Questions

PROBLEM 1: In order to save on the energy costs associated with bringing precursors to reaction temperature, it is common to use economizers, whereby a hot fluid from another part of the plant is passed through a heat exchanger. Aniline is used in the production of sulfanilic acid, which is used as a precursor for many sulfa drugs, by reacting it with sulfuric acid at 180°C. An engineer, Mr. Brightside, has been assigned the task of building an economizer for this reaction. Opening his eager eyes, he proposes diverting Syltherm 800 from the nearby concentrated solar power plant to a double-pipe, counterflow heat exchanger of length 3m. The initial design consists of a 6″ Schedule 40 Duralumin inner pipe to carry the Syltherm, while the outer pipe carrying the aniline is also a similar, 8″ Schedule 40 pipe. Eight struts of thickness 1/4″ are used to support the inner pipe. With destiny calling him, Mr. Brightside also proposes the use of a 12-fin assembly of thickness 1/8″ of the same material mounted to a central pin of diameter 1/2″ to provide enhanced heat transfer. The flow rates of the aniline and Syltherm are 30 and 120 gallons per minute, respectively, and the respective entry temperatures are 16°C and 320°C. In order to get permission of the CSP plant, the Syltherm must be returned to their cold holding tank at 232°C. Is this possible? Also, what is the exit temperature of the aniline? For each fluid, use the respective inlet temperature values when evaluating properties.

PROBLEM 2: Consider a box furnace consisting of a cube with side length L. Compute all view factors.

Solution

Problem 1

Solution:-

Given Data:-

T_{ci}= 16°C = 289.15K

T_{ce}=?

T_{hi}=320°C= 593.15K

T_{he}= 232°C = 505.15K

M_c= 30 gallons/min

M_h= 120 gallons/min

$Cp_{Aniline}$= 2.18 KJ/Kg K

$Cp_{Syltherm}$= 2.121 KJ/Kg K at 320°C

M_c= 1.89 Kg/s

M_h= 7.57 Kg/s

Fin pin

D=6"=**0.15m**, L=**3m**, D=1/2**"= 0.127m**

Fin Thickness= 1/8"= **0.003m**

Total root area of 12 fins= No. of fins*(π/4)D^2

$= 12*(\pi/4)*(0.012)^2$

= **0.0217m^2**

Bare area of schedule 40 Pipe= (Surface area of schedule 40 pipe)- Root area of fins.

$= \pi*0.15*0.003$

= 0.0014m^2

Perimeter=πD

= 3.14*0.127

= **0.39m**

Heat transfer from bare area

$Q_1=h.A.(T_0-T_\infty)$

T_0=320°C

T_{∞}= 16°C

Assume

H=132 Btu/hr ft^2 °F

= **$\underline{749.53\ W/m^2K}$**

Q_1= 749.53*0.0014*(320°-16°)

$\underline{Q_1 = 318.99\ Watts}$

For pin

M=$\sqrt{(\frac{hp}{KA})}$

$=\sqrt{(\frac{749.33*0.39}{61*\left(\frac{\pi}{4}\right)*(0.012)2})}$

$=\sqrt{(\frac{292.23}{0.00689})}$

= **$\underline{205.948}$**

mL= 205.948*0.003

=**$\underline{0.617}$**

Heat transfer from fins

Q_2=$\sqrt{hpKA\theta}$ **tanh** m_2***No. of fins**

$=\sqrt{749.53*0.39*61*\left(\frac{\pi}{4}\right)*(0.012*0.012)}*304*tanh*0.617*12$

$\underline{Q_2 = 2824.06\ Watts}$

$Q=Q_1+Q_2$

=2824.06+318.99

$\underline{Q = 3143.05\ Watts}$

Q=mCp(ΔT)

= mCp (T_{hi}-T_{he})

3143.05=7.57*2.12*(593.15-T_{he})

3143.05=9519.1-16.02T_{he}

T_{he}= 398.005K

T_{he}= 124.8°C

The Syltherm is not returned to their cold holding tank at 232°C

Hence this is Not possible.

