

Course Number: 28089

Course Name: Physics of turbulent flows

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

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

Objectives:

Topics:

- 1- Nature of turbulence
 - 1-1- What is turbulence
 - 1-2- The origin of turbulence
 - 1-3- Physical nature of turbulence
 - 1-3-1- Turbulence is irregular and unsteady
 - 1-3-2- Turbulence contains a wide range of different scales
 - 1-3-3- Turbulence contains irregular small scale eddies
 - 1-3-4- Turbulence occurs at high Reynolds number
 - 1-3-5- Turbulence dissipate energy
 - 1-3-6- Turbulence is a continuum phenomena
 - 1-3-7- Turbulence is 3-D in nature
 - 1-3-8- Turbulence is highly diffusive
 - 1-3-9- Turbulence is a flow characteristics
- 2- Important concepts in fluid dynamics
 - 2-1- Introduction
 - 2-2- Fluid properties
 - 2-2-1- Kinematics properties
 - 2-2-2- Transportive properties
 - 2-2-2-1- Variation with rate of shear
 - 2-2-2-2- Variation with pressure
 - 2-2-2-3- Newtonian fluid flow
 - 2-2-3- Thermodynamics properties
 - 2-3- Stresses applied to a fluid element
 - 2-3-1- state of stress
 - 2-3-2- Fluid at rest or fluid flowing with uniform velocity
 - 2-3-3- Inviscid fluid flow
 - 2-3-4- Viscous fluid flow
 - 2-4- Important properties of tensor stress
 - 2-4-1- Symmetry in tensor stress
 - 2-4-2- The average of normal stresses at a point are equal
 - 2-5- Characteristics of laminar flow

3- The equations of fluid motion

3-1- Introduction

3-2- Material derivative

3-3- The physical concept of velocity vector divergence

3-4- Continuity equation

3-5- Momentum equations

4- Stability theory of laminar flows

4-1- Introduction

4-2- Background and history

4-3- Primary stability theory

4-3-1- problem formulation

4-3-2- Orr-sommerfeld equation

4-3-3- Boundary condition of Orr-sommerfeld equation

4-3-4- Conservatively unstable and absolutely unstable

4-3-5- Inviscid stability theory

4-3-6- Viscous stability

4-3-7- Boundary layer stability on a flat plate

4-3-8- Comparison of stability results with experimental data

4-3-9- Parametric effects in linear stability theory

4-4- Secondary stability theory

4-5- Nonlinear stability theory

4-6- Receptivity stability theory

5- Transition to turbulence

5-1- Introduction

5-2- transition

5-2-1- Tollmien-Schlichting waves

5-2-2- Development of transversal vortices

5-2-3- Turbulent spots

5-3- The effects of different parameters on transition

5-3-1- The effect of free stream on transition

5-3-2- The effect of wall roughness on transition

5-3-3- The effect of wall cooling on transition

5-3-4- The effect of pressure gradient and wall roughness together on transition

5-3-5- The effect of oscillating free stream on transition

5-4- Transition in 3-D boundary layer

5-5- Prediction of transition point

6- Physics of turbulence

6-1- Introduction

6-2- The origin of turbulence

6-3- Eddies

6-4- Types of turbulent flows

6-5- Definition of turbulent flow

6-6- Definition of homogenous and isotropic

6-7- Scales and dimensions in turbulent flows

- 6-8- Kolmogrov local isotropic theory
- 6-9- Classification of length scales in turbulent flows
- 6-10- Eddy energy spectrum
- 6-11- Vorticity in turbulent flows
- 6-12- Vortex stretching
- 6-13- Energy cascading
- 6-14- Few practical implications resulting from turbulent flow
- 6-14-1- Turbulent diffusivity
- 6-14-2- Friction drag coefficient
- 6-15- Ways for studying turbulence
- 6-15-1- Dimensional analysis
- 6-15-2- Experimental methods
- 6-15-3- Numerical solution of governing equations
- 6-15-4- Simplifications of equations using statistical approach

- 7- Statistical approach to turbulence
- 7-1- Introduction
- 7-2- Different averaging in turbulence
- 7-2-1- Ensemble averaging
- 7-2-2- Temporal averaging
- 7-2-3- Spatial averaging
- 7-2-4- Ergodic condition
- 7-2-5- Average velocity and turbulent fluctuations
- 7-2-6- Higher order moments
- 7-3- Internal structure of turbulent flows in physical space
- 7-4- Probabilities
- 7-4-1- Definition of probability
- 7-4-2- Probability distribution function
- 7-4-3- Accumulation of probability distribution
- 7-4-4- Average and moments
- 7-4-5- Gaussian distribution
- 7-4-6- United probability distribution function

- 8- Basic turbulence theory
- 8-1- Introduction
- 8-2- Mean flow
- 8-2-1- Physical interpretation of Reynolds stresses
- 8-3- Dynamics of turbulent flows
- 8-3-1- Kinetic energy of mean flow
- 8-3-2- Kinetic energy of instantaneous velocity
- 8-3-3- Equations of fluctuating velocities
- 8-3-4- Equation of turbulent kinetic energy
- 8-3-5- Turbulent dissipation energy
- 8-4- Pressure effects
- 8-5- Equation of temperature distribution in turbulent flows
- 8-6- Vorticity
- 8-6-1- Vorticity in inviscid flows

- 8-6-2- Vorticity in viscous flows
- 8-6-3- Vorticity equation in turbulent flow
- 8-6-4- The effect of different eddies on each other

- 9- Homogenous and isotropic turbulence
 - 9-1- Introduction
 - 9-2- Homogenous turbulent flows
 - 9-3- Isotropic turbulent flows
 - 9-4- Taylor and integral length scales in isotropic flows
 - 9-5- Eulerian micro and integral time scales
 - 9-6- Taylor hypothesis

- 10- Bounded turbulent shear flows
 - 10-1- Introduction
 - 10-2- Turbulent flow in a 2D channel
 - 10-2-1- Investigation of equations of motion
 - 10-3- Equations of shear layers
 - 10-3-1- Higher order approximations
 - 10-3-2- Momentum equations in flow direction
 - 10-3-3- Momentum equation normal to the flow direction
 - 10-4- Turbulent boundary layers
 - 10-4-1- External turbulent boundary layer
 - 10-4-2- Internal turbulent boundary layer
 - 10-5- Viscous sub-layer
 - 10-5-1- Linear sub-layer
 - 10-5-2- Constant stress sub-layers
 - 10-5-3- Inertia sub-layer

- 11- Free turbulent shear flows
 - 11-1- Introduction
 - 11-2- equations of free shear layers
 - 11-3- Turbulent jets
 - 11-3-1- Similarity analysis in jets
 - 11-4- Wakes

- 12- Spectral analysis of turbulence
 - 12-1- Internal structure in wave number space
 - 12-1-1- Equation of homogenous turbulent dynamics in wave number space
 - 12-1-2- Isotropic turbulent analysis in wave number space
 - 12-1-3- Relation between $\overline{u'^2} f(\mathbf{r}, t)$ and $E(\mathbf{k}, t)$
 - 12-1-4- One dimensional spectral theory
 - 12-1-5- Taylor hypothesis
 - 12-2- Kolmogorov universal equilibrium theory
 - 12-2-1- Determination of $E(\mathbf{k}, t)$ using Kolmogorov hypothesis
 - 12-3- Transportation theories
 - 12-3-1- Heisenberg transportation theory

- 12-3-2- Pow transportation theory
- 12-3-3- Comparison Taylor and Kolmogrov dissipation lengths
- 12-3-4- Integral time and length dimensions

References: