Summary about the convective heat transfer

Convective heat transfer, also as heat convection, is one of the three ways of heat transfer. It happens between two moving fluids(liquid and gas, liquid and liquid, gas and gas, etc.), or a solid and a moving fluid(e.g., gas and solid). For example, heat transfer between a solid wall and air(interior or exterior) is convection.

Convection is mainly caused by the difference of temperature between the two moving fluid or between the solid and the fluid. Usually the heat is transferred from the hotter object to the cooler object. It might be observed by the changes of temperature of both side(the temperature of the hotter object decreases and the temperature of the cooler object increases).

Basically convection is distinguished into two types: free convection(or natural convection) and forced convection.

Free convection happens when two moving fluid or a solid and a moving fluid with different temperature contact without external force, the heat is transferred from the hotter part to the cooler part.

Forced convection happens when the two moving fluid or a solid and a moving fluid with different temperature contact due to external force, still, the heat is transferred from the hotter part to the cooler part.

Question:

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

Answer:

The thermal resistance of glass is a quite small value compared to the thermal resistance of convection between glass and air. Increasing the thickness of a single glass can increase the thermal resistance of the glass, but it does not significantly increase the total thermal resistance.

Review of the mistakes: reasons and self-reflection

Neglected the thickness of the solid wall when calculating the thermal resistance of the wall.

Just simply applied the formula without a better understanding of the principle of heat transfer and the factors that effect the thermal resistance of a solid object.($R_{wall} = \frac{L}{kA}$)

Question:

Consider a 0.8-m-high and 1.5-m-wide double-pane window consisting of two 6-mm-thick layers of glass(k=0.78 $W/m°C$) separated by a 13-mm-wide stagnant air space(k=0.026 $W/m°C$).

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 $\mathrm{h}_1 = 10\frac{W}{m^2°C}$ and $\mathrm{h}_2 = 40\frac{W}{m^2°C}$, which includes the effects of radiation.)

Answer:

The area of the surface:

$$A_{glass} = 0.8m * 1.5m = 1.2m^2$$

The thermal resistance of the convection between inner surface and the air:

$$R_{conv,1} = \frac{1}{\mathrm{h}_1 A} = \frac{1}{\frac{10W}{m^2°C}*1.2m^2} \approx 0.0833\frac{°C}{W}$$

The thermal resistance of the convection between outer surface and the air:

$$R_{conv,2} = \frac{1}{\mathrm{h}_2 A} = \frac{1}{\frac{40W}{m^2°C}*1.2m^2} \approx 0.0208\frac{°C}{W}$$

The thermal resistance of the conduction of a 6-mm-thick layers of glass:

$$R_{glass} = \frac{L_{glass}}{k_{glass}A} = \frac{0.006m}{0.78\frac{W}{m°C}*1.2m^2} \approx 0.0064\frac{°C}{W}$$

The thermal resistance of the conduction of a 13-mm-wide stagnant air space:

$$R_{air} = \frac{L_{air}}{k_{air}A} = \frac{0.013}{0.026\frac{W}{m°C}*1.2m^2} \approx 0.4167\frac{°C}{W}$$

Total thermal resistance of the window:

$$R_{total} = R_{conv,1} + R_{glass1} + R_{air} + R_{glass2} + R_{conv,2}$$
$$\approx 0.0833\frac{°C}{W} + 0.0064\frac{°C}{W} + 0.4167\frac{°C}{W} + 0.0064\frac{°C}{W} + 0.0208\frac{°C}{W}$$

$=0.5333\frac{°C}{W}$

And the steady rate of heat transfer through this double − pane window is:

$$\dot{Q} = \frac{T_{\infty 1} - T_{\infty 2}}{R_{total}} \approx \frac{20°C - (-10°C)}{0.5333\frac{°C}{W}} \approx 56.2535W$$

$$\because \dot{Q} = \frac{T_{\infty 1} - T_1}{R_{conv,1}}$$

∴ The temperature of the inner surface of the window is:

$$T_1 = T_{\infty 1} - \dot{Q} * R_{conv,1} \approx 20°C - 56.2535W * 0.0833\frac{°C}{W} \approx 15.3°C$$