Unit T13: Finite Element Analysis

Unit code:	J/503/7411
QCF level:	6
Credit value:	15

Aim

The aim of this unit is to give learners an understanding of finite element analysis and to develop the skills to enable them to carry out linear finite element analysis of solid mechanics applications.

Unit abstract

Many phenomena that are of interest to engineers and scientists can be described by a small number of partial differential equations. For example, the distribution of stresses within a loaded solid body, the flow of a fluid through a porous solid and the temperature distribution and heat flow in a heated or cooled body. Analytical solutions of these equations are possible for only a small number of very simple configurations. Almost all configurations of interest to engineers can be solved only by numerical methods, the most important of these being finite element analysis. Powerful and sophisticated finite element analysis software is now available to solve a wide range of engineering problems. This software is widely used in engineering organisations, particularly by those involved in design. However, to use finite element analysis software, learners must understand the basis of finite element analysis (FEA) and be able to analyse the results.

This unit gives learners an understanding of the basic theory of the finite element analysis method, an outline of the capabilities of finite element analysis software, types of analysis that can be carried out, and how finite element analysis may be used in mechanical engineering design. The importance of modelling, selecting and correctly applying appropriate constraints and loads to the model will be emphasised, as well as critical appraisal, checking of results and avoiding potential sources of errors. Learners will compare computed finite element analysis results for simple configurations with those obtained by hand calculation or from a practical experiments.

Learning outcomes

On successful completion of this unit a learner will:

1 understand finite element analysis

2 be able to carry out finite element analysis of a component using software

3 be able to evaluate the results of finite element analysis

4 be able to use finite element analysis to optimise design.

Unit content

1 Understand finite element analysis

Finite element analysis (FEA): types of element, eg simple tension, compression bar, beam, two dimensions, three dimensions; splitting the component into elements; equations for simple elements (force, stiffness, displacement); assembling the equations (structure stiffness matrix, force and displacement vectors); nodal displacements; methods of solution (applying loads, applying constraints, direct solutions, iterative solutions)

2 Be able to carry out finite element analysis of a component using software

Solid modelling software: two-dimensional models of engineering components; three-dimensional models of engineering components

FEA software: types of analysis; loads; constraints; meshing; choice of appropriate output

3 Be able to evaluate the results of finite element analysis

FEA shapes: conformity with expectations given applied loads; conformity with expectations given constraints

FEA calculations: ascertain through calculation if computed results are of the expected order of magnitude, eg for stress, for deformation, for natural frequency

FEA results: identify potential errors, eg sudden unexpected stress gradient, stress oscillations while moving along a curved surface; methods to overcome errors or deficiencies, eg local mesh refinement, mesh adjustment to improve accuracy; compare results with appropriate failure criteria, eg design factor considerations

4 Be able to use finite element analysis to optimise design

Component design: design objective, eg minimum mass, design variables, limits, evolution of FEA design eg limits, outcomes

Learning outcomes and assessment criteria

Learning outcomes On successful completion of this unit a learner will:	**Assessment criteria for pass** The learner can:
LO1 Understand finite element analysis	1.1 Derive force, stiffness and deformation equations for a simple tension element 1.2 Determine the nodal displacements and stresses for an element in tension 1.3 Derive the structure stiffness matrix and the force and displacement vectors for a simple component
LO2 Be able to carry out finite element analysis of a component using software	2.1 Use finite element analysis software to develop two and three dimensional models of engineering components 2.2 Analyse a component using loads and constraints that best represent the actual configuration 2.3 Critically assess the quality of the mesh
LO3 Be able to evaluate the results of finite element analysis	3.1 Critically assess a deformed shape with regard to loads and constraints 3.2 Determine accuracy of computed finite element analysis results 3.3 Evaluate finite element analysis results to determine if the design is safe 3.4 Use mesh adjustments to overcome deficiencies
LO4 Be able to use finite element analysis to optimise a simple design	4.1 Justify the choice of a design objective for a given engineering component 4.2 Justify the choice of design variable(s) and limits for a given engineering component 4.3 Critically evaluate the optimised solution produced by the finite element analysis design

Guidance

Links to National Occupational Standards, other BTEC units, other BTEC qualifications and other relevant units and qualifications

The learning outcomes associated with this unit are closely linked with:

Level 4	Level 5	Level 6
Unit 2: Engineering Science	*Unit 8: Engineering Design*	*Unit T4: Mechanical Engineering Design*
Unit 69: Advanced Computer-aided Design Techniques		*Unit T7: Modelling and Simulation for Engineers*
		Unit T14: Advanced Materials

The content of this unit has been designed and mapped against the Engineering Council's current Learning Outcomes for IEng Accreditation. The completion of the learning outcomes for this unit will contribute knowledge, understanding and skills towards the evidence requirements for IEng Registration.

See *Annexe B* for summary of mapping information for IEng Accreditation.

Essential requirements

Computers and software for learners to carry out FEA are needed for this unit. Laboratory facilities with equipment and instrumentation to enable learners to experimentally check the results of some simple configurations with the results obtained by FEA would be highly desirable.

Delivery

A total of 150 hours of notional learning time is recommended for this unit. The study time should be made up of:

1) a programme of 2 hours per week for a total of 24 weeks of lectures, alternating with sessions of guided learning in a CAE suite
2) two or three laboratory-based sessions of 2 hours each (4–6 hours) where learners carry out experimental testing of components that they are analysing in 1 above, with lecturer or technician support
3) self-study time for learners to practice the use of the software, to work on and to write up their assignments.

Assignments should describe the work carried out, comparison of the results obtained and critical appraisal of computed results, results from experimental work and from manual calculations (96–98 hours).

Assessment

Two or three individual reports as described above in '*Delivery'*.

Resources

Books

Fish J and Belytschko T – *A First Course in Finite Element Analysis*
(J Wiley and Sons, 2007) ISBN 978-0470035801

Entwistle K M – *Basic Principles of the Finite Element Method*
(Institute of Management, 1999) ISBN 978-1861250841

Website

www.mechengdesign.co.uk	This website contains interactive resources for mechanical engineering design.