Unit - II

Actuators :

Actuator is device which intiates an action.
action (movement)

classification

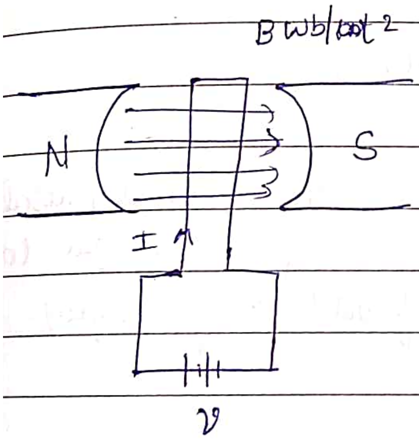
DC actuators

- series DC ~~motor~~ motor
- stepper motor

AC actuators

- Single phase
- Three phase
  - 3Ø induction motion

DC motor :→
input - DC electrical input
output - mechanical force



principle : current carrying conductor lying in a magnetic experiences force.

$F = BIL\sin\theta$

The direction of force flemings left hand rule

Construction : DC motor has two parts
① Stator → stationary
② Rotor → moving

Stator
Rotor (Armature)

in DC motor Rotor is called armature

★ Stator :

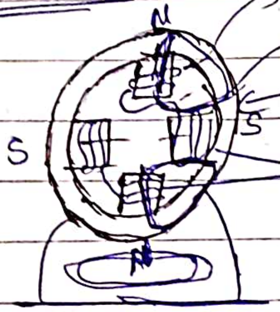
part which provides magnetic flux

high silicon content steel – permeability is high

$\boxed{\mu = \mu_0 \mu_r}$

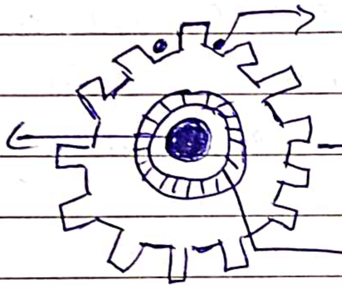
$\mu_r > 1000$

DC motor



→ poles
→ field coil (copper)
yoke (provides path for the flux) & and supports the electromagnets
→ electromagnets

★ Rotor (armature)



→ armature conductors
shaft ←
→ slots
→ Commutator (funct^n is to convert pulsating torque to steady torque)

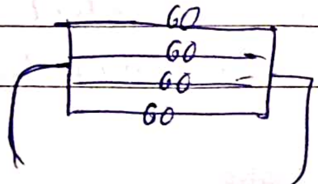
Working of dc motor

2 types of armature winding :

1) LAP → no of parallel paths equal no of poles

2) WAVE →

pole
P - 4pole Z = 240 (conductors)
A = 4 (parallel paths)

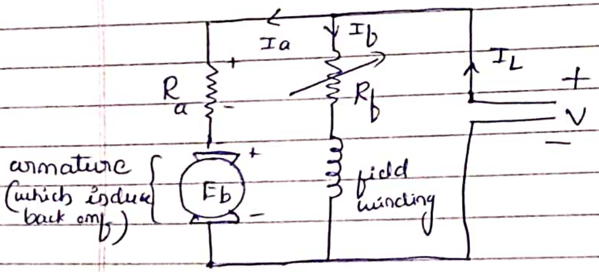


Equivalent circuit of a dc shunt motor :

if the field winding is connected in parallel with the armature winding, then it is a dc shunt motor.

E_b = back emf
V - dc supply voltage
R_a - armature equivalent resistance which is around 1 Ω
R_f = field resistance (rheostat) around 100 Ω
I_L = line current
I_a - armature current
I_f = field current

* field winding and armature winding are connected in parallel
* R_a = is in series with armature



KCL

$I_L = I_a + I_f$

KVL

$V = I_aR_a + E_b$

$I_f = \frac{V}{R_f}$

* In dc shunt motor flux (φ) remain constant

flux/pole

$E_b = \frac{P\phi Z N}{60A}$ total conductors, always 2

all are constant

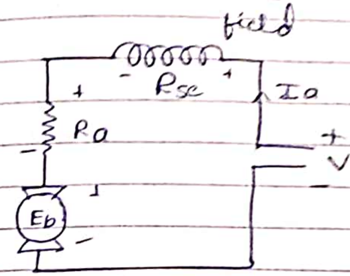
$N \propto \frac{1}{\phi}$ because φ constant

