Basic Electrical Engineering (TEE 101)

Lecture 52: Speed Torque Characteristic of Separately Excited DC Motor

By: Dr. Parvesh Saini

Content

This lecture covers:

- **Concept of Torque in DC Motors**
- **Speed Torque Characteristics of Separately Excited DC motor**

Concept of Torque in DC Motors

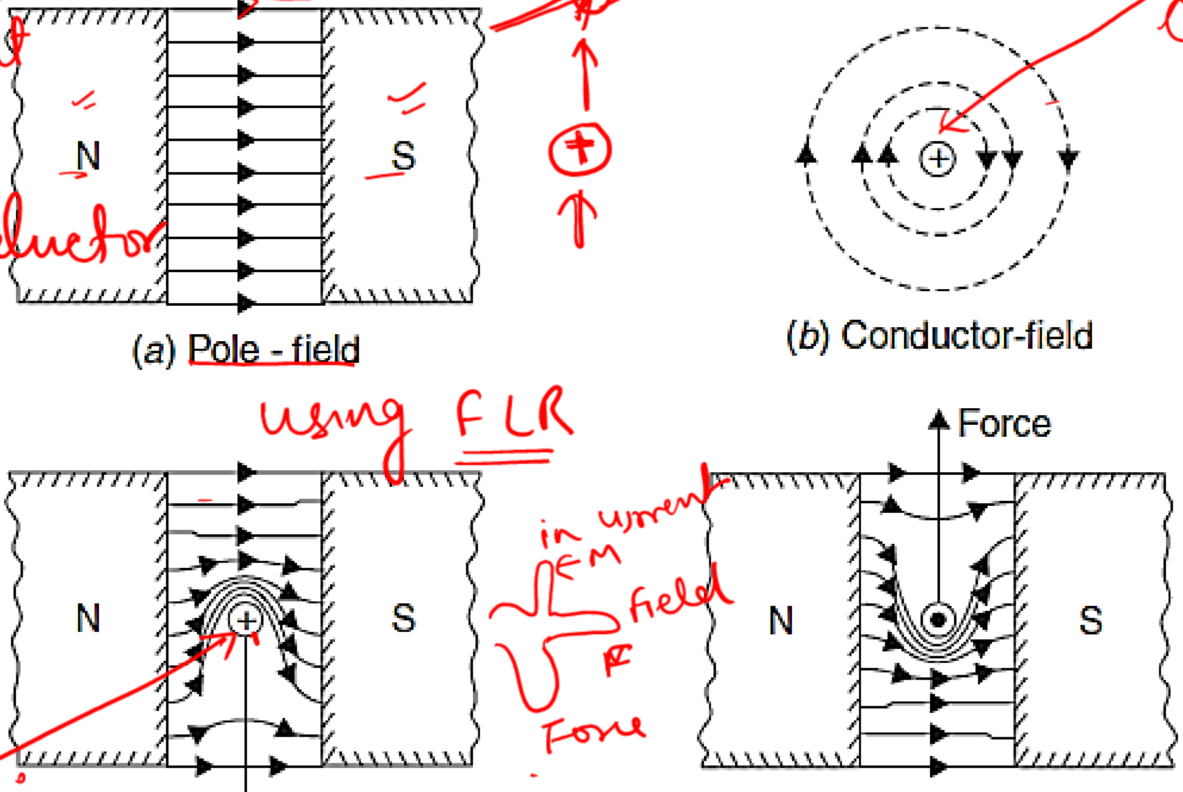
The principle of motor action can be stated as follows :
"*Whenever a current carrying conductor is placed in a magnetic field, it experiences a force whose direction is given by Fleming's left hand rule*".

⊕ ⊙ notation

⊕ The current in the conductor is entering

⊙ The current is coming out of the conductor

conductor



(a) Pole - field

(b) Conductor-field

(c) Force

(d)

