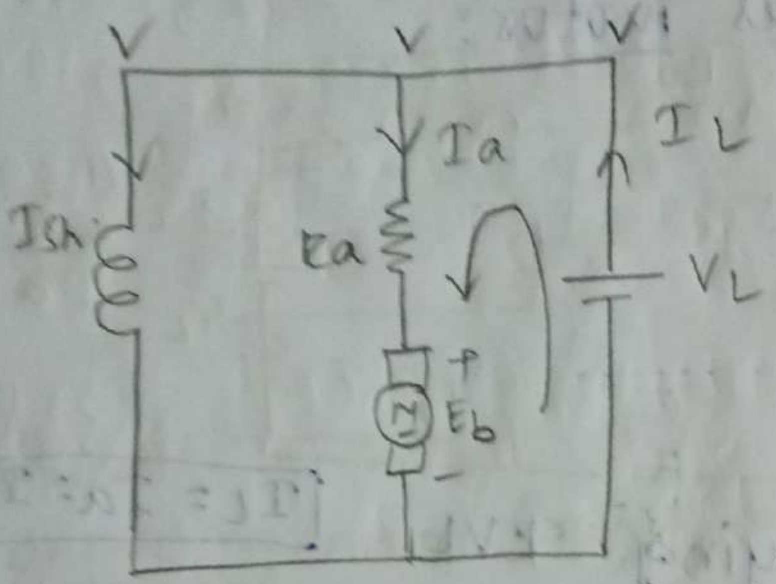
Mechanical power generated

$$\boxed{P_m = E_b I_a}$$

R_{se} = shunt resistance.

I_{se} = shunt current.

b) DC shunt motor:



Applying KVL

$$-V + I_a R_a + E_b = 0$$

$$\boxed{E_b = V - I_a R_a} \text{ BCD}$$

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

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

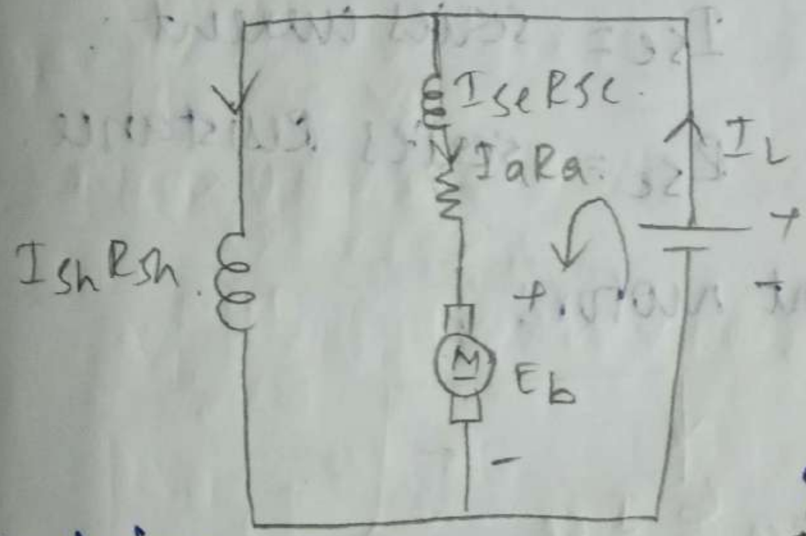
$$\boxed{P_s = V_L I_L} \quad \boxed{P_m = E_b I_a}$$

DC series motor:
Whenever the fieldwinding is connected in series with armature is called DC series motor.

DC shunt motor:
Whenever the field winding is connected in parallel with armature is called DC shunt motor.

(c) Compound motors:

long shunt compound motor:



$$\boxed{I_{sh} = \frac{V_L}{R_{sh}}}$$

$I_a = I_{se}$.

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

$\boxed{I_L = I_{se} + I_{sh}}$

Applying KVL

$-V_L + I_{se}R_{se} + I_aR_a + E_b = 0$.
$+ BCD$.

