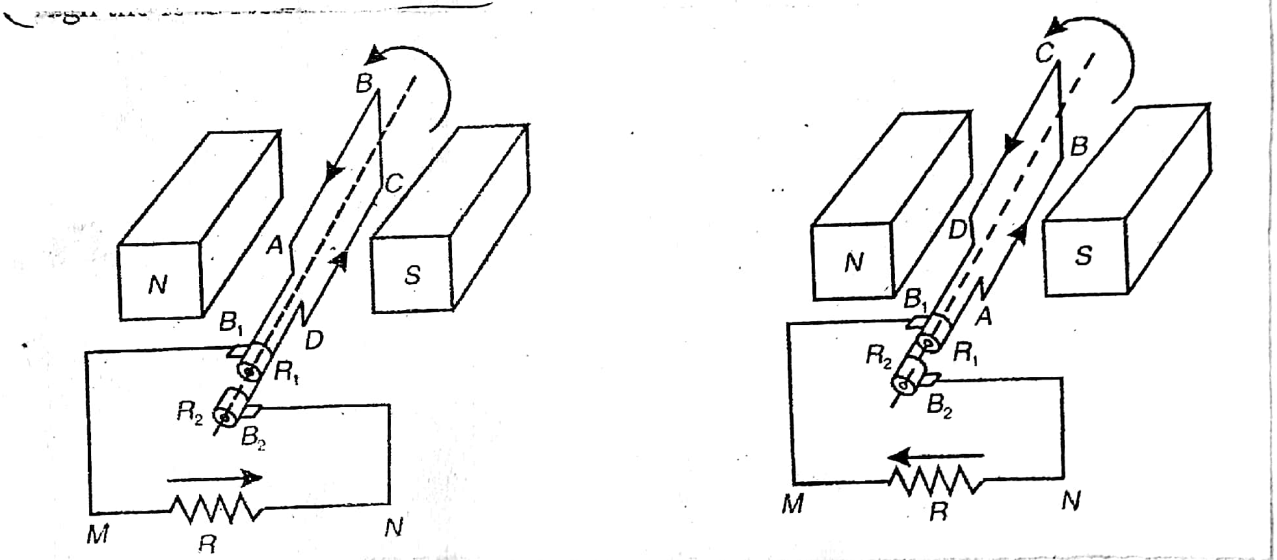
D.C GENERATORS :

INTRODUCTION : An Electrical Machine which Converts Mechanical energy into an Electrical energy is called an Electric generator.

The D.C generators Convert Mechanical energy into D.C Electrical energy.

WORKING PRINCIPLE :



- A D.C generator Works on the Principle of Electromagnetic Induction, The nature of the Induced EMF is Dynamically induced EMF.
- The equn: for the EMF Induced in each conductor is given by,

$$\boxed{e = BLV\sin\theta = E_m \sin\theta}$$

where B = Flux density produced by the poles in Wb/m^2 or Tesla.

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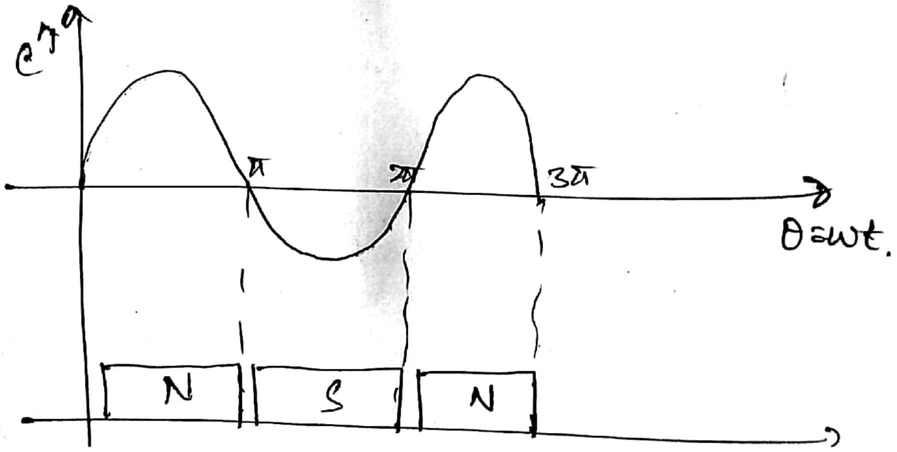
l = Length of the Conductor in meters.
V = Velocity with which the conductor is moving m/s.

Explanation: The two conductors are connected together to form a coil ABCD.

During one revolution, each of the conductors cut the flux from zero value to Maximum value & again zero value, when it is moving under a pole. ∴ The nature of the EMF induced in the conductor is sinusoidal in nature, as shown in fig below.



CONSTRUCTION OF A D.C MACHINE :-

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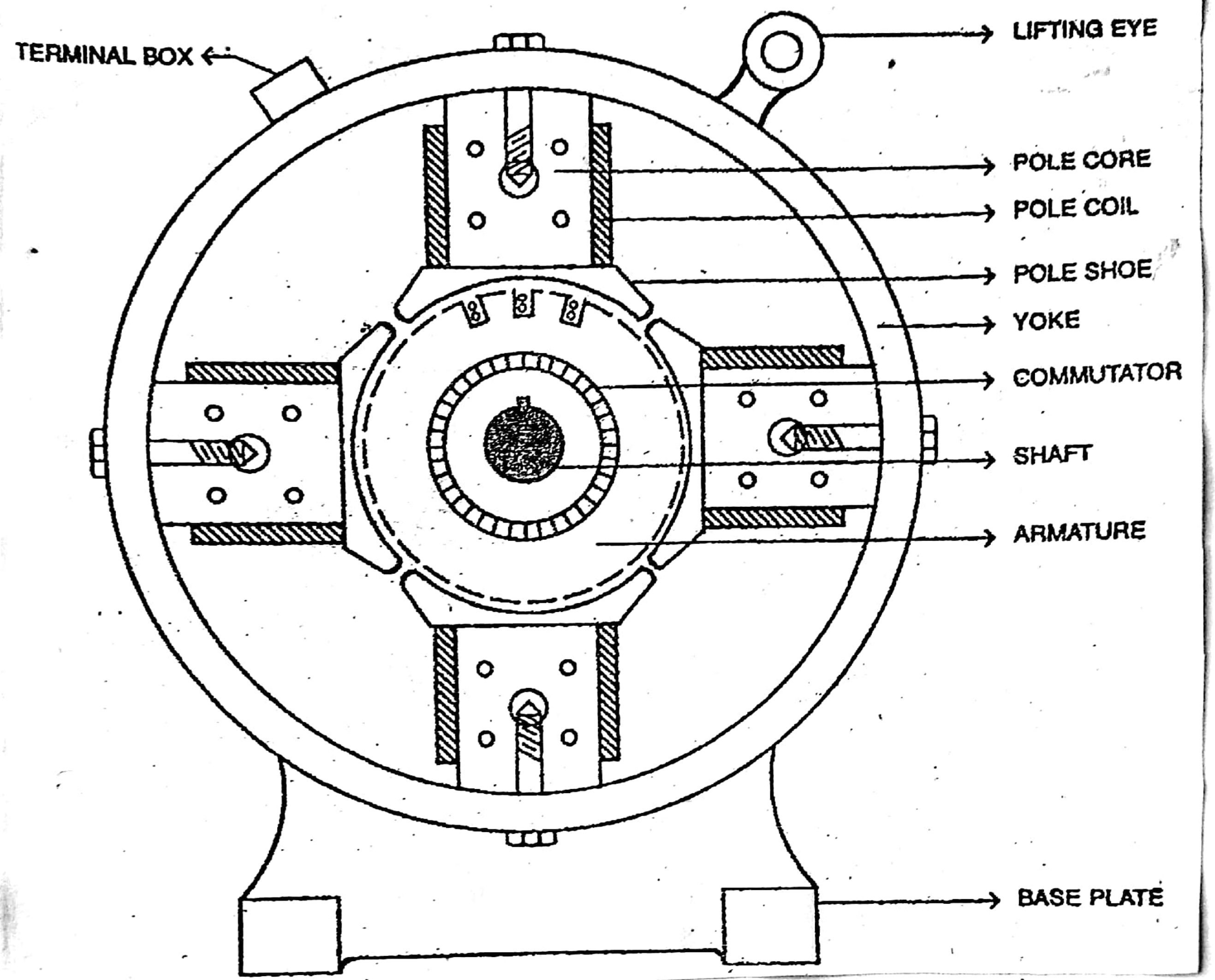

A D.C generator consists of 2-parts
(1) Stationary part.
(2) Rotating part.

