Chapter 31, Problem 1

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Test Bank Question preview

Question

A reciprocating air compressor has a 7% clearance and discharges ~~65 psia (450 kPa)~~ air at the rate of 48 lbm/min (0.36 kg/s). ~~Ambient air is at 14.7 psia and 65°F.~~ The polytropic exponent is 1.33. The equation for the volumetric efficiency is

$$\eta_v = 1 - \left(r_p^{1/n} - 1\right)\left(\frac{c}{100\%}\right)$$

The mass of air that is compressed each minute is most nearly

Answers

(A) 42 lbm/min (0.32 kg/s)

(B) 51 lbm/min (0.38 kg/s)

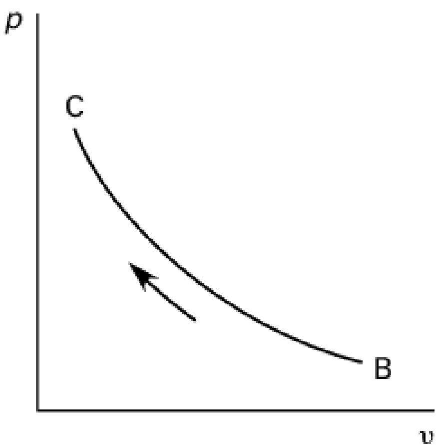
(C) 56 lbm/min (0.42 kg/s)

(D) 74 lbm/min (0.55 kg/s)

The answer is (C).

Solution

Content in blue refers to the NCEES Handbook.



Customary U.S. Solution

~~The compression ratio for a reciprocating compressor is~~

~~Compressibility Factor and Charts~~

$$r_p = \frac{p_C}{p_B} = \frac{65\ \frac{\text{lbf}}{\text{in}^2}}{14.7\ \frac{\text{lbf}}{\text{in}^2}} = 4.42$$

The volumetric efficiency is

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Difficulty

easy

Quantitative?

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PRODUCTS USED IN

$$\begin{aligned}\eta_v &= 1 - \left(r_p^{1/n} - 1\right)\left(\frac{c}{100\%}\right) \\ &= 1 - \left(4.42^{1/1.33} - 1\right)\left(\frac{7\%}{100\%}\right) \\ &= 0.856 \quad (85.6\%)\end{aligned}$$

The mass of air compressed per minute is

$$\begin{aligned}\dot{m} &= \frac{\dot{m}_{\text{actual}}}{\eta_v} = \frac{48\ \frac{\text{lbm}}{\text{min}}}{0.856} \\ &= 56.07\ \text{lbm/min} \quad (56\ \text{lbm/min})\end{aligned}$$

SI Solution

~~The compression ratio for the reciprocating compressor is~~

~~Compressibility Factor and Charts~~

$$p_R = \frac{p_C}{p_B} = \frac{450\ \text{kPa}}{101\ \text{kPa}} = 4.46$$

The volumetric efficiency is

$$\begin{aligned}\eta_v &= 1 - \left(r_p^{1/n} - 1\right)\left(\frac{c}{100\%}\right) \\ &= 1 - \left(4.46^{1/1.33} - 1\right)\left(\frac{7\%}{100\%}\right) \\ &= 0.855 \quad (85.5\%)\end{aligned}$$

The mass of air compressed per minute is

$$\begin{aligned}\dot{m} &= \frac{\dot{m}_{\text{actual}}}{\eta_v} = \frac{0.36\ \frac{\text{kg}}{\text{s}}}{0.855} \\ &= 0.4211\ \text{kg/s} \quad (0.42\ \text{kg/s})\end{aligned}$$

Chapter 36, Problem 3

< Return to Questions (/admin/questions/0?sfield=magento_id&stext=0000198296&sdka=&stype=&sdiff=)

Test Bank Question preview

Question

Dry air at 1 atm flows through 50 ft (15 m) of uninsulated duct. The flow rate of air through the duct is 500 ft^3/min (0.25 m^3/s), and the diameter of the duct is 12 in (30 cm). Air enters the duct at 45°F (7°C). The walls, air, and contents of the room through which the duct passes are at 80°F (27°C). The air leaving the duct is at 50°F (10°C). Assume normal temperature and pressure for surface temperatures. The film coefficient for air flowing inside the duct is given by the following equations.

$$h_i \approx (0.00351 + (1.583 \times 10^{-6})T_{^\circ\mathrm{F}})\left(\frac{G^{0.8}_{\mathrm{lbm/hr\text{-}ft^2}}}{D^{0.2}_{\mathrm{ft}}}\right) \quad [\mathrm{US}]$$

$$h_i \approx \frac{3.52\mathrm{v}^{0.8}_{\mathrm{m/s}}}{D^{0.2}_{\mathrm{m}}} \quad [\mathrm{SI}]$$

The film coefficient for air flowing inside the duct is most nearly

Answers

(A) 2 Btu/hr-ft^2-°F (12 W/m^2·K)

(B) 3 Btu/hr-ft^2-°F (17 W/m^2·K)

(C) 5 Btu/hr-ft^2-°F (28 W/m^2·K)

(D) 9 Btu/hr-ft^2-°F (51 W/m^2·K)

The answer is (A).

