Summary of convective heat transfer

The convection is one of the methods of heat transfer and it happens when there is a solid object that is close to a fluid and there is difference of temperature between them. Due to the difference of temperature there is an exchange of heat between the surface of the solid object and the particles of the fluid with it's in contact. In this case the temperature of the hotter object decreases, instead the temperature of the cooler object increases, so the heat flow is from hot to cold. An example of convection is in between a wall, that is a solid, and the air, that is a fluid. This phenomenon happens both to the external surface of the wall and also to the internal surface of the wall. To calculate the effect of the convection it is used the Newton law's: $\dot{Q_{conv}} = hA_s\,(T_s - T_\infty)$, where the $\dot{Q}_{conv}$ (W) corresponds to the heat flow, h (W/m^{2}K or W/m^2°C) is the coefficient of the convection heat transfer that depends on the materiality of the object, A (m^2) is the surface of the object, and T_s is the temperature of the surface of the object and T_∞ is the temperature of the fluid, both temperatures can be calculated in °C or in K. Another measurement can be calculated with the use of the Newton's law that is the resistance (R_{conv}) and it's calculated with this equation: $R_{conv} = {}^{1}/_{hA_s}$. The resistance is referred to the materiality of the object to hinder the exchange of heat and there is an inverse proportion between the resistance and the coefficient of convection and surface. In fact more high is the value of surface of the object and the coefficient of convection, less is the value of the resistance and vice versa.

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

Considering a single pane glass, we can see that the total thermal resistance is more effected by the convention resistance than the resistance of the glass panel because the higher resistance convective is located more in the inner surface. So increasing the thickness of a single pane glass there will not be a significantly increase of the total thermal resistance.

Exercise

Consider a 0.8-m-high and 1.5-m-wide double-pane window consisting of two 4-mm-thick layers of glass (k= 0.78 W/m^2°C) separated by a 13-mm-wide stagnant air space (k= 0.026 W/m^2°C). Determine the steady rate of heat transfer through this double- pane window and the temperature of its inner surface. Take the convection heat transfer coefficients on the inner and outer surfaces of the window to be h_1= 10 W/m^2°C and h_2=40 W/m^2 °C, which includes the effects of radiation . 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

A= 0.8*1.5= 1.2 m^2

$R_{g1} = R_{g2} = \frac{L_g}{K_g * A} = \frac{0.006}{0.78*1.2} = 0.0064\ {}^{°C}/_{W}$

$R_{airGap} = \frac{L_{airGap}}{K_{airGap} * A} = \frac{0.013}{0.024*1.2} = 0.4513\ {}^{°C}/_{W}$

$R_{conv1} = \frac{1}{h_1 * A} = \frac{1}{10*1.2} = 0.0833\ {}^{\circ}C/_{W}$

$R_{conv2} = \frac{1}{h_2 * A} = \frac{1}{40*1.2} = 0.0208\ {}^{\circ}C/_{W}$

$R_{tot} = R_{conv1} + R_{conv2} + 2*R_g + R_{airgap} = 0.0833 + 0.0208 + 2*0.0064 + 0.4153 = 0.56282\ {}^{\circ}C/_{W}$

$$\dot{Q} = \frac{\Delta T}{R_{tot}} = \frac{30}{0.5682} = 52.79\ W$$