Advanced Finite Element Analysis-ME712

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Office Hrs: MWF 10:00pm-11:00 am
Course website: https://bb.ndsu.nodak.edu/
Course Scheduling: MWF 11:00om-12:0 pm Dolve 117
Text: The following reference textbooks can be benefited.

Reference Textbooks

1. The Finite Element Method in Engineering, 5th edition, S S Rao, Elsevier, 2011.
2. Finite Element Modeling and Simulation with ANSYS Workshop, X. Chen, Y. Liu, CRC Press,2015
3. Advanced Topics in Finite Element Analysis of Structures, M. Asghari Bhatti, J Wiley 2006
4. An Introduction to the Finite Element Method, J.N. Reddy, McGraw-Hill, 2006.
5. Nonlinear Finite Elements for Continua and Structures, T. Belytschko, W .K. Liu, and B. Moran, Wiley 2000.
6. Concepts and Applications of Finite Element Analysis, Robert Cook, David Malkus, Michael Plesha, and Robert Witt, J. Wiley, 2002.
7. Finite Element Procedures / Klaus-Jürgen Bathe / Prentice-Hall, 1996
8. The Finite Element Method, Vol. 2, Solid Mechanics, Zienkiewicz, O. C. with R. L. Taylor, Butterwort-Heinemann, 2000
9. The Finite Element Method, Vol. 3, Fluid Mechanics, Zienkiewicz, O. C. with R. L. Taylor, Butterwort-Heinemann, 2000
10. Finite Elements of Nonlinear Continua, J. T. Oden, J Wiley, 1984.
11. Introduction to finite element analysis and design, N-H Kim and B.V. Sankar, J Wiley, 2018.
12. Fundamentals of Finite Element Analysis, D. Hutton, McGraw-Hill, 2004.

Prerequisites

BS in Mechanical, Civil, Structural or related engineering fields. Completion of first course in finite element analysis and first course in continuum mechanics is helpful.

Overview

This course will present the fundamentals of finite element method (FEM) formulations for linear and nonlinear solid and structural mechanics. It also covers the application of FEM to heat transfer and fluid mechanics problems. Basic concepts of continuum mechanics will be reviewed as necessary to provide the theoretical basis for general FE modellings. The course will emphasize on the theoretical basis and provides the general view of FE analysis procedures that can be applied using specially developed research computer programs. Some topics to be covered are: variational formulations, isoparametric formulations, linear/nonlinear solid mechanics formulations, large deformation analysis, beams and plates, material nonlinearities (nonlinear elastic, viscoelastic, elastoplastic), dynamics analysis, fluid mechanics, and contact analysis. The course is intended to provide the graduate students with a firm grasp theoretical base for solving solid and structural mechanics problems having material and/or geometric nonlinearity.

Lecture Topics

The lectures are to be selected from the following general outline/list:

Introduction to FEM
Finite element Solid Mechanics Analysis
Isoparametric Formulation

FEM in Fluid Mechanics and Heat Transfer Analysis
FEM in Beams and Plates Analysis
FEM in Eigenvalue and Time-Dependent Problems
Finite Elements in Nonlinear Solid and Structural Mechanics Analysis

- Concepts in Nonlinear Continuum Mechanics
- FEM implementation to material and geometrical nonlinearities
- FEM in dynamics and time-dependent problems
- FEM in contact and failure analysis

Implementation of the Finite Element Method

Grading

1. Mid-Term Exams 40%
2. Final Exam - 25%
3. Homework Assignments - 20%
4. Term Paper/Projects, including oral and written progress report - 15%

The homework problems are based on lecture materials.

Term Paper/Project

Term paper will include a critical, comprehensive review of a key reference topic as well as computer program development (project) or numerical solution utilizing the ANSYS, LSDyna or ABAQUS finite element programs. The term paper and project are focusing on the same topic. The research topic is to be selected after consultation with the instructor. Usually the topic of the term paper/project will be selected based on student background and interest or from a list of topics supplied by the instructor.

Term Paper/Project Purpose

The purpose of the term paper/project is to give the students the opportunity to investigate a specific subject with its related FE computational methods. Each student will have to (1) search for the relevant literature to gain an understanding of the topic, (2) present a summary of his/her findings in a research paper, (3) presents a lecture to the class regarding the topic including his/her understanding and contribution.

Also, the following purposes are sought by the literature search and presentation:

- Exploring a topic in greater detail than is possible in class,
- Developing literature research skills,
- Developing proficiency in write papers for technical audiences, and
- Developing proficiency in lecturing and making presentations to technical audiences

Literature review section of the term paper/project

The literature review should begin immediately. As the literature search proceeds, students should consult frequently with the instructor in order to guide the research and to help identify the key paper(s) that are to be reviewed. The key authors, abstract, bibliography for each paper identified should be kept (in electronic form) and serve as a starting point for the literature search. The objective is to identify and review several of the most recent publications (last 5 years) on the subject areas.