Solution

Content in blue refers to the NCEES Handbook.

Customary U.S. Solution

Find the absolute temperature of air entering the duct. [Temperature Conversions]

$$45^\circ\mathrm{F} + 459.69 = 504.69^\circ\mathrm{R}$$

At normal temperature and pressure, the pressure of air is 14.696 lbf/in^2. The gas constant, R, is 53.3 ft-lbf/lbm-°R. [Standard Dry Air Conditions at Sea Level] [Fundamental Constants]

Using the ideal gas law, calculate the density of air entering the duct.

Ideal Gas

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DISCIPLINES

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PRODUCTS USED IN

$$pV = mRT$$

$$\rho = \frac{m}{V} = \frac{p}{RT}$$

$$= \frac{\left(14.696\ \frac{\text{lbf}}{\text{in}^2}\right)\left(12\ \frac{\text{in}}{\text{ft}}\right)^2}{\left(53.3\ \frac{\text{ft-lbf}}{\text{lbm-}^\circ\text{R}}\right)(504.69^\circ\text{R})}$$

$$= 0.07867\ \text{lbm/ft}^3$$

Find the mass flow rate of air entering the duct.

Continuity Equation

$$\dot{m} = \rho Q$$
$$= \left(0.07867\ \frac{\text{lbm}}{\text{ft}^3}\right)\left(500\ \frac{\text{ft}^3}{\text{min}}\right)\left(60\ \frac{\text{min}}{\text{hr}}\right)$$
$$= 2360.1\ \text{lbm/hr}$$

The mass flow rate per unit area, *G*, is

$$G = \frac{\dot{m}}{A_{\text{flow}}} = \frac{\left(2360.1\ \frac{\text{lbm}}{\text{hr}}\right)\left(12\ \frac{\text{in}}{\text{ft}}\right)^2}{\left(\frac{\pi}{4}\right)(12\ \text{in})^2}$$
$$= 3006.49\ \text{lbm/hr-ft}^2$$

To calculate the initial film coefficients, find the bulk temperature. The film coefficients are not highly sensitive to small temperature differences.

$$T_{\text{bulk,air}} = \frac{1}{2}(T_{\text{air,in}} + T_{\text{air,out}}) = \left(\frac{1}{2}\right)(45^\circ\text{F} + 50^\circ\text{F})$$
$$= 47.5^\circ\text{F}$$

The film coefficient for air flowing inside the duct is

$$h_i \approx \left(0.00351 + (1.583 \times 10^{-6})T_{^\circ\text{F}}\right)\left(\frac{G^{0.8}_{\text{lbm/hr-ft}^2}}{D^{0.2}_{\text{ft}}}\right)$$

$$= \left(0.00351 + (1.583 \times 10^{-6})(47.5^\circ\text{F})\right) \times \left(\frac{\left(3006.49\ \frac{\text{lbm}}{\text{hr-ft}^2}\right)^{0.8}}{\left(\frac{12\ \text{in}}{12\ \frac{\text{in}}{\text{ft}}}\right)^{0.2}}\right)$$

$$= 2.17\ \text{Btu/hr-ft}^2\text{-}^\circ\text{F} \quad (2\ \text{Btu/hr-ft}^2\text{-}^\circ\text{F})$$

SI Solution

The diameter of the duct in centimeters is

$$D = \frac{30\ \text{cm}}{100\ \frac{\text{cm}}{\text{m}}} = 0.30\ \text{m}$$

The velocity of air entering the duct is

$$\mathrm{v} = \frac{Q}{A_{\text{flow}}} = \frac{0.25\ \frac{\text{m}^3}{\text{s}}}{\left(\frac{\pi}{4}\right)(0.30\ \text{m})^2}$$
$$= 3.537\ \text{m/s}$$

The film coefficient for air flowing inside the duct is

$$h_i \approx \frac{3.52\mathrm{v}_{\text{m/s}}^{0.8}}{D_{\text{m}}^{0.2}}$$
$$= \frac{(3.52)\left(3.537\ \frac{\text{m}}{\text{s}}\right)^{0.8}}{(0.30\ \text{m})^{0.2}}$$
$$= 12.3\ \text{W/m}^2\text{·K}\quad \left(12\ \text{W/m}^2\text{·K}\right)$$