Stationary Part consists of
(i) Yoke or Magnetic frame
(ii) Main pole along with Pole shoes & Pole coils
(iii) Base plate & Lifting eye.
(iv) Brush Box with Brushes.
(v) Terminal Box

Rotating part Consists of

(i) Armature Core & Armature Windings.
(ii) Commutators.
(iii) Shaft & Bearings.

YOKE (OR) MAGNETIC FRAME :

FUNCTIONS : It serves the purpose of Outermost cover of a D.C machine, so that insulating materials get protected from Harmful atmospheric elements like moisture, Dust & Various gases like SO_2, Acidic fumes, etc.

↳ The Yoke Supports the field System & forms a part of the Magnetic Circuit.

CHOICE OF MATERIAL : In order to reduce weight & to have better Magnetic properties, yokes of Large generators are made of cast steel & yokes of Small generators are made of cast Iron as they are cheap.

MAIN POLES, POLE SHOES & POLE COILS :

(a) POLE CORE & POLE SHOES

(b) POLE COILS (OR) FIELD WINDINGS.

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(a) POLE CORE & POLE SHOES

FUNCTIONS :

* Pole Core Carries the field windings necessary to produce the Magnetic flux, required for the generation of EMF.
* Pole Shoe directs the flux produced through airgap to Armature core.
* Pole shoes are cylindrical shape so that the flux produced spreads out Uniformly in the airgap & also it reduces the reluctance of the Magnetic path because of larger area of Cross section(a)

CHOICE OF MATERIAL : The main poles are made of an alloy steel of high relative permeability. The pole core is made of laminations of required shape & size, and are stamped to get a pole which is then bolted to the yoke.

(b) FIELD WINDING :

The field winding is wound on the pole core with a definite direction.

FUNCTIONS :

* To carry current due to which pole core, on which the field winding is placed, behaves as an Electromagnet, producing necessary flux.

* Field winding is wound in such a direction that alternate 'N' and 'S' poles are formed. The total no. of poles is denoted as P.

CHOICE OF MATERIAL : Copper is the best material as it is a good Conductor & has good pliability.

BRUSH BOX WITH BRUSHES :

FUNCTIONS :-

* Brushes are stationary & resting on the Surface of the Commutator.
* It collects Current from commutator and makes it available to the stationary external circuit via Terminal box.

CHOICE OF MATERIAL :-

* Brushes are normally made up of Soft material like Carbon to avoid wear & tear of Commutator.

ARMATURE CORE & ARMATURE WINDINGS :-

(a) ARMATURE CORE
(b) ARMATURE WINDING

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(a) ARMATURE CORE :-

FUNCTIONS:

*

* Armature core is cylindrical in shape mounted on the shaft. It has uniformly cut slots on its outer periphery on which Armature windings are placed.
* Armature core has Air ducts which serve the purpose of cooling

CHOICE OF MATERIAL:
* It is madeup of silicon steel laminations to minimise the eddy current losses.

(b) ARMATURE WINDING :- The outer periphery of the Armature is cut into number of slots to hold the Armature windings.
There are 2-types of winding
LAP WINDING → which carries more current
WAVE WINDING → which carries less current.

CHOICE OF MATERIAL :- It is made up of a conducting material like copper.

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COMMUTATOR :-

FUNCTIONS : Commutator collects the current from Armature Conductor and Converts Alternating Current into Direct Current (A.C to D.C)

CHOICE OF MATERIAL : It is cylindrical in Shape & is made up of Wedge shaped Segments of high conductivity Copper. These Segments are insulated from each other by a thin layer of insulating Mica.

SHAFT & BEARINGS :-

The Shaft of the D.C generator is rotated by a prime Mover, due to which the Armature rotates. For small generators, roller bearings are used at both ends of the Shaft.

EMF equation of a D.C Generator :

Let, P = Number of Poles.

N = Speed of Armature in r.p.m

ϕ = Flux per pole in Webers.

Z = Total number of Armature Conductors.

A = Number of parallel paths.

The Flux cut by the conductor in One revolution } $d\phi = P\phi$

Time take by the conductor to make one revolution } $dt = \frac{60}{N}$

$\therefore$ EMF Induced in One Conductor $\frac{d\phi}{dt} = \frac{P\phi}{\left(\frac{60}{N}\right)}$

$$\frac{d\phi}{dt} = \frac{PN\phi}{60} \text{ volts.}$$

$\therefore$ The EMF induced per parallel path } = EMF Induced per Conductor } $\times$ { Number of Conductors per parallel path

$$E_g = \frac{PN\phi}{60} \times \frac{Z}{A}$$

$$\boxed{E_g = \frac{PN\phi Z}{60A} \text{ volts}}$$

is called EMF equn. of a D.C generator.

Case (i) : For Lap Winding $A = P$, $\therefore E_g = \frac{N\phi Z}{60}$ volts

Case (ii) : For Wave Winding $A = 2$, $\therefore E_g = \frac{PN\phi Z}{120}$ volts

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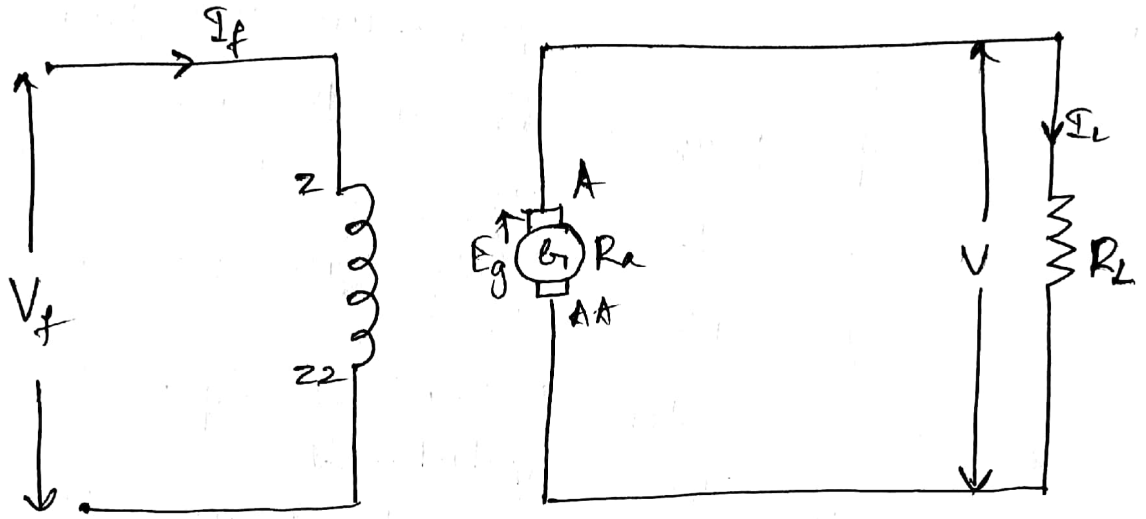
NOTE: SYMBOLIC REPRESENTATION OF A DC GENERATOR :



↳ The Symbolic representation of a D.C generator with its Armature & Field windings is shown in fig above.

↳ The Field winding is connected to a D.C voltage Source of Voltage V_f, due to which a Constant Current of I_f Amps flows through the field winding. A Magnetic flux 'ϕ' is produced by field winding.

↳ When the Armature is rotated by means of Prime mover, the Armature Conductors cut the Magnetic flux & hence an EMF 'E_g' is generated.

↳ When a load Resistance R_L is connected across the terminals of the Generator, a load Current 'I_L' flows through it. 'V' is the Terminal voltage of the D.C generator.