conductor

using FLR

in current EM field

Force

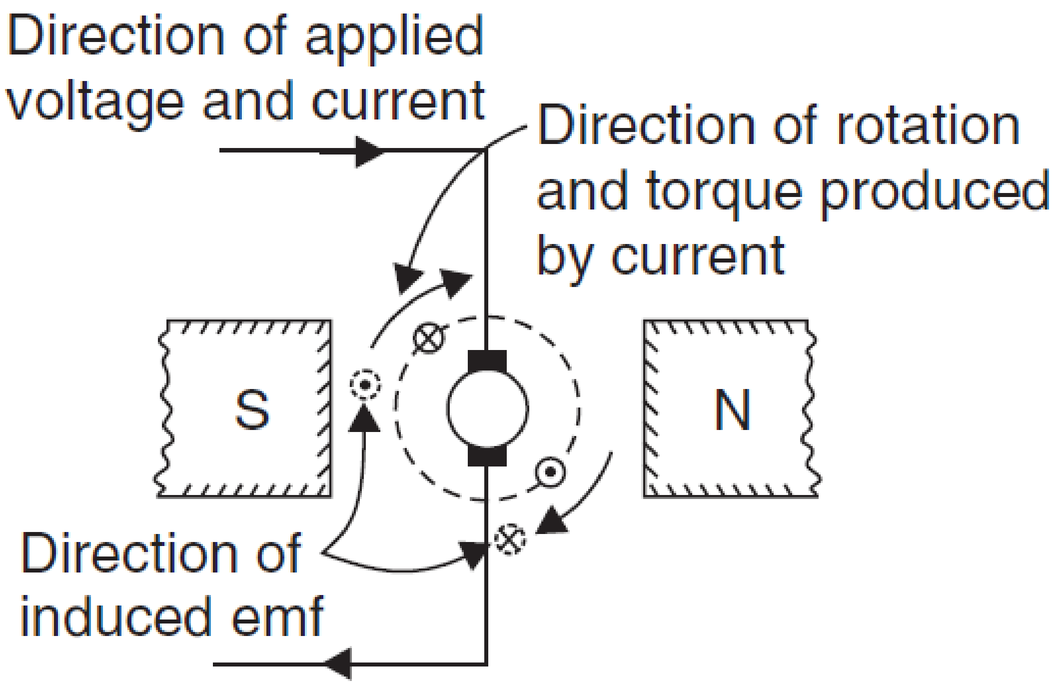
Current is in

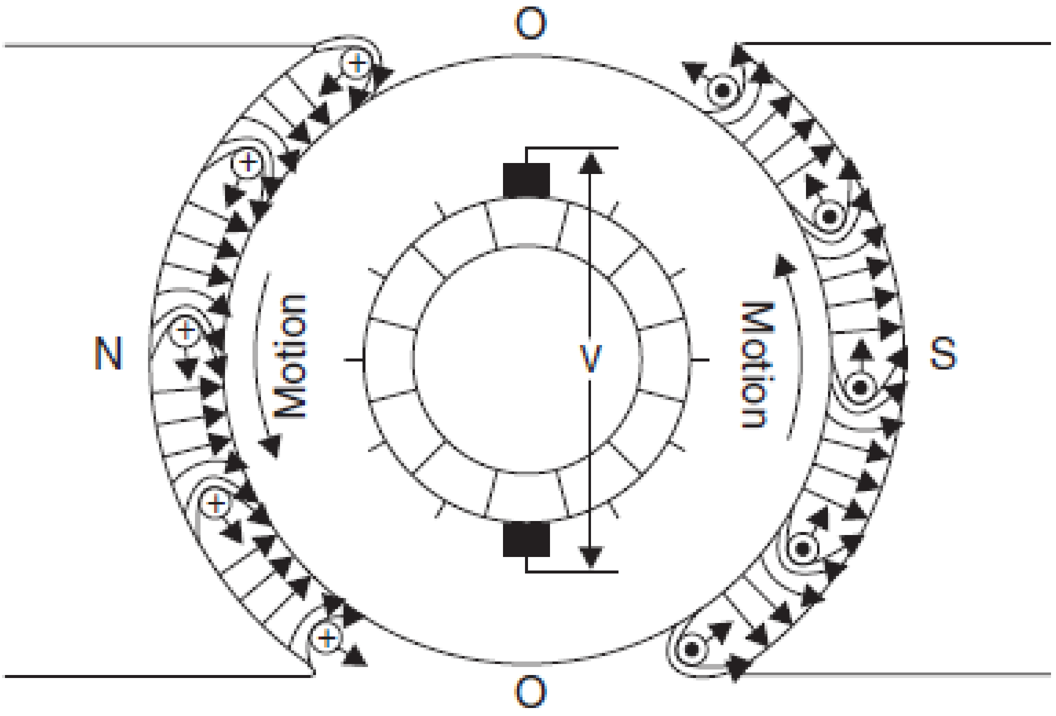
The current is out

Thumb in the direction of current

These curled fingers give direction of magnetic field

Torque Developed in a Motor





By: Dr. Parvesh Saini

Magnitude of torque developed by each conductor = $BIlr$ Nm

If the motor contains Z conductors, the total torque developed by the armature

$Ta = BIlrZ$ Nm

where B = gap density, T (Wb/m^2)

I = armature current in a conductor, A

l = active length of each conductor, m

r = the average radius at which conductors are placed, m

Z = total number of armature conductors.