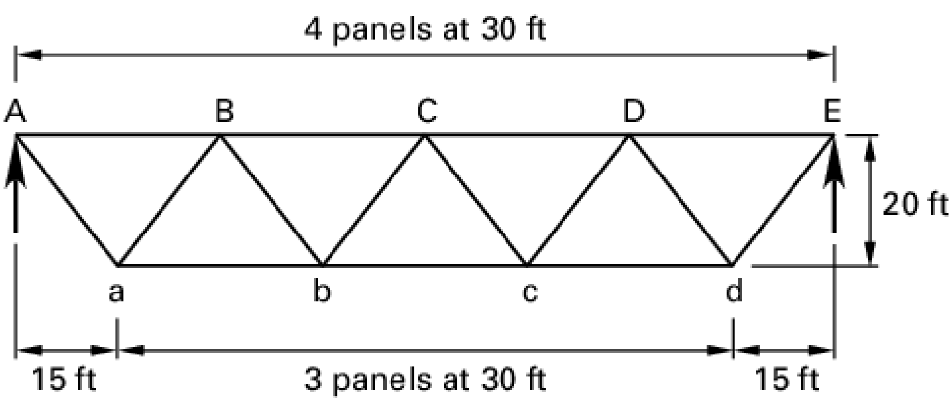
Chapter 45, Problem 12

Test Bank

Question preview

Question

The truss shown carries a moving uniform live load of 2 kips/ft and a moving concentrated live load of 15 kips.



The maximum force in member BC is most nearly

Answers

(A) 15 kips

(B) 80 kips

(C) 95 kips

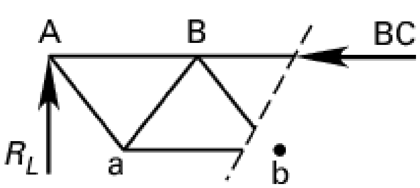
(D) ~~170~~ kips

The answer is (D).

Solution

Influence diagram for moment at point b:

The horizontal member BC cannot resist vertical shear.



With no loads between A and C, the force in member BC can be found by summing the moments about point b. Taking clockwise moments as positive,

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Solving Time

Difficulty

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$$\sum M_b = (45 \text{ ft})\, R_L - (20 \text{ ft})\,(\text{BC}) = 0$$

$$\text{BC} = \frac{45 R_L}{20 \text{ ft}}$$

$45R_L$ is the moment that the moment from force BC opposes. In general,

$$\text{BC} = \frac{M_b}{20 \text{ ft}}$$

If the load is between C and E,

$$R_L = \frac{x}{120 \text{ ft}} \qquad [x \text{ is measured from E}]$$

The moment caused by R_L is

$$M_b = (45 \text{ ft}) \left(\frac{x}{120 \text{ ft}}\right) = 0.375x$$

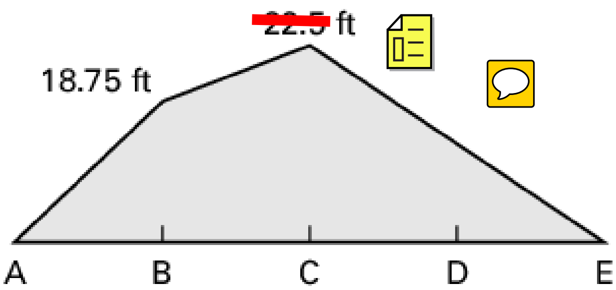
If the load is between A and B, the reaction is

$$R_L = \frac{x}{120 \text{ ft}}$$

The moment at b is also affected by the load between A and B.

$$M_b = 0.375x - (1)(x - 75 \text{ ft}) = 75 \text{ ft} - 0.625x$$

Plotting these values versus *x*,



Maximum moment due to uniform load:

The moment at b is maximum when the entire truss is loaded from A to E. The area under the curve is

$$\left(\frac{1}{2}\right)(30 \text{ ft})\,(18.75 \text{ ft}) + \left(\frac{1}{2}\right)(60 \text{ ft})\,(22.5 \text{ ft}) + (30 \text{ ft})\,(18.75 \text{ ft}) + \left(\frac{1}{2}\right)(30 \text{ ft})\,(22.5 \text{ ft} - 18.75 \text{ ft}) = 1575 \text{ ft}^2$$

The maximum moment is

$$M_b = \left(2 \frac{\text{kips}}{\text{ft}}\right)\left(1575 \text{ ft}^2\right) = 3150 \text{ ft-kips}$$

Maximum moment due to concentrated load:

Maximum moment will occur when the load is at C.

$$M_\mathrm{b} = (15\ \text{kips})\,(22.5\ \text{ft}) = 337.5\ \text{ft-kips}$$

Total maximum moment:

$$M_\mathrm{b} = 337.5\ \text{ft-kips} + 3150\ \text{ft-kips} = 3487.5\ \text{ft-kips}$$

Compression in BC:

$$\mathrm{BC} = \frac{M_\mathrm{b}}{20\ \text{ft}} = \frac{3487.5\ \text{ft-kips}}{20\ \text{ft}} = 174.4\ \text{kips} \quad (170\ \text{kips})$$

Chapter 61, Problem 3

Return to Questions (/admin/questions/0?sfield=magento_id&stext=0000198624&sdka=&stype=&sdiff=)

