Tutorial - 2

1. Calculate the critical radius of insulation for asbestos[k=0.172 W/mK] surrounding a pipe and exposed to room air at 300K with h = 2.8W/m2K. Calculate the heat loss from 475K, 60mm diameter pipe when covered with the critical radius of insulation and without

Sol: $k = 0.172\ W/m\text{-}K$; $T_\infty = 300K$; $h = 2.8\ W/m^2K$; $T = 475K$,

$d_1 = 60mm$.

Critical thickness of insulation;

$$r_c = \frac{k}{h} = \frac{0.172\ [W/m\text{-}K]}{2.8\ [W/m^2K]} = 0.06143\ [m]$$

$$r_c = 61.43\ mm$$

$$Q\ (\text{with insulation}) = \frac{2\pi(T_1 - T_\infty)}{\frac{\ln\left(\frac{r_c}{r_1}\right)}{k} + \frac{1}{h r_c}}$$

$$= \frac{2\pi(475 - 300)}{\frac{\ln\left(\frac{0.06143}{0.03}\right)}{0.172} + \frac{1}{2.8 \times 0.06143}}$$

$$Q = 110.16\ W/m.$$

$$Q\ (\text{without insulation}) = hA(T_1 - T_\infty)$$

$$= h \times 2\pi r_1 \times (T_1 - T_\infty)$$

$$= 2.8 \times 2\pi \times 0.03 (475 - 300)$$

$$Q = 92.36\ W/m.$$

2. A 10mm cable is to be laid in atmosphere of 20◦C with outside heat transfer coefficient 8.5W/m2K. The surface temperature of cable is likely to be 65◦C due to heat generation within. Will the rubber insulation of k=0.155 W/mK, be effective? If yes how much?

Sol: $r_1 = \frac{10}{2} = 5mm$; $T_\infty = 20°C$; $T_1 = 65°C$; $h = 8.5 W/m^2 K$.

For a cable (cylinder)

$$r_c = \frac{k}{h} = \frac{0.155}{8.5} = 0.018235 [m] = 18.235 [mm]$$

Hence, a rubber insulation of thickness

$t = r_c - r_1 = 18.235 - 5 = 13.235$ mm will be effective in heat dissipation.

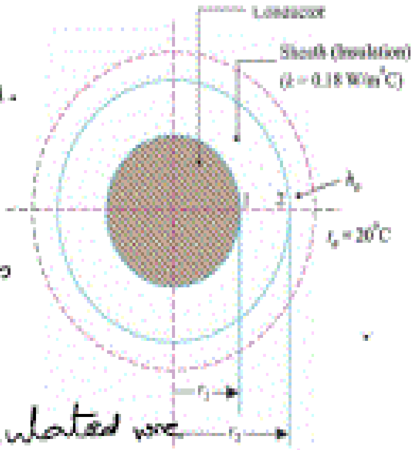
Maximum heat dissipation/m length,

$$\frac{Q_{max}}{L} = \frac{2\pi(T_1 - T_\infty)}{\frac{\ln\left(\frac{r_c}{r_1}\right)}{K} + \frac{1}{h r_c}}$$

$$= \frac{2\pi(65-20)}{\frac{\ln\left(\frac{18.235}{5}\right)}{0.155} + \frac{1}{8.5 \times 0.018235}}$$

$$\frac{Q_{max}}{L} = 19.1 \; W/m.$$

3. A small electric heating application uses wire of 2mm diameter with 0.8mm thick insulation (k=0.12 W/mK). The heat transfer coefficient on the insulated surface is 35W/m2K. Determine the critical thickness of insulation in this case and the percentage change in the heat transfer rate if the critical thickness is used, assuming the temperature difference between the surface of the wire and surrounding air remains unchanged.



Sol: $r_1 = \frac{2}{2} = 1\,mm = 0.001\,[m]$

$r_2 = 1 + 0.8 = 1.8\,mm = 0.0018\,m.$

$k = 0.12\,W/mK;\quad h = 35\,W/m^2K$

Critical thickness of insulation

$$r_c = \frac{k}{h} = \frac{0.12}{35} = 3.43\,mm.$$

Case 1: Heat flow through insulated wire

$$Q = \frac{2\pi L(T_i - T_\infty)}{\frac{\ln\left(\frac{r_2}{r_1}\right)}{k} + \frac{1}{hr_2}} = \frac{2\pi L(T_i - T_\infty)}{\frac{\ln\left(\frac{0.0018}{0.001}\right)}{0.12} + \frac{1}{35 \times 0.0018}}$$

$$Q_1 = \frac{2\pi L(T_i - T_\infty)}{20.77}$$

Case 2: Heat flow when critical thickness used

$$Q = \frac{2\pi L(T_i - T_\infty)}{\frac{\ln\left(\frac{r_c}{r_1}\right)}{k} + \frac{1}{hr_c}} = \frac{2\pi L(T_i - T_\infty)}{\frac{\ln\left(\frac{0.00343}{0.001}\right)}{0.12} + \frac{1}{35 \times 0.00343}}$$

$$Q_2 = \frac{2\pi L(T_i - T_\infty)}{18.66}$$

% increase in heat flow by using critical thickness

$$= \frac{Q_2 - Q_1}{Q_1} \times 100 = \frac{\frac{1}{18.6} - \frac{1}{20.77}}{1/18.6} \times 100 = 11.6\%.$$