The Faculty of Engineering and Science
Board of Studies for Industry and Global Business Development

AALBORG UNIVERSITET

Curriculum for the Master's Program in Design of Mechanical Systems

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Preface

Pursuant to Act 261 of March 18, 2015 on Universities (the University Act) with subsequent changes, the following curriculum for the Master's program in Design of Mechanical Systems is stipulated. The program also follows the Joint Programme Regulations and the Examination Policies and Procedures for the Faculty of Engineering and Science.

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Chapter 1: Legal Basis of the Curriculum, etc.

1.1 Basis in ministerial orders
The Master's programme in Design of Mechanical Systems is organised in accordance with the Ministry of Higher Education and Science's Order no. 1061 of June 30, 2016 on Bachelor's and Master's Programmes at Universities (the Ministerial Order of the Study Programmes) and Ministerial Order no. 1062 of June 30, 2016 on University Examinations (the Examination Order). Further reference is made to Ministerial Order no. 258 of March 18, 2015 (the Admission Order) and Ministerial Order no. 114 of February 3, 2015 (the Grading Scale Order) with subsequent changes.

1.2 Faculty affiliation
The Master's programme falls under The Faculty of Engineering and Science.

1.3 Board of Studies affiliation
The Master's program falls under the Board of Studies for Industry and Global Business Development in the School of Engineering and Science.

1,4 Board of External Examiners
The Master's programme is associated with the External Examiner Corps of higher education of engineering (mechanical engineering).

Chapter 2: Admission, Degree Designation, Program Duration and Competence Profile

2.1 Admission
Applicants with a legal claim to admission (retskrav):

- Bachelor of Science in Mechanical Engineering and Manufacturing

Applicants with one of the following degrees are entitled to admission:

- Bachelor of Science in Civil Engineering
- Bachelor of Science in Structural and Civil Engineering
- Bachelor of Science in Civil Engineering
- Bachelor of Science in Mechanical Engineering and Manufacturing
- Bachelor of Science in Mechanical Design
- Bachelor of Science in Mechanical Engineering

Applicants without legal claim to admission:
Students with another Bachelor degree may, upon application to the Board of Studies, be admitted after a specific academic assessment if the applicant is considered as having comparable educational prerequisites. The University can stipulate requirements concerning conducting additional exams prior to the start of study.

2.2 Degree designation in Danish and English
The Master's program entitles the graduate to the Danish designation civilingeniør, cand.polyt. (candidatus/candidata polytechnices) i design af mekaniske systemer. The English designation is: Master of Science (MSc.) in Engineering (Design of Mechanical Systems).

2.3 The program's specification in ECTS credits
The Master's program is a 2-year, research-based, full-time study programme. The programme is set to 120 ECTS credits.

2.4 Competence profile on the diploma
The following competence profile will appear on the diploma:

A Candidatus graduate has the following competency profile:
A Candidatus graduate has competencies that have been acquired via a course of study that has taken place in a research environment.
A Candidatus graduate is qualified for employment on the labour market on the basis of his or her academic discipline as well as for further research (PhD programmes). A Candidatus graduate has, compared to a Bachelor, developed his or her academic knowledge and independence so as to be able to apply scientific theory and method on an independent basis within both an academic and a professional context.
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2.5 Competence profile of the program

The graduate of the Master's program:

Knowledge

- Has attained thorough understanding of a broad range of theoretical, numerical and experimental techniques within the area of design of mechanical systems.
- Has knowledge in one or more subject areas that, in selected areas within mechanical engineering, is based on the highest international research in a subject area.
- Can understand and, on a scientific basis, reflect over subject area's related to mechanical engineering and identify scientific problems within that area.
- Demonstrate an understanding of research work and be able to become a part of a research environment.
- Demonstrate insight into the implications of research work, including research ethics.

Skills

- Be able to apply scientific methodology to the solving of a wide variety of problems within the field of specialization.
- Be able to perform scientific work in relevant topics of the field of the specialization.
- Be able to apply a wide range of engineering methods in research and development projects in the field of specialization.
- Be able to participate or lead projects in mechanical system design, product development, modeling and analysis of mechanical systems, materials technology, production technology, structural mechanics and design of lightweight structures.
- Can communicate research-based knowledge and discuss professional and scientific problems with both peers and non-specialists.
- Can use advanced laboratory test set ups and data collection methods.

