SNS COLLEGE OF TECHNOLOGY

Coimbatore-35
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DEPARTMENT OF FOOD TECHNOLOGY

19FTT201 – HEAT AND MASS TRANSFER

II YEAR III SEM

UNIT 1 – CONDUCTION

Topic 10 Tutorial - Tutorial - Conduction with Internal Heat Generation

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;

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

$$r_c = 61.43\ mm$$

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

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

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

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

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

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

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

Tutorial - Conduction with Internal Heat Generation

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

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.

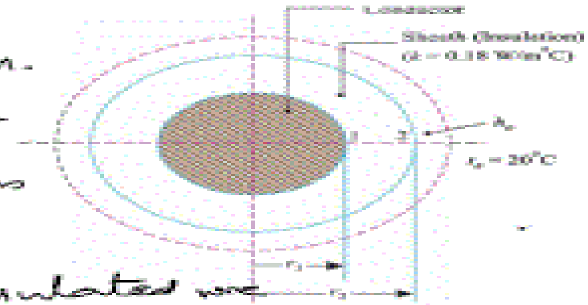
Maximum heat dissipation/m length,

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

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

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

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

$$Q = \frac{2\pi L(T_1 - T_\infty)}{\frac{\ln\left(\frac{r_2}{r_1}\right)}{k} + \frac{1}{h r_2}} = \frac{2\pi L(T_1 - T_\infty)}{\frac{\ln\left(\frac{0.0018}{0.001}\right)}{0.12} + \frac{1}{35 \times 0.0018}}$$

$$Q_1 = \frac{2\pi L(T_1 - T_\infty)}{20.77}$$

Case 2: Heat flow when critical thickness used

$$Q = \frac{2\pi L(T_1 - T_\infty)}{\frac{\ln\left(\frac{r_c}{r_1}\right)}{k} + \frac{1}{h r_c}} = \frac{2\pi L(T_1 - T_\infty)}{\frac{\ln\left(\frac{0.00243}{0.001}\right)}{0.12} + \frac{1}{35 \times 0.00243}}$$

$$Q_2 = \frac{2\pi L(T_1 - T_\infty)}{18.66}$$

% increase in heat flow by using critical thickness

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

Tutorial - Conduction with Internal Heat Generation

1.How does the thermal conductivity of a material change with respect to change in temperature of the same material?

a. thermal conductivity of a material increases with increase in its temperature

b. thermal conductivity of a material decreases with increase in its temperature

c. thermal conductivity of a material remains same with change in its temperature

d. unpredictable

ANSWER: thermal conductivity of a material increases with increase in its temperature

2.Convective heat transfer coefficient doesn't depend on

a) Surface area

b) Space

c) Time

d) Orientation of solid surface

Answer: a

Explanation: It is denoted by h and is dependent on space, time, geometry, orientation of solid surface.

3.The rate equation used to describe the mechanism of convection is called

Newton's law of cooling. So rate of heat flow by convection doesn't depend on

a) Convective heat transfer coefficient

b) Surface area through which heat flows

c) Time

d) Temperature potential difference

Answer: c
Explanation: It is directly proportional to all of above except time.

4.Which of the following is an example of forced convection?

a) Chilling effect of cold wind on a warm body

b) Flow of water in condenser tubes

c) Cooling of billets in the atmosphere

d) Heat exchange on cold and warm pipes

Answer: b
Explanation: In forced convection, the flow of fluid is caused by a pump, fan or by atmospheric winds.

Tutorial - Conduction with Internal Heat Generation

5.Heat transfer by molecular collision in

a) conduction

b) convection

c) radiation

d) scattering

Answer
Option – b)

6.Transient conduction means

a) very little heat transfer

b) heat transfer for a short time

c) heat transfer with a very small temperature difference

d) conduction when the temperature at a point varies with time

Answer

Option – d)

References

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