

Course Number: 28056
Course Name: Boundary Layer Theory

Course Type:
Prerequisite:
Level: Graduate
Group: Energy Conversion

Type & Max Unit: 3
Corequisite:
First Presentation:
Last Edition:

Objectives:

Topics:

1. Outline of Boundary Layer Theory
 - 1.1. The Concept of Boundary Layer
 - 1.2. Separation and Vortex Formation
 - 1.3. Flow regimes in a Boundary Layer and Ducts

2. The Concept of Viscosity
 - 1.1. Definition and Measurements of Viscosity
 - 1.2. Factors Affecting Viscosity
 - 1.2.1. Estimation of Gas Viscosities
 - 1.2.2. Estimation of Liquid Viscosities

3. Classification of Fluid Behavior
 - 3.1. Definition of a Newtonian Fluid
 - 3.2. Non-Newtonian Fluid Behaviour
 - 3.3. Time-Independent Fluid Behaviour
 - 3.4. Shear-Thinning Fluids
 - 3.4.1. Power Law or Ostwald de Waele Equation
 - 3.4.2. The Cross Viscosity Equation
 - 3.4.3. The Ellis Fluid Model
 - 3.4.4. Visco-plastic Fluid Behavior
 - 3.5. Shear-Thickening or Dilatant Behaviour
 - 3.6. Time Dependent Behaviour
 - 3.7. Thixotropic Behaviour
 - 3.8. Rheopectic Behaviour
 - 3.9. Visco-elastic behavior
 - 3.10. Oscillatory shear motion
 - 3.11. Elongational flow
 - 3.12. Origins of Non-Newtonian Behaviour
 - 3.13. Implications in Engineering Applications
 - 3.14. Concluding Remarks

4. Viscous Incompressible Flows
 - 4.1. Navier-Stokes Equation
 - 4.1.1. Nine Scalar Quantities of Stress System - Stress Tensor

- 4.2. Vector Notation & derivation in Cylindrical Coordinates - Navier-Stokes equation
- 4.3. A general way of deriving the Navier-Stokes equations from the basic laws of physics.
- 4.4. Exact Solutions Of Navier-Stokes Equations
 - 4.4.1. Parallel Flow in a Straight Channel
 - 4.4.2. Couette Flow
 - 4.4.3. Hagen Poiseuille Flow
- 4.5. Applications-
 - 4.5.1. Losses and Friction Factors
 - 4.5.2. Flow between Two Concentric Rotating Cylinders
 - 4.5.3. Calculation of Stress and Torque Transmitted
 - 4.5.4. Low Reynolds Number Flow Around a Sphere
 - 4.5.6. Theory of Hydrodynamic Lubrication

- 5. Laminar Boundary Layer
 - 5.1. Introduction
 - 5.2. Boundary Layer Equations
 - 5.2.1 About the boundary layer
 - 5.3. Boundary Layer Coordinates
 - 5.3.1. Application of Boundary Layer Theory
 - 5.4. Blasius Flow Over A Flat Plate
 - 5.4.1. Law of Similarity for Boundary Layer Flows
 - 5.4.2. Wall Shear Stress
 - 5.4.3. Boundary Layer Thickness
 - 5.5. Momentum-Integral Equations for The Boundary Layer
 - 5.5. Seperation of Boundary Layer
 - 5.5.1. The mathematical explanation of flow-separation
 - 5.6. Karman-Pohlhausen Approximate Method For Solution Of Momentum Integral Equation Over A Flat Plate
 - 5.7. Integral Method For Non-Zero Pressure Gradient Flows
 - 5.7.1. Point of separation
 - 5.8. Entry Flow In A Duct
 - 5.8.1. At the entrance region,
 - 5.9. Control of Boundary Layer Separation
 - 5.10. Mechanisms of Boundary Layer Transition
 - 5.11. Summary of this chapter

- 6. Turbulent Boundary Layer
 - 6.1. Introduction
 - 6.2. Characteristics of Turbulent Flow
 - 6.3. Frictional forces at the confining solid walls
 - 6.4. Laminar-Turbulent Transition
 - 6.5. Reynolds decomposition of turbulent flow
 - 6.5.1. Rules of mean time – averages
 - 6.6. Turbulent Boundary Layer Equations
 - 6.7. Turbulent Shear Stress Models
 - 6.8. Structure of a Turbulent Boundary Layer
 - 6.8.1. Shear stress and friction velocity

- 6.8.2. Length and velocity scales
 - 6.8.3. Inner Layer
 - 6.8.4. Outer Layer
 - 6.8.5. Overlap Layer- the Log Law
 - 6.8.6. Viscous Sub-layer
 - 6.8.7. Limits of the Various Regions
 - 6.8.8. Velocity-Defect Layer: Coles' Law of the Wake
 - 6.8.9. Effect of Roughness
 - 6.9. Friction Laws
 - 6.9.1. Drag Coefficients
 - 6.9.2. Flat-Plate Boundary Layer
 - 6.10. Pipe Flow
 - 6.10.1. Smooth-Walled Pipes
 - 6.10.2. Rough-Walled Pipes
 - 6.11. Frictional Losses
 - 6.12. Integral Analysis of the Turbulent Boundary Layer
 - 6.12.1. Characteristic Integral Lengths
 - 6.13. The Momentum – Integral Relation
 - 6.13.1. Zero – Pressure Gradient Boundary Layer
 - 6.13.2. General Case
 - 6.14. Application to Turbulent Flow
 - 6.9. Duct Flows with Very Large Reynolds Numbers
 - 6.10. Fully Developed Turbulent Flow in a Pipe For Moderate Reynolds Numbers
 - 6.11. Skin Friction Coefficient For Boundary Layers On A Flat Plate
 - 6.12. Summery
7. Mechanisms of Boundary Layer Transition
- 7.1. Introduction
 - 7.2. Several Events Of Transition
8. Thermal Boundary Layer
- 8.1 Definitions
 - 8.2 Modes of heat transfer
 - 8.3 The Prandtl number
 - 8.4 Dimensionless numbers in free and forced convection
 - 8.5 The energy equation
 - 8.6 Laminar boundary layers with isothermal walls
 - 8.7 Temperature profile in a turbulent boundary layer
 - 8.8 Heat-transfer coefficients
 - 8.9 Temperature integral results
 - 8.10 Engineering heat-transfer calculations
9. Boundary layer control
- 9.1. In nature
 - 9.2. In Sports
 - 9.3. Control of Boundary Layer in Engineering Applications
 - 9.3.1. On a cylinder

- 9.3.2. Maintaining a laminar boundary layer
- 9.3.3. Control of Boundary Layer Separation

References: