Liverpool John Moores University

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Title:	Engineering Analysis
Status:	Definitive
Code:	**6102MAN** (121986)
Version Start Date:	01-08-2021
Owning School/Faculty:	Engineering
Teaching School/Faculty:	Engineering

Team	Leader
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Academic Level:	FHEQ6	**Credit Value:**	20	**Total Delivered Hours:**	36
Total Learning Hours:	200	**Private Study:**	164		

Delivery Options
Course typically offered: Semester 1

Component	Contact Hours
Lecture	14
Tutorial	22

Grading Basis: 40 %

Assessment Details

Category	Short Description	Description	Weighting (%)	Exam Duration
Test	AS1	Invigilated FEA V.L.E. Test	50	
Test	AS2	Invigilated CFD VLE Test	50	

Aims

The module will introduce students to computational engineering analysis using finite element analysis (FEA) and computational fluid dynamics (CFD) and will extend their experience and skill with the aid of industry standard software.

Learning Outcomes

After completing the module the student should be able to:

1. Set up and validate efficient and accurate FEA and CFD models
2. Identify the limitations of FEA and CFD as part of the design process
3. Critically evaluate the output from FEA and CFD analysis
4. Apply the theory underpinning commercial FEA and CFD codes

Learning Outcomes of Assessments

The assessment item list is assessed via the learning outcomes listed:

Invigilated FEA VLE Test	1	2	3	4
Invigilated CFD VLE Test	1	2	3	4

Outline Syllabus

Practical aspects of FEA

Modelling strategy. Planning the analysis.

Loading, point loads, stress singularities, pressure loading, examples. Boundary conditions, use of symmetry, balanced loading and minimum constraint avoidance of free body motion, problems associated with inappropriate boundary conditions, basic contact in assemblies, examples.
Choice of element, mesh controls and mesh density, convergence of results, problems with element distortion, adaptive meshing. Managing the solution, types of solver, analysis of errors and warnings.

Post processing and results checking. Review of available results, stress, strain, displacement, primary and derived quantities etc. Interpretation of results, checking results, reaction forces, displaced shape, nodal and element plots, hand calculations.

Thermal analysis and thermal stress analysis. Planning the analysis, steady state, transient. Boundary conditions, temperature, convection, heat flux, radiation, solution output, temperature distribution, derived field quantities. Thermal stress analysis, sequential, coupled (description only) transfer of mesh and nodal temperatures to structural analysis. Examples

Modal Dynamics. Brief description of eigenvalue extraction techniques. Planning the analysis, boundary conditions, number of modes to extract, symmetry conditions, interpretation of results output. Examples

Shell and beam modelling. Modelling thin components, shells. Modelling using beam elements. Mixed meshing, solids, shells and beams. Examples

Theoretical aspects of FEA

Review of matrix algebra, matrix representation of linear simultaneous equations, types of matrix, multiplication, transpose, inverse, quadratic form, solution of equations using Gaussian elimination or equivalent. General FEA principles, application to simple one dimensional problems, comparison with traditional methods. Example using two stepped bar elements represented as springs, concept of nodes and elements, element stiffness matrix determination by direct approach, incorporation of loads and BC's, solution.

Global stiffness matrix assembly and solution. Example using three or more springs, derivation of element stiffness matrix using direct approach, element connectivity and assembly of global stiffness matrix, incorporation of loads and BC's to remove singularity, solution. Bandwidth and alternative element connectivity. Multiple load cases.

Practical aspects of CFD

Use of a commercial CFD code to solve engineering problems.
Approach to setting up a CFD model. Identification of the underlying physics applicable for a given problem. Prediction of expected results based classical theory and rough hand calculations. Examination of the typical boundary conditions available within a commercial CFD code and the study of their validity. Selection of the boundary conditions required to capture the expected physical behaviour at the limits of the modelled region.
Economic use of CFD, run time and computing resources required. Strategies to reduce the size of model required, use of symmetry in 2D and 3D models, transfer of boundary conditions from other models.
Meshing quality, mesh construction and strategies for mesh refinement, mesh independence, adaptive mesh refinement. Selection of an appropriate computational domain for external flows, refinement and optimisation of computational domain dimensions.
Monitoring the solution process, convergence control and relationships between convergence criteria and accuracy of solution, strategies for economic solution.
Simultaneous solution of mass and heat transfers (conjugate heat transfer) including flow freezing and its effects on solution time. Use and control of solution adaptive mesh refinement techniques and implications for run time and storage requirements.
Presentation and interpretation of CFD results. Extracting performance indicators, point values, surface integrals for loads and mean values of physical parameters.
Strategies for validation of results including checking of conservation laws, mesh and computational domain independence, comparison with existing data/theory.

Theoretical aspects of CFD

Qualitative revision of real fluid flow and Introduction to CFD with industrial examples of usage. Review of the governing equations of fluid flow including Navier-Stokes equations, energy equations and continuity equations.
Discretisation of the computational domain and numerical solution of the resulting algebraic equations. Problems with direct matrix inversion and need for iterative solution methods. Basic iterative schemes, Gauss-Seidel and Jacobi, solution

behaviour, convergence, stability, under and over relaxation.
Introduction to the modelling of boundary layer flow. Law of the wall (wall function) and its use in CFD modelling.
Turbulence - qualitative understanding. Brief introduction to time averaging and need for a turbulence model.
Discretization methods. Convection-diffusion problems. Brief explanations of need for upwinding.

Learning Activities

Lectures, tutorial and practicals

Notes

An important feature of the module is that the students gain an understanding of the need to adopt a disciplined approach when using numerical CAE tools within an engineering environment. During the module the students must demonstrate an approach to analysis that guarantees the production of accurate, physically sound and well validated results. The module will introduce the students to suitable FEA and CFD methodologies. Whilst the theoretical aspects of the methods will be covered in lectures the module is intended to be practical in nature with students having the opportunity to practice via a range of tutorials and assignments using industry standard software. The module assignments will require that the students drive the software tools in a competent and professionally sound manner.