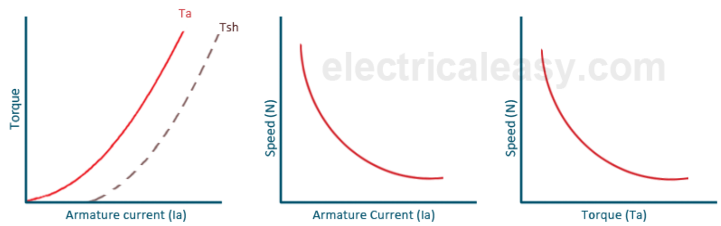
MODULE 3

CHARECTERESTICS OF DC MOTORS

Generally, three characteristic curves are considered important for DC motors which are,

(i) Torque vs. armature current, (ii) Speed vs. armature current and (iii) Speed vs. torque.

Characteristics Of DC Series Motors



Characteristics of DC series motor

Torque Vs. Armature Current (T_a-I_a)

- This characteristic is also known as **electrical characteristic**.
- We know that torque is directly proportional to the product of armature current and field flux
- Flux ϕ is directly proportional to Ia. Hence, before magnetic saturation Ta α Ia^2.
- Therefore, the Ta-Ia curve is parabola for smaller values of Ia.

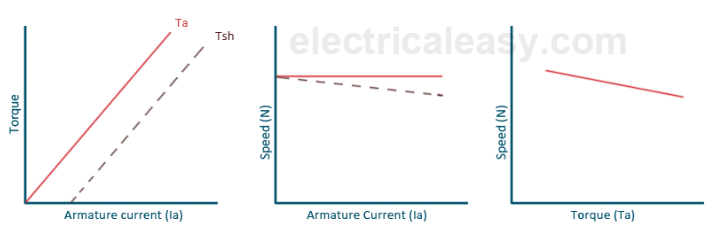
Speed Vs. Torque (N-Ta)

- This characteristic is also called as **mechanical characteristic**.
- It can be found that when speed is high, torque is low and vice versa.

Speed Vs. Armature Current (N-Ia)

- For small currents speed is inversely proportional to ϕ.
- As we know, flux is directly proportional to Ia, speed is inversely proportional to Ia.

Characteristics Of DC Shunt Motors



Characteristics of DC shunt motor

Torque Vs. Armature Current (Ta-Ia)

- In case of DC shunt motors, we can assume the field flux ϕ to be constant.
- Though at heavy loads, ϕ decreases in a small amount due to increased armature reaction.

- Torque is proportional to armature current.
- Hence, the Ta-Ia characteristic for a dc shunt motor will be a straight line through the origin.

Speed Vs. Armature Current (N-Ia)

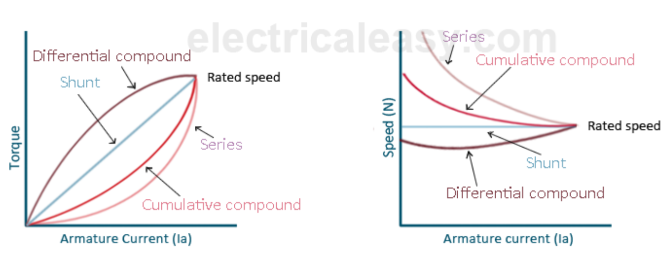
- As flux ϕ is assumed to be constant, we can say N ∝ Eb. But, as back emf is also almost constant, the speed should remain constant

Speed Vs. Torque (N-Ta)

- The speed vs Ia characteristic is shown in figure
- Speed decreases slowly when Ia increases

Characteristics Of DC Compound Motor

DC compound motors have both series as well as shunt winding Characteristics of both these compound motors are explained below.



Characteristics of DC compound motor

- **Cumulative compound motor**
  Cumulative compound motors are used where series characteristics are required
- But the load is likely to be removed completely

(b) Differential compound motor

- Since in differential field motors, series flux opposes shunt flux,
- The total flux decreases with increase in load.
- Due to this, the speed remains almost constant