Competencies

- Be able to work independently with a project on a specific problem within their field of interest on the highest possible level within their specialization.
- Be able to take part in technical development and research.
- Can manage work and development situations that are complex, unpredictable and require new solutions within the

area of mechanical engineering.
- Can independently initiate and implement discipline-specific and interdisciplinary cooperation and assume professional responsibility.
- Be able to direct the technical management of development projects within the industry.
- Be competent to solve new and complicated technical problems by the use of advanced mathematics, scientific and technological knowledge.
- Can independently take responsibility for own professional development and specialization.

Chapter 3: Content and Organization of the Program

The M.Sc. program in Design of Mechanical Systems aims at educating graduates, who are qualified to take part in technical development and research and who are able to direct the technical management of development projects within the industry.

The graduates are expected to have gained a broad knowledge within the areas of mechanical system design, product development, modelling and analysis of mechanical systems, materials technology, production technology, structural mechanics and design of lightweight structures. Also, the graduates are expected to be competent to solve new and complicated technical problems by the use of advanced mathematics, scientific and technological knowledge.

The program is structured in modules and organized as a problem-based study. A module is a program element or a group of program elements, which aims to give students a set of professional skills within a fixed time frame specified in ECTS credits, and concluding with one or more examinations within specific exam periods that are defined in the curriculum.

The program is based on a combination of academic, problem-oriented and interdisciplinary approaches and organized based on the following work and evaluation methods that combine skills and reflection:

- lectures
- classroom instruction
- project work
- workshops
- exercises (individually and in groups)
- teacher feedback
- reflection
- portfolio work

The third semester offers different ways of organisation – depending on the student's choice of content; project work at Aalborg University, study visit at an educational institution in Denmark or abroad, voluntary traineeship with project work at a company in Denmark or abroad, or a semester programme that comprises cross-disciplinary programme elements composed by the student. The total work load of the semester has to be equivalent to 30 ECTS, of which up to 15 ECTS can be elective courses. The project may be finalized with a project report or in the form of a scientific paper, or, if the project is continued at the 4th semester, with a midterm evaluation. For further information about the organisation of the module please see the Joint Programme Regulations, chapter 9.4.1.

At the 4th semester, the master thesis is completed. The master thesis can be combined with the 3rd semester in an extended master thesis.

3.1. Overview of the program

All modules are assessed through individual grading according to the 7-point scale *or* Pass/Fail. All modules are assessed by external examination (external grading) or internal examination (internal grading or by assessment by the supervisor only).

Semester	Module	ECTS	Grading	Exam
1.	Stress and Deformation Analyses of Load Carrying Structural Element	15[1]	7-point scale	Internal
	Stress and Deformation Analyses of Load Carrying Structural Element (INTRO semester)*	10	7-point scale	Internal
	Solid Mechanics with Microstructure	5	7-point scale	Internal
	Fracture Mechanics and Fatigue	5	7-point scale	Internal
	Finite Element Methods	5	7-point scale	Internal
	INTRO Course: Problem-based Learning, Theory of Elasticity and the Finite Element Method, MATLAB.*	5	Pass/Fail	Internal
2.	Engineering Design of Mechanical Systems	15	7-point scale	External
	Engineering Optimization – Concepts, Methods and Applications	5	7-point scale	Internal
	Mechanics of Composite Materials and Structures	5	7-point scale	Internal
	Energy and Variational Methods with Applications	5	7-point scale	Internal
3.	Industrial Development	20, 25, 30	7-point scale	Internal
	Internship[2]	20, 25, 30	7-point scale	Internal
	Elective courses**			
	Computational Fluid Dynamics (CFD) and Multiphase Flow	5	7-point scale	Internal
	Test and Validation	5	Pass/Fail	Internal
4.	Design of Mechanical Systems	30, 50, 60	7-point scale	External

***** For students without a B.Sc. in Mechanical Engineering and Manufacturing from Aalborg University a tailored project module of 10 ECTS and an INTRO Course of 5 ECTS are provided on the 1st semester and named INTRO semester. The INTRO semester will provide new students with the best possible start with their studies at Aalborg University and ensure they master basic engineering topics, which is a prerequisite for solving the semester project as well as following course modules on this and upcoming semesters on the M.Sc. program Design of Mechanical Systems.

