EM731 “Aeroelasticity”

Spring 2012, Tuesdays and Thursdays, 7:00PM-8:15PM
Engineering Bldg, Room E 423B
San Diego State University
Instructor: Dr. Luciano Demasi

Course objectives

The objective of this course is to teach the fundamentals of aeroelasticity. The course provides the necessary background on aerospace structural dynamics and aerodynamics with particular emphasis on the interaction fluid-structure which is typical of aeroelasticity. The course will also introduce the computational tools for the aeroelastic analysis and design of innovative airplane configurations including Joined Wings. The students will gain the theoretical background on the frequency-domain unsteady aerodynamic panel codes used by the industry (e.g., Doublet Lattice Method) and their coupling with structural commercial Finite Element Method software.
Leading commercial software such as **ZAERO** and **NASTRAN** will be discussed. The theory part will be complemented with practical training in using **FEMAP** and **NASTRAN**.

Course Outline

- *Review of structural dynamics concepts*
  - Degrees of Freedom
  - Generalized Coordinates
  - Equations of Motion
  - Mass, Stiffness and Damping matrices
  - Virtual Displacements
  - Virtual Work
  - Generalized Forces
  - Lagrange Equations
  - Natural Modes and Frequencies
  - Reduced Order System of Equations of Motion
  - Continuum Systems
  - Extensional Stiffness, Bending Stiffness, Torsional Stiffness
  - Geometric Conditions
  - Natural Conditions

- *Static aeroelasticity*
    - Divergence
    - Aileron Reversal, Efficiency of the Aileron
    - Uniform Lifting Surface
        - Shear Center
        - Elastic Axis
        - Torsional Divergence
        - Airload Distribution for an Elastic Wing
        - Sweep Effects (Swept-Back and Swept-Forward Wings)
        - Load Distribution for Elastic Swept-Back and Swept-Forward Wings

- *Unsteady Aerodynamics*
    - Substantial Derivative
    - Local Derivative
    - Convective Derivative
    - Compressible Isentropic and Inviscid Flow
    - Continuity Equation
    - Momentum Equation
    - Isentropic Relation
    - Speed of Sound
    - Mach Number
    - Circulation
    - Vorticity
    - Rotational Flow
    - Irrotational Flow
    - Velocity Potential
    - Bernoulli's Equation
    - Lord Kelvin Equation
    - Kelvin's Circulation Theorem
    - Boundary Conditions
    - Linearization of the Equations
    - Small Perturbation Velocity Potential
    - Pressure Coefficient
    - Acceleration Potential
    - Two-Dimensional Incompressible Case
    - Harmonic Oscillations of an Airfoil
    - Mathematical Definition of the Reduced Frequency
    - Physical Interpretation of the Reduced Frequency Concept

- *The Doublet Lattice Method*
    - Normalwash
    - Unsteady Aerodynamic Kernel
    - Aerodynamic Mesh
    - Concepts of Load Point and Control Point
    - Concepts of Receiving and Sending Panels
    - Normalwash Factor
    - Generalized Aerodynamic Force Matrix
    - Summary of the Vortex Lattice Method Theory for the Steady Case
    - The Infinite Plate Spline Method

- *Introduction to the Concept of Aeroelastic Flutter*
    - Physical Interpretation of the Classical Flutter
    - Modal Damping and Modal Frequency
    - Concepts of Stability, Stability Boundary and Instability
    - Calculation of the Flutter Speed via P-Method
    - Concept of Coalescence of Modal Frequencies
    - Two-Degree-of-Freedom Flutter Model
    - Engineering Solutions for Flutter
        - Review on the Structural Damping and Introduction to the K-Method
        - Concept of Dummy Structural Damping
        - P-K Method
        - Concepts of Violent Flutter, Moderate Flutter and Mild Flutter
        - Prediction of the Divergence Speed with a Flutter Analysis
        - Comparison Between the P Method and K Method
        - G method

- *Derivation of the Aeroelastic Equations in the Time Domain*
- *Derivation of the Aeroelastic Equations in the Frequency Domain*
- *Derivation of the Aeroelastic Equations in the Laplace Domain*
- *Lag Effects*
- *Least Square Method*
- *Rational Form for the Generalized Aerodynamic Force Matrix*
- *Roger Approximation*
- *State Space Representation of the Aeroelastic Equations in the Laplace Domain*
- *Aerodynamic Lag States*
- *Calculation of the Flutter Speed via Root Locus Technique*
- *Nonlinear Aeroelasticity: Consistent Flutter and Divergence Speeds*
- *Linearized Flutter Calculation*
- *Limit Cycle Oscillation*
- *Modally Reduced Order Aerodynamic Model*
- *Aeroelasticity of Joined Wing Configurations: problems and challenges*
- *Calculation of Natural Frequencies and Modes with **FEMAP** and **NASTRAN***
- *Computational Static Aeroelasticity using the software **FEMAP** and **NASTRAN** and Calculation of the Divergence Speed of Different Planar and Non-Planar Wing Configurations*
- *Computational Dynamic Aeroelasticity using the software **FEMAP** and **NASTRAN** and Calculation of the Flutter Speed of Different Planar and Non-Planar Wing Configurations*
- *Calculation of the Divergence Speed via Flutter Analysis with the software **FEMAP** and **NASTRAN***
- *Discussion of other commercial software for aeroelastic analysis such as **ZAERO***

Note: the content of the course may change depending on student's interests and time constraints