AERODYNAMICS

ENAS 304

Lecture : 3 **Year : III**
Tutorial : 1 **Part : I**
Practical : 3/2

Course Objectives:

The objective of this course is to introduce the fundamental concepts of internal and external flows as applied to aerospace engineering. It covers essential fluid mechanics and aerodynamic principles used in the design of airfoils and aircraft wings, along with recent technological advancements in modern flight vehicles. Students will gain an understanding of the key theoretical foundations, experimental approaches, and analytical methods used to evaluate the basic aerodynamic characteristics of aircraft configurations.

1 Introduction (3 hours)

1.1 Fundamental aerodynamic variables
1.2 Lift, drag, moment and related coefficients
1.3 Types of drag: Parasitic drag and induced drag
1.4 Types of flow: Continuum versus free molecule flow, inviscid versus viscous flow, incompressible versus compressible flow, Mach number regimes

2 Fundamental Principles and Equations (6 hours)

2.1 Vector operations
2.2 Fluid flow models: Control volume, infinitesimal fluid element, molecular
2.3 Conservation equations (Mass, momentum and energy)
2.4 Substantial derivative
2.5 Pathlines, streamlines, and streaklines of a flow
2.6 Pressure distribution and force integration

3 Inviscid, Incompressible Flow (12 hours)

3.1 Bernoulli's equation, low-speed wind tunnel flows
3.2 Governing equations and boundary conditions
3.3 Elementary flows (Uniform, sources, sinks and vortex)
3.4 Ideal lifting flow past a circular cylinder
3.5 Kutta-Joukowski theorem and lift generation
3.6 Source panel method for non-lifting flows
3.7 d'Alembert's paradox

4 Incompressible Flow Over Airfoils (12 hours)

- 4.1 Airfoil nomenclature and characteristics
- 4.2 Kutta condition and Kelvin's circulation theory
- 4.3 Thin airfoil theory (Symmetric, cambered)
- 4.4 Aerodynamic center
- 4.5 Vortex panel method for lifting flows
- 4.6 Qualitative picture of viscous flow

5 Finite Wing Theory (9 hours)

- 5.1 Downwash and induced drag
- 5.2 Vortex filament, Biot-Savart Law and Helmholtz's Theorems
- 5.3 Prandtl's lifting line theory: Elliptical and general lift distribution, effect of aspect ratio
- 5.4 Numerical lifting-line method
- 5.5 Case study of delta wings

6 Three-Dimensional Incompressible Flow (3 hours)

- 6.1 Three-dimensional source and doublet
- 6.2 Flow over a sphere: Relieving effect
- 6.3 Panel techniques for three-dimensional flows
- 6.4 Case study of flow over a sphere
- 6.5 Applied aerodynamics: Airplane lift and drag

Tutorial (15 hours)

1. MATLAB: Elementary flows
2. Calculation of lift on NACA airfoil tested in wind tunnel
3. Problems related to thin airfoil theory
4. Implementation of vortex panel method in MATLAB
5. Problems related to Prandtl's lifting line theory
6. Numerical problems on lifting-line method

Practical (22.5 hours)

1. Application of dimensional analysis for wind tunnel testing
2. Testing and instrumentation: Methods of qualitative and quantitative analysis
3. Flow visualization: Smoke flow
4. Flow visualization: Schlieren
5. Flow visualization: Particle Image Velocimetry
6. Determination of lift coefficient of an airfoil
7. Determination of drag coefficient of an airfoil

Final Exam

The questions will cover all the chapters in the syllabus. The evaluation scheme will be as indicated in the table below:

Chapters	Hours	Marks distribution*
1 and 2	9	10
3	12	20
4	12	20
5 and 6	12	10
Total	**45**	**60**

* There may be minor deviation in marks distribution.

References

1. Collinson, Anderson, J. D. (2017). Fundamentals of aerodynamics. McGraw-Hill.
2. Bertin, J. J., Smith, M. L. (2013). Aerodynamics for engineers. Pearson.
3. Kuethe, A. M., Chow, C.-Y. (1997). Foundations of aerodynamics: Bases of aerodynamic design (Latest Edition). Wiley.
4. Katz, J., Plotkin, A. (2001). Low-speed aerodynamics: From wing theory to panel methods (Latest Edition). Cambridge University Press.