$T = 0.159\,\phi Z I_a\, P/A$

* dc shunt motor used in constant speed applications

Equivalent circuit of a dc series motor

if the field winding is connected in series with armature winding, then it is dc series motor



R_{se} = internal equivalent resistance of the field winding

R_a - armature resistance

KVL :

$V = I_aR_{se} + I_aR_a + E_b$

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

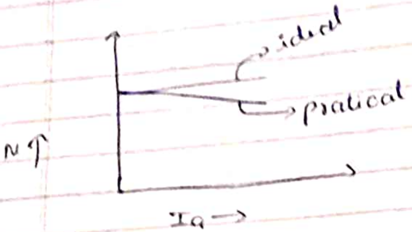
* The flux varies

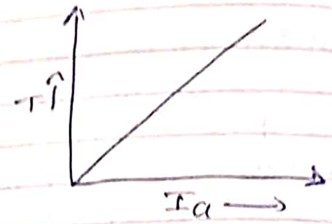
KCL

$I_L = I_a = I_f = I$

* when load changes, current changes so flux is not constant
* in dc series motor flux not constant
* The dc series motor is always started with sufficient load applied. since $N \propto \frac{1}{\phi}$ if less load is applied then φ is also very small, which results in dangerously high speed, which causes damage to motor & injury to people hence these motor are used where full load is supplied & then motor start.

DC shunt motor





$T \propto I_a$

Starting torque is very less

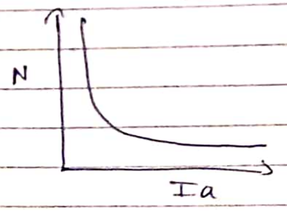
DC series motor

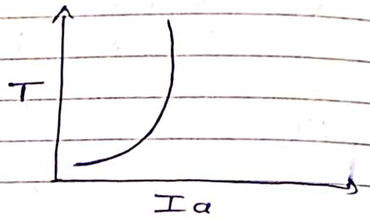
$I_a \propto \phi$

$\phi \propto \frac{1}{N}$

$T \propto \phi I_a$

$T \propto I_a I_a \rightarrow T \propto I_a^2$





* used for lifting applications
1) lift 2) cranes 3) electric traction 4) hoists

Q) A 6 pole lap wound dc shunt motor has 500 conductors in armature, The Ra is 0.05 Ω Resistance of shunt field is 25 Ω find the speed of the motor when it takes 120 A from 100 Volts dc supply flux/pole is 20 mw

$\rightarrow P = A$

→ $P = 6$ $Z = 500$ $R_a = 0.05$

$R_f = 25\,\Omega$ $N = ?$ $A = 6$ $\phi = .020\,W$

$I_L = 120\,A$ $V = 100$

$100 = \frac{\cancel{6} \times 20 \times 10^{-3} \times 500 \times N}{60 \times \cancel{6}}$

$N = \cancel{6}/\cancel{20}$

$I_L = I_a + I_f$

$I_L = I_a + \frac{V}{R_f}$

$I_a = 116A$

$V = I_a R_a + E_b$

$100 = 116 \times 0.05 + E_b$

$E_b = 94.2\,V$

$E_b = \frac{6 \times 20 \times 10^{-3} \times 500 \times N}{60 \times 6}$

$N = 5.6 \times 10^{-4}$ rpm

calculate speed when load on motor is reduced by 20%.

load reduced by 20%

$I_L = 120 \times 0.2 = 24$

$120 - 24 = 96A$

~~At~~ ~~$94.2 \times 60 \times 6$~~

$I_L = I_a + I_f$

$96 = I_a + 100/25$

$I_a = 92\,A$

$V = 92 \times 0.05 + E_b$

$E_b = \cancel{100}\,95.4$

$N = 572.4$ rpm

iii) 50% of load

$I_L = 60\,A \quad I_a = 56\,A$

$N = 583.5$ rpm

iv) 25% of 120 A

$I_a = 30 - 4$

$= 26\,A$

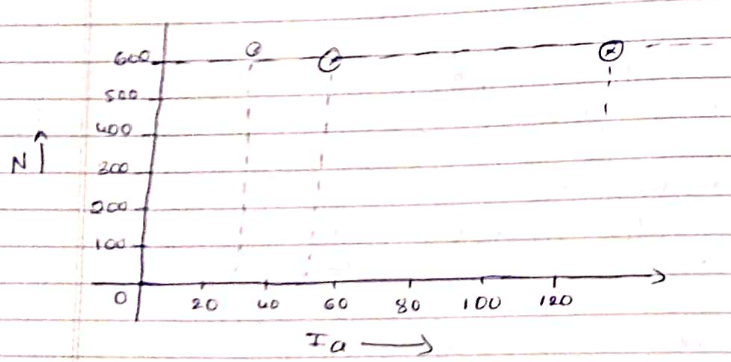
$E_b = 100 - 26 \times 0.05$

$= 98.7$ volts

$$N = \frac{E_b \times 60}{\phi\, 2} \frac{P}{A}$$

$$= \frac{98.7 \times 60}{20 \times 10^{-3} \times 500}$$

$N = 592.2$ rpm



Q) 230 V motor has an armature circuit resistance of 0.6 Ω, if full load armature current 30 A & no load armature current is 4 A, find the change in back emf. % change in Eb from no load to full load

→ (Dc shunt motor (because increasing & decrease of Ia possible in shunt motor)

$I_{a\,FL} = 30\,A$

I_a no load $= 4A$

$V = 230\,V$

$R_a = 0.6\,\Omega$

$V = I_a \cancel{R}R_a + E_b$

$E_b = V - I_a R_a$

$= 230 -$

$E_{b\,FL} = 212\,V$

$E_b = V - I_a R_a$

$= 230 - 4 \times 0.6$

$E_{b\,NL} = 227.6\,V$

$$\%\ \text{change}\ E_b = \frac{227.6 - 212}{227.6} \times 100 = 6.85\%$$

Q) 440 V dc shunt motor has an armature Resistance of 0.8 Ω and field resistance of 200 Ω, determine back emf when giving an output of 7.46 Kwatt at 85% efficiency

1 hp = 746 ~~k~~w

→ $V = 440\,V \quad R_a = 0.8\,\Omega$

$R_f = 200\,\Omega \quad E_b = ?$

$$\text{Efficiency} = \frac{\text{output}}{\text{input}}$$

$$0.85 = \frac{7.46 \times 10^3}{i/p}$$

~~input = 8776 watt~~ ~~8.7 K watt~~

$P = \cancel{E_b \times I_a}$

$$i/P = \frac{o/P}{\eta}$$

$= 8.776$ K watt

Input power $P = V \times I_L$

$$8.776 \times 10^3 = 440 \times I_L$$

$$I_L = 19.946\ A$$

$$I_F = \frac{V}{R_f} = 2.2\ A$$

$$I_a = I_L - I_f$$
$$= 17.246\ A$$

$$E_b = V - I_a R_a$$
$$E_b = 440 - 17.26 \times 0.8$$
$$E_b = 426.19 \text{ volts}$$

Q) 250 volt dc series motor has armature resistance of $0.08\ \Omega$ and $R_f = 0.02\ \Omega$ and produces full load torque when running at 500 rpm & taking current of 40 A calculate i) I_a ii) speed when producing half of full load torque

→ $V = 250$ $R_a = 0.08$ $R_{se} = 0.02$ $N_1 = 500$ rpm

$I_{1a} = 40\ A$

$$E_a I_a = \frac{T \times 2\pi \times N}{60}$$

$$V = I_a(R_{se} + R_a) + E_b$$
$$250 = 40(0.08 + 0.02) + E_b$$
$$E_b = 246\ V$$

$$246 \times 40 = \frac{T \times 2\pi \times 500}{60}$$

$$T = 187.93$$

$$T \propto I_a^2$$
$$T_1 \propto 40^2 \rightarrow ①$$
$$\frac{T_1}{2} \propto I_{a_2}^2 \rightarrow ②$$