~~$V_L = I_{se}R_{se}$~~

$$\boxed{E_b = V_L - I_{se}R_{se} - I_aR_a - BCD}$$

$$\boxed{E_b = V_L - I_a(R_{se} + R_a) - BCD}$$

Power in motor

$$\boxed{P_m = E_b I_L}$$

Power across source

$$\boxed{P_s = V_L I_L}$$

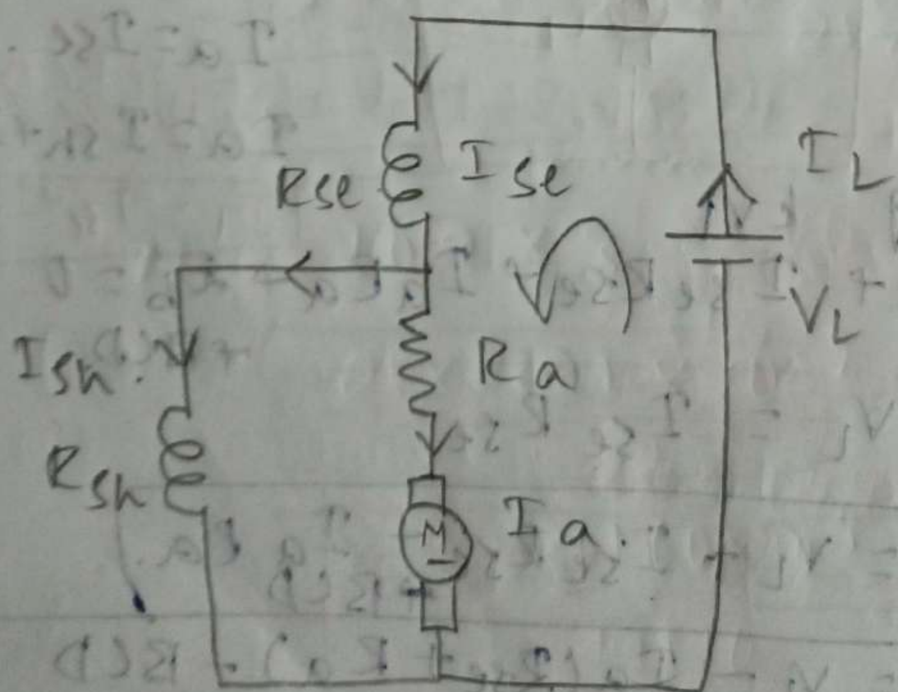
$$\boxed{I_{sh} = \frac{V}{R_{sh}}}$$

$$\boxed{I_L = I_{se} + I_{sh}}$$

I_{se} = series current.

R_{se} = series resistance.

short shunt motor:



$$-V_L + I_{se}R_{se} + I_aR_a + BCD = 0.$$
$$+ E_b$$

$$\boxed{E_b = V_L - I_{se}R_{se} - I_aR_a - E_b - BCD.}$$

$$\boxed{I_L = I_{se}}$$

$$\boxed{I_L = I_{se} = I_{sh} + I_a}$$

$$V_L\ \cancel{I_L} + I_{se}R_{se} = I_{sh}R_{sh}.$$

$$\boxed{I_{sh} = \frac{I_{se}R_{se} + V_L}{R_{sh}}.}$$

Q) A DC 6 pole shunt motor has wave connected armature with 87 slots, each slot containing 6 conductors the $\phi = 30 mWb$. The armature has Resistance $= 0.10 \Omega$. Calculate N, when motor is connected to 250V supply & taking $I_a = 80A$.

$P = 6, \quad A = 2$

$Z = 87 \times 6$

$\phi = 30 mWb = 30 \times 10^{-3}$

$R_a = 0.10 \Omega$

$V_L = 250V$

$I_a = 80A.$

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

$E_b = V - I_a R_a + BCD$

$= 250 - 80 \times 0.10 + 2$

$= 250 - 8 + 2$

$= 250 - 10 = 240.$

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$I_L = I_a + I_{sh}$.

$P_s = V_L I_L$

$P_m =$

$$E_b = \frac{\phi Z N P}{60 A}$$

$$240 = \frac{30 \times 10^{-3} \times 87 \times 6 \times N \times 6}{60 \times 2}$$

$$\frac{240 \times 120}{3 \times 87 \times 6 \times 6 \times 10^{-2}} = N$$

$$\frac{24 \times 12}{3 \times 36 \times 87} = \frac{288}{9396} = N = 0.03065$$

$= 306.5$

Q) A 4 pole DC shunt motor has $\phi = 0.04$ Wb & Armature is lap wound with 720 conductors