**Courses on 3rd semester are elective and the student can choose up to 10 ECTS course credits. The two courses listed are often followed by students from Design in Mechanical Systems.

[1] Students having a bachelor within Mechanical Engineering and Manufacturing, follow this module
[2] The academic traineeship has to be approved by the study board before the beginning of the semester.

3.2 Design of Mechanical Systems, 1st Semester

3.2.0 Problem Based Learning and Project Management

Title:
Problem Based Learning and Project Management (Problembaseret læring og projektledelse)

Prerequisites:
None, but the course is compulsory for students not acquainted to the Aalborg PBL model

Objective:
The objective is to make newly started Master students coming from institutions other than AAU prepared to enter the problem based learning environment at AAU and manage study projects in close collaboration with peers.

Type of instruction:
Three half day workshops centered around the individual student working with an individual challenge or curiosity in relation to using a PBL approach. Peer learning is also a hallmark, since the students will discuss and reflect their individual challenges/curiosities in a peer learning group.

Learning outcomes: After completion of the course the student should be able to

Day 1:
- describe and discuss the Aalborg PBL model based on the three key words: group work, project work, problem orientation
- identify an initial individual challenge when using a PBL approach

Day2:
- develop and practice peer feedback skills
- practice collaborative learning in a group
- design a plan of action to deal with an initial individual PBL challenge or curiosity

Day 3:
- practice presentation skills
- practice critical skills when giving feedback to peers
- reflect on own and peer skills in relation to PBL practice

Form of examination:
Internal assessment during the course/class participation according to the rules in the Examination Policies and Procedures of Faculty of Engineering and Science, Aalborg University. In this case the assessment is primarily based on the oral performance during the course, which means that the student has to be active during the course time and participate in discussions. The course is an integrated part of the project for those not acquainted to the Aalborg PBL model, and is a precondition for participation in the project examination. In this way there will be no diploma for the course and it will not be visible on the academic transcripts.

Evaluation criteria:
As stated in the Joint programme regulations

3.2.1 A Stress and Deformation Analyses of Load Carrying Structural Elements (15 ECTS)

For students with a B.Sc. in Mechanical Engineering and Manufacturing from Aalborg University.

Title: **Stress and Deformation Analyses of Load Carrying Structural Elements**
(Spændings- og deformationsanalyse af kraftoverførende konstruktion)

Goal: Students who complete the module are expected to:

Knowledge

- Have gained an in-depth understanding of theoretical and experimental determination of the stress and deformation states occurring in a structural element when carrying a mechanical load.
- Have attained an understanding for methods of analysis and experimental methods and the characteristics of their applications and limitations.

Skills

- Be able to set up the governing equations for the theory of elasticity.
- Be able to demonstrate the properties of the strain and stress tensors.
- Be able to account for the implementation and practical use of the analytical, numerical, and experimental methods applied in the project.
- Be able to give a critical evaluation of the methods applied for stress and deformation analyses and the results obtained.
- Be able to use correct terminology.
- Be able to compare theoretical and experimental results.
- Be able to critically evaluate applied methods and their results.

Competences

- Be able to analyze a load carrying element on the basis of model considerations, using continuum mechanics, and by applying numerical methods including the finite element method.
- Be able to investigate the behavior of a structural element under mechanical loading with experimental techniques such as strain gauges and digital image measurement techniques.
- Be able to compare theoretical and experimental results carefully, and critically evaluate the methods applied and the results obtained.
- Be able to apply the background and the insight obtained, on intuitive design optimization, and suggest geometrical changes or a redesign including change of material.

Teaching Method: The module is carried out as group-based problem-oriented project work. The group work is carried out as an independent work process in which the students themselves organize and coordinate their workload in collaboration with a supervisor. The project is carried out in groups with normally no more than 6 members.

Form of examination: Internal, oral group examination

Evaluation criteria: As stated in the Joint Programme Regulations

3.2.1 B Stress and Deformation Analyses of Load Carrying Structural Elements (INTRO semester) (10 ECTS)

For students without a B.Sc. in Mechanical Engineering and Manufacturing from Aalborg University (INTRO semester).

