

Course : Electrical Machines  
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Project Name : Analysis of a DC Shunt Motor



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♦ **Project Goal :**

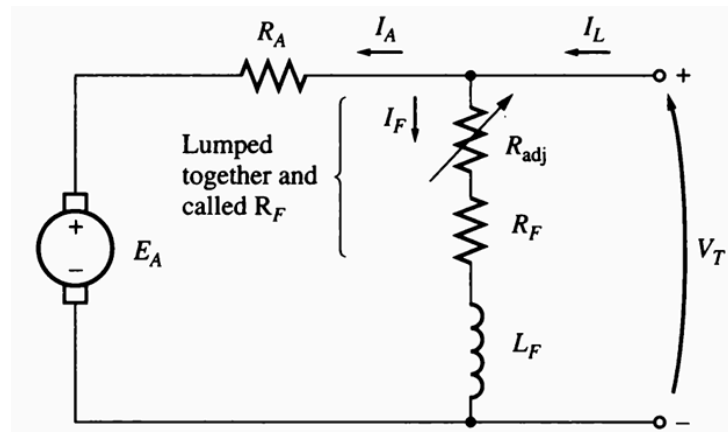
- Efficiency calculation for **Shunt-excited DC** motor using Excel

➤ In the next few slides I will use the given parameters to find the efficiency , then i will explain everything about the excel sheet.

♦ **The given parameters :**

Shunt-excited DC motor:  $R_f = 240 \Omega$ ,  $L_{af} = 1.8 H$ ,  $R_a = 0.6 \Omega$ ,  $L_f = 120 H$ ,  $L_a = 12 mH$ ,  $V_a = 240 V$ ,  $5 hp$ , rated speed  $1220 rpm$ , rated torque  $29.2 N.m$ ,  $B_m = 0$ ,  $J_m = 1 kg.m^2$

♦ **The equivalent circuit of a shunt dc motor + information about it :**



- A shunt DC motor is a type of DC motor in which the field winding is connected in parallel with the armature winding. This parallel configuration ensures that the field winding receives a constant voltage supply, resulting in a relatively stable magnetic field. Because of this, shunt DC motors are well known for their ability to maintain nearly constant speed under varying load conditions.

- The shunt DC motor consists of two primary windings:
  - a) Armature winding: Located on the rotor, this winding carries the main current responsible for torque production.
  - b) Field (shunt) winding: Located on the stator, this winding produces the magnetic field required for motor operation.

➤ **Important note :**

At steady state, inductors behave like short circuits for DC. That means:

$$V_L = L \frac{di}{dt} = 0$$

And because the current  $i(t)$  is constant  $\frac{di}{dt} = 0$

→ so we should not use the values of  $L_a$  ,  $L_f$  ,  $L_{af}$

➤ **Steps for calculations 😊**

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

- $V$  = supply voltage (V)
  - $I_f$  = field current (A)
  - $R_f$  = the field resistance ( $\Omega$ )
- From the given parameters =  $V_a = 240 \text{ v}$  ,  $R_f = 240 \Omega$

So →  $I_f = V_a / R_f = 240 / 240 = 1 \text{ A}$

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

- $\omega$  = Angular speed (rad/s)
  - $N$  = Rotational speed (rpm)
- From the given parameters =  $N = 1220 \text{ rpm}$

So →  $\omega = (2\pi * 1220) / 60 = 127.75810 \text{ rad/sec}$

$$P_{\text{out}} = T \cdot \omega$$

- T = torque (N.m)
  - $\omega$  = Angular speed (rad/s)
  - Output Power is mechanical
- From the given parameters T = 29.2 N.m ,  $\omega$  = 127.75 rad/sec

So  $\rightarrow P_{\text{out}} = 29.2 \cdot 127.75 = 3730.53 \text{ watt}$

$$V = E_a + I_a R_a$$

$$P_{\text{mech}} = E_a \cdot I_a$$

- E = EMF (V)
  - $R_a$  = armature resistance ( $\Omega$ )
  - $I_a$  = armature current (A)
  - $V_a$  = armature voltage (volt)
  - $P_{\text{mech}} = P_{\text{out}}$  ( watt)
- By using substitution to find the value of  $I_a$

$$I_a = \frac{V \pm \sqrt{V^2 - 4R_a P_{\text{mech}}}}{2R_a}$$

So  $\rightarrow$  using the given and the calculated values to find it ,  $I_a = 16.2 \text{ A}$

$$P_{\text{in}} = V \cdot I_{\text{total}} = V \cdot (I_a + I_f)$$

- Using the values above to find the  $P_{\text{in}}$  ( electrical input power )

