ME-662 CONVECTIVE HEAT AND MASS TRANSFER

A. W. Date
Mechanical Engineering Department
Indian Institute of Technology, Bombay
Mumbai - 400076
India

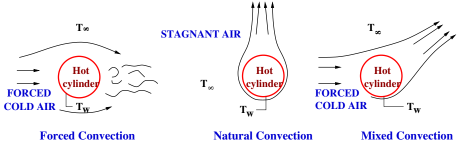
LECTURE-2 FLOW CLASSIFICATIONS

LECTURE-2 FLOW CLASSIFICATIONS

Purpose - L2($\frac{1}{10}$)

1. In Convectiive Heat & Mass Transfer, we are concerned with Bulk Fluid Motion.
2. As such, everything that affects Bulk Flow, influences 'h' and 'g'
3. All flows are governed by 3D, time-dependent Partial Differnetial Equations (PDEs) of Mass, Momentum and Energy transfer
4. Not all flows can be elegantly treated by *Analytical Methods*. Hence, *Numerical Methods* become necessary
5. Complete equations under all types of boundary conditions and complexities of flow domains can only be solved by *Computational Fluid Dynamics* techniques.
6. The scope of the subject is very vast. Hence, one must deal with *Classes of Flows*

Forced and Free Convection - L2($\frac{2}{10}$)

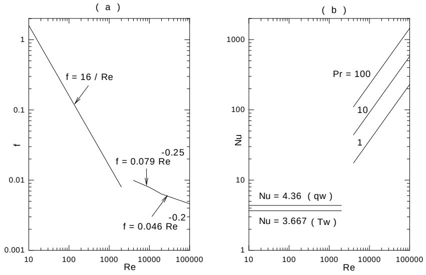


1. If the fluid motion is caused by external means (pump, blower etc) - *Forced Convection*
2. If the fluid motion is induced by Density differences arising from Temperature differences, - *Free or Natural Convection*
3. If the two motions are comparable - *Mixed Convection*

1. $Nu_m = C\, Re_D^m\, Pr^m$ (Forced $Gr/Re^2 << 1$)
2. $Nu_m = C\, Gr_D^m\, Pr^m$ (Free $Gr/Re^2 >> 1$)
3. $Nu_m = C\, (Gr/Re^2)_D\, Pr^m$ (Mixed $Gr/Re^2 \simeq 1$)
4. Grshof number Gr is ratio of Buoyancy and Viscous Forces

Laminar and Turbulent Flows - L2($\frac{3}{10}$)

1. Reynolds number is the ratio of Inertia and Viscous Forces
2. If Re $< Re_{cr}$ - Laminar
3. If Re $> Re_{cr}$ - Turbulent
4. If Re $\simeq Re_{cr}$ - Transition
5. For Ducted flows , $Re_{cr} \simeq 2200$
6. Critical Reynolds or Grashof numbers are estimated for all types of flows

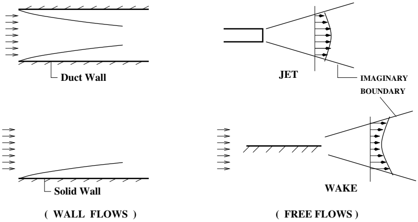


Incompr and Compr Flows - L2($\frac{4}{10}$)

1. Incompressible Flows
   1. Routinely occur in Liquids
   2. In Gases , Incompressible Flows occur when Mach number Ma = $V/V_{sound} < 0.3$
   3. Density is constant or, function of Temperature $\rho(T)$ only
2. Compressible Flows
   1. Occur in Gases
   2. Ususally, $Ma > 0.3$
   3. Density is function of Pressure and Temperature $\rho(p, T)$

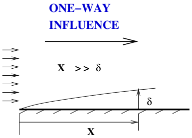
Wall and Free Flows - L2($\frac{5}{10}$)

1. We are interested in determining 'h' or 'g' at the interface between Solid-Liquid/Gas or between Liquid-Gas
2. Flows with such interfaces are termed as **Wall Flows** . (eg. Internal Duct Flow, External Flow over Tube, Wind flow over a Lake)
3. Our interest is in Wall Flows only

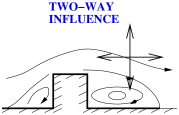


In **Free Flows** such as **Jets or Wakes** , there are no interfaces. (eg. Discharge of hot water into a Water Body, Flow behind a Ship) Hence, not of interest.