$P = 4$, $\phi = 0.04$ Wb $A = P$

$Z = 720$

shunt field resistance is 240 Ω &

$Ra = 0.2\,\Omega$ & BCD is 1 V per

$R_{sh} = 240\,\Omega$

brush. Determine Drop the N of

machine running as motor at

60 A.

$BCD = 2 \times 1$

$= 2V.$

$P = 4.$

$I_L = 60A.$

$V_L = 240V.$

$Eb = V - I_a R_a - BCD$

$Eb = 240 - (I_a)(0.2) - 2.$

$I_L = I_a + I_{sh}.$

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

$= \frac{240}{240.}$

$= 1$

$60 = I_a + I_{sh}.$

$60 = I_a + 1$

$I_a = 59.$

$Eb = 240 - (59)(0.2) - 2.$

$Eb = 226.2$

$$\frac{226.2\pi}{0.04 \times 720 \times} = E_b \quad \frac{\phi ZNP}{60A}$$

$$\frac{226.2 \times 60}{0.04 \times 720 \times} = N$$

$$\frac{13572}{28.8} = N$$

$$N = 471.25 \text{ rpm.}$$

Power lost in the form of heat.

losses in DC machine:

loses

- Cu loss
  - armature $I_a^2 R_a$
  - series $I_{se}^2 R_{se}$
  - shunt $I_{sh}^2 R_{sh}$
- Iron or (Observed in core machine)
  - W_h → histrisus losses
  - W_e → eddicurrent losses.
  - depends on materials used
- Mech. (usually observed in shaft of machine.)
  - friction
  - windage.

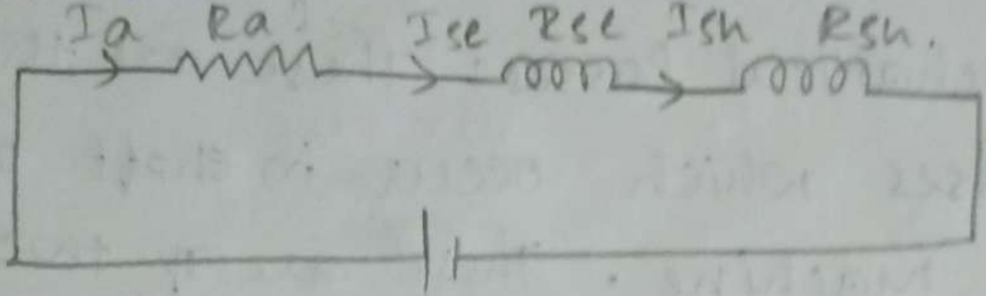
for mechanical energy we use shaft.

$B_h \Rightarrow$ max. flux density $\quad \eta_h \Rightarrow$ histone co-efficient

To reduce We we laminate core

t = thickness of each lamination

(i) Cu losses:



Cu losses $= I_a^2 R_a + I_{se}^2 R_{se} + I_{sh}^2 R_{sh}$

load will be connected to shaft. It will be coupled directly.

(ii) iron loss: η_e = eddycurrent co-efficient.

$$\boxed{\begin{array}{l} \text{hysterysis}(W_h) = \eta_h B_m^{1.6} f V. \\ \text{eddy losses}(W_e) = \eta_e B_{max}^2 f^2 t^2 \end{array}}$$

η_h = histyrisis co-efficient.

$B_m^{1.6}$ = maximum flux density.

f = frequency.

V = volume of core.

t = thickness of lamination → to minimise the eddycurrent losses.

η_e = eddycurrent co-efficients.

B_{max} = Maximum flux density.

f = frequency.

t = thickness.

Mechanical losses: These are the losses which occur in shaft of DC machine. These are of two types. 1) friction loss.

2) windage loss.

copper losses: Power wasted in the form of I^2R and these type of losses occur in dc winding of the machine are called copper losses. These are of three types.

Efficiency (η) 1) armature.

2) series

3) shunt.

Efficiency (η): The ratio of output power and input power is known as efficiency. It is denoted by η

$$\eta = \frac{\text{output power}}{\text{input power}}$$

$$\eta = \frac{P_0}{P_i}$$

$$= \frac{P_0}{P_0 + \text{losses}}$$

$$\boxed{\% \eta = \frac{P_0}{P_0 + \text{losses}} \times 100}$$

Q) A 230V shunt motor delivers 30 Hp at the shaft at 1120RPM if the motor has efficiency of 87% at this load determine

i) Total input power

ii) line current. (I_L)

$V_L = 230V$. $N = 1120$ RPM.