Title: **Stress and Deformation Analyses of Load Carrying Structural Elements**
(Spændings- og deformationsanalyse af kraftoverførende konstruktion)

Goal: Students who complete the module are expected to:

Knowledge

- Have gained an in-depth understanding of theoretical and experimental determination of the stress and deformation states occurring in a structural element when carrying a mechanical load.
- Have attained an understanding for methods of analysis and experimental methods and the characteristics of their applications and limitations.

Skills

- Be able to set up the governing equations for the theory of elasticity.
- Be able to demonstrate the properties of the strain and stress tensors.
- Be able to account for the implementation and practical use of the analytical, numerical, and experimental methods applied in the project.
- Be able to give a critical evaluation of the methods applied for stress and deformation analyses and the results obtained.
- Be able to use correct terminology.
- Be able to compare theoretical and experimental results.
- Be able to critically evaluate applied methods and their results.

Competences

- Be able to analyze a load carrying element on the basis of model considerations, using continuum mechanics, and by applying numerical methods including the finite element method.
- Be able to investigate the behavior of a structural element under mechanical loading with experimental techniques such as strain gauges and digital image measurement techniques.
- Be able to compare theoretical and experimental results carefully, and critically evaluate the methods applied and the results obtained.
- Be able to apply the background and the insight obtained, on intuitive design optimization, and suggest geometrical changes or a redesign including change of material.

Teaching Method: The module is carried out as group-based problem-oriented project work. The group work is carried out as an independent work process in which the students themselves organize and coordinate their workload in collaboration with a supervisor. The project is carried out in groups with normally no more than 6 members.

Form of examination: Internal, oral group examination

Evaluation criteria: As stated in the Joint Programme Regulations

3.2.2 Solid Mechanics with Microstructure (5 ECTS)

Title: **Solid Mechanics with Microstructure**
(Materialemekanik)

Goal: Students who complete the module are expected to:

Knowledge

- Have gained an understanding of basic mechanical properties of engineering materials and modeling procedures used to quantify these properties, as well as the ways in which these properties characterize material response.

Skills

- Be able to understand basic continuum mechanical theories and apply them to simple structural components.
- Be able to substantiate different observable deformation modes by underlying physical mechanisms.
- Be able to document knowledge related to the application of selected analytical/numerical methods for materials characterization.

Competences

- Have gained an awareness of various responses exhibited by solid engineering materials when subjected to mechanical loadings and an explanation of the physical mechanisms associated with design-limiting behavior of engineering materials.
- Have gained an understanding of predictive analytical and computational frameworks that provide quantitative skills to deal with materials-limiting problems in engineering design.

Teaching Method: The form(s) of teaching will be determined and described in connection with the planning of the semester. The description will account for the form(s) of teaching and may be accompanied by an elaboration of the roles of the participants (see chapter 3). The course/project theme is performed in either English or Danish dependent of the language skills of the participants.

Form of examination: Internal, oral/written examination

Evaluation criteria: As stated in the Joint Programme Regulations

3.2.3 Fracture Mechanics and Fatigue (5 ECTS)

Title: **Fracture Mechanics and Fatigue**
(Brudmekanik og udmattelse)

Goal: Students who complete the module are expected to:

Knowledge

- Have gained a comprehensive understanding of fracture mechanics.
- Have gained knowledge in applying classical methods in designing against fatigue fracture by studying notches and their effect, by studying strain-fatigue, and by analysing eigen-stress states.
- Have gained an understanding of how to apply fracture mechanics in the assessment of reliability of practical designs and machine elements.

Skills

- Be able to assess the stability of cracks using Griffith's and Irwin's fracture criteria, energy release rate, and toughness concepts
- Be able to apply linear elastic solutions for sharp cracks and obtain the stress intensity factor.
- Be able to assess mixed mode loading and apply crack growth direction hypotheses
- Be able to assess crack growth by fatigue, partial damage and load spectra.
- Be able to assess crack initiation, notches and their effect.
- Be able to determine life time and apply methods for improving the fatigue strength and life time of machine elements and welded details.

Competences

- Be able to understand and apply linear elastic concepts in assessing the stability of cracked structures under static and fatigue loading.
- Be able to distinguish between different fatigue regimes, i.e. elastic or plastic, and un-cracked or pre-cracked, and apply correct methodology to each case in relevant structures.
- Be able to determine the lifetime of welded components, and explain fatigue in welded components on the basis of fracture mechanical concepts.

