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Department: Mechanical

Course title: Convection Heat Transfer

Topic Name: Module – I. Convection heat transfer and fluid dynamics fundamentals.

-1 Introduction to convection heat transfer. –

- Energy transport in a fluid. Importance of fluid motion (fluid mechanics
- – isothermal fluid mechanics) to heat transfer.
- The domain that participates in heat transfer – external vs. internal domain.
- Fluid flow in the context of convection heat transfer.
- The domain that participates in heat transfer – external (unbounded) vs. internal (bounded) domain.
- Externally induced flow – forced convection.
- Heat transfer induced flow – natural convection.
- Heat transfer with simultaneous externally induced flow and heat transfer induced flow – mixed convection.
- Fluid flow types (externally- or heat transfer-induced flows): Laminar, turbulent, transition, mixed, periodic.
- Basic differences between laminar and turbulent flows (isothermal or with heat transfer); Fourier's law applied to a fluid in motion.
- Flow in the vicinity of a surface vs absence of surfaces. Influence of a solid surface (stationary of moving) of fluid motion. Free shear flows (wakes and jets) and boundary layers (surface flows).

-2 Conservation equations.

- Concept of no-slip and its corresponding aspect to heat transfer at a surface.
- The (hydrodynamic) boundary layer concept for isothermal flow (i.e. no heat transfer). Its importance to fluid dynamics.
- Local vs global – wall shear stress and skin friction coefficient. Relation to normal velocity gradient.
- Non-isothermal boundary layer – surface temperature greater or less than fluid temperature. The thermal boundary layer and its importance to Newton's law of cooling. Concept of heat transfer coefficient.
- Local heat transfer coefficient definition. Relation to temperature gradients at the surface – in the fluid and in the surface.
- Nusselt number and its significance.
- Stanton number and its significance.
- Continuity (mass conservation) - in differential and integral forms.
- Displacement thickness – its physical significance.

- Conservation of momentum (2nd law of motion) – in differential and integral forms. Momentum thickness – its physical significance.
- Conservation of energy (1st law of thermodynamics to an open system) in differential and integral forms. Energy thickness – its physical significance.

-3 Boundary layers – Fluid flow and heat transfer at a surface.

- Derivation from basics and final form of the equations for 2-dimnesional flows. Details of the mathematics will be available in the notes and will not be derived in the lecture, however, major steps and approximations/assumptions will be discussed.
- Non-dimensional form of the conservation equations.
- Reynolds number, Prandtl number and their physical significance.
- Effects of heat transfer with surface on (isothermal) boundary layer – temperature dependent properties.
- The "simplest" boundary layer: Flat plate boundary layer and boundary layer approximations. "Smooth (hydrodynamically)" surface.
- Boundary conditions for heat transfer (idealizations): Iso-thermal or Isoheat flux surface for practical situations.
- Study of practical situations with flat plate boundary layer approximations and its limitations.

-4 Forced convection at a flat plate.

- Case-I: Laminar freestream & smooth edge for and surface conditions.
- Correlations for local and average skin friction coefficient, heat transfer coefficient and Nusselt number; their limitations. Selection of property values.
- Case-II: Laminar freestream & rough edge for and surface conditions).
- Case-III: Turbulent freestream & smooth/rough edge for and surface conditions.
- Correlations for local and average skin friction coefficient, heat transfer coefficient and Nusselt number; their limitations. Selection of property values.
- Development of hydrodynamic and thermal boundary layers for three Prandtl number ranges

-**5 Forced convection over a cylinder / sphere.**

- Flow over a cylinder – coaxial flow
- Flow over a cylinder – cross flow
- Development of hydrodynamic and thermal boundary layers for three
- Prandtl number ranges ($Pr << 1$, Pr · 1, $Pr >> 1$). Separation, wake.
- Correlations for local and average skin friction coefficient, heat transfer coefficient and Nusselt number; their limitations. Selection of

property values.

- Flow over a sphere
- Correlations for local and average skin friction coefficient, heat transfer coefficient and Nusselt number; their limitations. Selection of property values.

-6 Forced convection in a tube/duct

- Circular tube
- Development of hydrodynamic and thermal boundary layers.
- Effect of Prandtl number ($Pr \ll 1$, $Pr \approx 1$, $Pr \gg 1$).
- Entrance region – hydrodynamic and thermal. Fully developed flow: velocity and temperature profiles. Practical geometries of entrance region, e.g. heat exchanger.
- Correlations for hydrodynamic and thermal entry lengths; and local and average skin friction coefficient, heat transfer coefficient and Nusselt number for and wall conditions; their limitations. Selection of property values.
- Heat transfer in non-circular ducts.