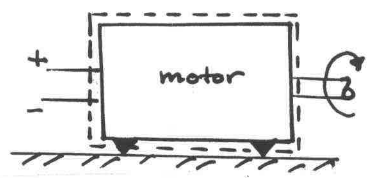
PROBLEM 2.59

KNOWN: Operating data are provided for an electric motor at steady state.

FIND: Determine the electric power required by the motor and the power developed by the output shaft. Determine the rate of heat transfer for the motor.

SCHEMATIC & GIVEN DATA:

10 amp
110V



$\mathcal{T} = 10.2\ \text{N}\cdot\text{m}$
1000 RPM

ENGR. MODEL: 1. As shown in the schematic, the motor is the closed system. 2. The system is at steady state.

ANALYSIS: (a) Using Eq. 2.21,

$$\dot{W}_{electric} = -(\text{Voltage})(\text{current})$$
$$= -(110\ \text{Volts})(10\ \text{amp})\left|\frac{1\ \text{watt/amp}}{1\ \text{volt}}\right| = -1100\ \text{watt}\left|\frac{1\ \text{kW}}{10^3\ \text{W}}\right|$$
$$= -1.1\ \text{kW} \longleftarrow \dot{W}_{electric}$$

(b) Using Eq. 2.20,

$$\dot{W}_{shaft} = (\text{Torque})(\text{angular velocity})$$
$$= (10.2\ \text{N}\cdot\text{m})\left(1000\ \frac{\text{Rev}}{\text{min}}\left|\frac{2\pi\ \text{rad}}{\text{Rev}}\right|\left|\frac{1\ \text{min}}{60\ \text{s}}\right|\right)\left|\frac{1\ \text{kW}}{10^3\ \text{N}\cdot\text{m/s}}\right|$$
$$= 1.07\ \text{kW} \longleftarrow \dot{W}_{shaft}$$

Thus for the motor,

$$\dot{W} = \dot{W}_{electric} + \dot{W}_{shaft}$$
$$= (-1.1\ \text{kW}) + (1.07\ \text{kW}) = -0.03\ \text{kW} \longleftarrow \dot{W}$$

(c) An energy rate balance for the motor at steady state reads

(1) $$\cancel{\frac{dE}{dt}}^{\,0} = \dot{Q} - \dot{W} \Rightarrow \dot{Q} = \dot{W}$$
$$= -0.03\ \text{kW} \longleftarrow \dot{Q}$$

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1. Owing to the effects of electrical resistance and friction within the motor, the power out is less than the power in. At steady state, the difference in these power quantities is carried out of the motor by heat transfer.