Teaching Method: The form(s) of teaching will be determined and described in connection with the planning of the semester. The description will account for the form(s) of teaching and may be accompanied by an elaboration of the roles of the participants (see chapter 3). The course/project theme is performed in either English or Danish dependent of the language skills of the participants.

Form of examination: Internal, written/oral examination.

Evaluation criteria: As stated in the Joint Programme Regulations

3.2.4 Finite Elements Methods (5 ECTS)

Title: **Finite Element Methods**
(Elementmetoder)

Goal: Students who complete the module are expected to:

Knowledge

- Be able to use the finite element method in static stress analysis.
- Have knowledge of element technology, such as bar, beam, solid and shell elements.
- Be able to apply methods for error estimation and adaptive mesh generation.
- Be able to solve structural dynamics and vibrations problems using methods such as free vibrations, modal methods and direct time integration methods.
- Be able to apply nonlinear finite element methods including solution of systems of nonlinear equations, geometrically nonlinear problems, contact problems, and nonlinear material models.
- Be able to perform linearised buckling analysis.
- Be able to solve exercises using a commercial finite element program (e.g., ANSYS).

Skills

- Demonstrate a basic understanding of concepts, theory and applications of finite element analysis from a mechanical engineering view point.
- Be able to perform linear and nonlinear static and dynamic stress analysis including the use of commercial finite element software.

Competences

- Be able to apply the concepts, theories and techniques covered in the area of linear and nonlinear finite element analysis on practical problems.
- Be able to apply the concepts and theories to the solution of relevant problems using commercial software programs.

Teaching Method: The form(s) of teaching will be determined and described in connection with the planning of the semester. The description will account for the form(s) of teaching and may be accompanied by an elaboration of the roles of the participants (see chapter 3). The course/project theme is performed in either English or Danish dependent of the language skills of the participants.

Form of examination: Internal, oral/written examination

Evaluation criteria: As stated in the Joint Programme Regulations

3.2.5 INTRO Course: Problem-based Learning, Theory of Elasticity and the Finite Element Method, MATLAB (5 ECTS)

For students without a B.Sc. in Mechanical Engineering and Manufacturing from Aalborg University (INTRO semester).

Title: **Problem-based Learning, Theory of Elasticity and the Finite Element Method, MATLAB**
(Problembaseret læring, elasticitetsteori og finite element metodeteori, MATLAB)

Goal: Students who complete the module are expected to:

Knowledge

- Have knowledge and understanding of project organized problem based learning.
- Have knowledge about group work/conflicts and ways to solve conflicts.
- Have knowledge and comprehension of planning and structuring the documentation of a project.
- Have knowledge and understanding of central concepts, theories, and methods concerning theory of elasticity.
- Have knowledge and understanding of the governing conditions and equations to be fulfilled in any linear elastic continuum subjected to static loads.
- Have knowledge and understanding of central concepts and theories concerning the finite element method.
- Have knowledge and understanding of central terms and governing equations for a linear static finite element problem.
- Have knowledge and comprehension of the basic features of MATLAB as a programming language.

Skills

- Be able to apply the project organized learning to actual problem related work in groups of up to 6 persons.
- Be able to apply systematic methods within the topics of this course.
- Be able to apply index notation and tensor calculus to manage a linear elastic mechanical problem.
- Be able to account for considerations related to the use of concepts, theories, and methods from the finite element method in practise.
- Be able to use the basic computational facilities of MATLAB.

Competences

- Independently be able to define and analyse scientific problems.
- Be able to design, code, and debug a program in MATLAB.

Teaching Method: The form(s) of teaching will be determined and described in connection with the planning of the semester. The description will account for the form(s) of teaching and may be accompanied by an elaboration of the roles of the participants (see chapter 3). The course/project theme is performed in either English or Danish dependent of the language skills of the participants.

Form of examination: Internal, oral examination.

Evaluation criteria: As stated in the Joint Programme Regulations

3.3 Design of Mechanical Systems, 2nd Semester

3.3.1 Engineering Design of Mechanical Systems (15 ECTS)

Title: **Engineering Design of Mechanical Systems**
(Konstruktion af mekaniske systemer)

Prerequisites: The module adds to the knowledge obtained in 1st Semester.