Test Bank Question preview

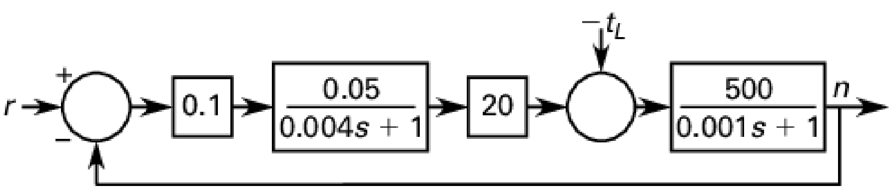
Question

A constant-speed motor/magnetic clutch drive train is monitored and controlled by a speed-sensing tachometer. The entire system is modeled as a control system block diagram, as shown. (The lowercase letters represent small-signal increments from the reference values.) When the control system is operating, the desired motor speed, *n* (in rpm), is set with a speed-setting potentiometer. The setting is compared to the tachometer output. The comparator output error (in volts), controls the clutch. A current, *i* (in amps), passes through the clutch coil. The external load torque, $t_L m$ (in in-lbf), is seen by the clutch and is countered by the clutch output torque, *t* (in in-lbf). See *Illustration for problem 3, 4, and 5*.

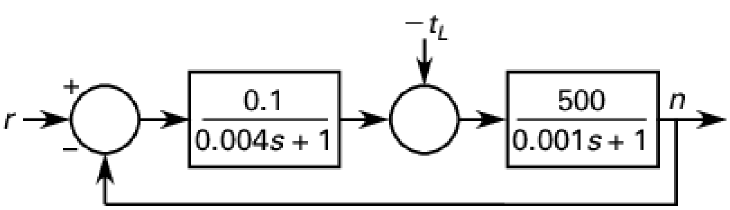
Describe the closed-loop response to a step change in the load torque. Is the response damped or oscillatory? Is there a steady-state error? Why or why not?

Solution

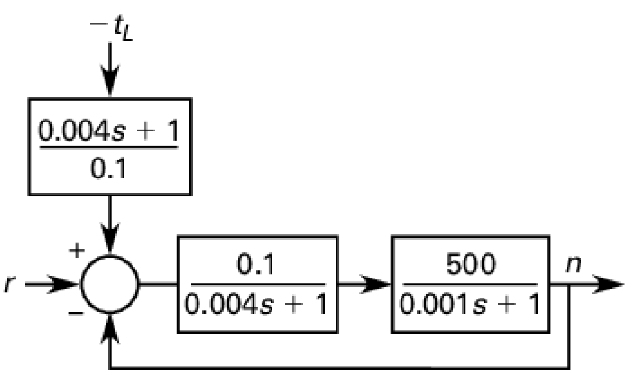
First, redraw the system in more traditional form.



From Fig. 61.5, use case 1 to combine boxes in series.



Use case 5 to combine the two summing points.



Use case 1 to combine boxes in series.

QUESTION DATA

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Flashcard

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Solving Time

Difficulty

easy

Quantitative?

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DISCIPLINES

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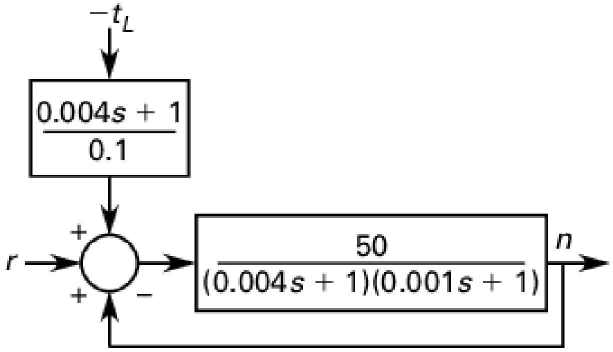
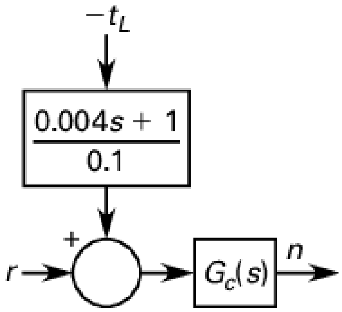


Using From Fig. 61.5, use case 3 to simplify the rules for simplifying block diagrams, simplify the feedback loop.



$$G_c(s) = \frac{\frac{50}{(0.004s+1)(0.001s+1)}}{1+\frac{50}{(0.004s+1)(0.001s+1)}}$$
$$= \frac{50}{(0.004s+1)(0.001s+1)+50}$$
$$= \frac{50}{\left(4\times10^{-6}\right)s^2+0.005s+51}$$

The closed-loop transfer function from *r* to *n* is

$$T_1(s) = \frac{N(s)}{R(s)} = G_c(s)$$
$$= \frac{50}{\left(4\times10^{-6}\right)s^2+0.005s+51}$$

