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Mech 262 - Assignment 7

Corey Hughes

1) Given: · Hot oil $C_p = 2200\ J/kg°C$ $T_{in,h} = 160°C$ $\dot{m} = 0.2 kg/s$
· water $C_p = 4180\ J/kg°C$ $T_{in,c} = 18°C$ $\dot{m} = 0.1 kg/s$

Find: · Rate of heat transfer
· Outlet temps

· 2 shell / 12 tube

$D = 0.018m$ $L = 3m/pass$

$U = 340\ W/m^2°C$

$C_c = \dot{m} C_{pc} = (0.1 kg/s)(4180\ J/kg°C) = 418\ W/°C$ $C_{min} = 418 W/°C$

$C_h = \dot{m} C_{ph} = (0.2 kg/s)(2200\ J/kg°C) = 440\ W/°C$ $C_{max} = 440 W/°C$

$\dot{Q}_{max} = C_{min}(T_{h,in} - T_{c,in}) = (418 W/°C)(160°C - 18°C) = 59356 W$ ✓

$NTU = \frac{UA_s}{C_{min}} = \frac{(340 W/m^2°C)(12)(3m)(\pi(0.018m))}{418 W/°C} = 1.7$ ✓

$\frac{C_{min}}{C_{max}} = \frac{418 W/°C}{440 W/°C} = 0.95$ ✓ $\therefore \varepsilon = 61\%$ ✓

$\dot{Q} = \varepsilon \dot{Q}_{max} = 0.61(59356W) = 36.2 kW$ ✓

$T_{h,out} = T_{h,in} - \frac{\dot{Q}}{C_h} = 160°C - \frac{36207W}{440 W/°C} = 77.7°C$ ✓

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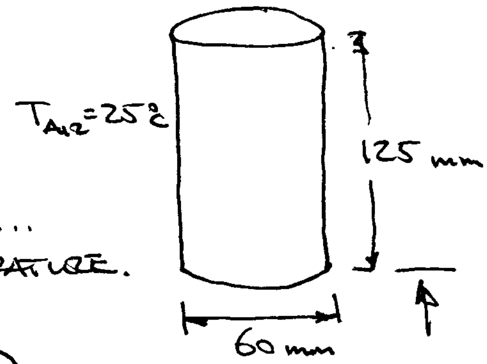
$T_{c,out} = T_{c,in} + \frac{\dot{Q}}{C_c} = 18°C + \frac{36207W}{418 W/°C} = 104.6°C$ ✓

#2 - SOLUTION.

a) $T_i = 3°C$, $T_f = 10°C$

$h = 10\ W/m^2 \cdot °C$ ← ONLY INSULATION



AS ITS LIQUID...

ASSUME WELL MIXED AND...

UNIFORM INTERNAL TEMPERATURE.

ASSUME ITS ON A WELL INSULATED TABLE.

$$A_s = \pi D L + \frac{\pi D^2}{4}$$

$$= \pi(0.06)(0.125) + \frac{\pi(0.06)^2}{4}$$

$$= 0.0264\ m^2$$

$$V = \frac{\pi D^2}{4} L = \frac{\pi(0.06)^2}{4} \times 0.125$$

$$= 3.53 \times 10^{-4}\ m^3$$

$$\rho = 999.9\ kg/m^3$$

$$C_p = 4205\ J/kg \cdot °C$$

$$b = \frac{h A_s}{\rho V C_p} = \frac{(10)(0.0264)}{(999.9)(3.53\times10^{-4})(4205)}$$

$$= 1.779 \times 10^{-4}$$

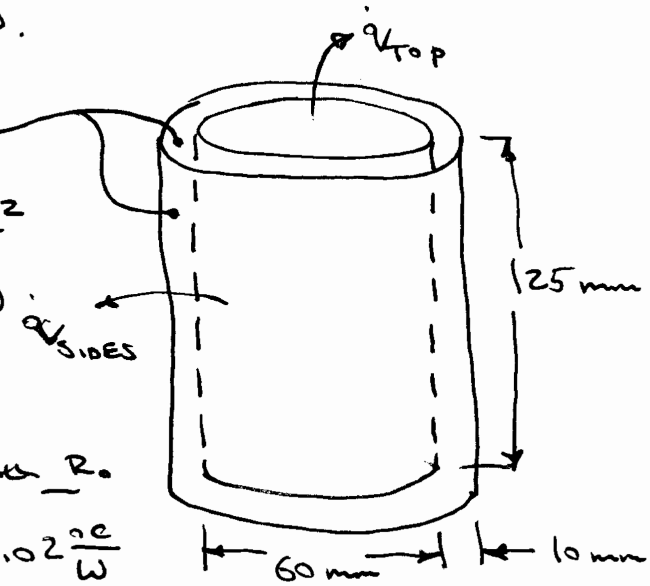
So
$$t = \frac{\ln\left[\frac{T(t) - T_\infty}{T_i - T_\infty}\right]}{-b} = \frac{\ln\left[\frac{10-25}{3-25}\right]}{-1.779} = \frac{-0.383}{-1.779\times10^{-4}}$$