Goal: Students who complete the module are expected to:

Knowledge

- Have gained knowledge and understanding of advanced engineering design of mechanical systems and structures.
- Be able to understand and apply advanced analysis tools for evaluating the performance of advanced mechanical systems and structures.

Skills

- Be able to apply advanced engineering design on mechanical systems and structures.
- Be able to use advanced materials for structural design.
- Be able to understand and apply advanced analysis tools for evaluating the performance of advanced mechanical systems and structures.
- Be able to apply synthesis and analysis in the design process, and demonstrate their interdependence.
- Be able to apply systematic rational design methods.

Competences

- Be able to design solutions for a load carrying mechanical system or structure, with an industrial partner or with industrial relevance.
- Be able to consider a problem of sufficient complexity to encompass the use of advanced analytical, numerical or experimental analysis tools for predicting the performance of the mechanical system or structure during operation.
- Be able to analyse challenging designs from a structural point of view, where lightweight design, use of advanced materials like composite materials, design problems involving fatigue, and mechanical systems with complicated dynamic behaviour during operation may be considered.
- Be able to document a final design with respect to performance using virtual prototypes or analytical models, and include manufacturing considerations.

Teaching Method: The module is carried out as group-based problem-oriented project work. The group work is carried out as an independent work process in which the students themselves organize and coordinate their workload in collaboration with a supervisor. The project is carried out in groups with normally no more than 6 members.

Form of examination: Oral examination with participation of an external examiner.

Evaluation criteria: As stated in the Joint Programme Regulations

3.3.2 Engineering Optimization – Concepts, Methods and Applications (5 ECTS)

Title: **Engineering Optimization – Concepts, Methods and Applications**
(Ingeniørmæssig optimering – begreber, metoder og anvendelser)

Prerequisites: The module adds to the knowledge obtained in 1st Semester.

Goal: Students who complete the module are expected to:

Knowledge

- Have gained an in-depth understanding of important concepts and methods of optimization for efficient solution of optimization problems within different areas of engineering, including design optimization of mechanical systems.

Skills

- Be able to use optimization concepts and topics.
- Be able to use numerical methods of unconstrained optimization.
- Be able to use numerical (mathematical programming) methods for optimization of multi-dimensional functions with constraints.
- Be able to solve multicriterion optimization problems.
- Be able to apply other methods of optimization, such as integer problems, response surface methods, genetic algorithms, etc.
- Be able to perform general applications of optimization methods: parameter identification, optimization as an analysis tool for problems governed by an extremum principle, surrogate and metamodelling problems.

Competences

- Be able to apply the concepts, theories and methods for solution of engineering optimization problems.
- Be able to account for the considerations involved in the process of formulating and modeling an engineering optimization problem, choosing an advantageous method of solution, and implementing it in practice.

Teaching Method: The form(s) of teaching will be determined and described in connection with the planning of the semester. The description will account for the form(s) of teaching and may be accompanied by an elaboration of the roles of the participants (see page 5). The course/project theme is performed in either English or Danish dependent of the language skills of the participants.

Form of examination: Internal, written/oral examination.

Evaluation criteria: As stated in the Joint Programme Regulations

3.3.3 Mechanics of Composite Materials and Structures (5 ECTS)

Title: **Mechanics of Composite Materials and Structures**
(Kompositmaterialers og -konstruktioners mekanik)

Prerequisites: The module adds to the knowledge obtained in 1st Semester.

Goal: Students who complete the module are expected to:

Knowledge

- Have gained an in-depth understanding of the overall topical area of composite materials including their properties, manufacturing, analysis and design.
- Be able to document understanding of the following concepts and theories:
    - Applications of composites.
    - Fibers and polymer resin materials: Types and properties.
    - Manufacturing methods, their processing characteristics and influence on the mechanical properties of composites.
    - Laminae and laminates: Micro-mechanical models, modeling of the laminae, classical lamination theory (CLT).
    - Analysis of composite structures: Beam, plate and shell modeling.
    - Thermal effects.
    - Fracture and failure.
    - Sandwich structures.
    - Adhesive bonded and mechanical joints, load introduction aspects, 3D effects and general principles for design.
    - Finite element analysis of laminated composite structures.