Format of the Term Paper

Minimum length of paper: 15 pages of single-spaced format (excluding abstract, tables, figures, references).

An electronic version of the paper is to be submitted to the instructor. Progress report, power point or word processor file, etc. should also be submitted.

Computer Programming and/or **FE Software package**

If appropriate, and in order to carry out the project a computer program is to be written in MATLAB, FORTRAN or any other structured language. Use of subroutines is encouraged and statement numbers should appear in a monotonically increasing order. Include comment statements as necessary. Listing of the program must be submitted with solution. The program must also be submitted to the instructor at the end of the semester.

Students may choose to run your project by a FE package such as LS-Dyna, ANSYS, ABAQUS, …. A complete report on the elements used, the characteristics of elements and the solution procedure is required.

Tentative Term-Paper Topics

FEM in composite analysis
FEM contact-impact analysis
FEM in fatigue/fracture mechanics
Obtain the tangential stiffness matrix for shell element and geometrical nonlinear (full derivation)
Locking phenomenon plate and shells (shear, membrane and volumetric locking)
Various strategies in the solutions of Navier-Stokes problems (a detailed 2-d or 3-d example)
Viscoelastic formulations and implementations
Adaptive meshing in nonlinear FE
Finite elements in vibration and stability analysis
Finite elements for simultaneous heat transfer & fluid flow
Finite elements in biomedical engineering

Oral Presentation

(25% of the research paper weight) -- Each student must prepare a 25-minute lecture and be prepared to answer 5 minutes of questions from the class and instructor.

The following factors would determine the Term paper/Project grade:

- Understanding the subject and novelty and contribution
- Clarity and completeness of report
- Presentation flow and style and relevancy
- Details of the examples in your presentation
- Efforts spent on the work

Organization of the Term Paper

- Abstract (1 page maximum)
- Introduction.
- Review of the literature associated with your subject
- Reasons for this study, i.e. give the engineering and scientific relevance for the paper.
- Body of the paper
- Summary of the theoretical formulation of the problem
- Numerical finite element model details including; assumptions and idealization of the formulations and the domain or the structure, material model(s), initial/boundary conditions. Provide justification or reasons for each assumption. Report and discuss any analytical and experimental observations or studies that are relevant to the model(s). Give specific details of other models that may have been considered, if appropriate. Underline your contribution in places and if any.
- Numerical results including tabular and graphic/plots of the FE analysis
- Conclusions and Recommendations
- Bibliography- use standard and complete citations. These references should give the complete citation of the paper, book, etc; i.e. title, authors, journal, vol, date, page. Use a consistent format for the citations in both lists.
- Tables and Figures

Due Dates

10/06/23	Abstract + Outline of Term Paper/Project. The Abstract should be one page (single-spacing). The Outline (two pages, maximum) should provide a general overview of the paper, note key references, and describe briefly the FEM strtegy associated with the project.
11/06/23	Progress Report. Expanded more detailed form of 10/06/23 as a written brief to instructor
12/04/23	Starting Student Presentations in class (hard copies/ppt to instructor)
12/08/23	Research Paper/Project (hard copy and electronic versions of term paper).
12/14/23	final exam.

NDSU Academic Honesty Statement and CEA Honor System

All work in this course must be completed in a manner consistent with NDSU University Senate Policy, Section 335. Code of Academic Responsibility and Conduct (available on the Web at http://www.ndsu.edu/fileadmin/policy/335.pdf). Violation of this code will result in a penalty or penalties to be determined by the instructor to fit the gravity of the offense and the circumstances of the particular case. The instructor may: (1) fail the student for the particular assignment or test, (2) give the student a failing grade in the course, or (3) recommend that the student drop the course.

Students taking CoE courses are required to sign the Honor Pledge at the beginning of each semester as outlined below. "On my honor I will not give nor receive unauthorized assistance in completing assignments and work submitted for review or assessment. Furthermore, I understand the requirements in the College of Engineering and Architecture Honor System and accept the responsibility I have to complete all my work with complete integrity."

The Engineering Honor System can be found on the CEA homepage at http://www.ndsu.edu/coe/undergraduate_students/honor_code/

Attendance

Students should realize that there are materials covered in class which are not discussed in the textbook. The student is responsible for ALL material presented in class whether or not he or she was present in class. If they miss a class, it is the student's responsibility to obtain notes from a classmate. Full credit can be received for work turned in late due to an excused absence. It is the student's responsibility to contact the instructor in such a case. If the student is going to miss a test for a good reason, he/she should telephone or e-mail the instructor BEFORE the test to arrange for a make-up exam.

Disabilities

Any student with disability who needs accommodations is encouraged to speak with the instructor as soon as possible to make appropriate arrangements for those accommodations.