So  $\rightarrow P_{\text{in}} = 240 \cdot ( 1 + 16.2 ) = 4128.001 \text{ watt}$

$$\text{Efficiency}(\eta) = \frac{\text{Output Power}}{\text{Input Power}} \times 100\%$$

So  $\rightarrow \text{Efficiency} = (3730.53 / 4128.001) \cdot 100 = 90.3715 \%$

➤ The losses in the shunt DC motor :

- Copper losses:
  - Armature:  $I_a^2 R_a$
  - Field:  $I_f^2 R_f$

So → the armature loss =  $16.2^2 + 0.6 = 157.4640$  watt , field loss =  $1^2 + 240 = 240$  watt

- The total loss is = Pinput - Output →  $4128.001 - 3730.53 = 397.471$  watt
- And also using armature loss + field loss =  $157.4640 + 240 = 397.464$  watt

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### In the Excel Sheet

#### ♦ My project goal :

Study how a DC shunt motor behaves under different conditions.

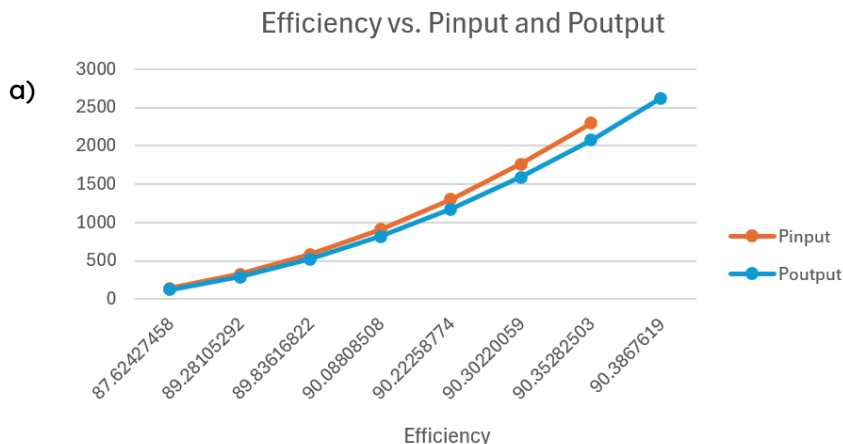
#### ♦ What i Did :

In this experiment, I changed the armature voltage while keeping the field resistance constant, which caused the field current to vary. I also changed the torque and angular speed, which affected the output power. As a result of these changes, the armature current changed, leading to a change in the input power. Since both input power and output power changed, the efficiency of the motor also changed.

#### ♦ What i Found :

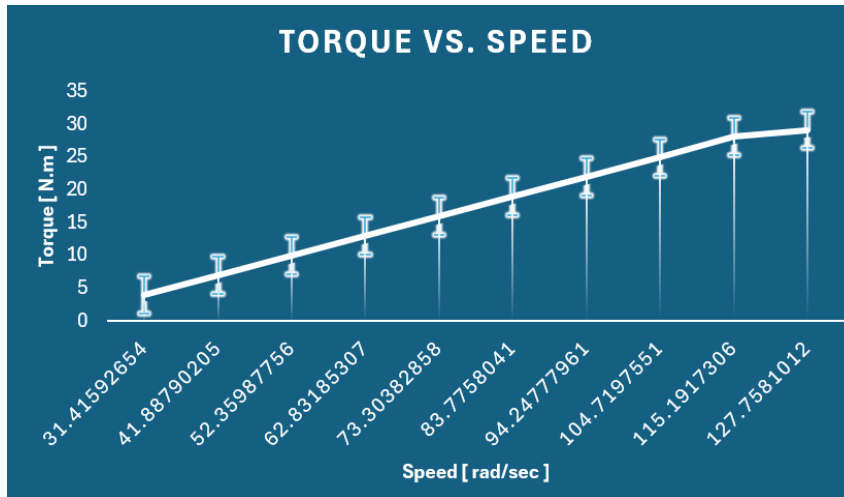
- Efficiency : The motor became more efficient as voltage and power increased. It reached over 90% at higher loads.
- Output Power : Output power increased as input voltage increased.
- Torque and Speed : Torque increased with speed.
- Power Losses : Losses (especially from the armature winding) also increased with voltage and current.

#### ♦ Plots and Results :



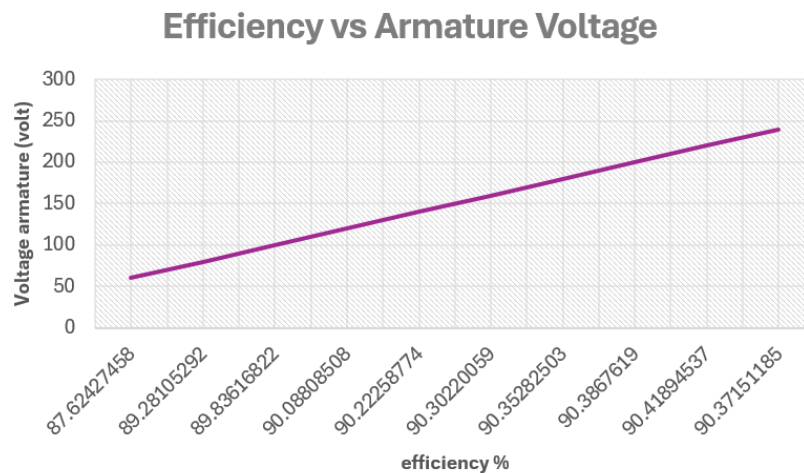
- Both Pinput and Poutput increase as efficiency increases, which is expected.
- The gap between Pinput and Poutput reflects losses — and that gap gets slightly bigger at higher power levels, also expected.

b)



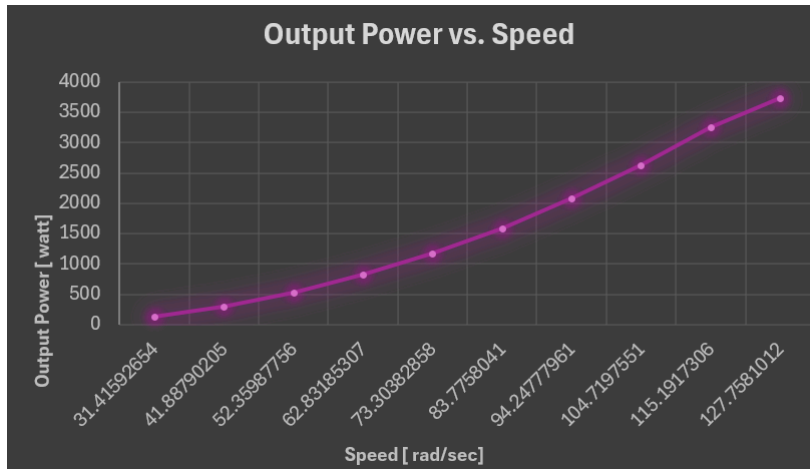
- The motor showed steady torque behavior as speed increased, as expected for a shunt motor

c)



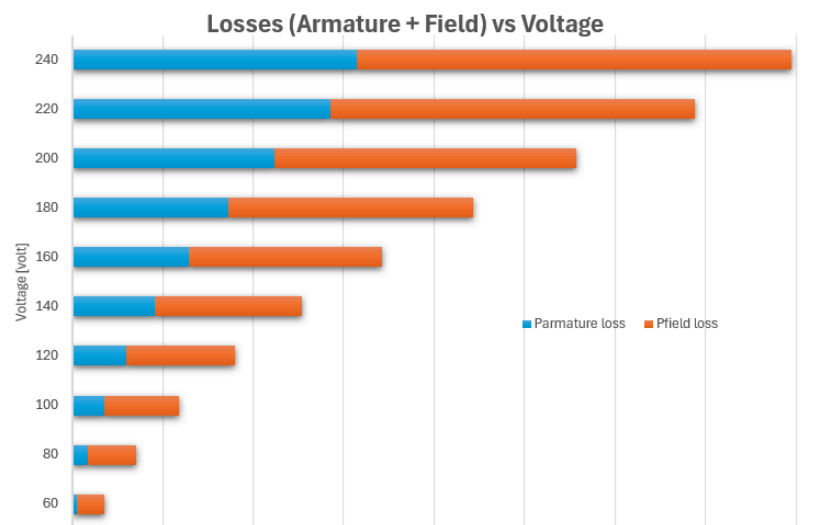
- Efficiency increases as the armature voltage increases.
- At lower voltages, the efficiency is lower because more power is lost in the motor (mostly due to copper losses).

d)



- As the speed increases, the output power also increases.

e)



- This stacked bar chart shows how total copper losses (field and armature) increase with voltage