Tuesday, October 15, 2019

Homework 2

Short summary on convection heat transfer

Convection heat transfer is a situation where heat transfer happens between any fluid or air gets heated by gaining temperature and starts moving from the source. It's a procedure of transferring heat energy through liquid or gas whereas conductive heat transfer occurs only between two solid objects. But convection can also take place between solid and liquid.

The rate of convective heat transfer depends on few aspects such as temperature difference between the two objects, the velocity of liquid, gas or air and the time. Another thing is the convective heat transfer coefficient (h) which does not depend on the material but on the fact that how fast liquid or gas passes through the other object or material. If we imagine an interior and exterior area, the convective heat transfer takes place -

- between the outside air and the exterior surface
- between the inside air and the interior surface

There are two types of convection system-

Natural convection: When air or liquid gets warmer without any external force. Then it moves naturally and generates a flow. It continues resulting in making space for the cooler object. That is called natural convection.
Forced convection: This occurs due to an external force where the warmer fluid or gas object is forced to change their place or move because of an external pressure.

Why increasing the thickness of a single pane glass does not increase the total resistance?

The increase of the thickness of a single pane window influences the increase of total resistance as it changes the heat transfer rate, but that is quite insignificant and that is useless. Because the constant (K) of the glass is always the same. The total resistance is basically the compilation of convection resistance between the glass and the air. That is why, it does not matter if we change the thickness or not.

Write an explanation about what mistakes you made in the class that resulted in wrong answers!

While calculating the steady rate of heat transfer through a double-pane window and the temperature of its inner surface, I made a mistake. When I was calculating the temperature T1 of the interior wall surface, I used the convection heat transfer coefficient h2 instead of h1, but later I realized that while calculating T1, the resistance was between the glass and the air of airgap. That is why, I answer came out wrong.

Solve the same problem as that of double pane window with the 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's distance.

The thermal resistance of convection between elements-

$$R_{g_1} = R_{g_2} = \frac{L_g}{(K_g \times A)} = \frac{0.006}{0.78 * 0.8 * 1.5} = 0.0064\,°\frac{C}{W}$$

$$R_{airGap} = \frac{L_{airGap}}{(K_{airGap} \times A)} = \frac{0.013}{0.026 * 1.2} = 0.417\ °C/W$$

$$R_{conv_1} = \frac{1}{h_1 \times A} = \frac{1}{10 * 1.2} = 0.083\,°C/W$$

$$R_{conv_2} = \frac{1}{h_2 \times A} = \frac{1}{40 * 1.2} = 0.021\,°\frac{C}{W}$$

The total resistance of a double pane window-

$$R_{tot} = 0.083 + 0.021 + 2 * 0.0064 + 0.417 = 0.534\,°\frac{C}{W}$$

The heat transfer rate-

$$\dot{Q} = \frac{\Delta T}{R_{Tot}} = \frac{30}{0.534} = 56.18\ W$$

The inner surface temperature-

$$\dot{Q} = \frac{T_{\infty 1} - T_1}{1/h_1 A}$$

$$\Longrightarrow 56.17 = \frac{20 - T_1}{0.083}$$

$$T_1 = 15.32\ °C$$

In the equation, we have an optimal range for the airgap's distance in the double pane glass window. This is because of the connection between the airgap's distance and thermal resistance. Within 0-6mm of distance, the resistance starts increasing. From 6-13 mm, resistance hardly changes but stays almost same. After reaching a certain point, which is 13 mm, the air inside the gap starts to flow by creating a repetitive movement and reaches the maximum resistance. Therefore, on that point, the heat transfer rate decreases at a significant rate.