Unit 5004: Computational Modelling in Virtual Engineering

Unit Code: L/651/0858

Level: 5

Credits: 15

Introduction

The work of an engineer increasingly involves the use of powerful software modelling tools (virtual modelling). These tools allow us to predict potential manufacturing difficulties, suggest how a product or component is likely to behave in service, and undertake rapid and low-cost design iteration and optimisation, to reduce costs, pre-empt failure and enhance performance.

This unit introduces students to the application of relevant Computer Aided Design (CAD) and analysis engineering tools in contemporary engineering. They will learn about standards, regulations, and legal compliance within the context of engineering.

Topics included in this unit are: dimensioning and tolerances, standardisation and regulatory compliance (BS, ASTM, ISO, etc.), material properties and selection, manufacturing processes, 2D, 3D, CAD, solid modelling, one-dimensional and multi-dimensional problems, meshing and boundary conditions, and the finite element and volume methods.

On successful completion of this unit students will learn about computational fluid dynamics (CFD) simulations, finite element models, faults in the application of simulation techniques and the modelling method and data accuracy.

Learning Outcomes

By the end of this unit students will be able to:

LO1 Explore the capabilities and limitations of computer-based models in meeting design fundamentals and their use in solving problems in engineering.

LO2 Develop finite element model(s) in order to find and solve potential structural or performance issues.

LO3 Perform CFD simulations to evaluate pressure and velocity distributions within an engineering setting.

LO4 Discuss faults in the application of simulation techniques to evaluate the modelling method and data accuracy.

Essential Content

LO1 **Explore the capabilities and limitations of computer-based models in meeting design fundamentals and their use in solving problems in engineering**

Engineering design fundamentals:

Dimensioning and tolerances

Standardisation and regulatory compliance (BS, ASTM, ISO, etc.)

How to manufacture and what to manufacture:

Material properties and selection

Manufacturing processes: capability, cost issues and selection

Relevance of Industry 4.0 tools/trends in support of solving engineering problems and facilitate seamless systems integration.

Design tools:

2D and 3D CAD

Solid modelling

File types, export and compatibility

Case studies involving use of various computer-based models for Engineering problem solving.

Interpretation and presentation of results through a series of guided exercises:

Results obtained, comparison of data, benefits and limitations; exploit uses of databases, data formats and data analytics

Generalisation of provided information, recommendations on current and future applications

Use of documentation within the context e.g. job cards/build records, 2D and 3D drawing/models, bill of materials (BOM), cost analysis reports, compliance reports, standard operating instructions (SOIs), standard process instructions (SPIs), engineering query notifications (EQNs), drawing query notifications (DQNs).

LO2 **Develop finite element model(s) in order to find and solve potential structural or performance issues**

Fundamentals of FEM (Finite Element Modelling):

Meshing, nodes and element types

Types of boundary conditions

FEM and FEA; applications, advantages, and limitations.

Finite element formulation:

One-dimensional problems, Multi-dimensional problems, Beams.

Finite element method:

Define the problem: simplify an engineering problem into a problem that can be solved using FEA

Develop models: define material properties and boundary conditions; choose appropriate functions, formulate equations, solve equations, visualise and explain the results.

LO3 **Perform CFD simulations to evaluate pressure and velocity distributions within an engineering setting**

Fundamentals of CFD (Computational Fluid Dynamics):

CFD and the finite volume method background

Meshing and boundary conditions

Applications, advantages and limitations of CFD.

CFD simulation and analysis:

Apply CFD to simple design/aerodynamics problems: define the problem, provide initial boundary conditions for the problem, set-up a physical model, define material properties and operating conditions

Interpretation of CFD results

Examine the solution of CFD simulations using graphical and numerical tools; suggest and make revision of the models.

