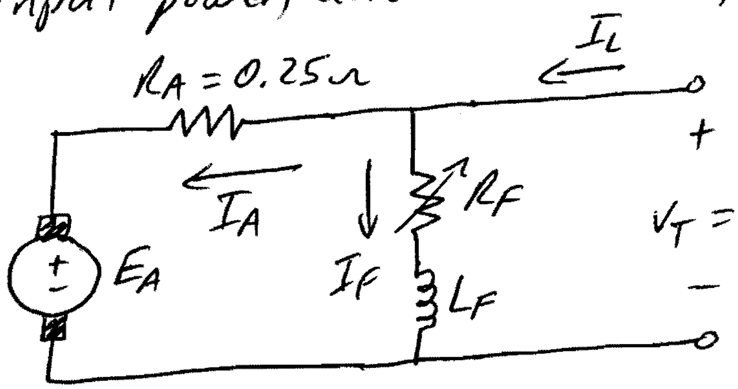
ex. A 230V shunt DC motor has an armature resistance of 0.25 Ω and a field circuit resistance of 115 Ω. At full load, the armature draws a current of 38 A and the motor has a shaft speed of 1100 RPM. Assume core, mechanical, brush, and stray losses of 700W.

a) What is the induced & load torque, output power, input power, and efficiency at full load?



By KVL, $V_T = I_A R_A + E_A$

$$E_A = 230 - 38(0.25) = \underline{\underline{220.5\,V}}$$

$$P_{conv} = E_A I_A = 220.5(38)$$

$$P_{conv} = \omega_m \tau_{ind} = \underline{\underline{8379\,W}}$$

$$\tau_{ind} = \frac{8379}{1100(\pi/30)} = \underline{\underline{72.74\,N\cdot m}}$$

ex. cont.

a) cont.

$$P_{OUT} = P_{conv} - \text{losses}$$
$$= 8379 - 700$$
$$\underline{\underline{P_{out} = 7679\,W = 10.3\,hp}}$$

$$\tau_{LP} = \frac{P_{OUT}}{\omega_m} = \frac{7679}{1100(\pi/30)} = \underline{\underline{66.66\ N\cdot m}}$$

$$I_F = \frac{V_T}{R_F} = \frac{230}{115} = 2A$$

$$I_L = I_A + I_F = 38 + 2 = \underline{40A} \quad (KCL)$$

$$P_{IN} = V_T I_L = 230(40) = \underline{9200\,W}$$

$$P_{electrical} = P_{IN} - P_{conv} = 9200 - 8379 = \underline{\underline{821\,W}}$$

OR

$$= I_A^2 R_A + I_F^2 R_F = 38^2(0.25) + 2^2(115)$$

$$\text{Efficiency} = \eta = \frac{P_{OUT}}{P_{IN}} \times 100\% = \frac{7679}{9200} \times 100\%$$

$$\underline{\underline{\eta = 83.47\%}}$$

ex. cont.

b) Now, adjust the field resistance to 130Ω. If the armature current & losses remain the same, what happens to the machine speed and other quantities?

$$E_{A_b} = 230 - 38(0.25) = \underline{220.5\ V}$$ ← No change

$$I_{F_b} = \frac{230}{130} = \underline{1.76923\ A}$$

Back in Chapter 7, we found $E_A = K'\phi\, n_m$

So $E_{A_a} = 220.5\ V = K'\phi_a\, 1100$

$$E_{A_b} = 220.5\ V = K'\phi_b\, n_{m_b}$$

Further, $\phi \propto I$. So, $\dfrac{\phi_a}{\phi_b} = \dfrac{I_{F_a}}{I_{F_b}} = \dfrac{2}{1.76923}$

Taking the ratio of E_A, we have

$$\frac{E_A}{E_A} = \frac{220.5}{220.5} = 1 = \frac{K'\phi_a\, 1100}{K'\phi_b\, n_{m_b}}$$

$$\hookrightarrow n_{m_b} = \frac{\phi_a}{\phi_b}(1100) = \frac{2}{1.76923}(1100) = \underline{\underline{1243.48\ RPM}}$$

sped up!

ex. cont.

b) cont. $P_{conv_b} = E_A I_A = (220.5)(38) = \underline{8379\,W}$

← No change

$$\tau_{ind_b} = \frac{P_{conv_b}}{\omega_{m_b}} = \frac{8379}{1243.48(\pi/30)} = \underline{64.35\ N\cdot m}$$

← less torque

$$P_{OUT_b} = P_{conv_b} - losses = 8379 - \underset{\substack{\uparrow \\ \text{assume} \\ \text{constant}}}{700} = \underline{7679\,W}$$

← No change

$$\tau_{out_b} = \tau_{LO_b} = \frac{7679}{1243.48(\pi/30)} = \underline{\underline{58.79\ N\cdot m}}$$

$$I_{L_b} = I_A + I_{F,b} = 38 + 1.76923 = \underline{39.76923\,A}$$

$$P_{IN_b} = V_T I_{L_b} = 230(39.76923) = \underline{9146.923\,W}$$

← lower

$$P_{electrical_b} = P_{IN_b} - P_{conv_b} = 9146.923 - 8379$$
$$= \underline{\underline{767.9\,W}}$$

$$\text{Efficiency} = \eta_b = \frac{P_{OUT_b}}{P_{IN_b}} \times 100\%$$
$$= \frac{7679}{9146.923} \times 100\%$$

$$\underline{\underline{\eta_b = 83.95\%}}$$