Skills

- Be able to apply concepts, theories and methods for analysis and design of composite materials and complex structures made from composite materials to real-life problems.

Competences

- Be able to undertake development and product design using composite materials.
- Be able to develop procedures for production and verification of components made from composite materials.

Teaching Method: The form(s) of teaching will be determined and described in connection with the planning of the semester. The description will account for the form(s) of teaching and may be accompanied by an elaboration of the roles of the participants (see page 5). The course/project theme is performed in either English or Danish dependent of the language skills of the participants.

Form of examination: Internal, written/oral examination.

Evaluation criteria: As stated in the Joint Programme Regulations

3.3.4 Energy and Variational Methods with Applications (5 ECTS)

Title: **Energy and Variational Methods with Applications**
(Energi- og variationsmetoder med anvendelser)

Prerequisites: The module adds to the knowledge obtained in 1st Semester.

Goal: Students who complete the module are expected to:

Knowledge

- Have gained an in-depth understanding of energy and variational methods and classical principles of stationarity to derive governing equations of statics and dynamics, and their application for solution of general problems in structural mechanics, including:
    - Energy methods and energy minimization principles as the foundation of the finite element method
    - Variational methods (methods of Ritz, Galerkin, Rayleigh and Rayleigh-Ritz)
    - Different applications of those such as analysis of statics, buckling and vibration of beams, plates and similar
    - Dynamics of discrete multi-dof and multi-body mechanical systems
    - Exact and approximate solutions to the natural frequencies and modal analysis problems for multi-dof/continuous vibration systems
    - Approximate methods for nonlinear mechanical vibrations

Skills

- Be able to apply energy and variational methods for the solution of problems in statics and dynamics involving discrete and continuous, multi-rigid-body and multi-dof vibrational mechanical systems
- Be able to adequately simulate and analyze dynamics of linear and non-linear mechanical systems

Competences

- Be able to apply energy minimization / maximization principles to derive the relationships between stresses, strains, displacements, material properties, and external effects (e.g., tractions and volume forces) in the form of balance of the kinetic and potential energies and the work done by internal and external forces.
- Be able to use the variational calculus as a convenient and robust tool for formulating the governing equations of statics and dynamics of rigid and solid bodies in applied mechanics.
- Be able to apply the energy and variational methods to find approximate analytical and numerical (e.g. finite element) solutions of complex problems in statics, stability and dynamics of mechanical systems
- Be able to formulate equations of motion for multi-body mechanical systems and for discrete multi-dof and continuous vibration systems using Lagrange and Newton-Euler equations.
- Be able to understand and analyze the dynamic behavior (mode shapes and eigenfrequencies) of linear vibration systems
- Be able to use appropriate (e.g., harmonic balance) methods to analyze behavior of nonlinear vibration systems.

Teaching Method: The form(s) of teaching will be determined and described in connection with the planning of the semester. The description will account for the form(s) of teaching and may be accompanied by an elaboration of the roles of the

participants (see chapter 3). The course/project theme is performed in either English or Danish dependent of the language skills of the participants.

Form of examination: Internal, oral/written examination

Evaluation criteria: As stated in the Joint Programme Regulations

3.4 Design of Mechanical Systems, 3rd Semester

3.4.1 Industrial Development (20, 25, 30 ECTS)

The extent of the project must reflect the allotted time in ECTS

Title: **Industrial Development**
(Industrielt udviklingsarbejde)

Prerequisites: This module is based on knowledge obtained in 2nd semester.

Goal: Students who complete the module are expected to:

Knowledge

- Have gained knowledge and understanding of advanced engineering design of mechanical systems and structures.
- Be able to understand and apply advanced analysis tools for evaluating the performance of advanced mechanical systems and structures.
- Have knowledge and comprehension of the relation between synthesis and analysis in the design process.

Skills

- Be able to describe the problem solved and the criteria applied for its solution.
- Be able to evaluate the concepts, theories, and methodologies applied in the solution of the problem.
- Be able to account for the choices made during the solution of the problem, and substantiate that these are made on a high professional level.
- Be able to assess the limitations of the concepts, theories, and methodologies applied in the solution of the problem.

Competences

- Be able to analyze and solve an actual problem, of industrial relevance, through application of systematic research and development processes, including advanced analytical, experimental, and/or numerical methods and models.

