Engineering Tripos Part IIA, 3D7: Finite Element Methods, 2023-24

Module Leader

Prof F Cirak [1]

Lecturers

Prof F Cirak, Dr B Liu

Lab Leader

Prof G Wells [2]

Timing and Structure

Lent term. 16 lectures and coursework.

Aims

The aims of the course are to:

- Provide an introduction to the finite-element (FE) method, which is widely used to obtain numerical solutions to engineering problems.
- Explain the key ideas of the FE approach, cover its theoretical foundations, and present some illustrative applications.

Objectives

As specific objectives, by the end of the course students should be able to:

- Develop the weak form of the governing equation for various problems.
- Explain the difference between strong and weak formulations.
- Compute shape functions in one, two and three dimensions for different elements.
- Obtain the stiffness and mass matrices and the right-hand side vector for different elements.
- Explain the idea and motivation behind isoparametric formulations.
- Apply numerical integration on different finite elements.
- Assemble the stiffness and mass matrices for a mesh.
- Explain how to apply various loadings and boundary conditions.
- Generate suitable meshes for different problems.
- Set up a finite element mesh, apply appropriate boundary conditions and solve the resulting system in a finite element program.
- Appreciate sources of errors associated with finite element analysis.
- Explain key features of different methods for time-dependent problems.

Content

Introduction to finite element analysis (1L Dr B Liu)

- Overview and key ideas

- Modelling and applicability

Elastic rods and beams (3L Dr B Liu)

- Strong and weak equations of static rods
- Linear shape functions in one dimension
- Assembly and application of boundary conditions
- Construction of higher-order shape functions
- Euler beams and Hermitian shape functions

Heat conduction and elasticity in two and three dimensions (8L Prof F Cirak)

- Strong and weak formulations for heat conduction
- Shape functions for two and three dimensional elements
- Isoparametric mapping and numerical integration
- Application of boundary conditions
- Assembly of element matrices and vectors
- Stability considerations
- Generalisation to elasticity
- Aspects of solid modelling and meshing

Modelling issues (2L Dr B Liu)

- Model analysis and critical time step
- Error estimates and convergence of finite element method

Time dependent problems (2L Dr B Liu)

- Strong and Weak formulation for time-dependent problems
- Consistent and lumped mass matrix
- Explicit and Implicit time integration

Coursework

Use of a finite-element package to solve a stress-analysis problem related to the experiment performed in Module 3C7.

Computational Stress Analysis

Learning objectives:

- Quantify the choice of elements on the obtained results.
- Identify the importance of the choice of boundary conditions.
- Compare finite element results with experimental and analytical results.
- Explore the influence of mesh refinement on computed results.

Practical information:

- The coursework can be completed remotely. Support session will he held online.
- This activity involves the installation/configuration of software. Instructions will be provided.
- 3C7 experimental data can be obtained from the Lab Leader.

Full Technical Report:

Students will have the option to submit a Full Technical Report.

Booklists

Please refer to the Booklist for Part IIA Courses for references to this module, this can be found on the associated Moodle course.

Examination Guidelines

Please refer to Form & conduct of the examinations [3].

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Links
[1] mailto:fc286@cam.ac.uk
[2] mailto:gnw20@cam.ac.uk
[3] https://teaching.eng.cam.ac.uk/content/form-conduct-examinations