Boundary Layer and Recirculating Flows - L2($\frac{6}{10}$)



Boundary Layer Flow



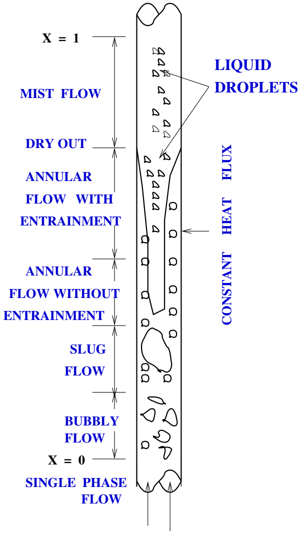
Recirculating Flow over a Surface Mounted Rib

1. **Long and Thin Flows** are called Boundary Layer Flows .
2. Boundary layer flows are predominantly unidirectional - One-Way Influence
3. Flows are governed by Parabolic Equations

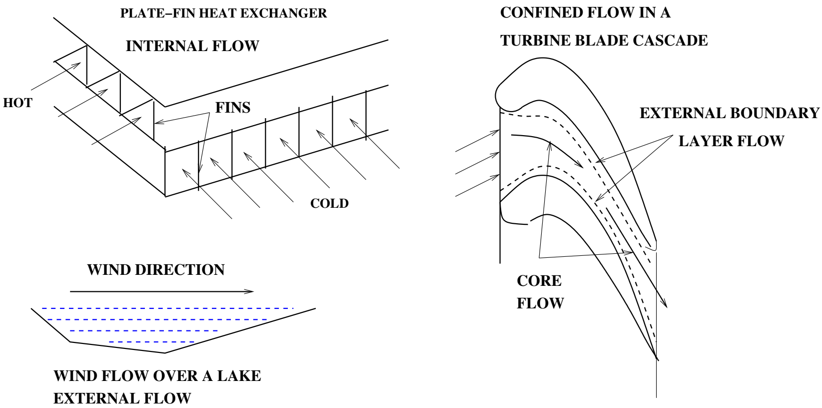
1. In Recirculating Flows, there is no predominant flow direction - Two-Way Influence
2. Flows are governed by Elliptic Equations

Single and Two Phase Flows - L2($\frac{7}{10}$)

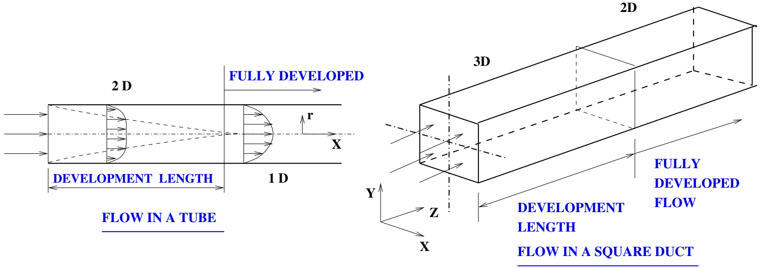
1. Two Phase Flows are encountered in Evaporators, Cyclone Separators, Boiling Water Reactors, Fluidised Bed Dryers or PF Combustors etc.
2. Involve Simultaneous H & M Transfer with or without Phase Change
3. Complex Physics and Mathematics



Internal and External Flows - L2($\frac{8}{10}$)



1D-2D-3D Flows - L2($\frac{9}{10}$)



Flow-Dimensionality is determined by number of Independent variables (or, cooridinates) on which Flow Variables such as pressure, velocity, temperature etc depend.

Scope of Present Lectures - L2($\frac{10}{10}$)

1. Forced and Free Convection
2. Laminar and Turbulent Flows
3. Incompressible and Compressible Flows
4. Boundary Layer and Recirculating Flows
5. Wall and Free Flows
6. Single and Two Phase Flows
7. 1D-2D -3D Flows

Flow Situations marked in Blue will be covered in this Course.