ADVANCED FLUID MECHANICS

Course Code: 13ME2301

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Pre requisites: Basic Fluid mechanics

Course Educational Objectives:

To make the student understand

1. lift and drag for flow past a cylinder with and without circulation
2. viscous incompressible flows and their applications
3. concept of boundary layer
4. concept of turbulent flow
5. compressible fluid flow and its applications

Course Outcomes:

The student will be able to

1. determine the lift and drag for flow past a cylinder with and without circulation
2. apply Navier-Stokes equations to solve viscous incompressible fluid flow problems
3. explain boundary layer formation, separation and control
4. apply Prandtl's mixing length hypothesis to solve the turbulent fluid flow problems
5. explain the effect of Mach number in compressible fluid flow through a variable area
6. solve normal shock wave problems
7. solve oblique shock wave problems
8. apply Fanno flow equations to solve the compressible fluid flow problems with friction

UNIT-I

Rotational and irrotational flows – velocity potential – circulation – relationship between stream function and potential function – basic solutions of stream and potential functions for uniform flow, source or sink, doublet and vortex flow – stationary circular cylinder - cylinder with circulation.

Normal stresses – shear stresses - Navier-Stokes equations – flow through a parallel channel – very low Reynolds number flow – order of magnitude analysis, and approximation of N-S equations – boundary layer equations.

UNIT-II

Momentum integral equations – flow over a flat plate – displacement thickness – momentum thickness – boundary layer separation – drag – bluff bodies – aerofoils.

Laminar–turbulent transition – time mean and time dependent description – conservation of mass – momentum equations and Reynolds stresses – boundary layer equations – shear stress models, eddy viscosity, Prandtl's mixing length – laminar sub layer –turbulent boundary layer on a flat plate.

UNIT-III

Wave propagation in an elastic solid medium – propagation of sound waves – Mach number – Mach angle – equation of sound wave.

Energy equation – energy equation for non-flow and flow processes – adiabatic energy equation – stagnation enthalpy - stagnation temperature - stagnation pressure – stagnation velocity of sound – reference velocities – Bernoulli's equation – effect of Mach number on compressibility.

UNIT-IV

Comparison of isentropic and adiabatic processes – Mach Number variation - expansion in nozzles – compression in diffusers – stagnation and critical states – area ratio as a function of mach number – impulse function - mass flow rate, flow through nozzles - convergent nozzles – convergent-divergent nozzles – flow through diffusers.

Development of a shock wave – rarefaction wave – governing equations, Fanno line, Rayleigh line -Prandtl-Meyer relation – Mach number downstream of the shock wave – static pressure ratio across the shock - temperature ratio across the shock – density ratio across the shock - stagnation pressure ratio across the shock.

UNIT-V

Nature of flow through oblique shock waves – fundamental relations - Prandtl's equation – Rankine-Hugoniot equation.

The Fanno curves – Fanno flow equations – variation of flow parameters.

TEXT BOOKS:

1. A.K. Mohanty, "*Fluid Mechanics*", 2nd Edition, PHI Learning Private Limited, New Delhi, 2010.

2. S.M. Yahya, "*Fundamentals of Compressible Flow With Aircraft And Rocket Propulsion (SI UNITs)*", 3rd Edition, New Age International Publishers, New Delhi, 2003.

REFERRENCES:

1. Som and Biswas, "*Introduction to Fluid Mechanics and Fluid Machines*", 2nd Edition, Tata McGraw-Hill, 2004.

2. S.W. Yuan, "*Foundations of Fluid Mechanics*", Prentice-Hall, 1967.

3. Patrick H. Oosthuizen and William E. Carscallen, "*Compressible Fluid Flow*", McGraw-Hill Companies, Inc., New York, 1997.