Submission 2 - Technical Environmental Systems

Monday, October 14, 2019 11:10 PM

1. **Summary - Convective Heat Transfer.**
Explain why increasing the thickness of a single pane glass does not increase the total resistance.

Convective heat transfer refers to the transfer of heat between fluids and solids. There are two types of convection - natural convection & forced convection. Natural convection occurs due to difference in density caused by temperature variation in fluids. Forced convection occurs due to the presence of an external force, such as wind.

The rate of convective heat transfer depends on: Temperature difference, Velocity of fluid, Nature of fluid

According to Newton's law of cooling, the rate of convective heat transfer $(\dot{Q_{conv}})$:

$$\dot{Q_{conv}} = hA_s(T_s - T_\infty),$$
$$where\ 'h'\ is\ a\ coefficient\ related\ to\ the\ velocity\ of\ the\ fluid$$

$$\dot{Q_{conv}} = \frac{(T_s - T_\infty)}{R_{conv}} \quad \Rightarrow \quad R_{conv} = \frac{1}{hA_s}\ ,$$
$$where\ R_{conv}\ is\ the\ thermal\ resistace\ of\ the\ surface\ to\ heat\ convection$$

Increasing the thickness of a single pane glass does not increase the thermal resistance. This is because, heat transfer through the glass pane occurs through conduction. The conductive resistance of the single pane glass is calculated as: $\mathrm{R_{cond}} = \frac{\mathrm{L}}{kA}$
Since the thickness of the glass pane cannot be increased by a significant amount, the value of $\mathrm{R_{cond}}$ remains marginal in comparison to R_{conv} between the air and the glass surface, which is significantly higher. The alternative here is to opt for a double pane glass, which increases the overall resistance due to poor thermal conductivity of the air gap.

2. **Write an explanation about mistakes made in class which resulted in wrong answers.**
None...

3. **Solve the same problem as that of the double pane window with an air-gap thickness of 13 mm and glass thickness of 6 mm. Comment on your results and explain why we have an optimal range for the air-gap thickness.**

$$A = 0.8 \times 1.5 = 1.2\ m^2$$
$$k_{glass} = 0.78\ W/m°C$$
$$k_{air} = 0.026 \frac{W}{m} °C$$
$$L_{glass} = 6\ mm$$
$$L_{air} = 13\ mm$$

$h_1 = 10\, W/m°C$
$h_2 = 40\, W/m°C$

$$R_{total=} \ R_{1conv} + (R_{glass} \times 2) + R_{air} + R_{2conv}$$
$$= \frac{1}{h_1 A} + \left(\frac{L_{glass}}{k_{glass} A} \times 2\right) + \left(\frac{L_{air}}{k_{air} A}\right) + \frac{1}{h_2 A}$$
$$= \frac{1}{12} + \frac{0.012}{0.936} + \frac{0.013}{0.0312} + \frac{1}{48}$$
$$= 0.08333 + 0.01282 + 0.41666 + 0.02083$$
$$\Rightarrow R_{total=} \ = 0.53364\, °\frac{C}{W}$$

$$\dot{Q}_{conv} = \frac{(T_{\infty 1} - T_{\infty 2})}{R_{total}} = 20 \ - \frac{(-10)}{0.53364} = 56.2176\, W$$

The results shows that the air gap provides additional resistance to heat transfer due to poor thermal conductivity of air. Thus, the rate of heat transfer is further reduced.
The air gap thickness has an optimal range within which the thermal heat transfer through the double pane glass can be reduced. This is because the air gap provides high conductive resistance to heat. However, when this gap increases in width beyond the threshold, the effect of conductive heat transfer reduces and convection begins to take place within the air gap. Therefore, the resistance to heat transfer decreases.