The exit temperature of Aniline is given by,

M_c $Cp_{Aniline}$ [Tc_e-Tc_i]= M_n $Cp_{Syltherm}$ [T_{he}-T_{hi}]

1.89*2.18*[T_{ce}-289.15]

=7.57*2.12*[593.15-398]

4.12T_{ce}-1191.35=3131.84

T_{ce}=1049.31 K

T_{ce}=776.16°C

Problem2

Solution:-

Introduction:- The computation of view factors is a key element in spacecraft contamination due to outgassing of materials. By definition the view factor **F_{ij}** between two surfaces i and j, is the fraction of radiation leaving surface i that is intercepted by the surface j, and is given by:

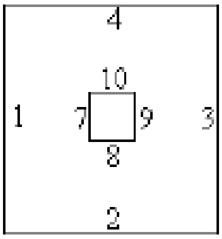
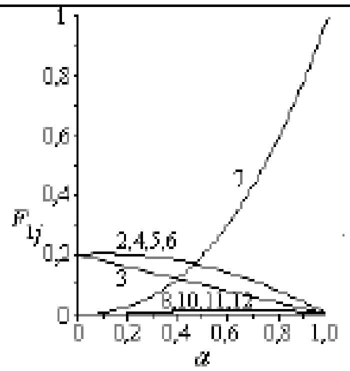
$$F_{ij} = \frac{1}{A_i} \iint_{A_i A_j} \frac{\cos\theta_i \cos\theta_j}{\pi r^2} \delta_{ij} dA_i dA_j$$

where δ_{ij} is determined by the visibility of dA_j to dA_i i.e. = 1 if dA_j is visible to dA_i and = 0 otherwise.

Cube

The inner surface of a cube is considered for computing the view factor. Theoretically the total view factor from one face to all others is equal to 1, however due to numerical computation the result may deviate a few percent. The dimensions of the cube are lxlxl.

Box inside concentric box

Case	View factor	Plot
Between all faces in the enclosure formed by the internal side of a cube box (faces 1-2-3-4-5-6), and the external side of a concentric cubic box (faces (7-8-9-10-11-12) of size ratio $a \le 1$.  (A generic outer-box face #1, and its corresponding face #7 in the inner box, have been chosen.)	From an external-box face: $\begin{cases} F_{11}=0, F_{12}=x, F_{13}=y, F_{14}=x, \\ F_{15}=x, F_{16}=x, F_{17}=za^2, F_{18}=r, \\ F_{19}=0, F_{1,10}=r, F_{1,11}=r, F_{1,12}=r \end{cases}$ From an internal-box face: $\begin{cases} F_{71}=z, F_{72}=(1-z)/4, F_{73}=0, F_{74}=(1-z)/4, \\ F_{75}=(1-z)/4, F_{76}=(1-z)/4, F_{77}=0, F_{78}=0, \\ F_{79}=0, F_{7,10}=0, F_{7,11}=0, F_{7,12}=0 \end{cases}$ with z given by: $\begin{cases} z=F_{71}=\frac{(1-a)^2}{4\pi a^2}\left(\ln\frac{p}{q}+s+t\right) \\ p\equiv\left(2\frac{3-2a+3a^2}{(1-a)^2}\right)^2 \\ q\equiv 2\frac{18+12a+18a^2}{(1-a)^2} \\ s\equiv u\left(2\arctan\frac{2}{u}-w\arctan\frac{w}{u}\right) \\ t\equiv v\left(2\arctan\frac{2}{v}-w\arctan\frac{w}{v}\right) \\ u\equiv\sqrt{8}, v\equiv\frac{\sqrt{8(1+a^2)}}{1-a}, w\equiv 2\frac{1+a}{1-a} \end{cases}$ and: $\begin{cases} r\equiv a^2(1-z)/4 \\ y\simeq 0.2(1-a) \\ x\equiv(1-y-za^2-4r)/4 \end{cases}$ (e.g. for a=0.5, F_{11}=0, F_{12}=0.16, F_{13}=0.10, F_{14}=0.16, F_{15}=0.16, F_{16}=0.16, F_{17}=0.20, F_{18}=0.01, F_{19}=0, $F_{1,10}$=0.01, $F_{1,11}$=0.01, $F_{1,12}$=0.01), and (F_{71}=0.79, F_{72}=0.05, F_{73}=0, F_{74}=0.05, F_{75}=0.05, F_{76}=0.05, F_{77}=0, F_{78}=0, F_{79}=0, $F_{7,10}$=0, $F_{7,11}$=0, $F_{7,12}$=0). Notice that a simple interpolation is proposed for $y \equiv F_{13}$ because no analytical solution has been found.	From face 1 to the others:  From face 7 to the others: