

ME/CEE 426-1 Advanced Finite Element Methods I

Instructor: Dr. Mark Fleming

Class Schedule: Tu/Th 3:30 – 4:50 pm

The finite element method is a powerful tool for obtaining accurate solutions for a wide range of engineering problems. This method can be used for stress analysis in many areas and disciplines, including automotive crashworthiness, rockets blasting into space, and biological tissue modeling. This class will focus on non-linear finite element methods for structural applications. Students will learn the fundamentals and implementation of the non-linear finite element method, as well as state-of-the-art engineering applications.

Course Objectives

- Understand fundamentals and implementation of the non-linear finite element method
- Learn explicit and implicit solution techniques for finite element problems
- Learn fundamentals of modal vibration analysis using finite elements
- Learn the implementation of the finite element method through Matlab programming
- Apply the finite element method to solve stress analysis problems using professional software (Abaqus)

Applications

- Computational fracture mechanics
- Large deformation analysis
- Manufacturing analysis
- Impact analysis (vehicle crashworthiness, electronics drop testing)
- Modal vibration analysis
- Analysis involving non-linear materials
- Modeling rubber materials
- Modeling soils and granular material

Homework

There will be approximately five homework assignments during the quarter. The homework assignments will be used to reinforce the fundamentals of the theory being taught.

Computer assignments

There will be one Matlab programming assignment and one Abaqus software assignment. For the Matlab assignment, students will modify an existing code to learn the implementation issues of non-linear finite element analysis. For the Abaqus assignment, students will learn FEA applications by solving a structural analysis engineering problem.

Grading

Homework (25%), Computer assignments (25%), Midterm (25%), Final Project (25%)

Textbook

Most of the fundamentals and theory will be taught from the following:

Ted Belytschko, Wing Kam Liu, Brian Moran (2014). Nonlinear Finite Elements for Continua and Structures. *John Wiley & Sons, Ltd.* [2014 edition]

Software

Matlab will be used for the programming assignment.

Abaqus finite element software will be used for FEA application assignment.

Course Outline

1. Introduction to non-linear finite element analysis
2. Fundamentals of non-linear finite elements in 1D
 - a. Total Lagrangian and updated Lagrangian FEA formulations
3. Continuum mechanics for solids and structures
 - a. Deformation and motion
 - b. Strain and stress
 - c. Governing equations
4. Non-linear FEM solution methods
 - a. Explicit dynamics analysis
 - b. Implicit methods for quasi-static and dynamic analysis
 - c. Linearization and stability analysis
5. Basics of non-linear FEA using Abaqus
6. FEA application: Computational fracture mechanics
7. Constitutive material models for finite element analysis
 - a. Linear elasticity
 - b. Nonlinear elasticity for rubber like materials
 - c. Plasticity
 - d. Granular materials
8. Non-linear finite elements in multiple dimensions
 - a. Updated Lagrangian formulation and implementation
 - b. Corotational formulations