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* A & AA Represent positive & Negative terminals of Armature Respectively
* Z & ZZ Represent positive & Negative terminals of Field winding Respectively.

NOTE : The Terminal Voltage of the D.C generator is slightly less than generated Voltage, because

(i) The Armature Conductors have a small resistance known as Armature Resistance 'R_a' & hence a small Voltage drop 'I_aR_a' due to current flowing through the Armature conductors.

(ii) The current in the Armature sets up its own flux known as Armature flux, this opposes the main flux & hence the main flux gets reduced & Hence the EMF induced in the D.C generator also gets reduced.
This is known as Armature Reaction Drop (A.R.D)

(iii) The contact b/n the Commutator & the Brushes has some resistance known as Brush contact Resistance. ∴ The Voltage in a D.C generator due to Brush contact resistance is two times the Voltage drop per brush.

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Generated EMF = Terminal Voltage + Armature Resistance Drop + Armature Reaction Drop + Brush Contact Resistance Drop

$$E_g = V + I_a R_a + A.R.D + B.C.D$$

or

$$V = E_g - I_a R_a - A.R.D - B.C.D$$

TYPES OF GENERATORS :

- Self excited D.C generator
  - D.C Shunt generator
  - D.C Series generator
  - D.C Compound generator.
    - Cummulatively compounded
      - Long Shunt
      - Short Shunt
    - Differentially compounded
      - Long Shunt
      - Short Shunt
- Seperately excited D.C generator

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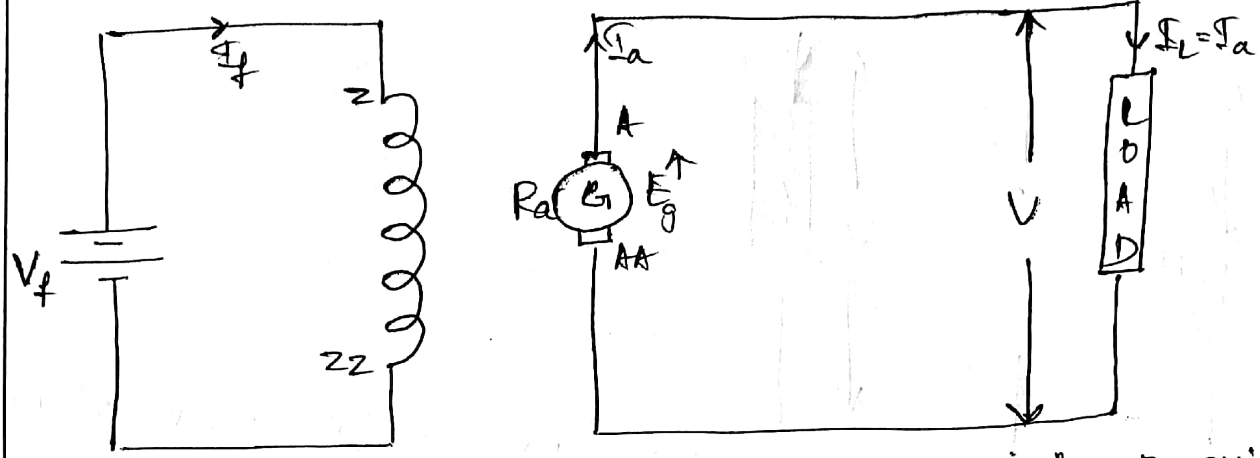
SEPERATELY EXCITED D.C GENERATOR :



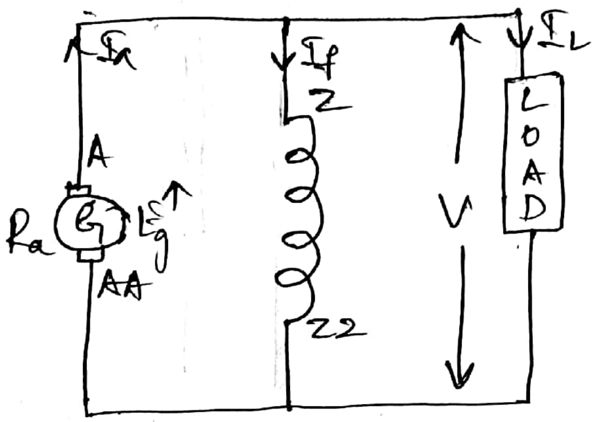
* The excitation to the field winding is provided by a Seperate D.C voltage 'V_f'. This Voltage drive a current I_f through the field winding due to which a Magnetic flux is produced.
* When the Armature is rotated by a Prime mover, the Armature conductors cut the Magnetic flux & hence an EMF 'E_g' is Induced.
* When the load is connected across the Armature terminals, a Current I_L flows through the load.
* If 'V' is the Terminal Voltage of D.C generator, then $I_a = I_L$

&

$$V = E_g - I_a R_a - A.R.D - B.C.D$$

where, A.R.D → Armature Reaction Drop
B.C.D → Brush Contact Resistance Drop

SELF EXCITED D.C GENERATOR :



* The excitation to the field winding is provided by the generator itself.
* Here the Pole Cores have a residual flux ϕ_r, when the Armature is rotated by the Prime mover, the Armature Conductors Cut the residual flux & A Small amount of EMF is induced.
* This is Cummulative process, the increase of Induced EMF & the increase of flux, help each other and the Terminal Voltage is builtup to its rated value.

$$I_a = I_L + I_f \quad \&$$

$\therefore$ Terminal Voltage $\Big\}$ $V = E - I_a R_a - A.R.D - B.C.D$

where, A.R.D → Armature Reaction Drop
B.C.D → Brush Contact Drop.

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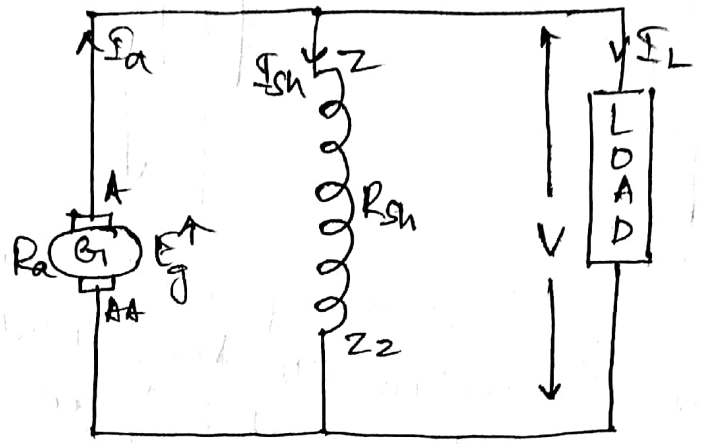
D.C SHUNT GENERATOR :

* The Shunt field winding consists of a large number of thin turns of copper, So that its resistance is quite high & I_{sh} is very Small.



* I_{sh} & hence the flux produced remains allmost Constant, irrespective of the load current, over operating range of the generator.
* It is called as Shunt generator because the field winding is Connected across the Armature Terminals.
* From the circuit, $I_{sh} = \frac{V}{R_{sh}}$ where, R_{sh} = Resistance of Shunt field Winding.

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

Terminal Voltage $V = E_g - I_a R_a - A.R.D - B.C.D$ where,

A.R.D → Armature Reaction Drop.

B.C.D → Brush Contact Drop.

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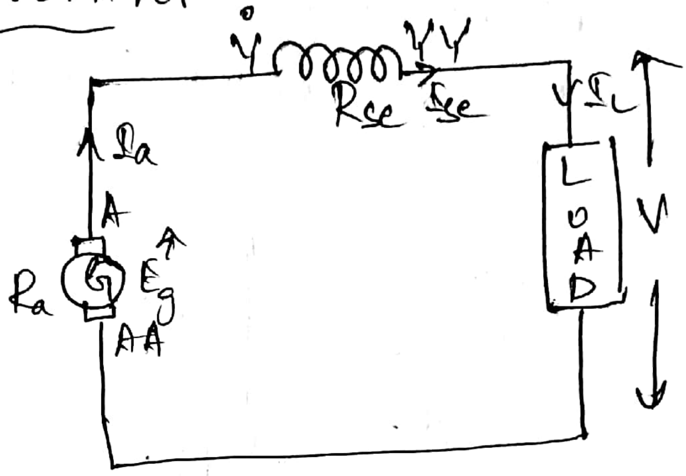
D.C SERIES GENERATOR :



* The Series field winding Consists of a few thick Copper turns, hence its resistance is very small.
* Whatever the current flows through the load same current flows through Armature & field winding.
* This is called Series generator, because the field winding is connected in Series with Armature.

