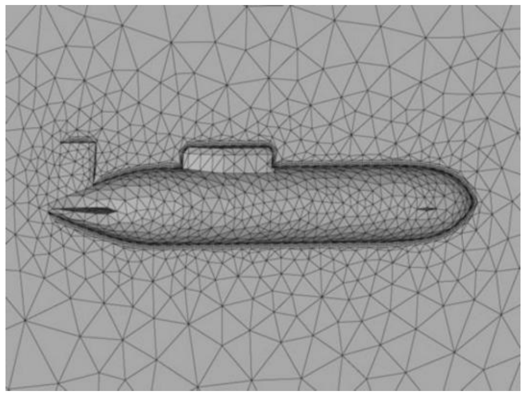
2.094

Finite Element Analysis of Solids and Fluids

Spring 2008, TR 11:00-12:30 (Room 1-390)



The objective is to teach in a unified manner the fundamentals of finite element analysis of solids, structures and fluids. This includes the theoretical foundations and appropriate use of finite element methods.

TOPICS

- The formulation of finite element methods for **linear static analysis of solids and structures**:
    - Two- and three-dimensional solids
    - Beam, plate and shell structures

- The displacement-based finite element procedures, when they are effective, and mixed finite element methods for almost incompressible media and beams, plates and shells.

- The formulation of finite element methods for **nonlinear static** analysis:
    - Geometric nonlinearities (large displacements and large strains)
    - Material nonlinearities (nonlinear elasticity and elasto-plasticity)

- The formulation of finite element methods for the analysis of **heat transfer** in solids: conduction, convection and radiation conditions

- The formulation of finite element methods for **fluid flows**:
    - Incompressible flows
    - Navier-Stokes equations including heat transfer

- The formulation of finite element methods for **fluid-structure interactions:**
    - Acoustic fluids coupled to structures
    - Navier-Stokes fluids coupled to structures

- The **appropriate use** of finite element procedures:
    - Setting up an appropriate model
    - Interpreting the results, and assessing the solution error

The methods studied in this course are practical procedures that are employed extensively in the mechanical, civil, ocean and aeronautical industries. Increasingly, the methods are used in computer-aided design.

VARIOUS

Instructor:	Professor Klaus-Jürgen Bathe Room: 3-356, Tel x3-6645 Office hours: by appointment
T.A.:	Do-Nyun Kim Room: 3-359, Tel x3-0071 Email: <kingddo@MIT.EDU> Office hours: Tuesdays 3-5pm or by appointment
Prerequisites:	Undergraduate statics and mathematics
Textbook:	***Finite Element Procedures***, K.J. Bathe. Prentice Hall, 1996 You will find references to special topics in the textbook.
Web page:	http://web.mit.edu/2.094/www
Request:	While this class is held during what is for some a lunch hour, please refrain from eating (drinking is allowed). Also, please do not chat and do not use your laptop during the lecture.
Grades:	The student's course grade will be based on:

- Weekly homework, given out Thursdays and to be handed-in the following Thursday, except no homework due on exam days

- Term project, due May 1, 2008
  (project proposal due March 4, 2008)

- Two 1½ hour exams: on April 1 and May 8, 2008.

The April 1 exam tests on all material presented in the course up to and including the lecture of March 13.
The May 8 exam tests on all material presented in the course.

READING ASSIGNMENTS

The reading assignments will be given in the lectures and will refer to the textbook ***Finite Element Procedures***. We will discuss specific material in Chapters 1, 3, 4, 5, 6, 7 and 8.

Other complementary reading material:

- Inelastic Analysis of Solids and Structures, M. Kojic and K.J. Bathe, Springer, 2005.

- The Finite Element Analysis of Shells – Fundamentals, D. Chapelle and K.J. Bathe, Springer, 2003.

COMPUTER ASSIGNMENTS

You will not be required to develop a computer program. However, some homework will require that you use the graphical user interface of the finite element program system ADINA. For this purpose you will obtain a 900-nodes PC version of ADINA which you can freely install. The manuals for the program are also on the CD.

TERM PROJECT

Every student is required to complete a term project. The objective of this task is that each student obtains hands-on experience in solving analysis problems using a typical finite element code. The term project should address a problem solution in solids and structures, fluid flows or fluid-structure interactions using ADINA.

Some suggested projects:

1. Large deformation analysis of a rubber sheet with holes.
2. Large deformation analysis of a thick-walled rubber cylinder subjected to internal pressure.
3. Large displacement collapse analysis of an elastic thin structure (beam, plate, shell structure).
4. Elasto-plastic collapse analysis of a structure, for example a truss bridge.
5. Thermal stress analysis of a structure.

6. Analysis of fluid flow in a chamber or around an obstruction.
7. Analysis of a forced or natural convection fluid flow problem.
8. Analysis of a problem related to your research.
9. Develop a nonlinear finite element program based on STAP (see textbook)

Note: Please choose a (tractable) problem that you can analyze in depth in the very limited time available.

The project work is typically started around the beginning of March and typically involves the following steps:

- Choose **a physical problem** and consider **a "simple" mathematical model** of the problem (geometry, loading, material data, boundary conditions) such that in the first instance you can compare your finite element solution results with some analytical results.

- Solve this **"simple" mathematical model** using ADINA. Obtain an accurate solution by choosing appropriate elements and meshes.

- Next **increase the complexity of the mathematical model** (for example, assume that the material response is nonlinear) and re-solve. Obtain an accurate solution. Ask "what if" questions and experiment with the finite element method.

- In each case, **interpret the calculated response** considering the accuracy of the solution of the mathematical model and the adequacy of the mathematical model for the physical problem.

Please hand-in on March 4, 2008 a short description (a few sentences) of the project you would like to select. This description must be approved for you to proceed.