$$= 2153.2\ s$$

$$\boxed{t = 35.9\ \text{minutes}}$$

#2 – SOLUTION (CONTINUED).

b) INSULATION: $k = 0.13\ W/m\cdot°C$



$$A_{TOP} = \frac{\pi D^2}{4} = \frac{\pi (0.06)^2}{4} = 0.00283\ m^2$$

$$A_{SIDES} = \pi D L = \pi (0.06 + 2(0.01))(0.125)$$
$$= 0.0314\ m^2$$

RECALL: $\dot{q} = \frac{\Delta T}{R_o}$ SO FIND OVERALL R_o

$$R_{TOP} = \frac{1}{hA} = \frac{1}{(10)(0.00283)} = 42.02\ \frac{°C}{W}$$

$$R_{SIDES} = \frac{1}{hA} + \frac{\ln(r_2/r_1)}{2\pi k L}$$ ← ITS A CYLINDER

$r_2 = 30 + 10 = 40$ mm

$r_1 = 30$ mm.

$$= \frac{1}{(10)(0.0314)} + \frac{\ln(40/30)}{2\pi(0.13)(0.125)}$$

$$= 3.185 + 2.817$$

$$= 6.00$$

$$R_o = \frac{1}{\frac{1}{R_{TOP}} + \frac{1}{R_{SIDES}}} = 5.25\ \frac{°C}{W}$$

NOW NOTE IN ... $b = \frac{hA_s}{\rho V C_p}$ — IT IS ASSUMED THAT THE ONLY INSULATION IS h AND THAT $R = \frac{1}{hA}$

SO ... $$\boxed{b = \frac{1}{R \times \rho V C_p}}$$

IN OUR CASE THEN ... $$b = \frac{1}{(5.25)(999.9)(3.53\times10^{-4})(4205)}$$
$$= 1.28\times10^{-4}$$

$$\text{SO } t = \frac{-0.383}{-1.28\times10^{-4}}$$ ← FROM PAGE ①.

$$= 2984.4\ s$$

$$\boxed{t = 49.74 \text{ minutes.}}$$

3) Given: $D = 2in$ brass balls $= 0.0508m$

$K = 64.1\ Btu/h\cdot ft\cdot F = 364\ W/m\cdot°C$

$\rho = 532\ lbm/ft^3 = 8522\ kg/m^3$

$C_p = 0.092\ Btu/lbm°F = 385\ J/kg°C$

$T_i = 250°F = 121.1°C$

$T_{water} = 120°F$ for 2min $= 48.9°C$

120 balls/min

$h = 42\ Btu/h\cdot ft^2\cdot °F = 238.5\ W/m^2°C$

$V = 1/6\,\pi D^3 = 1/6\,\pi(0.0508m)^3 = 6.86\times10^{-5}m^3$ (A)

$A_s = \pi D^2 = \pi(0.0508m)^2 = 8.11\times10^{-3}m^2$ (B)

Find: a) Convert to SI units

b) Temp after quenching

c) Rate at which heat needs to be removed from water in order to keep its temp at 120°F

b) $T(t) = e^{-bt}(T_i - T_\infty) + T_\infty$

$= e^{-(0.00859)(120s)}(121.1°C - 48.9°C) + 48.9°C$

$$b = \frac{hA_s}{mC_p} = \frac{(238.5\ W/m^2°C)(8.11\times10^{-3}m^2)}{(8522\ kg/m^3)(6.86\times10^{-5}m^3)(385\ J/kg°C)} = 0.00859/s \quad (C)$$

$= 74.67°C$ ✓

c) 120 ball/min = 2 ball/s

$Q = mC_p(T(t) - T_i) = (6.86\times10^{-5}m^3)(8522\ kg/m^3)(385\ J/kg°C)(74.67 - 121.1)°C$

$= 10457\ J$

$Q = (2\ balls/s)(10457\ J) = 20.9\ kW$ ✓

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