PERFOMENCE CURVES OF SHUNT MOTORS

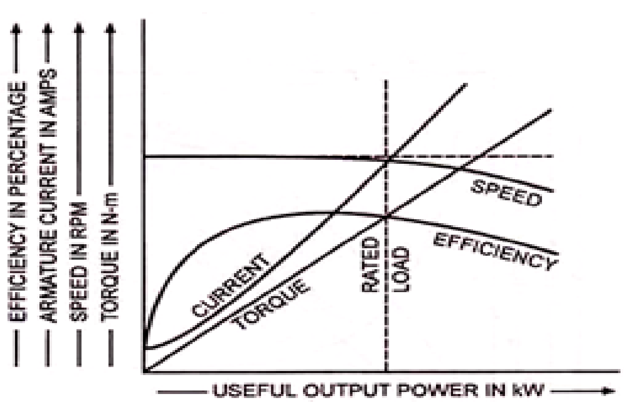
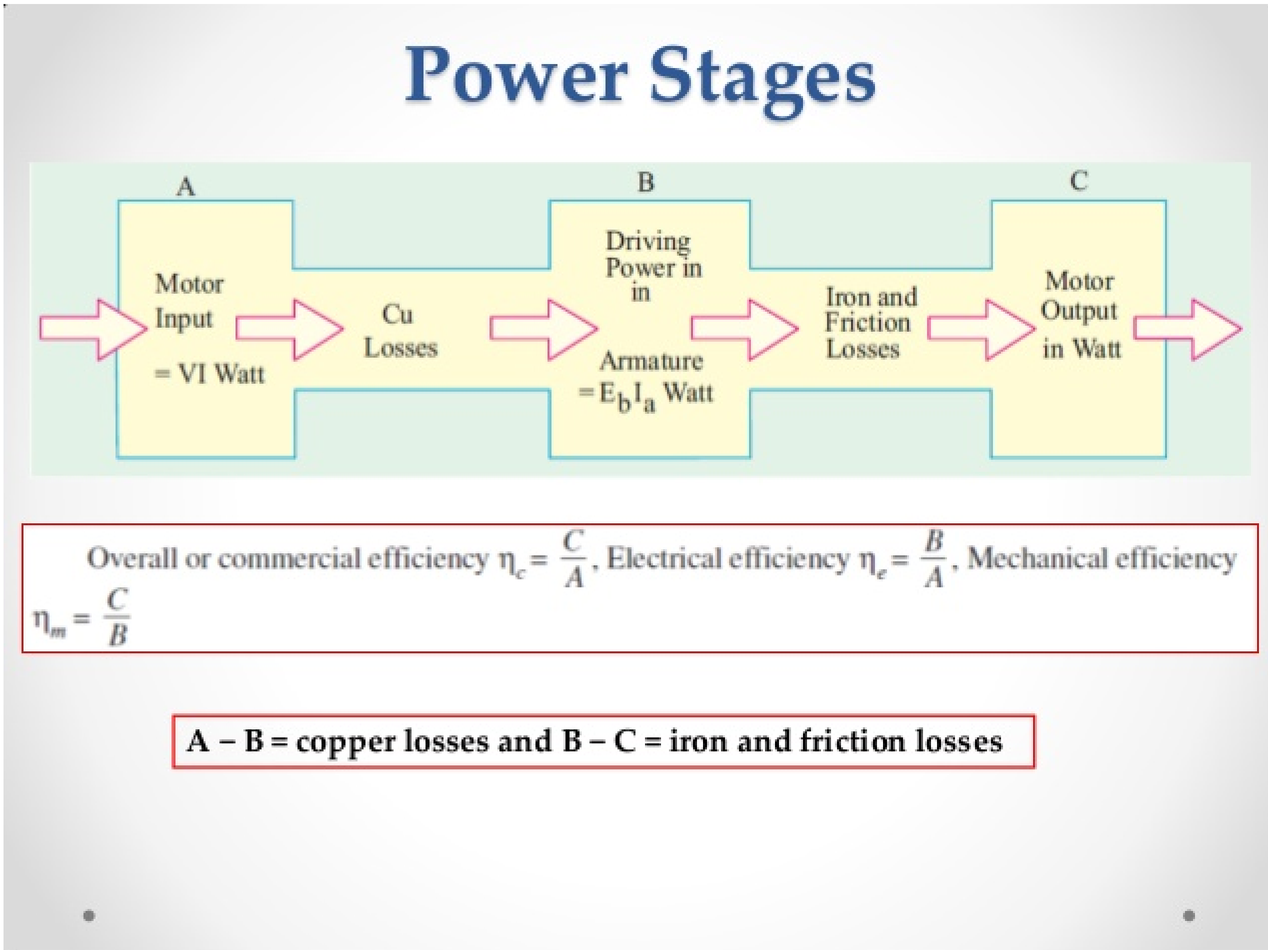


Fig. 1.17. ***Performance Curves of a DC Shunt Motor***

POWER STAGES IN DC MOTORS



2.30 CONDITION FOR MAXIMUM EFFICIENCY

The efficiency of a d.c. generator is not constant but varies with load. Consider a shunt generator delivering a load current I_L at a terminal voltage V.

