(1)

(a) From Figure 1-10*c*, a reasonable maximum flux density would be about 1.2 T. Notice that the saturation effects become significant for higher flux densities.

(b) At a flux density of 1.2 T, the total flux in the core would be

$$\phi = BA = (1.2\ \text{T})(0.05\ \text{m})(0.05\ \text{m}) = 0.0030\ \text{Wb}$$

(c) The total reluctance of the core is:

$$\mathcal{R}_{\text{TOT}} = \mathcal{R}_{\text{stator}} + \mathcal{R}_{\text{air gap 1}} + \mathcal{R}_{\text{rotor}} + \mathcal{R}_{\text{air gap 2}}$$

At a flux density of 1.2 T, the relative permeability μ_r of the stator is about 3800, so the stator reluctance is

$$\mathcal{R}_{\text{stator}} = \frac{l_{\text{stator}}}{\mu_{\text{stator}} A_{\text{stator}}} = \frac{0.60\ \text{m}}{(3800)\left(4\pi \times 10^{-7}\ \text{H/m}\right)(0.05\ \text{m})(0.05\ \text{m})} = 50.3\ \text{kA} \cdot \text{t/Wb}$$

At a flux density of 1.2 T, the relative permeability μ_r of the rotor is 3800, so the rotor reluctance is

$$\mathcal{R}_{\text{rotor}} = \frac{l_{\text{rotor}}}{\mu_{\text{stator}} A_{\text{rotor}}} = \frac{0.05\ \text{m}}{(3800)\left(4\pi \times 10^{-7}\ \text{H/m}\right)(0.05\ \text{m})(0.05\ \text{m})} = 4.2\ \text{kA} \cdot \text{t/Wb}$$

The reluctance of both air gap 1 and air gap 2 is

$$\mathcal{R}_{\text{air gap 1}} = \mathcal{R}_{\text{air gap 2}} = \frac{l_{\text{air gap}}}{\mu_{\text{air gap}}\ A_{\text{air gap}}} = \frac{0.0005\ \text{m}}{\left(4\pi \times 10^{-7}\ \text{H/m}\right)\left(0.0018\ \text{m}^2\right)} = 221\ \text{kA} \cdot \text{t/Wb}$$

Therefore, the total reluctance of the core is

$$\mathcal{R}_{\text{TOT}} = \mathcal{R}_{\text{stator}} + \mathcal{R}_{\text{air gap 1}} + \mathcal{R}_{\text{rotor}} + \mathcal{R}_{\text{air gap 2}}$$

$$\mathcal{R}_{\text{TOT}} = 50.3 + 221 + 4.2 + 221 = 496\ \text{kA} \cdot \text{t/Wb}$$

The required MMF is

$$\mathcal{F}_{\text{TOT}} = \phi \mathcal{R}_{\text{TOT}} = (0.003\ \text{Wb})(496\ \text{kA} \cdot \text{t/Wb}) = 1488\ \text{A} \cdot \text{t}$$

Since $\mathcal{F} = Ni$, and the current is limited to 1 A, one possible choice for the number of turns is $N = 2000$. This would allow the desired flux density to be achieved with a current of about 0.74 A.

(2)

SOLUTION

(a) The current in the bar at starting is

$$i = \frac{V_B}{R} = \frac{100\ \text{V}}{0.25\ \Omega} = 400\ \text{A}$$

Therefore, the force on the bar at starting is

$$\mathbf{F} = i(\mathbf{l} \times \mathbf{B}) = (400\ \text{A})(1\ \text{m})(0.5\ \text{T}) = 200\ \text{N, to the right}$$

(b) The no-load steady-state speed of this bar can be found from the equation

$$V_B = e_{\text{ind}} = vBl$$

$$v = \frac{V_B}{Bl} = \frac{100\ \text{V}}{(0.5\ \text{T})(1\ \text{m})} = 200\ \text{m/s}$$