$\therefore \quad I_a = I_{se} = I_L$

Terminal Voltage } $V = E - I_a(R_a + R_{se}) - A.R.D - B.C.D$

where A.R.D = Armature Reaction Drop.
B.C.D = Brush Contact Drop.

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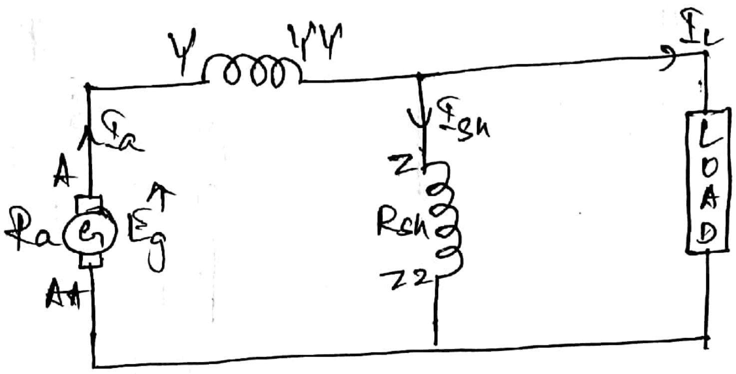
COMMULATIVELY COMPOUNDED D.C GENERATORS :

(a) LONG SHUNT :



The Total flux $\phi = \phi_{sh} + \phi_{se}$

where, ϕ_{sh} = Flux produced by shunt field winding.

ϕ_{se} = Flux produced by series field winding.

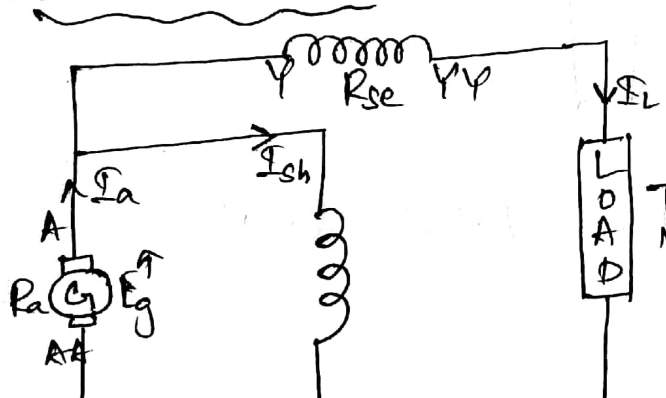
$$I_{sh} = \frac{V}{R_{sh}} \quad \& \quad I_a = I_L + I_{sh}$$

Terminal Voltage $\}$ $V = E - I_a(R_a + R_{se}) - A.R.D - B.C.D$

where A.R.D = Armature Reaction Drop
B.C.D = Brush Contact Drop

(b) SHORT SHUNT :

$$I_{sh} = \frac{V + I_L R_{se}}{R_{sh}} \quad \& \quad I_a = I_L + I_{sh}$$



Terminal Voltage $\}$ $V = E - I_a R_a - A.R.D - B.C.D$

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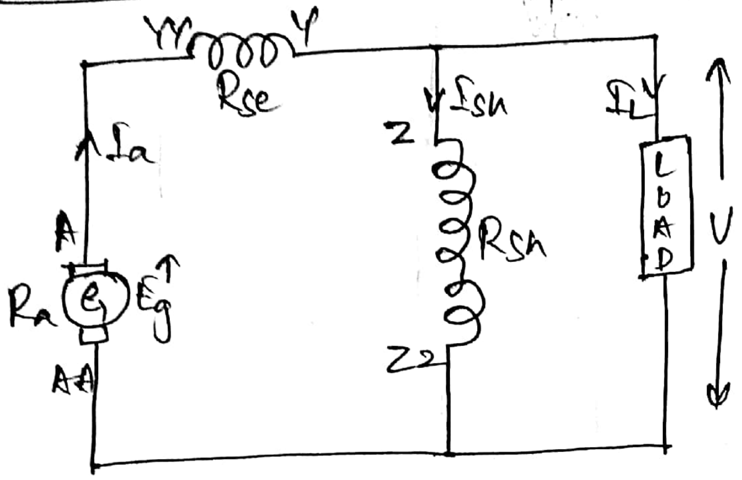
DIFFERENTIALLY COMPOUNDED D.C GENERATORS :-

(a) LONG SHUNT :-



Resultant Flux } $\phi = \phi_{sh} - \phi_{se}$

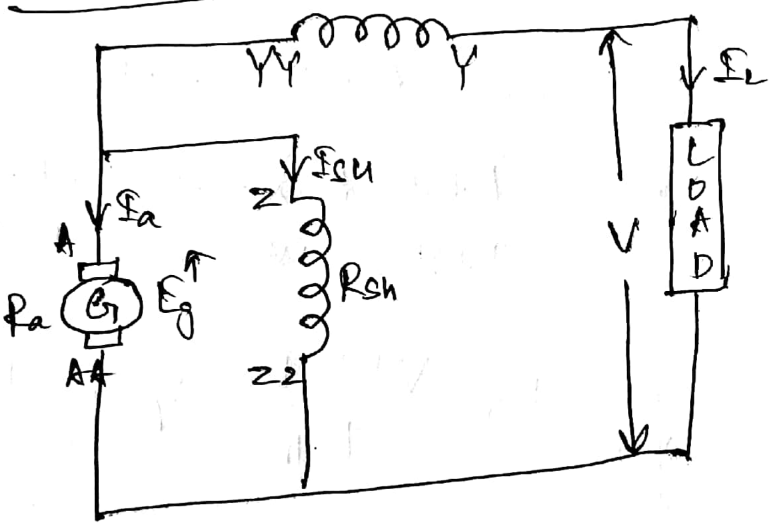
where, ϕ_{sh} = Flux produced by shunt field winding.

ϕ_{se} = Flux produced by series field winding.

$I_{sh} = \frac{V}{R_{sh}}$ & $I_a = I_L + I_{sh}$

Terminal Voltage } $V = E_g - I_a(R_a + R_{se}) - A.R.D - B.C.D$

(b) SHORT SHUNT :-



$I_{sh} = \frac{V + I_L R_{se}}{R_{sh}}$

&

$I_a = I_L + I_{sh}$

Terminal Voltage } $V = E - I_a R_a - I_L R_{se} - A.R.D - B.C.D$

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D.C MOTORS :

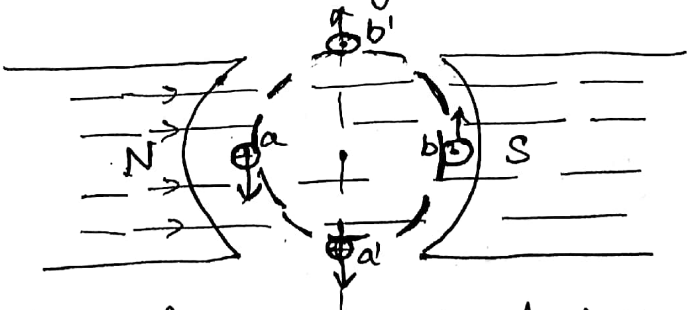
INTRODUCTION :- An Electrical Machine which converts Electrical energy into Mechanical energy is called an Electric Motor.

The D.C Motor converts D.C electrical energy into Mechanical energy

WORKING PRINCIPLE :- A D.C Motor works on the Principle that, "Whenever a Current carrying Conductor is placed in a Magnetic field, it experiences a force (F)"

$$F = BIL \sin\theta \text{ Newtons}$$

where, F = Force experienced in Newtons.
B = Flux density of the Magnetic field.
I = Current flowing through the conductor.
l = Length of the conductor in meters



↳ All the Armature conductors mounted on the periphery of the Armature drum, get subjected to Mechanical force called Torque & the Armature of the Motor starts rotating.