$$\text{Generator output} = V I_L$$

$$\begin{aligned}\text{Generator input} &= \text{Output} + \text{Losses}\\ &= V I_L + \text{Variable losses} + \text{Constant losses}\\ &= V I_L + I_a^2 R_a + W_C\\ &= V I_L + (I_L + I_{sh})^2 R_a + W_C \qquad [\because I_a = I_L + I_{sh}]\end{aligned}$$

The shunt field current I_{sh} is generally small as compared to I_L and, therefore, can be neglected.

$$\therefore \quad \text{Generator input} = V I_L + I_L^2 R_a + W_C$$

Now

$$\eta = \frac{\text{output}}{\text{input}} = \frac{V I_L}{V I_L + I_L^2 R_a + W_C}$$

$$= \frac{1}{1 + \left(\dfrac{I_L R_a}{V} + \dfrac{W_C}{V I_L}\right)} \qquad ...(i)$$

The efficiency will be maximum when the denominator of eq. (*i*) is minimum *i.e.*,

$$\frac{d}{dI_L}\left(\frac{I_L R_a}{V} + \frac{W_C}{V I_L}\right) = 0$$

LOSSES IN A ROTATING DC MACHINE

- Copper losses
  - Armature Cu loss
  - Field Cu loss
  - Loss due to brush contact resistance
- Iron Losses
  - Hysteresis loss
  - Eddy current loss
- Mechanical losses
  - Friction loss
  - Windage loss

The above tree categorizes various types of losses that occur in a dc generator or a dc motor. Each of these is explained in details below.

Copper Losses

- These losses occur in armature and field copper windings.
- **Copper losses** consist of Armature copper loss, Field copper loss and loss due to brush contact resistance.

  Armature copper loss = $I_a^2 R_a$
- This loss contributes about 30 to 40% to full load losses.
- The armature copper loss is variable and depends upon the amount of loading of the machine.

  Field copper loss = $I_f^2 R_f$

- In the case of a shunt wounded field, field copper loss is practically constant.
- It contributes about 20 to 30% to full load losses.

  Brush contact resistance also contributes to the copper losses. Generally, this loss is included into armature copper loss.

Iron Losses (Core Losses)

- As the armature core is made of iron and it rotates in a magnetic field, a small current gets induced in the core itself too.
- Due to this current, **eddy current loss** and **hysteresis loss** occur in the armature iron core.
- Iron losses are also called as **Core losses or magnetic losses.**

Hysteresis loss is due to the reversal of magnetization of the armature core.

- When the core passes under one pair of poles,
- it undergoes one complete cycle of magnetic reversal

Eddy current loss:

- When the armature core rotates in the magnetic field, an emf is also induced in the core
- Though this induced emf is small,
- it causes a large current to flow in the body due to the low resistance of the core.
- This current is known as eddy current.
- The power loss due to this current is known as eddy current loss.

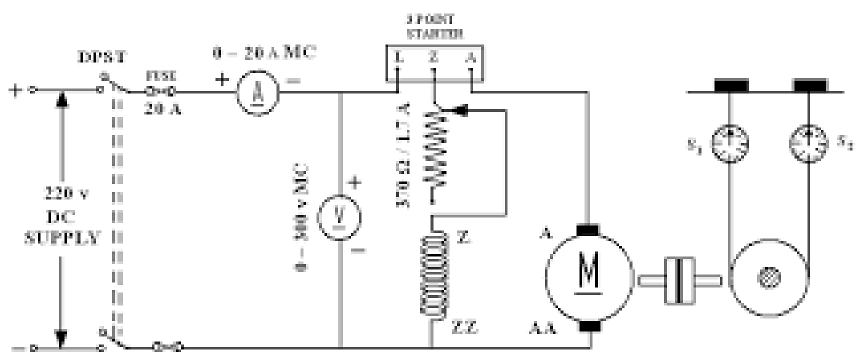
Mechanical Losses

- Mechanical losses consist of the losses due to friction in bearings and commutator.
- Air friction loss of rotating armature also contributes to these.
- These losses are about 10 to 20% of full load losses.

Stray Losses

- These losses are difficult to account.
- They are usually due to inaccuracies in the designing and modeling of the machine.
- Most of the times, stray losses are assumed to be 1% of the full load.

LOAD TEST(BREAK TEST)



BRAKE TEST ON DC SHUNT MOTOR

- The load testing of DC machine is needed to determine the rating of a machine.
- When we run a machine, then some energy is lost in the machine,
- which converts into the heat and cause temperature rise.
- If a machine produces too much heat then it can affect the insulation of the machine and ultimately it can cause the breakdown of the machine.

