GASDYNAMICS: FUNDAMENTALS AND APPLICATIONS

PROF. SRISHA RAO M V

Department of Aerospace Engineering

IISc Bangalore

PRE-REQUISITES : Fluid Dynamics, Thermodynamics, Solution of ODE and PDE, Basic numerical techniques.

INTENDED AUDIENCE : Engineering students of Aerospace, Mechanical, Chemical, Applied Mechanics can take this course. Students of Physical sciences also can take the course.

COURSE OUTLINE :

In the previous century, humanity quickly moved from enabling mechanical flight to flying farther, higher, and faster. Now, humanity is endeavoring to explore and colonize other planets. Similarly, engineers are seeking to make compact and efficient systems in the domains of energy and power. All these scenarios and several more, including natural events like explosive volcanic eruptions, involve the high-speed Flow of gases. Speeds at which the compressible nature of gases becomes significant. In this course on the fundamentals and applications of gasdynamics, we shall understand and model the compressible flow phenomena of gases from first principles. We will discover the importance of Mach number (M), the ratio of the flow velocity to the speed of sound, in describing such flows. We will find a close coupling of thermodynamics and fluid dynamics. We shall encounter and explain counter-intuitive behavior as the flow Mach number changes from subsonic ($M<1$) to supersonic ($M>1$). These are wave-dominated flows. The shock wave is a particularly exciting phenomenon existing only in supersonic flows. We will learn about shock waves and their interactions, and means of producing them in a controlled manner in the laboratory. The understanding of gasdynamics gained will be applied to design and analyze typical engineering systems like nozzles, diffusers, intakes, shock tubes, wind tunnels, pipe flows, to name a few. Flow visualizations taken in the unique high-speed experimental facilities at the Indian Institute of Science will enable deeper insights. Special topics on hypersonic flows and shock wave boundary layer interactions will be introduced towards the end of the course.

This is an elective course suitable at advanced undergraduate or postgraduate levels. Participants must have undergone a basic course in fluid dynamics and thermodynamics and must be familiar with the solution of ordinary differential equations and partial differential equations.

The assignments and final exam shall be conducted online. Typical numerical examples will be discussed in the lectures, and practice problems will be supplied. Assignments will be of an applied nature where some problems must be solved using simple numerical techniques on the computer. Tests will involve both conceptual and numerical type questions.

ABOUT INSTRUCTOR :

Prof. Srisha Rao M V is currently an Assistant Professor at the Department of Aerospace Engineering, Indian Institute of Science, Bengaluru. He completed his ME and Ph.D. from the Indian Institute of Science and has done post-doctoral research in Muroran Institute of Technology, Japan. His research interests lie in supersonic and hypersonic flows, experimental high-speed aerodynamics, optical flow diagnostics, and data analytic techniques. He has designed and established several unique testing facilities such as the supersonic ejector test facility, high-speed gaseous mixing test facility, and the nozzle-isolator interaction test facility.

Recently, he has worked on image analytics for unsteady flow analysis and start-unstart characterisation of hypersonic intakes. He has been teaching the Gasdynamics course at IISc for the past five years and has taught courses on Aerodynamics, Flight Mechanics, Aerodynamics test facilities and Experimental Techniques. He has over 29 journal articles, a book chapter, and over 61 conference publications. He has given invited lectures at national and international conferences and workshops including the Fluid Mechanics and Fluid Power, National Symposium on Shock Waves, Propulsion Seminar Series (VSSC, ISRO), 1st Symposium on Hypersonics (KIAST, South Korea).

COURSE PLAN:

Week 1: Introduction (Why study gasdynamics, Mach number, and flow regimes)

Thermodynamics (Review of basics, Calorifically perfect gas, and Thermally perfect gas) (2 Lectures)

Week 2: Flow Equations (Integral forms and Differential forms)

Quasi-1D Flow (The quasi-1D approximation, speed of sound)

Isentropic Flow (Stagnation properties and Star properties, Compressible Pitot)

Week 3: Normal Shock Wave (principle and derivation of flow properties across the normal shock, Rayleigh Pitot formula)

Moving Shock Wave and its Reflection

Week 4: Unsteady 1D flow and the shock tube

Oblique Shock Wave

Prandtl Meyer Expansion (Shock-expansion analysis of diamond airfoil)

Week 5: Compressible flow through variable area ducts (choking phenomena, normal shock in supersonic flow) 2 Lectures

Nozzle flow and Operating points (underxpanded and overexpanded flow)

Week 6: Diffuser flow and flow starting

High-speed wind-tunnel operation

High-speed air intakes and their characteristics

Week 7: One Dimensional Flow with Friction Fanno flow (2 Lectures)

Week 8: One Dimensional Flow with Heat Addition Rayleigh flow (2 Lectures)

Week 9: Generalized Quasi-1D Flow (a typical example of nozzle flow with friction, and heat release in variable area duct) (2 lectures)

Velocity Potential Equation for compressible flow (1 lecture)

Week 10: Small perturbation theory and applications (2 Lectures)

Method of Characteristics (MOC) for Steady Supersonic Flows

Week 11: Design of supersonic nozzle contour using MOC

Week 12: Introduction to Shock-wave boundary layer interaction (Special topic)

Introduction to Hypersonic flow (Special topic)