It is more convenient to express Ta in terms of armature current Ia, total flux per pole φ and number of poles p.

$$I = \frac{I_a}{a}$$

$$B = \frac{\phi}{A}$$

where a = number of parallel paths,

and A = the cross-sectional area of flux path at radius r.

$$A = \frac{2\pi rl}{p}$$

$$T_a = \frac{Z\phi l I_a r}{2\pi r l} \times \frac{p}{a} \qquad = \frac{Z\phi I_a p}{2\pi a} \text{ Nm}$$

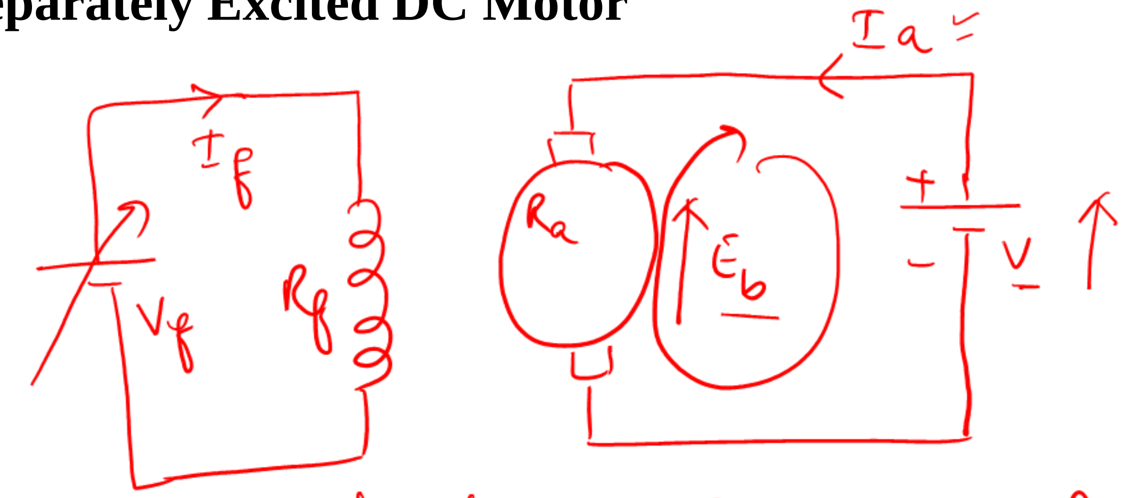
$$T_a = k\phi I_a \text{ Nm}$$

where $k = \frac{Zp}{2\pi a}$ is a *constant for any machine*

From the above equation for torque, we find that
$T \propto \varphi I_a$

By: Dr. Parvesh Saini

Speed Torque Characteristic of Separately Excited DC Motor



KVL Equation of the armature circuit is given by:

$$E_b + I_a R_a - V = 0 \quad \text{—— (1)}$$

$$V = E_b + I_a R_a \quad \text{—— (2)}$$

Now the back emf E_b is given by:

$$E_b = \frac{N P \phi Z}{60 a} \quad \text{—— (3)}$$

or, $$E_b = \boxed{\frac{ZP}{60a}} N \phi \quad \text{—— (4)}$$

$$E_b = K_e \phi N \quad \text{—— (5)}$$

N = rpm

E_b = back emf

{Replace N with "ω" equation}

But; $\omega = \frac{2\pi N}{60}$ rad/sec

$$N = \frac{60\omega}{2\pi}$$

eqn (5) is

$$E_b = K_e \phi \times \frac{60\omega}{2\pi} = \boxed{\frac{K_e 60}{2\pi}} \phi \omega$$

hence, $$E_b = K_t \phi \omega \quad \text{—— (6)}$$

By: Dr. Parvesh Saini

Now we can substitute E_b from eq^n (5) to eq^n (2) i.e

$$V = K_e \phi N + I_a R_a$$

or $$N = \frac{V - I_a R_a}{K_e \phi}$$

or, $$N = \frac{V}{K_e \phi} - \frac{I_a R_a}{K_e \phi} \quad \text{——— (7)}$$

Also; $$T_a = K \phi I_a$$

or $$\boxed{I_a = \frac{T_a}{K \phi}} \quad \text{——— (8)}$$

Substitute

or, $$N = \frac{V}{K_e \phi} - \frac{T_a r_a}{K K_e \phi^2} \quad \text{——— (9)}$$