$$I_{a_2} = 28.28\ A$$

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

$E_b \propto \phi N$ $\phi \propto I_a$

$E_b \propto I_a N$

$$\frac{E_{b_1}}{E_{b_2}} = \frac{I_{a_1} N_1}{I_{a_2} N_2} \rightarrow ①$$

$$E_{b_1} = V - I_{1a}(R_a + R_{se})$$
$$= 250 - 40(0.1)$$
$$= 246\ V$$
$$E_{b_2} = 247.2\ V$$

by putting in eq ①

$$\frac{246}{247.2} = \frac{40 \times 500}{28.28 \times N_2}$$

$$\boxed{N_2 = 710.66 \text{ rpm}}$$

I_a is only 5 A

3)

$Z = 540 \quad \phi = 30\ mwb$

$I_f = 1A \quad V = 220V$

$P = 4 \quad R_a = 0.1\Omega$

$I_L = 32A$

$P_o = 5.6kW$

$I_L = I_a + I_f$

$32 = I_a + 1$

$I_a = 31A$

$V = I_aR_a + E_b$

$220 = 31 \times 0.1 + E_b$

$E_b = 216.9V$ //

$$T = \frac{0.159 \phi Z I_a P}{A}$$

$$= \frac{0.159 \times 30 \times 540 \times 31 \times \cancel{4} \times 10^{-3}}{\cancel{4}}$$

$T = 79.849$ Nm

$$E_b = \frac{P\phi ZN}{60 \times A}$$

$$216.9 = \frac{4 \times 30 \times 10^{-3} \times 540 \times N}{60 \times 4}$$

$N = 803.33$ rpm //

4)

$V = 220V$

$I_L = 100A$

$N = 700rpm$

~~$N \propto I_a^2$~~

~~$N_2 = \frac{70}{100}, 700$~~

$N_2 = 490$ rpm

T_1

$T_2 = 0.7T_1$

if torque is reduced by 30% means $T_2 = 0.7T_1$

$R_a + R_{se} = 0.1\Omega$

$T \propto I_a^2$

$$\frac{T_1}{T_2} = \frac{(100)^2}{(I_{a_2})^2}$$

$$\frac{\cancel{T_1}}{0.7\cancel{T_1}} = \frac{(100)^2}{(I_{a_2})^2}$$

$I_{a_2} = 83.66$

$E_{b_1} = V - I_{a_1}(R_a + R_{se})$

$= 220 - 100(0.1)$

$E_{b_1} = 210V$

$E_{b_2} = V - I_{a_2}(R_a + R_{se})$

$E_{b_2} = 211.63$

$$\frac{E_{b_1}}{E_{b_2}} = \frac{I_{a_1}}{I_{a_2}} \frac{N_1}{N_2}$$

~~$\frac{210}{211.63} = \frac{700}{N_2}$~~

~~$N_2 = 705.43$ rpm~~

$$\frac{210}{211.63} = \frac{100}{83.66} \times \frac{700}{N_2}$$

$N_2 = 843.21$ rpm

5)

$V = 24V$

$N = 1200$ rpm

$I_L = 0.5A$

$R_a = 0.2\Omega$

$I_L = I_a + I_f$ } negligible

~~Ebow~~ $I_L = I_a$

$I_a = 0.5A$

$V = I_aR_a + E_b$

$E_{b_1} = V - I_{a_1}R_a$

$= 24 - 0.5 \times 0.2$

$= 24 - 0.1$

$E_{b_1} = 23.9$ volts

$N_1 = 1200$ rpm

$N_2 = 1120$ rpm

$T \propto I_a$

$E_a \propto N$

$$\frac{E_{b_1}}{E_{b_2}} = \frac{N_1}{N_2}$$

$$\frac{23.9}{E_{b_2}} = \frac{1200}{1120}$$

$E_{b_2} = 22.30V$

$P = V \times I_{a_2}$

$E_{b_2} = V - I_aR_a$

$22.3 = 24 - I_{a_2} \times 0.2$

$I_{a_2} = 8.5A$

$P = 24 \times 8.5$

$P = 204$ Watt