LO4 **Discuss faults in the application of simulation techniques to evaluate the modelling method and data accuracy**

Simulation results:

Extracting relevant information from simulation-based exercises

Interpretation and presentation of results of CFD simulations

Validation and verification of computational modelling

Discuss in groups industry case studies involving simulation techniques in the context of data accuracy and faults.

Learning Outcomes and Assessment Criteria

Pass	Merit	Distinction
LO1 Explore the capabilities and limitations of computer-based models in meeting design fundamentals and their use in solving problems in engineering		
P1 Explore the capabilities and limitations of any two computer-based models used within an industrial environment to solve problems in engineering.	**M1** Analyse the capabilities and limitations of a range of computer-based models. **M2** Analyse the processes and applications used in solving problems in engineering.	**D1** Evaluate the application of computer-based models to an industrial environment that would improve efficiency and problem-solving, with recommendations.
LO2 Develop finite element model(s) in order to find and solve potential structural or performance issues		
P2 Analyse the role of finite element analysis in modelling products and systems. **P3** Develop a finite element model to analyse a given practical example to solving potential structural or performance-based issues.	**M3** Critically analyse the finite element model that help to find and solve potential structural or performance-based issues.	**D2** Justify recommendations for recognising and solving potential structural or performance-based issues for a range of practical examples, supported by the outcomes of finite element product and systems models for a range of practical examples.

Pass	Merit	Distinction
LO3 Perform CFD simulations to evaluate pressure and velocity distributions within an engineering setting		
P4 Demonstrate the importance of CFD simulations to evaluate pressure and velocity distributions in the engineering setting. **P5** Perform CFD simulation to evaluate pressure and velocity distributions within an engineering setting.	**M4** Evaluate the application and limitations of CFD in an engineering context.	**D3** Provide supported and appropriate recommendations for improving efficiency and the generation of suitable meshes for CFD simulations.
LO4 Discuss faults in the application of simulation techniques to evaluate the modelling method and data accuracy		
P6 Discuss potential faults in the application of simulation techniques. **P7** Discuss the use of modelling methods and data accuracy in computer simulations.	**M5** Trace potential faults in the application of simulation techniques. **M6** Assess the results of modelling with respect to outcomes and data accuracy and make recommendations for improvements.	**D4** Critically evaluate the application of simulation techniques as part of the decision-making process in an engineering situation.

Recommended Resources

Note: See HN Global for guidance on additional resources.

Print Resources

Chandrupatla T. and Belegundu A. (2021) *Introduction to finite elements in engineering.* Cambridge University Press.

Ciarlet P. and Luneville E. (2023) *The Finite Element Method: From Theory to Practice.* Wiley-ISTE.

Kurowski P.M. (2022) *Finite element analysis for design engineers.* SAE International.

Muftu S. (2022) *Finite Element Method: Physics and Solution Methods.* 1st Ed. Academic Press.

Okada H. and atluri S.N. (2020) *Computational and Experimental Simulations in Engineering: Proceedings of ICCES2019.* Springer Link.

Rao S.S. (2017) *The Finite Element Method in Engineering.* 6th Ed. Butterworth-Heinemann.

Tu J., Yeoh G.H., Liu C. and Tao Y. (2023) *Computational fluid dynamics: a practical approach.* Elsevier.

Volkov K. (2020) *Computational Models in Engineering.* IntechOpen.

Journals

Note: Example journals listed below provide a broad range of articles related to unit content and those relevant for the qualification. Staff and students are encouraged to explore these journals and any other suitable journals to support the development of academic study skills, and subject specific knowledge and skills as part of unit level delivery.

Computational Engineering and Physical Modeling

Finite Elements in Analysis and Design

International Journal for Computational Methods in Engineering Science and Mechanics

Progress in Computational Fluid Dynamics

Novel Computational Modelling (Applied Engineering Journal)

Virtual Engineering Journals

Virtual Engineering New Finding Journal

Links

This unit links to the following related units:

Unit 4001: Engineering Design

Unit 5017: Advanced Manufacturing Technology.