The closed-loop transfer function from − t_L to *n* is

$$T_2(s) = \frac{N(s)}{-T_L(s)} = \left(\frac{0.004s+1}{0.1}\right)G_c(s)$$
$$= \frac{(500)(0.004s+1)}{\left(4\times10^{-6}\right)s^2+0.005s+51}$$

The response to a step change in input t_L is

$$N(s) = -T_L(s)\left(\frac{0.004s+1}{0.1}\right)G_c(s)$$
$$= \left(\frac{-T_L}{s}\right)\left(\frac{(500)(0.004s+1)}{\left(4\times10^{-6}\right)s^2+0.005s+51}\right)$$
$$= \frac{-\left(1.25\times10^{8}\right)\left(\frac{T_L}{s}\right)(0.004s+1)}{s^2+1250s+\left(1.275\times10^{7}\right)}$$

The response to a step change in t_L will be similar to a step change in *r*. However, the numerator, 0.004*s* + 1, will cause the response to deviate from second order. The response will still be oscillatory and very fast.

Use the final value theorem to find the steady-state error.

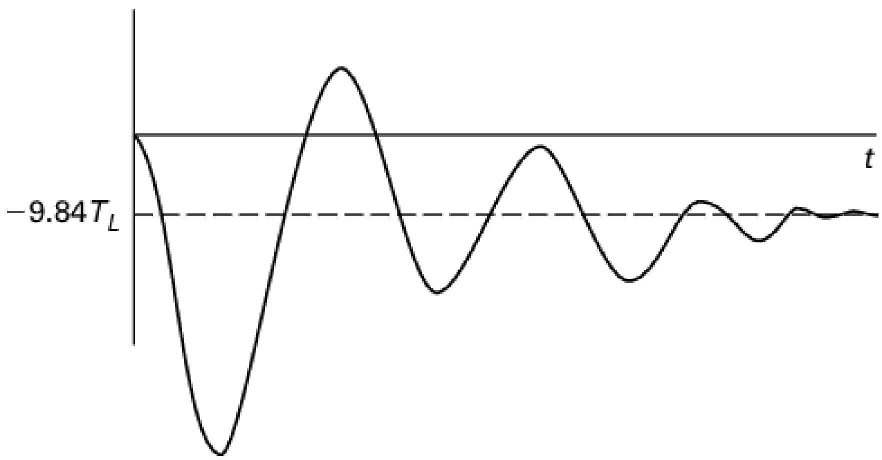
$$n = \lim_{s\to 0} sN(s)$$
$$= \lim_{s\to 0}\left(\frac{-s\left(1.25\times 10^{8}\right)\left(\frac{T_L}{s}\right)(0.004s+1)}{s^2+1250s+\left(1.27\times 10^{7}\right)}\right)$$
$$= -9.84T_L$$

The new steady-state error for both r and t_L inputs is

$$e = R - n = R - (0.98R - 9.84T_L) = 0.02R + 9.84T_L$$

Thus, the load torque, $-t_L$, contributes to the steady-state error.

The response is oscillatory. The plot of the response due to a step change in $-t_L$ is

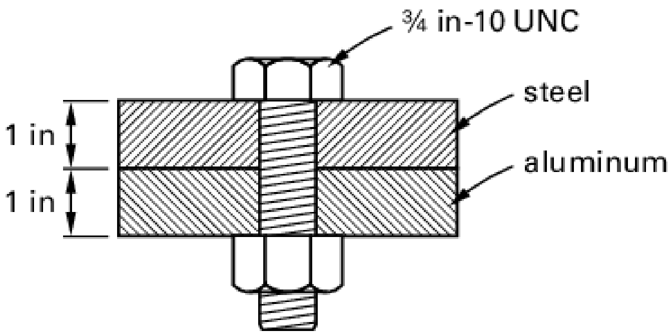


Chapter 50, Problem 3

Test Bank Question preview

Question

A 1 in thick steel plate and 1 in thick aluminum plate are held together with a $\frac{3}{4}$ in-10 UNC bolt and nut. The bolt is snug, with no initial preload. The modulus of elasticity of the steel and aluminum are 30×10^6 lbf/in^2 and 10×10^6 lbf/in^2, respectively. The coefficients of linear thermal expansion of steel and aluminum are 6.5×10^{-6} 1/°F and 12.8×10^{-6} 1/°F, respectively. The temperature is increased by 250°F. The tensile stress in the bolt is most nearly



Answers

(A) 24,000 psi

(B) 26,000 psi

(C) 28,000 psi

(D) 31,000 psi

The answer is (A).

Solution

Content in blue refers to the NCEES Handbook.

The unconstrained thermal deformations are

Thermal Deformations

$$\begin{aligned}
\Delta_{\text{th}} &= \alpha L\left(T - T_o\right) \\
\Delta_{\text{th,bolt}} &= \alpha L_o\left(T_2 - T_1\right) \\
&= \left(6.5 \times 10^{-6}\ \frac{1}{^\circ\text{F}}\right)(2\ \text{in})(250^\circ\text{F}) \\
&= 0.00325\ \text{in} \\
\Delta_{\text{th,steel}} &= \alpha L_o\left(T_2 - T_1\right) \\
&= \left(6.5 \times 10^{-6}\ \frac{1}{^\circ\text{F}}\right)(1\ \text{in})(250^\circ\text{F}) \\
&= 0.001625\ \text{in} \\
\Delta_{\text{th,aluminum}} &= \alpha L_o\left(T_2 - T_1\right) \\
&= \left(12.8 \times 10^{-6}\ \frac{1}{^\circ\text{F}}\right)(1\ \text{in})(250^\circ\text{F}) \\
&= 0.0032\ \text{in}
\end{aligned}$$

QUESTION DATA

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The unrealized elongation of the bolt is

$$\begin{aligned}\Delta &= \delta_{\text{th,aluminum}} + \delta_{\text{th,steel}} - \delta_{\text{th,bolt}} \\ &= 0.0032 \text{ in} + 0.001625 \text{ in} - 0.00325 \text{ in} \\ &= 0.001575 \text{ in}\end{aligned}$$

Rearrange the equation for thermal deformation, and solve for the mechanical strain due to the unrealized elongation of the bolt.

Thermal Deformations

$$\begin{aligned}\Delta_{\text{th}} &= \alpha L \left(T - T_o\right) \\ \varepsilon_{\text{bolt}} &= \alpha \left(T - T_o\right) = \frac{\Delta_{\text{th}}}{L} \\ &= \frac{0.001575 \text{ in}}{2 \text{ in}} \\ &= 0.0007875\end{aligned}$$

Use Hooke’s law to calculate the tensile stress in the bolt.

$$\begin{aligned}\sigma &= \left(\varepsilon_{\text{bolt}}\right)\left(E\right) \\ &= \left(0.0007875 \ \frac{\text{in}}{\text{in}}\right)\left(30 \times 10^6 \ \frac{\text{lbf}}{\text{in}^2}\right) \\ &= 23{,}625 \text{ lbf/in}^2 \quad (24{,}000 \text{ psi})\end{aligned}$$

Chapter 28, Problem 1

Test Bank

Question preview

Question

A 10 in (250 mm) bore, 18 in (460 mm) stroke, two-cylinder, four-stroke internal combustion engine operates with an indicated mean effective pressure of 95 psig (660 kPa) at 200 rpm. The actual torque developed is 600 ft-lbf (820 N·m). The friction horsepower is most nearly

Answers

(A) 17 hp (13 kW)

(B) 22 hp (17 kW)

(C) 45 hp (33 kW)

(D) 78 hp (60 kW)

The answer is (C).

Solution

Content in blue refers to the NCEES Handbook.

Customary U.S. Solution

The actual brake horsepower is

Torques

$$T_{\text{ft-lbf}} = 5250 \times \frac{\text{horsepower}}{\text{rpm}}$$

$$\begin{aligned} \text{bhp} &= \frac{NT_{\text{lbf-ft}}}{5250} \\ &= \frac{\left(200\ \frac{\text{rev}}{\text{min}}\right)(600\ \text{ft-lbf})}{5250\ \frac{\text{ft-lbf}}{\text{hp-min}}} \\ &= 22.85\ \text{hp} \end{aligned}$$

~~The number of power strokes per minute is~~

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Solving Time

Difficulty

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Quantitative?

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PRODUCTS USED IN

$$n = \frac{(\text{no. strokes per rev.})(N)(\text{no. cylinders})}{\text{no. strokes per cycle}}$$

$$= \frac{\left(2\ \frac{\text{strokes}}{\text{rev}}\right)\left(200\ \frac{\text{rev}}{\text{min}}\right)(2)}{4\ \frac{\text{strokes}}{\text{cycle}}}$$

$$= 200 \text{ power strokes/min}$$

The stroke in feet is

$$L = \frac{18 \text{ in}}{12\ \frac{\text{in}}{\text{ft}}} = 1.5 \text{ ft}$$

The bore area is

$$A = \left(\frac{\pi}{4}\right)(10 \text{ in})^2 = 78.54 \text{ in}^2$$

The ideal (indicated) horsepower is

Internal Combustion Engines

$$\text{hp} = (\text{MEP})\left(\frac{LAN}{K}\right) = (\text{MEP})\left(\frac{LAN}{33{,}000}\right)$$

$$= \frac{\left(95\ \frac{\text{lbf}}{\text{in}^2}\right)(1.5 \text{ ft})(78.54 \text{ in}^2)\left(200\ \frac{\text{power strokes}}{\text{min}}\right)}{33{,}000\ \frac{\text{ft-lbf}}{\text{hp-min}}}$$

$$= 67.83 \text{ hp}$$

The friction horsepower is

$$\begin{aligned} \text{fhp} &= \text{ihp} - \text{bhp} \\ &= \text{ideal hp} - \text{actual bhp} \\ &= 67.83 \text{ hp} - 22.85 \text{ hp} \\ &= 44.98 \text{ hp} \quad (45 \text{ hp}) \end{aligned}$$

