AE 3030 – Aerodynamics

HOURS: 4-0-4

CATALOG DESCRIPTION:

Aerodynamics of airfoils and wings in subsonic, transonic and supersonic flight. Laminar and turbulent boundary layers and effects of viscosity on aerodynamic performance.

PREREQUISITES:

AE 2010 Thermodynamics and Fluids Fundamentals

COURSE OBJECTIVES:

Students will:

1. Learn how lift, drag and pitching moment are generated
2. Learn airfoil and wing geometric parameters and aerodynamic performance characteristics (C_p, C_l, C_m, C_d, Drag Polar)
3. Learn similarity parameters, physical characteristics and aerodynamics trends associated with continuum flow regimes (Subsonic, Transonic, Supersonic, Hypersonic, Steady, Unsteady, Viscous, Inviscid)
4. Learn how the Potential Flow approach can be used to predict incompressible and compressible aerodynamics
5. Learn the boundary-layer concept for modeling the effects of viscosity
6. Be introduced to Non Continuum Flows / Non Newtonian Fluids
7. Be introduced to the Computational Fluid Dynamics (CFD) approach

LEARNING OUTCOMES:

Students will be able to:

1. Use analytical methods to estimate lift and drag (including viscous effects) on airfoils, wings and bodies of revolution in subsonic and supersonic flight.
   - Thin Airfoil Theory, Finite Wing Theory, compressibility corrections, transonics, sweep effects, area rule, supersonic linearized theory, shock expansion wave method, Newtonian Theory, flat plate boundary layer results in laminar/turbulent flow
2. Use numerical methods to calculate aerodynamic loads and moments (including viscous effects) on 2-D and 3-D bodies in in incompressible and compressible flow
   - Panel methods and integral boundary layer methods
3. Describe physical characteristics (including momentum and thermal) of laminar and turbulent boundary layers, transition and separation

TOPICAL OUTLINE:

1) Aerodynamics Intro and Course Overview *(1 hour)*
2) Fluid Motion Basics *(1 hour)*
   - Streamlines, pathlines, steady vs. unsteady, rotation and vorticity, boundary layer
3) Viscous Flow *(21 hours)*
   - Incompressible *(16 hours)*:
     - Simple solutions to the Navier-Stokes equations, boundary layer equations: exact solutions, Blasius solution, pressure gradient effects
     - Physics of turbulence and its effects, turbulent flat plate solutions, factors affecting transition
     - Momentum Integral Method, Thwaites Method, Head's Method, Squire-Young formula for drag, empirical methods for transition estimate, Michel's Criteria
   - Overview of Non-Newtonian fluid effects on skin friction

     Compressible *(5 hours)*:
     - Compressibility corrections to boundary layer equations, prediction of skin friction and heat transfer

4) Potential Flow *(2 hours)*
    - Derivation of Velocity Potential Equations for Compressible and Incompressible Flows
5) Low Speed Aerodynamics *(15 hours)*
    - Elementary solutions for incompressible Potential Flow: uniform flow, source/sink, doublet, vortex *(1 hour)*
    - Flow around 2-D cylinder, concept of circulation, Kutta-Joukowsky Theorem, drag in separated flow, Cp distribution *(3 hours)*
    - Airfoils *(6 hours)*:
    - Thin Airfoil Theory, Kutta Condition, Cl, Cm, lift curve slope, center of pressure, aerodynamic center
    - Overview of panel methods, numerical tools for prediction of skin friction drag around airfoils
6) Wings *(5 hours)*:
    - Physical characteristics, trailing vortices, vortex sheet, starting vortex, downwash, induced drag, effect of aspect ratio
    - Prandtl's lifting line theory and numerical tools
    - Induced drag, elliptical lift distribution, span efficiency factor, drag polars including viscous effects,
    - Vortex dominated flows and leading edge vortices
7) High Speed Aerodynamics *(15 hours)*
8) Derivation of Linearized Potential Flow Equation, small disturbance approximations *(1 hour)*
    - Subsonic Flow over Airfoils *(3 hours)*
        - Prandtl-Glauert Rule, compressibility corrections and effects on lift, drag and Cp distribution
    - Subsonic Flow over Wings and Bodies *(3 hours)*
        - Modifications to lifting line analysis to include compressibility effects, Potential Flow over Body of Revolution using Gothert's Rule, closed form expressions for Cp and Cd
    - Transonic Effects on Airfoils, Wings and Bodies of Revolution *(4 hours)*
        - Transonic flow effects on Cl, Cd, Cm and Cp, finding Critical Mach Number of airfoils and bodies of revolution, Wave drag, Drag divergence; elimination of drag rise by sweep, area rule, supercritical airfoils.
    - Supersonic and Hypersonic Flow Prediction *(4 hour)*
        - Determination of lift and drag using linearized supersonic flow, shock-expansion wave theory, Newtonian Theory, Modified Newtonian Theory
9) Computational Fluid Dynamics *(2 hours)*
    - Overview of Reynolds Averaged Navier-Stokes (RANS) approach and capabilities
    - Understanding and exposure to numerical flow analysis process: grid generation, flow solution, post processing

Exams *(3 hours)*