Heat transfer

Equation of heat conduction

In Cartesian co-ordinates,

$$\nabla^2 T + \frac{\dot{q}}{k} = \frac{1}{\alpha}\frac{dT}{dt}$$

where,
∇ = Laplace operator
$\dot{q}$ = Heat generation per unit volume
α = Thermal diffusivity

- *Steady state condition:* $\nabla^2 T + \frac{\dot{q}}{k} = 0$ - Poisson equation
- *No heat sources:* $\dot{q} = 0$ - Diffusion equation
- *No heat source and steady state:* $\dot{q} = 0$ and $\frac{dT}{dt} = 0$ - Laplace equation

In cylinderical co-ordinates,

$$\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial T}{\partial r}\right) + \frac{\dot{q}}{k} = \frac{1}{\alpha}\frac{dT}{dt}$$

In spherical co-ordinators,

$$\frac{\partial^2 T}{\partial r^2} + \frac{2}{r}\frac{\partial T}{\partial r} + \frac{1}{r^2 \sin\psi}\frac{\partial}{\partial \psi}\left(\sin\psi\frac{\partial T}{\partial \psi}\right) + \frac{1}{r^2 \sin\psi}\frac{\partial}{\partial \psi}\left(\frac{\partial^2 T}{\partial \phi}\right) + \frac{\dot{q}}{k} = \frac{1}{\alpha}\frac{dT}{dt}$$

If temperature variation is only in radial direction, then for steady state conditions with no heat generations, conduction equation becomes,

$$\frac{\partial^2 T}{\partial r^2} + \frac{2}{r}\frac{\partial T}{\partial r} = 0 \Rightarrow \frac{\partial}{\partial r}\left(r^2\frac{\partial T}{\partial r}\right) = 0$$

Boiling

Nucleate boiling: $q_s = \mu_l h_{fg}\big(g\sigma^{-1}(\rho_l - \rho_v)\big)^{\frac{1}{2}}\big(\big(\frac{C_{pl}}{C_{sg}}\big)\frac{\triangle T_e}{h_{fg}Pr^{1.7}}\big)^3$
Critical heat flux / Burnout point / Boiling crisis: $q_s = 0.18 h_{fg}(g\sigma(\rho_l - \rho_v)\rho_v^2)^{\frac{1}{4}}$