SI Solution

From Eq. 18.30 actual brake horsepower is

$$\text{bkW} = \frac{nT}{9549} = \frac{\left(200\ \frac{\text{rev}}{\text{min}}\right)(820 \text{ N·m})}{9549\ \frac{\text{N}\cdot\text{m}}{\text{kW·min}}}$$

$$= 17.17 \text{ kW}$$

The number of power strokes per minute is

$$N = \frac{(2n)(\text{no. cylinders})}{\text{no. of strokes per cycle}}$$

$$= \frac{\left(2\ \frac{\text{strokes}}{\text{rev}}\right)\left(200\ \frac{\text{rev}}{\text{min}}\right)(2)}{4\ \frac{\text{strokes}}{\text{cycle}}}$$

$$= 200 \text{ power strokes/min}$$

The stroke in meters is

$$L = \frac{460 \text{ mm}}{1000\ \frac{\text{mm}}{\text{m}}} = 0.46 \text{ m}$$

The bore area is

$$A = \left(\frac{\pi}{4}\right)\left(\frac{250 \text{ mm}}{1000\ \frac{\text{mm}}{\text{m}}}\right)^2 = 4.909 \times 10^{-2} \text{ m}^2$$

The variation of the PLAN formula can be used to give the power in kilowatts. The constant *K* is 60. From Eq. 28.52, the ideal (indicated) horsepower is

Internal Combustion Engines

$$p_{\text{kW}} = (\text{MEP})\left(\frac{LAN}{K}\right) = (\text{MEP})\left(\frac{LAN}{60}\right)$$

$$= \frac{(660 \text{ kPa})(0.46 \text{ m}) \times (4.909 \times 10^{-2} \text{ m}^2)\left(200\ \frac{\text{power strokes}}{\text{min}}\right)}{60}$$

$$= 49.68 \text{ kW}$$

The friction horse power is

$$\begin{aligned} \text{ideal kW} - \text{actual kW} &= 49.68 \text{ kW} - 17.17 \text{ kW} \\ &= 32.51 \text{ kW} \quad (33 \text{ kW}) \end{aligned}$$

Test Bank

Question preview

Question

A room is maintained at design conditions of 75°F (23.9°C) dry-bulb and 50% relative humidity. The air outside is at 95°F (35°C) dry-bulb temperature and 75°F (23.9°C) wet-bulb temperature. The outside air is conditioned and mixed with some room exhaust air. The mixed, conditioned air enters the room and increases 20°F (11.1°C) in temperature before being removed from the room. The sensible and latent loads are 200,000 Btu/hr (60 kW) and 50,000 Btu/hr (15 kW), respectively. Air leaves the coil at 50.8°F(10°C). The volume of air flowing through the coil is most nearly

Answers

(A) 4200 ft^3/min (120 m^3/min)

(B) 5800 ft^3/min (160 m^3/min)

(C) 7500 ft^3/min (210 m^3/min)

(D) 9300 ft^3/min (260 m^3/min)

The answer is (C).

Solution

Content in blue refers to the NCEES Handbook.

Customary U.S. Solution

The mixed, conditioned air undergoes a temperature increase of 20°F before leaving the room at 75°F. Therefore, the mixed conditioned air enters the room at

$$T_{\text{mixed}} = 75^\circ\text{F} - 20^\circ\text{F} = 55^\circ\text{F}$$

Calculate the volumetric flow rate of air entering the room, Q_{mixed}, using the equation for determining the sensible heat load.

Heat Gain Calculations Using Standard Air Values

$$\begin{aligned} q_s &= 1.10 Q_{\text{mixed}} \Delta T \\ Q_{\text{mixed}} &= \frac{q_s}{1.10\Delta T} \\ &= \frac{200{,}000\ \frac{\text{Btu}}{\text{hr}}}{\left(1.10\ \frac{\text{Btu-min}}{\text{ft}^3\text{-hr-}^\circ\text{F}}\right)(20^\circ\text{F})} \\ &= 9091\ \text{ft}^3/\text{min} \end{aligned}$$

QUESTION DATA

Vendor

0000187955

Solving Time

Difficulty

easy

Quantitative?

No

Status

Active

Created On

02/12/2020 02:07:17 AM

Published On

02/12/2020 02:07:17 AM

Modified On

10/20/2020 11:55:45 PM

OTHER VERSIONS

DISCIPLINES

KNOWLEDGE AREAS

PRODUCTS USED IN

The air entering the room is a mix of return air from the room and air from the coil. Use the equation for the mixing of air streams. Since the mixed air consists of both a fraction of return air and a fraction of coil air, the fraction of the return air, f_{return}, can be expressed as $1 - f_{\text{coil}}$.

