Heat transfer

Supervised Practical Work no1
Conduction

N. RANC

Exercise 1: Study of an infinite wall in steady state regime

A one dimensional, steady state conduction without heat problem occurs in a plane wall having a thermal conductivity $k = 0.92\,WK^{-1}m^{-1}$ and a thickness $e = 0.2\,m$. The temperature T_1 and T_2 are imposed on the each wall surface.

1. Write the heat transfer equation in this example and the boundary conditions
2. Deduce the temperature distribution in the wall.
3. Express the heat flux in the wall and show that the relation between the flux and the temperature difference is $\phi = -\frac{1}{R_{th}}(T_2 - T_1)$ and express the thermal resistance R_{th}
4. Calculate the thermal resistance and the flux for the temperatures $T_1 = 0°C$ and $T_2 = 20°C$.

We consider now a wall constituted of two materials : concrete (thickness $e_1 = 0.2\,m$, heat conductivity $k_1 = 0.92\,WK^{-1}m^{-1}$) and thermal insulator the expanded polystyrene (thickness $e_2 = 0.04\,m$, heat conductivity $k_2 = 0.04\,WK^{-1}m^{-1}$)

1. Determine the temperature at the interface between concrete and the insulator.
2. Express and quantify the heat flux across the wall.

Exercise 2: Rod submitted to heat source and convection : Biot number signification

An infinite length rod with a radius $R = 1.5\,mm$ and a thermal conductivity $k = 50\,WK^{-1}m^{-1}$ is submitted to a constant an uniform heat source per unit volume noted s. On the external surface a convection boundary condition is applied with $h = 10\,Wm^{-2}K^{-1}$ the heat transfer coefficient. The temperature of the fluid is equal to the ambient temperature T_∞ is apply and the temperature in the center and on the rod surface are respectively noted T_0 and T_{ext}.

1. Write the heat transfer equation and the boundary condition.

2. Solve the heat equation.

3. Express the temperature difference $T_0 - T_{ext}$ according to the heat flux through the external surface φ_R in the steady state regime.

4. Same question for temperature difference $T_{ext} - T_\infty$.

5. Express the ratio $\frac{T_0 - T_{ext}}{T_{ext} - T_\infty}$ according the Biot number $Bi = \frac{hR}{2k}$ in the steady state regime.

6. Calculate the Biot number and explain the consequence of a small Biot number on the temperature field in the steady state regime.

We now consider that at time $t = 0$, the temperature of the rod is constant and equal to $T_i = 50°C$. For $t > 0$ the heat source is equal to zero and the temperature of the rod decreases and the temperature is supposed to be uniform in the rod.

1. Determine the time evolution of the rod temperature.

EXERCISE 3: Semi infinite media submitted to a cyclic heat flux

In this exercise, a semi-infinite domain of thermal conductor material ($k = 1.5\,WK^{-1}m^{-1}$, $\rho = 1500\,kgm^{-3}$, $C = 2000\,JK^{-1}kg^{-1}$ submitted to a sinusoidal temperature $\vartheta(t) = T(t) - T_0 = \vartheta_0 \sin \omega t$ is consider.

1. Write the heat equation of this problem and the boundary conditions.

2. Show that the temperature variation $\vartheta(t, x) = T(x, t) - T(0)$ can be expressed as $\vartheta = \bar{\vartheta}(x) \sin \omega t$and give the differential equation verified by $\bar{\vartheta}(x)$.

3. Solve the last equation and give the expression of $\vartheta(t, x)$.

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