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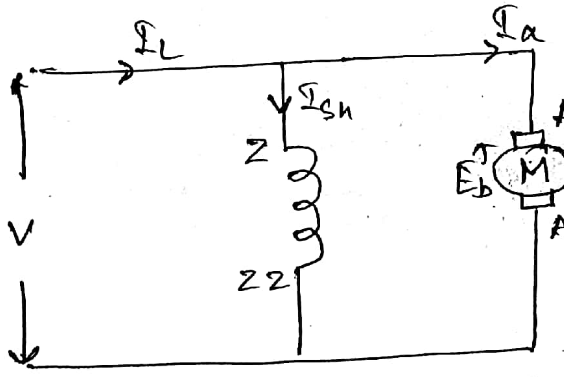
↳ According to Fleming's left hand rule, the conductor 'a' experiences a force 'F' in Downward direction and the conductor 'b' experiences an equal force 'F' in the Upward direction. This constitute a couple, tending to rotate the Armature in Anticlockwise direction.

NOTE : Symbolic representation of a D.C Shunt motor.

'V' is the applied voltage, due to which a Current I_a flows through the Armature conductors.

$I_L \rightarrow$ Line Current
&
$I_{sh} \rightarrow$ Current flowing in Shunt field winding

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



Voltage 'V' has to overcome,

(a) Back EMF
(b) Armature Resistance Drop
(c) Armature Reaction Drop
(d) Brush contact Resistance Drop.

$\therefore$ Voltage eqn of a D.C Motor is

$$V - E_b - I_a R_a - A.R.D - B.C.D = 0$$

(or)

$$V = E_b + I_a R_a + A.R.D + B.C.D$$

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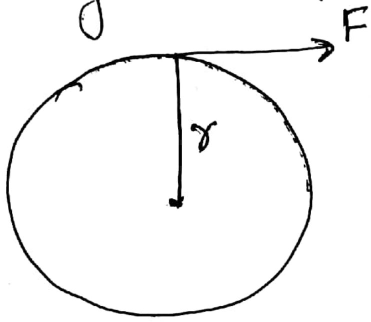
TORQUE EQUATION :- Consider the Armature of a D.C motor having radius 'r' & let 'F' be the tangential force acting on it.



Torque exerted on the Armature $\Big\}$ $T_a = F \times r$ Nm ......(a)

Workdone by the force 'F' in One revolution $\Big\}$ W = Force X Distance Covered in One revolution

$W = F \times 2\pi r$ watt sec

Power developed by the Armature $\Big\}$ $P = F \times 2\pi r \times \{\text{Number of revolutions per second}\}$

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

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

$$P = \frac{2\pi N T_a}{60} \text{ watts } ...... (b)$$

The Electrical equivalent of Mechanical power $\Big\}$ $P = E_b I_a$ ...... (c)

$$\frac{2\pi N T_a}{60} = E_b I_a = \left(\frac{PN\phi Z}{60A}\right) I_a$$

$$\frac{2\pi \cancel{N} T_a}{\cancel{60}} = \left(\frac{P\cancel{N}\phi Z}{\cancel{60}A}\right) I_a$$

$$\boxed{T_a = \frac{1}{2\pi} \times \phi Z I_a \left(\frac{P}{A}\right) \text{ Nm}}$$

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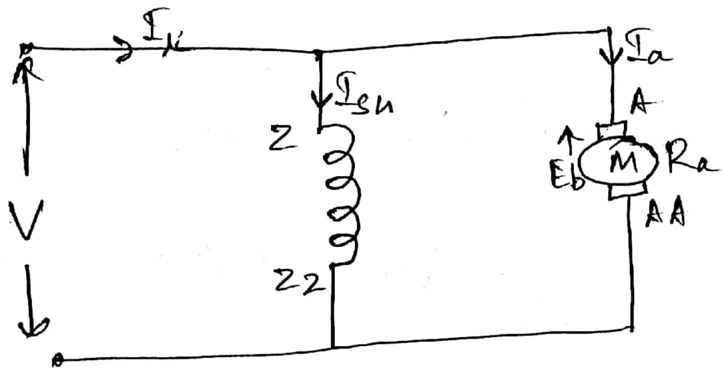
$$\boxed{T_a = 0.159\, \phi Z I_a \left(\frac{P}{A}\right) \text{ Nm}}$$

Show that the Mechanical power developed by a D.C. Shunt motor is maximum when the Back EMF is equal to half the applied voltage.



Let,

V = Applied voltage
E_b = Back EMF
I_a = Armature current
R_a = Resistance of Armature conductors

Voltage equn: of D.C motor is,

$$V = E_b + I_a R_a$$

Multiplying both sides by I_a,

$$V I_a = E_b I_a + I_a^2 R_a$$

where, $V I_a$ = Electrical Power i/p to the Armature [Armature i/p]
$I_a^2 R_a$ = Copper loss in the Armature.
$E_b I_a$ = Electrical equivalent of Mechanical power developed in the Armature including Iron & Mechanical losses. [Total Armature o/p]

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Mechanical Power of the Motor } $P_m = VI_a - I_a^2 R_a$

For Maximum power to be developed } $\frac{dP_m}{dI_a} = 0.$

$$V - 2I_a R_a = 0$$

$I_a R_a = \frac{V}{2}$ Substitute in eqn (a)

$$V = E_b + \frac{V}{2}$$

$\therefore \boxed{E_b = \frac{V}{2}}$

Thus the Mechanical Power developed by a Motor is maximum when the Back EMF is equal to half the applied voltage.

↳ This is purely Theoritical, In practice the current will be far greater than the normal current of the motor. Besides half the i/p power is wasted in the form of heat & other losses, bringing down the motor efficiency to less than 50%.

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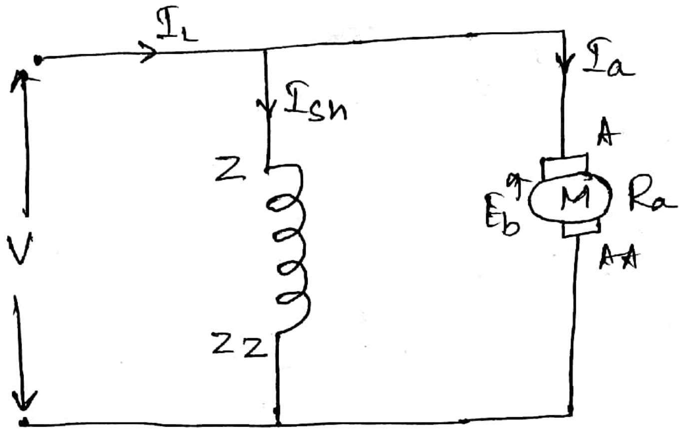
(*) Define Back EMF. Explain the Significance of Back EMF.



$$E_b = \frac{PN\phi Z}{60A} \text{ volts}$$

→ As soon as the Armature of the D.C motor starts rotating, Dynamically Induced EMF (E_b) is produced in the Armature conductors. The direction of this induced EMF is found by Fleming's right hand rule such that it opposes the applied Voltage (V). This induced EMF is known as Back EMF (E_b)

SIGNIFICANCE : Due to presence of Back EMF (E_b) the D.C motor becomes Self regulating machine i.e the motor is made to draw as much Armature Current as is just sufficient to develop the Torque required by the load.

w.k.t $I_a = \dfrac{V - E_b}{R_a}$

→ When the load on the motor is decreased, the driving torque is excess of the requirement, so the Armature is accelerated.

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As the Armature speed increases, the Back EMF E_b also increases & causes armature current to decrease. The motor will stop accelerating when the armature current is just sufficient to produce the reduced torque required by the load.

↳ When the load on the Motor is increased the Armature is slowed down.

As the Armature speed decreases, the Back EMF E_b also decreases & causes the Armature current to increase. The motor will stop slowing down when the armature current is just sufficient to produce the ~~reduced~~ increased torque required by the load.

Speed of a DC Motor [Show that the speed of a DC motor is directly proportional to the Back EMF & inversely proportional to the Flux/pole]

Voltage equation of a D.C motor is,

$$V = E_b + I_a R_a$$

$$E_b = V - I_a R_a$$

$$\frac{PN\phi Z}{60A} = V - I_a R_a$$

$$\therefore \quad N = \frac{V - I_a R_a}{\phi} \times \frac{60A}{PZ} \text{ rpm}$$

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But $V - I_a R_a = E_b$

$$\therefore \quad N = \frac{E_b}{\phi} \times \frac{60A}{PZ}$$

For a particular machine P, Z & A are constants

$$N = K \frac{E_b}{\phi}$$

$$\boxed{N \propto \frac{E_b}{\phi}}$$

Thus Speed is directly proportional to Back EMF E_b & inversely proportional to flux ϕ.

For a Series Motor :-

Let N_1, I_{a1} & ϕ_1 be the speed, Armature Current & flux per pole in first case.

Let N_2, I_{a2} & ϕ_2 be the speed, Armature Current & Flux per pole in second case.

w.k.t $\quad N_1 \propto \frac{E_{b1}}{\phi_1}$ where $E_{b1} = V - I_{a1} R_a$

&

$N_2 \propto \frac{E_{b2}}{\phi_2}$ where $E_{b2} = V - I_{a2} R_a$

$$\therefore \quad \boxed{\frac{N_2}{N_1} = \frac{E_{b2}}{E_{b1}} \times \frac{\phi_1}{\phi_2}}$$

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Before Saturation of Magnetic poles Occur, $\phi \propto I_a$

$$\therefore \boxed{\frac{N_2}{N_1} = \frac{E_{b2}}{E_{b1}} \times \frac{I_{a1}}{I_{a2}}}$$

For a Shunt Motor :

w.k.t $$\frac{N_2}{N_1} = \frac{E_{b2}}{E_{b1}} \times \frac{\phi_1}{\phi_2}$$

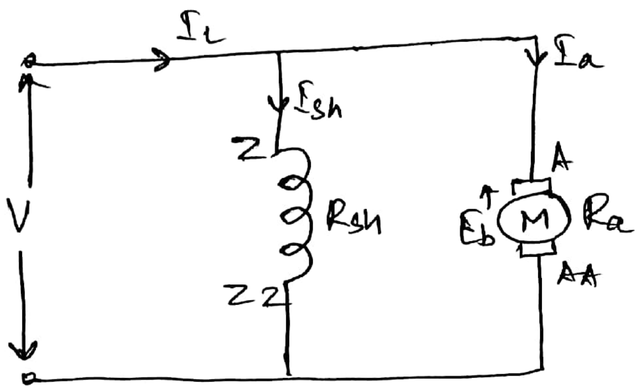
here $\phi_1 = \phi_2$

$$\therefore \boxed{\frac{N_2}{N_1} = \frac{E_{b2}}{E_{b1}}}$$

CLASSIFICATION OF D.C MOTORS :

- D.C Compound Motor
  - Cummulatively compounded D.C motor
    - Long Shunt
    - Short Shunt
  - Differentially compounded D.C motor
    - Long Shunt
    - Short Shunt
- D.C Shunt Motor
- D.C Series Motor

D.C SHUNT MOTOR :-



↳ In this type of motor, the shunt field winding is connected across the Armature.

↳ V is the applied voltage due to which a current I_L flows through the line, A current I_{sh} flows through the shunt field winding & current I_a through the armature conductors.

The shunt field current } $I_{sh} = \frac{V}{R_{sh}}$

The Armature Current } $I_a = I_L - I_{sh}$

The Back EMF $E_b = V - I_a R_a - A.R.D - B.C.D$

where, ARD = Armature Reaction Drop.
BCD = Brush Contact Resistance Drop.

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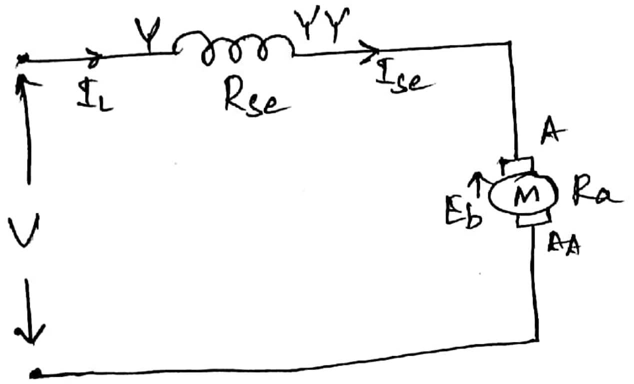
D.C SERIES MOTOR :- In this type of motor, the series field winding is connected in series with Armature



↳ V is the applied voltage due to which a current I_1 flows through the line, the series field winding & through the Armature conductors.

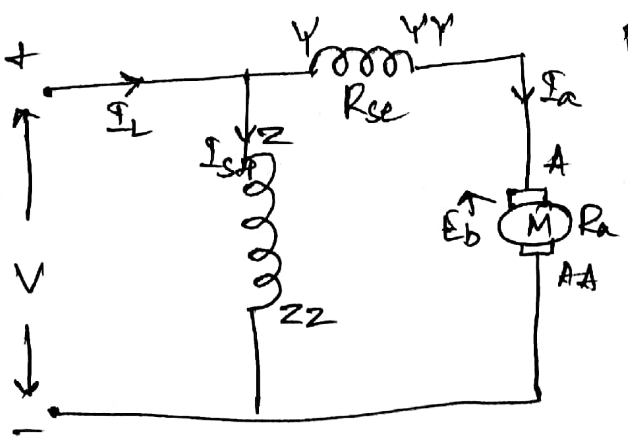
$$\therefore\ I_L = I_{se} = I_a$$

Back EMF $E_b = V - I_a(R_a + R_{se})$ - A.R.D - B.C.D

D.C COMPOUND MOTORS :-

(1) Cummulatively Compounded D.C motors

(i) LONG SHUNT :- If the fluxes ϕ_{sh} produced by shunt field winding and ϕ_{se} produced by series field winding are in the same direction and are additive, then the motor is said to be cummulatively compounded.



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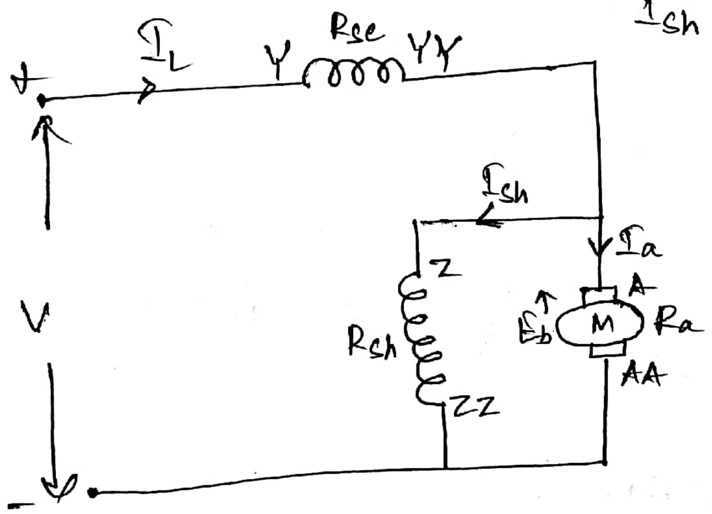
↳ For Cummulatively Compounded motors, the currents enter the positive terminals of the two field windings.

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

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

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

(ii) SHORT SHUNT :



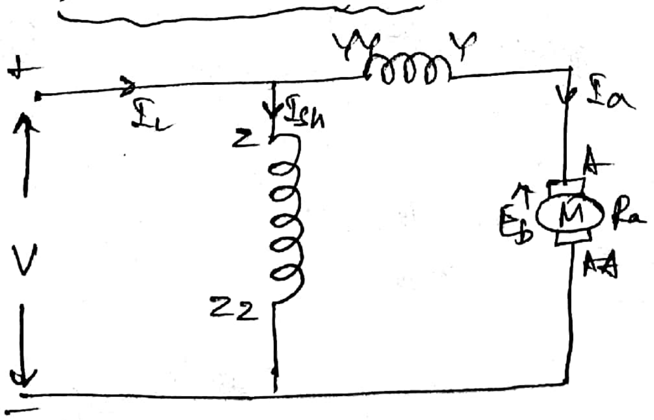
$$I_{sh} = \frac{V - I_L R_{se}}{R_{sh}}$$

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

$$E_b = V - I_L R_{se} - I_a R_a - A.R.D - B.C.D$$

(2) Differentially Compounded D.C Motors

(i) LONG SHUNT : If the fluxes ϕ_{sh} & ϕ_{se} produced by shunt & series field winding oppose each other, the motor is said to be differentially compounded.



