The Hong Kong University of Science and Technology

UG Course Syllabus

Aerodynamics

MECH 3640

3 credits

Pre-requisites: CENG 2220 or CIVL 2510 or MECH 1907 or MECH 2210

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Course Description

This course examines the flow phenomena governing flight vehicle motion in aerospace engineering, from subsonic to supersonic regimes. Students will be able to calculate aerodynamic forces, such as lift and drag, in simplified scenarios and explain other physical effects in aerodynamics.

The course extends fundamental concepts in fluid mechanics to aerospace applications. It covers incompressible inviscid flow around 2D airfoils, 3D effects for finite-span wings, viscous phenomena, and compressibility effects in high-speed flows (see below for the Course Outline).

The course is delivered via weekly lectures and tutorials, while assessment is conducted via homework assignments and a final examination. Students will also engage in an integrative project involving wind tunnel experiments and numerical simulations. This comprehensive approach ensures a robust balance between theoretical understanding and practical application in the field of aerodynamics.

Intended Learning Outcomes (ILOs)

By the end of this course, students should be able to:

1. Apply the basic tools of incompressible inviscid aerodynamic analysis to estimate lift for an airfoil.
2. Explain and quantify the effects of viscosity on airfoil performance.
3. Explain the differences in aerodynamic performance between an infinite-span (2D) airfoil and a finite-span (3D) wing.
4. Account for the effects of compressibility in aerodynamics.

Assessment:

Assessment Tool	Contribution to Overall Course grade (%)
Homework	20%
Project	40%
Final examination	40%

Required Texts and Materials

The main textbook for this course is *Fundamentals of Aerodynamics* (John D. Anderson).

Course AI Policy

The use of generative artificial intelligence (AI) is permitted for the homework and project.

Course Outline

1. Introduction + Basic Concepts in Fluid Dynamics [L1−4]
   - A brief history of flight
   - Conservation laws for mass and momentum
   - Streamlines, vorticity, stream function, velocity potential, Laplace's equation
   - Terminology in aerodynamics
   - Circulation, irrotationality, linear superposition of potential flows
   - Bernoulli's equation, Kutta−Joukowski theorem for lift prediction
2. Incompressible Flow around Airfoils (2D) [L5−7]
   - Vortex strength distribution, streamline condition, Kutta condition
   - Thin airfoil theory (TAT): lift and moment coefficients for symmetric and cambered airfoils, angle-of-attack effects, airfoil-shape effects
   - Lift and drag polar curves, stall characteristics, high-lift devices
   - Failure of TAT: vortex panel method as an alternative tool
3. Incompressible Flow around Wings (3D) [L8−10]
   - Effects of finite wingspan: trailing vortices, downwash velocity, induced drag
   - Flow physics near the wingtip: 2D airfoils vs 3D wings
   - Lifting line theory (LLT): lift and induced drag for untwisted elliptical wings and twisted generic wings
   - Design considerations: wing taper, aspect ratio, wingtip devices, parasite drag
   - Failure of LLT: vortex lattice method as an alternative tool
4. Viscous Effects in Incompressible Flow [L11−12]
   - Blasius' theory for a laminar boundary layer over a flat plate
   - Basic characteristics of turbulent flows
5. Basic Concepts in Compressible Flow [L13]
   - Speed of sound, Mach cones, isentropic flow in a duct
   - Choking, supersonic flow in a 1D converging−diverging nozzle
6. Shock Waves + Expansion Fans [L14−16]
   - Normal shocks, oblique shocks
   - Prandtl−Meyer expansion fans
7. Airfoils in Compressible Flow [L17−18]
   - Derivation of the full potential equation
   - Linearized potential equation for small disturbances
   - Subsonic regime: Prandtl−Glauert similarity transformation, similarity rules, subsonic wings
   - Supersonic regime: wave equation, linearized pressure coefficient, calculation of lift and wave drag, comparison with shock-expansion theory
8. Airfoils in Transonic Flow [L19−20]
   - Critical Mach number, transonic drag rise, drag-divergence Mach number
   - Design considerations: sweep-back, supercritical airfoils, area rule