

8-1. The following information is given about the simple rotating loop shown in Figure 8-6:

$$B = 0.8 \text{ T}$$

$$V_B = 24 \text{ V}$$

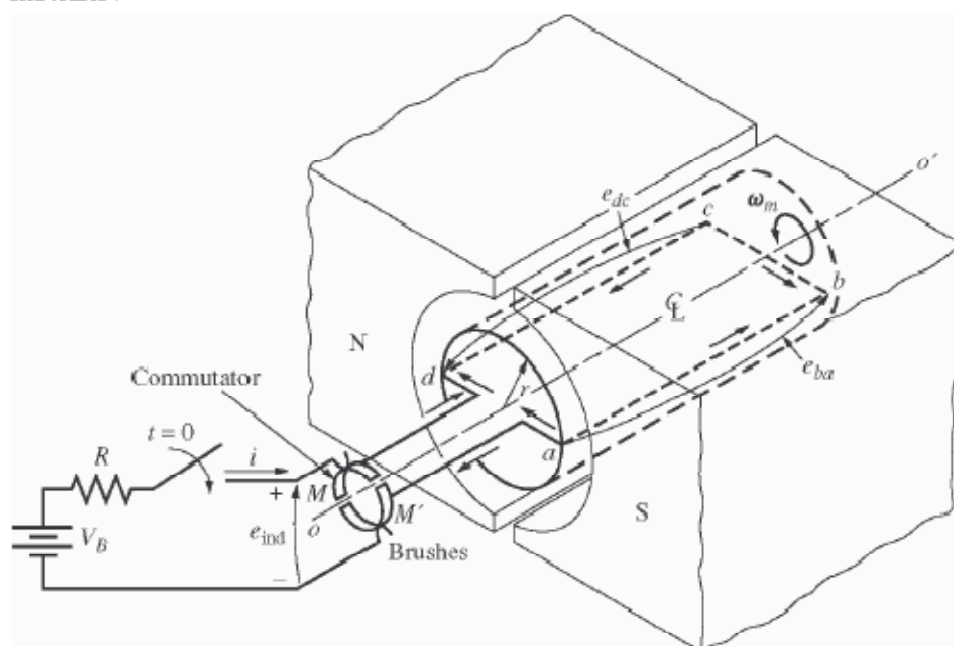
$$l = 0.5 \text{ m}$$

$$R = 0.4 \, \Omega$$

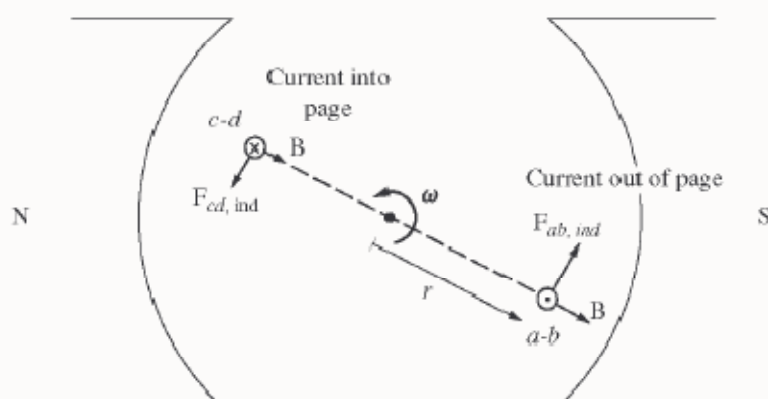
$$r = 0.125 \text{ m}$$

$$\omega = 250 \text{ rad/s}$$

- Is this machine operating as a motor or a generator? Explain.
- What is the current i flowing into or out of the machine? What is the power flowing into or out of the machine?
- If the speed of the rotor were changed to 275 rad/s, what would happen to the current flow into or out of the machine?
- If the speed of the rotor were changed to 225 rad/s, what would happen to the current flow into or out of the machine?



(a)



(b)

(a) If the speed of rotation ω of the shaft is 500 rad/s, then the voltage induced in the rotating loop will be

$$\begin{aligned}e_{ind} &= 2r l B \omega \\e_{ind} &= 2(0.125 \text{ m})(0.5 \text{ m})(0.8 \text{ T})(250 \text{ rad/s}) = 25 \text{ V}\end{aligned}$$

Since the external battery voltage is only 24 V, this machine is operating as a *generator*, charging the battery.

(b) The current flowing out of the machine is approximately

$$i = \frac{e_{ind} - V_B}{R} = \frac{25 \text{ V} - 24 \text{ V}}{0.4 \Omega} = 2.5 \text{ A}$$

(Note that this value is the current flowing while the loop is under the pole faces. When the loop goes beyond the pole faces, e_{ind} will momentarily fall to 0 V, and the current flow will momentarily reverse. Therefore, the *average* current flow over a complete cycle will be somewhat less than 2.5 A.)

(c) If the speed of the rotor were increased to 275 rad/s, the induced voltage of the loop would increase to

$$\begin{aligned}e_{ind} &= 2r l B \omega \\e_{ind} &= 2(0.125 \text{ m})(0.5 \text{ m})(0.8 \text{ T})(275 \text{ rad/s}) = 27.5 \text{ V}\end{aligned}$$

and the current flow out of the machine will increase to

$$i = \frac{e_{ind} - V_B}{R} = \frac{27.5 \text{ V} - 24 \text{ V}}{0.4 \Omega} = 8.75 \text{ A}$$

(d) If the speed of the rotor were decreased to 450 rad/s, the induced voltage of the loop would fall to

$$\begin{aligned}e_{ind} &= 2r l B \omega \\e_{ind} &= 2(0.125 \text{ m})(0.5 \text{ m})(0.8 \text{ T})(225 \text{ rad/s}) = 22.5 \text{ V}\end{aligned}$$

Here, e_{ind} is less than V_B , so current flows into the loop and the machine is acting as a motor. The current flow into the machine would be

$$i = \frac{V_B - e_{ind}}{R} = \frac{24 \text{ V} - 22.5 \text{ V}}{0.4 \Omega} = 3.75 \text{ A}$$

- 8-7.** An eight-pole, 25-kW, 120-V DC generator has a duplex lap-wound armature, which has 64 coils with 16 turns per coil. Its rated speed is 2400 r/min.
- (a) How much flux per pole is required to produce the rated voltage in this generator at no-load conditions?
- (b) What is the current per path in the armature of this generator at the rated load?
- (c) What is the induced torque in this machine at the rated load?
- (d) How many brushes must this motor have? How wide must each one be?
- (e) If the resistance of this winding is $0.011\ \Omega$ per turn, what is the armature resistance R_A of this machine?

SOLUTION

$$(a) \quad E_A = K\phi\omega = \frac{ZP}{2\pi a} \phi\omega$$

In this machine, the number of current paths is

$$a = mP = (2)(8) = 16$$

The number of conductor is

$$Z = (64 \text{ coils})(16 \text{ turns/coil})(2 \text{ conductors/turn}) = 2048$$

The equation for induced voltage is

$$E_A = \frac{ZP}{2\pi a} \phi\omega$$

so the required flux is

$$\begin{aligned} 120 \text{ V} &= \frac{(2048 \text{ cond})(8 \text{ poles})}{2\pi(16 \text{ paths})} \phi(2400 \text{ r/min}) \frac{2\pi \text{ rad}}{1 \text{ r}} \frac{1 \text{ min}}{60 \text{ s}} \\ 120 \text{ V} &= 40,960 \phi \\ \phi &= 0.00293 \text{ Wb} \end{aligned}$$

- (b) At rated load, the current flow in the generator would be

$$I_A = \frac{25 \text{ kW}}{120 \text{ V}} = 208 \text{ A}$$

There are $a = mP = (2)(8) = 16$ parallel current paths through the machine, so the current per path is

$$I = \frac{I_A}{a} = \frac{208 \text{ A}}{16} = 13 \text{ A}$$

- (c) The induced torque in this machine at rated load is

$$\tau_{\text{ind}} = \frac{ZP}{2\pi a} \phi I_A$$

$$\tau_{\text{ind}} = \frac{(2048 \text{ cond})(8 \text{ poles})}{2\pi(16 \text{ paths})} (0.00293 \text{ Wb})(208 \text{ A})$$

$$\tau_{\text{ind}} = 99.3 \text{ N} \cdot \text{m}$$

(d) This motor must have 8 brushes, since it is lap-wound and has 8 poles. Since it is duplex-wound, each brush must be wide enough to stretch across 2 complete commutator segments.

(e) There are a total of 1024 turns on the armature of this machine, so the number of turns per path is

$$N_p = \frac{1024 \text{ turns}}{16 \text{ paths}} = 64 \text{ turns/path}$$

The total resistance per path is $R_p = (64)(0.011 \Omega) = 0.704 \Omega$. Since there are 16 parallel paths through the machine, the armature resistance of the generator is

$$R_A = \frac{0.704 \Omega}{16 \text{ paths}} = 0.044 \Omega$$