$P_{out} = 30$ Hp.

$\eta = 87\%$. $= 30 \times \cancel{10^3}\ 746$.

$$\eta = \frac{P_o}{P_i} \times 100$$

$$87 = \frac{30 \times 746}{P_i} \times 100$$

$$P_i = \frac{30 \times 746}{87} \times 100$$

$$P_i = 25724.137$$
$$= 25724$$

$$\cancel{I_L = \frac{V_L}{P_i} = \frac{230}{25724}}$$

$$P_i = I_L V_L$$

$$I_L = \frac{P_i}{V_L}$$

$$= \frac{25724}{230} = 111.843A$$

$\cdot 40$

8) A shunt generator delivers 195A at a terminal voltage of 250V the armature & sh. R are 0.02 Ω, 50 Ω respectively. The iron & friction losses = 950W. find 1) Emf generated.

2) Cu losses.

3) output of generator.

4) η.

$I_L = 195A$.

$V_L = 250V$.

$R_a = 0.02 \Omega$

$R_{sh} = 50 \Omega$.

$W_i \& W_f$ = 950 W.

friction, so take it as mechanical loss.

$\eta_h B_m^{1.6} f V$

$I_a = I_L + I_{sh}$.

$W_{cu} = ?$

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

Emf =

$= \frac{250}{50}$.

$I_a = 195 + 5$

$= 200$.

$= 5$.

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$E_{mf} = I_a R_a + V_L + BCD$

$= (200)(0.02) + 250 + 2$

$= 4 + 252$

$= 256$

$W_{cu} = I_a^2 R_a + I_{sh}^2 R_{sh}$

$= (200)(200)(0.02) + (5)(5)(50)$

$= (200)(4) + (25)(50)$

$= 800 + 1250$

$= 2050 \, W$

$P_0 = V_L I_L$

$= (250)(200)$

$= 500$

$= (250)(195)$

$= 48750$

$\eta = \frac{P_0}{P_i}$

$950 + 2050$

$= \frac{P_0}{P_0 + loss}$

$\frac{48750}{51750}$

$= \frac{48750}{48750 + 300} \times 100 = 94.2\%$

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$$\eta = \frac{P_0}{P_0 + \text{losses}}$$

$$\text{losses} = W_{cu} + W_i + W_m$$

$$= 950 + 2050$$

$$= 3000.$$

~~W_i &~~.

Q) A long shunt compound generator, gives 240V at full load out put of 100 Amp resistance ~~of 100 Ω~~. The resistance of various windings of the machine are $R_a = 0.1\,\Omega$, $R_{se} = 0.02\,\Omega$, $R_{sh} = 100\,\Omega$. The iron loss on full load is 1000W. Windage & friction losses 500W. calculate full load efficiency of the machine.

$V_L = 240V$	$R_a = 0.1\,\Omega$
$I_L = 100A$	$R_{se} = 0.02\,\Omega$
$W_i = 1000W$	$R_{sh} = 100\,\Omega$
$W_m = 500W$	

$$\eta = \frac{P_0}{P_0 + \text{losses}}$$

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

$$E_g = I_a R_a + I_{se} R_{se} + V_L + E_L \; BCD$$

$$P_0 = V_L \times I_L$$

$$P_0 = (100)(240)$$

$$= 24000$$

$$I_{sh} = \frac{V}{R_{sh}} = \frac{240}{100} = 2.4$$

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

$$= 2.4 + 100$$

$$= 102.4$$

$$E_g = 102.4(0.1 + 0.02) + 240 + 2$$

$$= (102.4)(0.12) + 242$$

$$= 12.288 + 242$$

$$= 254.288$$

$P_{cu} = (I_a^2 R_a) + I_{se}^2 R_{se} + I_{sh}^2 R_{sh}$

$= (102.4)(102.4)(0.1) + (102.4)$ lated

$(102.4)(0.02) +$

$(2.4)(2.4)(100)$

$= 1048.57 + 213 + 576.$

$= 1837.57.$

$\text{losses} = 1837.57 + 1000 + 500.$

$= 3337.57.$

$$\eta = \frac{24000}{240000 + 3337.57} \times 100.$$

$$= \frac{24000}{27337} \times 100.$$

$= 87.79.$

$= 87.8.$

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