- Therefore, the load must be set to a value that it can operate within the temperature limit.
- The maximum value of the load that can be delivered by the machine without any harm is called the continuous rating of that machine.

PROCEDURE:

- Keep the auto transformer and field control rheostat at minimum resistance position.
- Loosen the rope on the brake drum and put some water inside the rim of the brake drum.
- Connect the circuit as shown in the circuit diagram.
- Switch on the motor and adjust the potentiometers till the armature attains the rated voltage and increase the field rheostat till the motor attains the rated speed.
- Record the readings of the instruments at no-load condition.
- Gradually, increase the load on the brake drum and record the readings as per the given table.
- Do not exceed the armature current more than its rated value.
- Gradually, reduce the load and switch off the supply.
- Maintain Constant armature voltage and constant field current during the total experimen

DETERMINATION OF EFFICIENCY

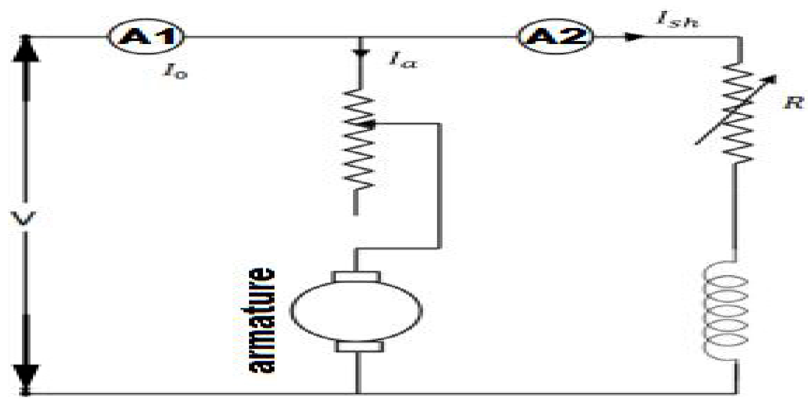
$$Efficiency\ (\eta)\ =\ \frac{output}{input}\cdots\cdots(1)$$

$$or,\ \eta\ =\ \frac{input\ -\ losses}{input}\cdots\cdots(2)$$

$$or,\ \eta\ =\frac{output}{output\ +\ losses}\cdots\cdots(3)$$

SWIMBURN'S TEST

The efficiency of DC machine like any other machine is determined by the ratio of output power to that of the input power.



PROCEDURE:

- Keep the auto transformer and field control rheostat at minimum resistance position.
- Loosen the rope on the brake drum and put some water inside the rim of the brake drum.
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- Record the readings of the instruments at no-load condition.

CALCULATION OF EFFICIENCY

- No load power input = VI_0 watts.
  In **Swinburne's test** no load power input is only required to supply the losses. The losses occur in the machine mainly are:
- Iron losses in the core
- Friction and windings losses
- Armature copper loss.
- Since the no load mechanical output of the machine is zero in Swinburne's test, the no load input power is only used to supply the losses.
- The value of armature copper loss =Ia2Ra
  Here, R_a is the armature resistance.
- Now, no to get the constant losses we have to subtract the armature copper loss from the no load power input.
- After calculating the no load constant losses now we can determine the efficiency at any load.
- Let, I is the load current at which we have to calculate the efficiency of the machine.
- Then, armature current (I_a) will be ($I - I_{sh}$), when the machine is motoring.
  And ($I + I_{sh}$), when the machine is generating.

Calculation of efficiency when the machine is motoring on load

Power input = VI

Armature copper loss,

Constant losses,

∴ Efficiency of the motor:

Calculation of Efficiency When the Machine is Generating on Load

Power input = VI

Armature copper loss, $P_{CU} = I_2 R_a = (I + I_{sh})^2 R_a$

Constant losses,

∴ Efficiency of the generator:

$$\eta_g = \frac{output}{input} = \frac{input - losses}{input} = \frac{VI - (P_C U + W_C)}{VI}$$

Applications of dc motors

Type of Motor	Characteristics	Applications
Shunt	Speed is fairly constant and medium starting torque.	1. Blowers and fans 2. Centrifugal and reciprocating pumps 3. Lathe machines 4. Machine tools 5. Milling machines 6. Drilling machines
Series	High starting torque. No load condition is dangerous. Variable speed.	1. Cranes 2. Hoists, Elevators 3. Trolleys 4. Conveyors 5. Electric locomotives
Cumulative compound	High starting torque. No load condition is allowed.	1. Rolling mills 2. Punches 3. Shears 4. Heavy planers 5. Elevators
Differential compound	Speed increases as load increases.	Not suitable for any practical applications