$r_a \Rightarrow$ armature Resistance

eq^n (9) can be used to plot speed-Torque characteristics of a S.E.D.C.M

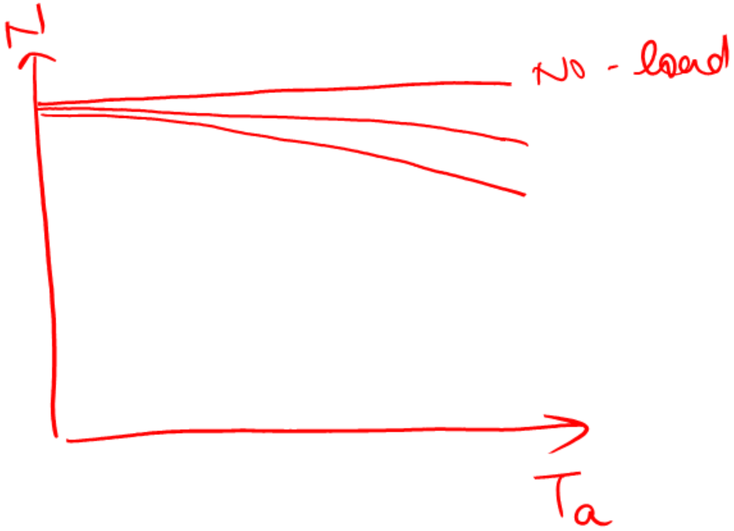
r_a

$V =$ applied voltage

$T_a =$ armature Torque

$\phi =$ flux per pole

K_e & K are the motor constants



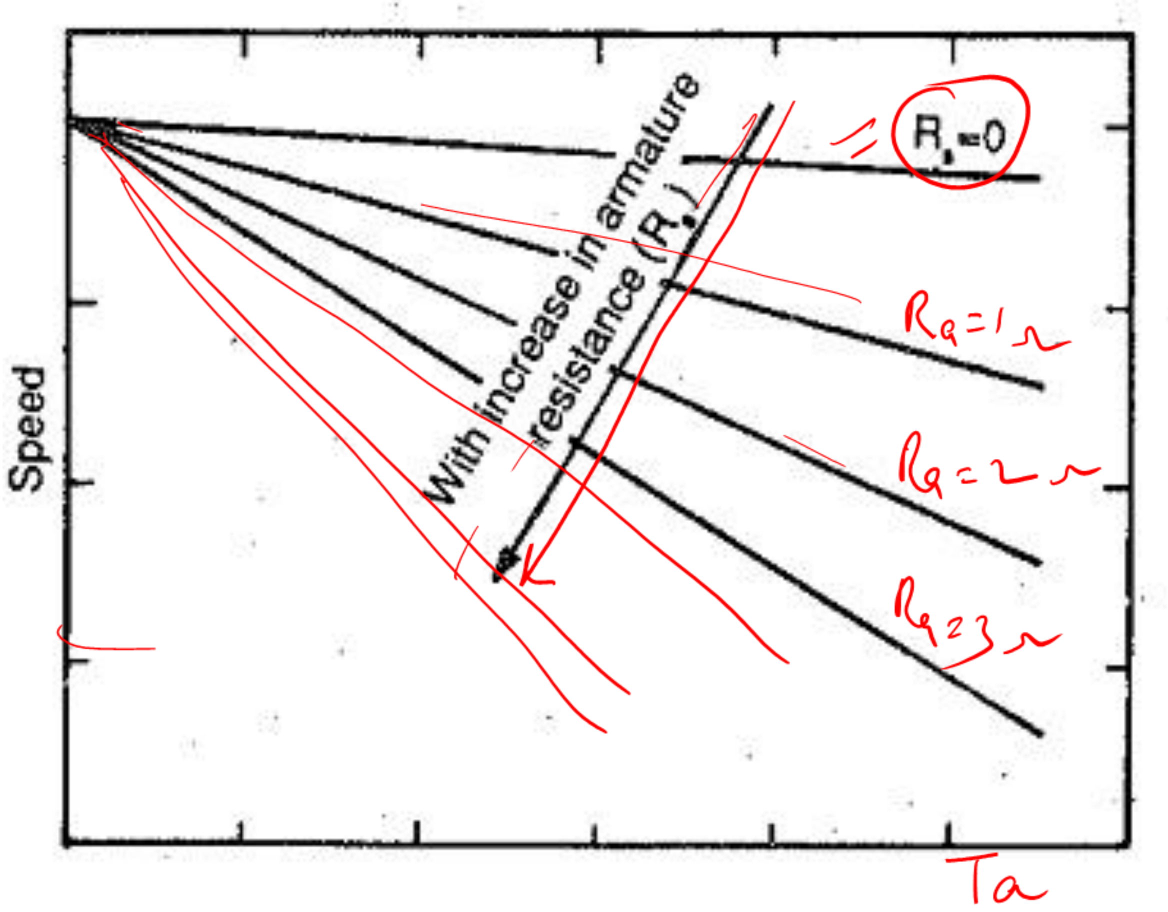
$$N = \frac{V}{K_e \phi} - \frac{T_a \, r_a}{K K_e \phi^2}$$