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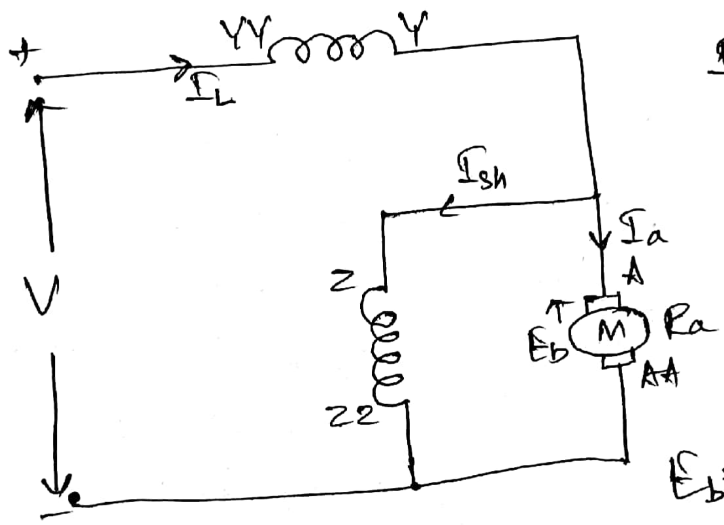
↳ In Differentially Compound Motors, the current through Series field winding enter the Negative terminal & Current through Shunt field winding enter the positive terminal.

↳ $I_{sh} = \frac{V}{R_{sh}}$

$I_a = I_L - I_{sh}$ &

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

SHORT SHUNT :-



$I_{sh} = \frac{V - I_L R_{se}}{R_{sh}}$

$I_a = I_L - I_{sh}$

&

$E_b = V - I_L R_{se} - I_a R_a - A.R.D - B.C.D$

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CHARACTERISTICS OF D.C MOTORS : The 3-important characteristics of D.C motors are,

(i) T_a/I_a characteristic (or) Electrical characteristic

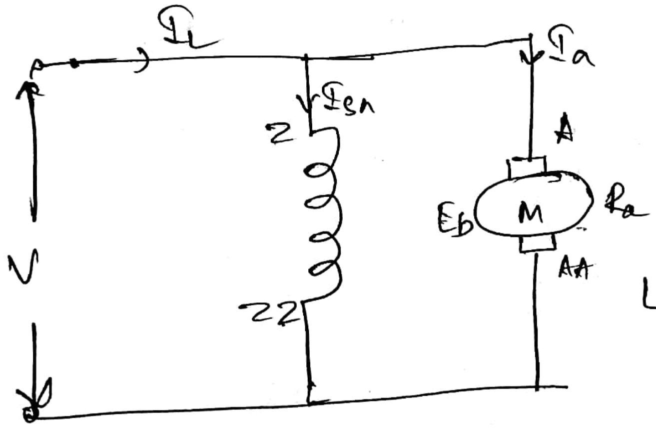
(ii) N/I_a characteristic

(iii) N/T_a characteristic (or) Mechanical characteristic

(1) CHARACTERISTICS OF D.C SHUNT MOTORS :

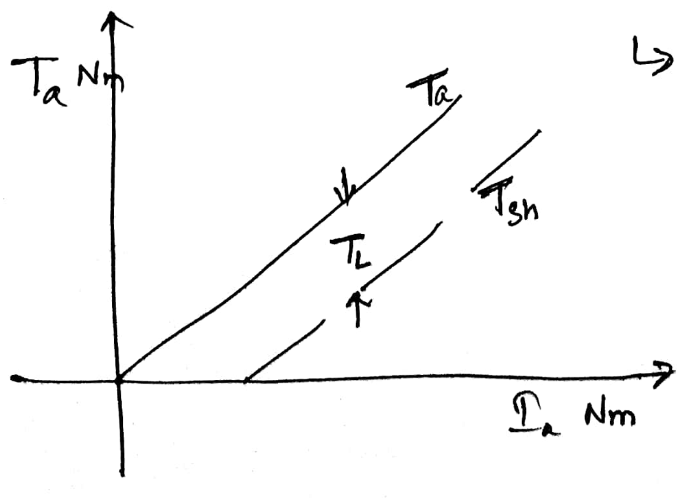
(i) T_a/I_a characteristic : w.k.t

$$T_a = 0.159\,\phi Z I_a \left(\frac{P}{A}\right)$$



↳ Shunt field current I_{sh} is constant ∴ ϕ is constant. Z, P & A are constants

↳ ∴ $T_a \propto I_a$, Hence T_a/I_a characteristic is a straight line as shown.



↳ The shaft torque 'T_{sh}' is always less than Armature Torque 'T_a' due to Iron losses & Mechanical losses. (T_L)

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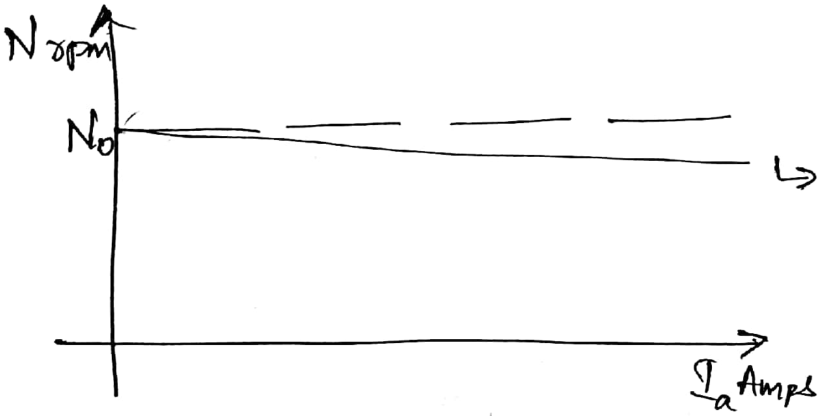
∴ From T_a/I_a Charaterístic, We observe that a D.C Shunt motor has a Medium Starting Torque & hence does not suit where larger loads are to be Started.

(ii) N/I_a Charaterístic :



↳ w.k.t Back EMF, $E_b = \frac{PN\phi Z}{60A}$

$\therefore N \propto \frac{E_b}{\phi}$

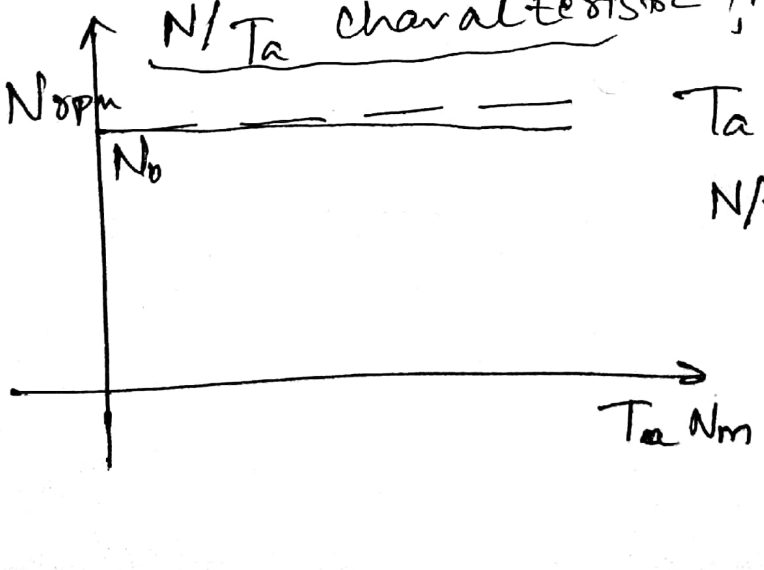
↳ For a D.C Shunt motor, ϕ is Constant

$\therefore N \propto E_b \propto V - I_aR_a$

↳ As I_a increases, I_aR_a increases & hence the speed decreases. But the drop I_aR_a is very small compared to V, Hence the decrease of speed as Armature current increases is also small.

