ES98F-15 Modelling and Simulation of Engineering Materials

23/24

Department
School of Engineering
Level
Taught Postgraduate Level
Module leader
Lukasz Figiel
Credit value
15
Module duration
10 weeks
Assessment
60% coursework, 40% exam
Study location
University of Warwick main campus, Coventry

Description

Introductory description

This module will provide students with fundamental principles and practical aspects of modelling and simulation with the Finite Element Method to analyse advanced engineering materials (e.g. composite materials) through lectures, case studies and workshop activities.

Module aims

The principal aim is to provide students with a firm foundation in the engineering simulations techniques using the Finite Element Method, and apply it to predict an overall behaviour of advanced engineering materials from their microstructures.

The classical Finite Element Method approach to solving the equations of solid mechanics will be covered, but our primary focus will be to explore and understand recent approaches to predicting performance for advanced engineering materials by connecting the Finite Element Method with multiscale homogenization approaches, both in the linear and non-linear regimes.

Outline syllabus

This is an indicative module outline only to give an indication of the sort of topics that may be covered. Actual sessions held may differ.

1. Introduction (Week 1) - overview of the main concepts and challenges related to the modelling and simulation of advanced materials
2. Revision of the main concepts from solid mechanics (Week 1 and 2) - deformation, strain, tractions, stress, balance laws and constitutive laws, examples of PDEs for mechanics-related problems
3. General formulation of Finite Element Method equations (Week 3) - weak form, Galerkin approximation, shape functions, discrete systems, stiffness matrix assembly, reduced system of equations
4. Isoparametric formulation of of the Finite element method (Week 4) - isoparametric concept, 2D elements, numerical integration, stress and strain calculation
5. Finite element method for multidimensional problems (Week 5) - finite elements in the 2D linear elasticity, discretization error
6. Overview of Computational Micromechanics (Week 6): separation of scales; representative volume element; Hill-Mandel condition; upper and lower bounds
7. Effective Elastic Response of Microstructured Materials (Weeks 6-7): separation of scales; representative volume element; Hill-Mandel condition; upper and lower bounds
8. Theory of homogenization for elastic composite materials (Week 7): two-scale analysis; asymptotic expansion; effective properties
9. Non-linear modelling of composite materials (Weeks 8-9): deformation gradient; strain- vs. stress-controlled approaches; mean-field approaches; full-field approaches; computational homogenization; higher-order computational homogenization approach
10. Non-linear modelling of polycrystalline and porous materials (Week 10): crystal plasticity, slip systems; multiplicative decomposition of the deformation gradients; mean-field vs. full-field approaches; plasticity of porous materials

Learning outcomes

By the end of the module, students should be able to:

- Appreciate the concept of the Finite Element Method (FEM) for solving solid mechanics problems
- Solve 1D linear elasticity problems using the FE approach
- Implement and solve numerically (with the FEM) linear elastictity problems in 2D
- Appreciate the role of micromechanics and understand various homogenization methods
- Recognise elements of a nonlinear simulation framework
- Integrate the computational homogenization procedure into the finite element method-based solution procedure

Indicative reading list

J. Fish & T. Belytschko. A First Course in Finite Elements, Wiley, 2007 (available from the Library).

R. de Borst; M. A. Crisfield, Nonlinear finite element analysis of solids and structures, 2012 (available from the Library)

J. Fish, Practical multiscaling, Wiley, 2013 (available from the Library).

S. Torquato, Random heterogeneous materials, Springer, 2002 (available online from the Library)

U.F. Kocks, C.N. Tome, H.-R. Wenk, Texture and Anisotropy, Cambridge University Press, 2000 (available in the Library)

View reading list on Talis Aspire

Subject specific skills

1. Ability to predict and analyse the behaviour of advanced engineering materials using modelling and simulation
2. Develop skills related to model formulation and computer implementation within the finite-element solution framework

Transferable skills

1. Soft skills - develop an ability to discuss a range of topics related to the application of mathematical modelling and computer simulations in the field of materials engineering
2. Technical writing skills - develop an ability to write concise and scientifically rigorous reports.

Study

Study time

Type	Required
Lectures	10 sessions of 2 hours (13%)
Practical classes	10 sessions of 2 hours (13%)
Private study	110 hours (73%)
Total	150 hours

Private study description

Private study and independent learning towards the viva voce and the coursework report.

Costs

No further costs have been identified for this module.

Assessment

You must pass all assessment components to pass the module.

Assessment group D

	Weighting	Study time	Eligible for self-certification
Assessment component			
Report	60%		Yes (extension)

For a given problem of an engineering material implement a computational procedure to calculate its effective elastic properties

Reassessment component is the same

	Weighting	Study time	Eligible for self-certification
Assessment component			
Viva Voce	40%		No

It will examine knowledge in fundamental aspects of the module as well as some practical aspects. The range of material will be clearly indicated.

Reassessment component is the same

Feedback on assessment

1. Written group feedback on the Viva Voce.
2. Written individual feedback on the report.

Past exam papers for ES98F

Availability

Courses

This module is Core optional for:

- Year 1 of TESA-H1B1 Postgraduate Taught Predictive Modelling and Scientific Computing