(i) Let V & r_a are constant
ϕ is a variable

(ii) V & ϕ are constants
r_a is a variable

$r_a = 0$ —

$$N = \frac{V}{K_e \phi}$$



$$N = \frac{V}{k_e\phi} - \frac{T_a r_a}{k k_e \phi^2}$$

r_a & ϕ constant & V as variable

$V = 0$

$$N = -\frac{T_a r_a}{k k_e \phi^2}$$

$N = -K' T_a$

$\boxed{N \propto -T_a}$ ⇐ inverse relation

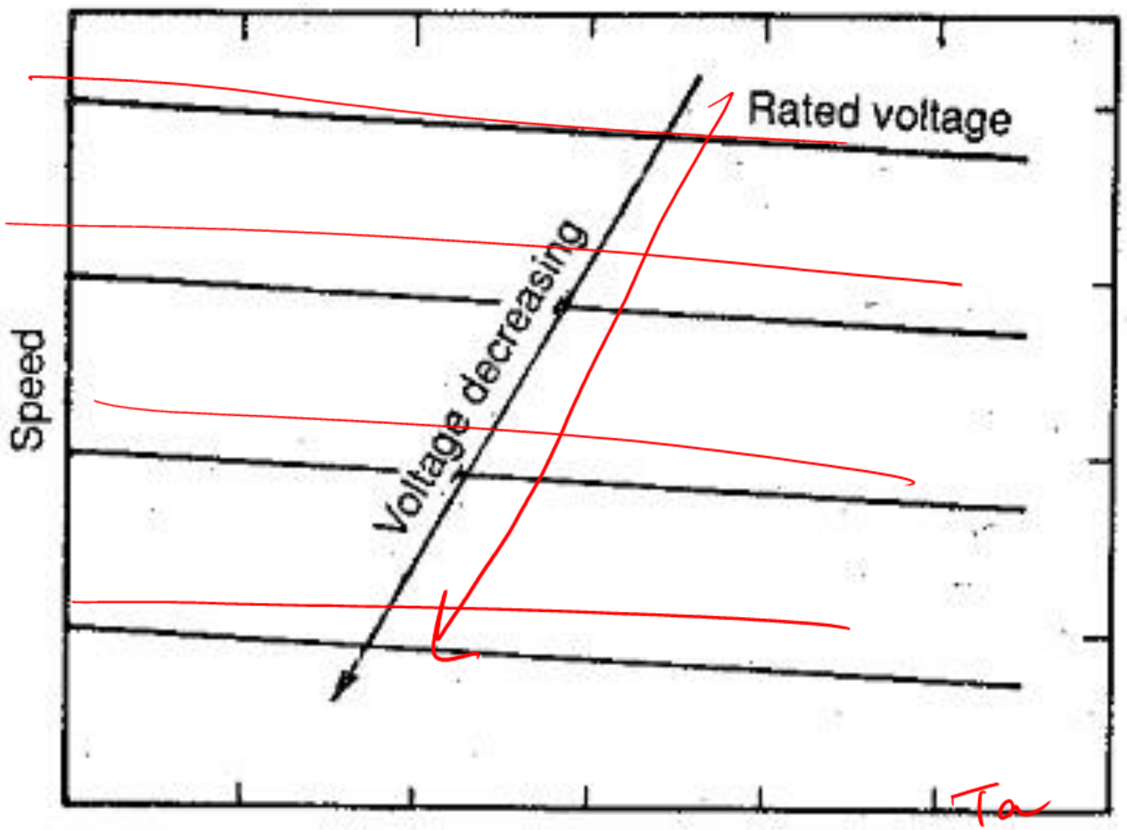
linear relation with $-ve$ slope

$V = 10V$

$$N = \frac{10}{k_e\phi} - \frac{T_a r_a}{k k_e \phi^2}$$

$r_a, K_e\ \phi$ ⇐ constant

$N = K'' - K' T_a$



By: Dr. Parvesh Saini

Thank You