↳ Hence, for all Practical purposes, A D.C Shunt motor is allmost a Constant Speed motor.

(iii) N/T_a charalteristic :-



$T_a \propto I_a$ and hence N/T_a charateriestic Similar to N/I_a charaterístic.

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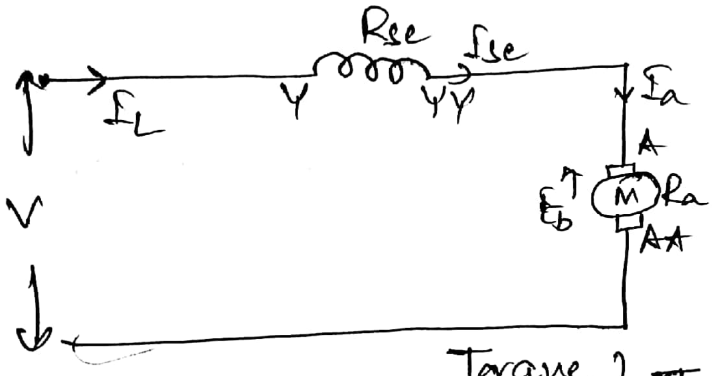
(2) CHARACTERISTICS OF D.C SERIES MOTORS :

(i) T_a / I_a characteristic :



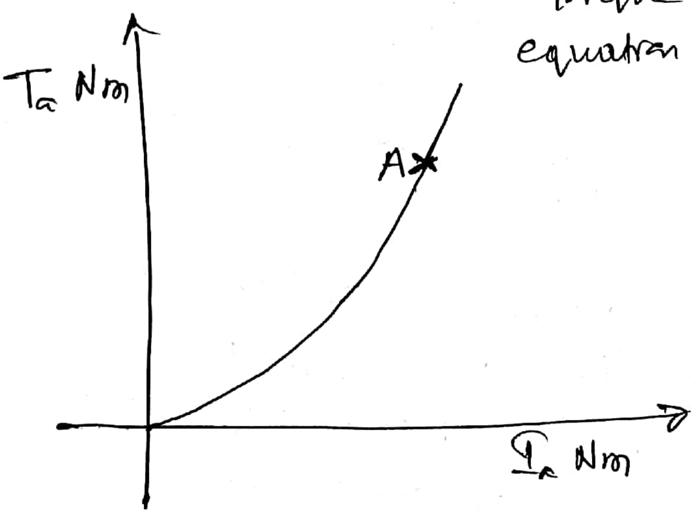
Torque equation } $T_a = 0.159\, \phi Z I_a \left(\frac{P}{A}\right)$

$T_a \propto \phi I_a$ but $\phi \propto I_a$

$\therefore \boxed{T_a \propto I_a^2}$

After saturation, Flux remains constant

$\therefore \boxed{T_a \propto I_a}$



↳ from the characteristic : Upto point A, $T_a \propto I_a^2$ & hence the curve is a parabola.

↳ Beyond point 'A', $T_a \propto I_a$ & hence the curve is a straight line.

↳ from this characteristic, We find that the starting Torque of a D.C Series motor is very high.

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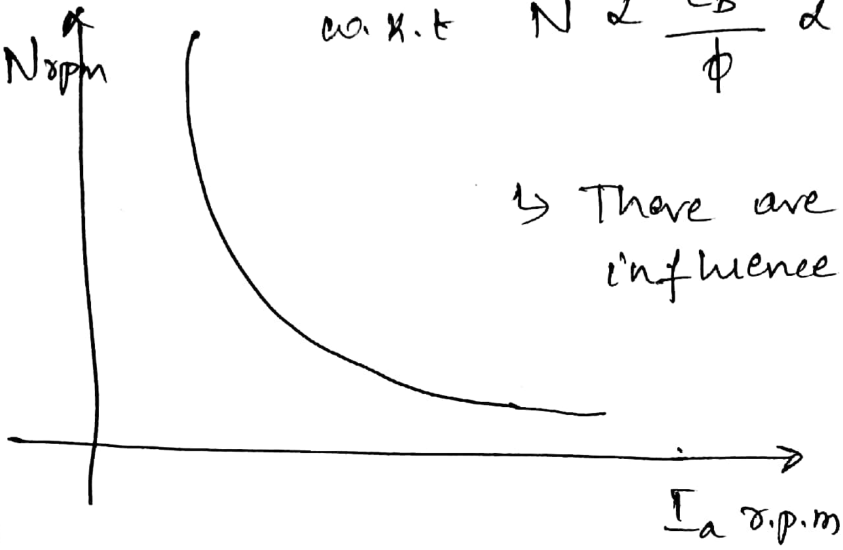
(ii) N/I_a Characteristic :



w.r.t $N \propto \frac{E_b}{\phi} \propto \frac{V - I_a(R_a + R_{se})}{\phi}$

↳ There are 2 factors which influence the Speed of the motor

(i) $I_a(R_a + R_{se})$ increases & hence the Speed decreases

(ii) The Flux ϕ also increases due to which the speed decreases.

↳ The decrease of speed due to first factor i.e negligably small as compared to the decrease in speed due to second factor.

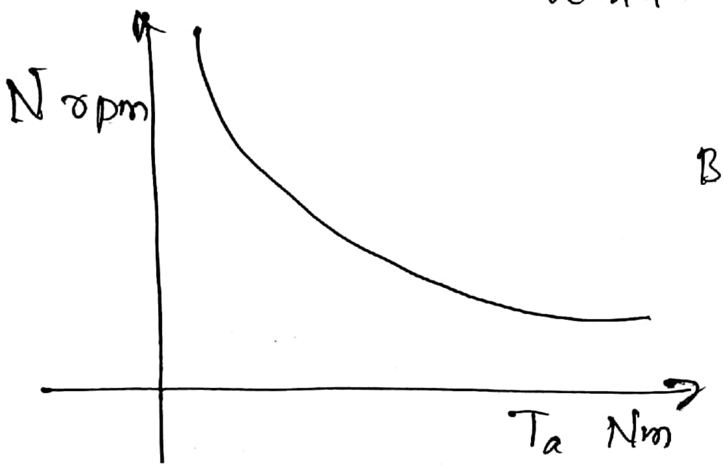
$\therefore N \propto \frac{1}{\phi}$ But $\phi \propto I_a$

$\therefore \boxed{N \propto \frac{1}{I_a}}$

↳ From the characteristic, As the load increases, the Speed decreases over a wide range. Hence D.C Series motor i.e a Variable speed motor.

NOTE : At No load, I_a i.e very small, Hence if a D.C motor is started without any load on it, the Speed i.e very high & it may run out of foundation due to centrifugal forces. Hence, A D.C Series motor should never be started without load.

(iii) N/T_a characteristic :-



W.K.T $T_a \propto I_a^2$

$I_a \propto \sqrt{T_a}$

But $N \propto \frac{1}{I_a}$

$\therefore N \propto \frac{1}{\sqrt{T_a}}$

1) For smaller values of Ta, 'N' is very large & for higher value of Ta the speed decreases.

APPLICATIONS OF D.C MOTORS :

(1) SHUNT MOTORS

(i) Blowers & Fans
(ii) Centrifugal & Reciprocating pumps
(iii) Lathes, Drilling Machines & Milling machines.
(iv) Machine tools
(v) Boring Machines, Spinning & Weaving machines
(vi) For driving constant speed line shafting

$\therefore$ Shunt motors are used when we need medium starting Torque & constant speed.

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(2) SERIES MOTORS

(i) Traction purposes : Electric locomotives, Trolley cars, etc

(ii) Hoists & Cranes

(iii) Conveyors

(iv) Elevators

Series motors are used when we need very high starting Torque & Variable Speed.

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