Air-Handling Unit Mixed-Air Plenums

$$\begin{aligned} T_{\text{mixed}} &= (\text{fraction } \cancel{\text{outdoor air}})\, T_{\text{coil}} \\ &\quad + (\text{fraction return air})\, T_{\text{return}} \\ &= f_{\text{coil}} T_{\text{coil}} + f_{\text{return}} T_{\text{return}} \\ &= f_{\text{coil}} T_{\text{coil}} + (1 - f_{\text{coil}})\, T_{\text{return}} \end{aligned}$$

Solving for the fraction of the coil air gives

$$\begin{aligned} f_{\text{coil}} &= \frac{T_{\text{mixed}} - T_{\text{return}}}{T_{\text{coil}} - T_{\text{return}}} \\ &= \frac{55^{\circ}\text{F} - 75^{\circ}\text{F}}{50.8^{\circ}\text{F} - 75^{\circ}\text{F}} \\ &= 0.8264 \end{aligned}$$

Find the volume of the air flowing through the coil.

$$\begin{aligned} Q_{\text{coil}} &= f_{\text{coil}} Q_{\text{mixed}} \\ &= (0.8264)\left(9091\ \frac{\text{ft}^3}{\text{min}}\right) \\ &= 7513\ \text{ft}^3/\text{min} \quad (7500\ \text{ft}^3/\text{min}) \end{aligned}$$

SI Solution

The mixed conditioned air undergoes a temperature increase of 11.1°C before leaving the room at 23.9°C. Therefore, the mixed conditioned air enters the room at

$$T_{\text{mixed}} = 23.9^{\circ}\text{C} - 11.1^{\circ}\text{C} = 12.8^{\circ}\text{C}$$

Convert the standard density of air to kg/m^3. [Measurement Relationships] [Standard Dry Air Conditions at Sea Level]

$$\begin{aligned} \rho &= \frac{\left(0.075\ \frac{\text{lbm}}{\text{ft}^3}\right)\left(3.281\ \frac{\text{ft}}{\text{m}}\right)^3}{2.205\ \frac{\text{lbm}}{\text{kg}}} \\ &= 1.201\ \text{kg/m}^3 \end{aligned}$$

Find the specific heat of air at room temperature using a table of thermal properties of ideal gas. [Thermal and Physical Properties of Ideal Gases (at Room Temperature)]

$$c_p = 1.004\ \text{kJ/kg·K} = 1.004\ \text{kJ/kg·}^{\circ}\text{C}$$

Calculate the volumetric flow rate of air entering the room using the equation for determining the sensible heat load.

$$
\begin{aligned}
q_s &= \dot{m} c_p \Delta T = (\rho Q_{\text{mixed}})\, c_p \Delta T \\
Q_{\text{mixed}} &= \frac{q_s}{\rho c_p \Delta T} \\
&= \frac{60 \text{ kW}}{\left(1.201 \ \dfrac{\text{kg}}{\text{m}^3}\right)\left(1.004 \ \dfrac{\text{kJ}}{\text{kg}\cdot{}^\circ\text{C}}\right)(11.1^\circ\text{C})} \\
&= 4.483 \text{ m}^3/\text{s}
\end{aligned}
$$

The air entering the room is a mix of return air from the room and air from the coil. Use the equation for the mixing of air streams. Since the mixed air consists of both a fraction of return air and a fraction of coil air, the fraction of the return air, f_{return}, can be expressed as $1 - f_{\text{coil}}$.

Air-Handling Unit Mixed-Air Plenums

$$
\begin{aligned}
T_{\text{mixed}} &= (\text{fraction } \cancel{\text{outdoor air}})\, T_{\text{coil}} \\
&\qquad + (\text{fraction return air})\, T_{\text{return}} \\
&= f_{\text{coil}} T_{\text{coil}} + f_{\text{return}} T_{\text{return}} \\
&= f_{\text{coil}} T_{\text{coil}} + (1 - f_{\text{coil}})\, T_{\text{return}}
\end{aligned}
$$

Solving for the fraction of the coil air gives

$$
\begin{aligned}
f_{\text{coil}} &= \frac{T_{\text{mixed}} - T_{\text{return}}}{T_{\text{coil}} - T_{\text{return}}} \\
&= \frac{12.8^\circ\text{C} - 23.9^\circ\text{C}}{10^\circ\text{C} - 23.9^\circ\text{C}} \\
&= 0.7986
\end{aligned}
$$

Find the volume of the air flowing through the coil.

$$
\begin{aligned}
Q_{\text{coil}} &= f_{\text{coil}} Q_{\text{mixed}} \\
&= (0.7986)\left(4.483 \ \frac{\text{m}^3}{\text{s}}\right)\left(60 \ \frac{\text{s}}{\text{min}}\right) \\
&= 214.8 \text{ m}^3/\text{min} \quad (210 \text{ m}^3/\text{min})
\end{aligned}
$$