ASSIGNMENT

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ROLL NO. - 21ME8029

SECTION - A

MEC403 - HEAT AND MASS TRANSFER

Ques 1: A very long 25 mm diametre Cu of thermal conductivity 380 W/m°K rod extends from a surface at 120°C. The temperature of surrounding air is 25°C and heat transfer coefficient over the rod is 10 W/m²°K. Calculate,

(i) Heat loss from the rod.

(ii) How long the rod should be in order to be consider infinite.

Soln: Given, $d = 25\ mm$, $T_0 = 120°C$

$K = 380\ W/m°K$, $h = 10\ W/m^2°K$, $T_\infty = 25°C$

$\Rightarrow P = \pi d = \pi \times 25 \times 10^{-3} = 0.0157\ m \times 5 = 0.0785\ m$

$\Rightarrow \theta_0 = T_0 - T_\infty = 120° - 25° = 95°C$

$\Rightarrow$ Cross-sectional area, $A = \frac{\pi}{4}d^2 = \frac{\pi}{4}(25\times10^{-3})^2 = 1.96\times10^{-5}\ m^2$

$\times 25 = 4.9\times10^{-4}\ m^2$

Now, as the rod is very long $\therefore$ it is

(i) Consider as an Infinite long fin.

$\therefore$ Expression for heat loss is, $q = \sqrt{hPkA}\,\theta_0$

$\Rightarrow q = \sqrt{10\times(0.0157)\times 380\times(1.96\times10^{-5})\times125\times(95)}$

$\Rightarrow \boxed{q = 36.36\ W}$

(ii) An Infinite long fin has the tip temperature, $T = T_\infty$ i.e. very similar to insulated tipped fin.

$\therefore q_{infinite\ fin} = q_{insulated\ tip}$

$\Rightarrow \sqrt{hPkA}\,\theta_0 = \sqrt{hPkA}\,\theta_0 \tanh mL$

$\Rightarrow \tanh mL \approx 1 \Rightarrow \tanh mL \geq 0.99$

$\Rightarrow mL \geq \tanh^{-1}(0.99) \Rightarrow mL \geq 2.646$

$$\Rightarrow \quad L \geq \frac{2.646}{m}$$

Now, $m = \sqrt{\frac{hP}{kA}} = \sqrt{\frac{10 \times \pi \times 25 \times 10^{-3}}{380 \times \frac{\pi}{4} \times 625 \times 10^{-6}}} = 2.052$

Hence, $L \geq \frac{2.646}{2.052} \Rightarrow \boxed{L \geq 1.29\ m}$

Ques 2: A very long rod 5mm in diametre has one end maintained at 100°C. The surface of the rod is exposed to ambient air at 25°C. with convective heat transfer coefficient of $100 W/m^2 K$.

Determine, (i) Temperature distribution along rod constructed from pure Cu, 2024 Al alloy, AISI 316 stainless steel. What are the corresponding heat losses from the end.

(ii) Estimate how long the rod must be for assumption of infinite length to yield an accurate estimate of heat loss.

Sol^n : Given, Perimeter, $P = \pi d = \pi(5\times10^{-3}) = 0.0157\ m$

Cross-sectional area, $A = \frac{\pi}{4}d^2 = \frac{\pi}{4}(25\times10^{-6}) = 1.96\times10^{-5}\ m^2$

$k = 100\ W/m^2{}^\circ K$, $T_0 = 100^\circ C$, $T_\infty = 25^\circ C$

Since, the rod is very long it is assumed to be infinite long fin.

$\Rightarrow$ ∴ Temperature distribution, $\frac{\theta}{\theta_0} = \frac{T - T_\infty}{T_0 - T_\infty} = e^{-mx}$

$\Rightarrow \frac{T - 25}{100 - 25} = e^{-mx} \Rightarrow \boxed{T(x) = 75e^{-mx} + 25}$

$\Rightarrow$ ∴ Heat loss, $q = \sqrt{hPkA}\,\theta_0 = \sqrt{100\times(0.0157)\times(1.96\times10^{-5})}\sqrt{k} \times (100 - 25)$

$\Rightarrow \boxed{q = 0.416\sqrt{k}\ \ W}$

(i)

- Pure Copper ($k = 398\ W/m^\circ K$)

$m = \sqrt{\frac{hP}{kA}} = \sqrt{\frac{100\times(0.0157)}{398\times(1.96\times10^{-5})}} = 14.186$

⇒ Temperature distribution, $\boxed{T = 75e^{-14.186x} + 25}$

⇒ Heat loss, $q = 0.416 \times \sqrt{398} \Rightarrow \boxed{q = 8.299\ W}$

- 2024 Aluminium alloy ($K = 180\ W/m°K$)

⇒ $m = \sqrt{\frac{hP}{KA}} = \sqrt{\frac{100 \times (0.0157)}{180 \times (1.96 \times 10^{-5})}} = 21.0952$

⇒ Temperature distribution, $\boxed{T = 75e^{-21.0952x} + 25}$

⇒ Heat loss, $q = 0.416\sqrt{180} \Rightarrow \boxed{q = 5.581\ W}$

- AISI Stainless Steel ($K = 14\ W/m°K$)

⇒ $m = \sqrt{\frac{hP}{KA}} = \sqrt{\frac{100 \times (0.0157)}{14 \times (1.96 \times 10^{-5})}} = 75.6411$

⇒ Temperature distribution, $\boxed{T = 75e^{-75.6411x} + 25}$

⇒ Heat loss, $q = 0.416\sqrt{14} \Rightarrow \boxed{q = 1.556\ W}$

(iii) If fin is infinitely long then end temperature become T_∞ and result in equivalent to insulated tip fin of finite length.

$\Rightarrow q_{\text{infinite fin}} = q_{\text{insulated tip}}$

$\Rightarrow \sqrt{hPKA}\,\theta_0 = \sqrt{hPKA}\,\theta_0 \tanh mL \Rightarrow \tanh mL \approx 1$

$\Rightarrow \tanh mL \geq 0.99 \Rightarrow mL \geq \tanh^{-1}(0.99)$

$\Rightarrow mL \geq 2.646 \Rightarrow \boxed{L \geq \frac{2.646}{m}}$

- For Copper $\rightarrow$ ($K = 398\ W/m^\circ K$)

$m = \sqrt{\frac{hP}{KA}} = 14.1867 \Rightarrow L \geq \frac{2.646}{14.1867} \Rightarrow \boxed{L \geq 0.186\ m}$

- 2024 Aluminium alloy ($K = 180\ W/m^\circ K$)

$m = \sqrt{\frac{hP}{KA}} = 21.0952 \Rightarrow L \geq \frac{2.646}{21.0952} \Rightarrow \boxed{L \geq 0.125\ m}$

- AISI Stainless steel ($K = 14\ W/m^\circ K$)

$m = 75.6411$, $L \geq \frac{2.646}{75.6411} \Rightarrow \boxed{L \geq 0.0349\ m}$