Organization: The project can be combined with up to 10 ECTS of courses, which reduces the ECTS of the project accordingly (e.g., a 20 ECTS project combined with 10 ECTS of course-work). The semester must add up to a total workload of 30 ECTS. The project may be finalized with a project report or in the form of a scientific paper with supporting appendices.

Teaching Method: The project work is carried out as an independent work process in which the students themselves organize and coordinate their workload in collaboration with a supervisor. The project may be carried out individually or in groups.

Form of examination: Internal, Oral examination (please see the program's study guide for further information)

Evaluation criteria: As stated in the Joint Programme Regulations

3.4.1 Internship (20, 25, 30 ECTS)

Title: **Internship**
(Projektorienteret forløb i en virksomhed)
The extent of the project must reflect the allotted time in ECTS

Prerequisites: This module is based on knowledge obtained in 2nd Semester.

Goal: Students who complete the module are expected to:

Knowledge

- Have gained knowledge and understanding of advanced engineering design of mechanical systems and structures.
- Be able to understand and apply advanced analysis tools for evaluating the performance of advanced mechanical systems and structures.
- Have knowledge and comprehension of the relation between synthesis and analysis in the design process.

Skills

- Be able to describe the problem solved and the criteria applied for its solution.
- Be able to evaluate the concepts, theories, and methodologies applied in the solution of the problem.
- Be able to account for the choices made during the solution of the problem, and substantiate that these are made on a high professional level.
- Be able to assess the limitations of the concepts, theories, and methodologies applied in the solution of the problem.

Competences

- Be able to analyze and solve an actual problem, of industrial relevance, through application of systematic research and development processes, including advanced analytical, experimental, and/or numerical methods and models.

Organization: The project can be combined with up to 10 ECTS of courses, which reduces the ECTS of the project accordingly (e.g., a 20 ECTS project combined with 10 ECTS of course-work). The semester must add up to a total workload of 30 ECTS. The project may be finalized with a project report or in the form of a scientific paper with supporting appendices.

Teaching Method: The student is included in the company's daily work and carry out independent project work on an industrial problem relevant for the company. Concurrent to the work in the company, the student makes a project report, which is evaluated after the ending of the internship.

Form of examination: Internal, Oral examination (please see the program's study guide for further information)

Evaluation criteria: As stated in the Joint Programme Regulations

3.5 Elective courses, 3rd Semester

3.5.1 Computational Fluid Dynamics (CFD) and Multiphase F (5 ECTS)

Title: Computational Fluid Dynamics (CFD) and Multiphase Flow/Numerisk strømningslære (CFD) og flerfasestrømning

Objective: Students who complete the module should:

Knowledge

- Have knowledge about the methods behind Computational Fluid Dynamics (CFD)
- Have knowledge about various spatial and temporal discretisation schemes
- Have knowledge about the pressure-velocity coupling method for solving the Navier-Stokes equations numerically
- Have knowledge about meshing strategies and boundary conditions
- Have knowledge about the fundamentals of turbulence, the energy cascade and Kolmogorov hypotheses
- Have knowledge and understanding within Reynolds-Averaged Navier-Stokes (RANS) and turbulence modelling
- Have knowledge about the fundamentals of multiphase flow
- Have knowledge about different modelling approaches for multiphase flow and multiphase models in the context of CFD
- Have knowledge about turbulence-particle interaction in multiphase flow

Skills and Competences

- Be able to use the finite volume method to numerically solve simple problems
- Be able to perform a mesh independency study in CFD analyses
- Be able to perform CFD analyses of a turbulent flow with regards to selection of turbulence model and near wall modelling/meshing strategy
- Be able to perform CFD analyses for non-reacting multiphase flow, for both the Euler-Euler and Euler-Lagrange approaches
- Be able to apply proper terminology in oral, written and graphical communication and documentation within CFD, turbulence and multiphase flows

Type of instruction: Lectures supplemented by workshops, exercises, hands-on and self-studies.

Examination format: Oral examination which can be based on a mini-project in accordance with the rules in the Examination Policies and Procedures, Addendum to the Joint Programme Regulations of Faculty of Engineering and Science, Aalborg University.

Assessment criteria: As stated in the Joint Programme Regulations.

3.5.2 Test and Validation (5 ECTS)

Title: **Test and Validation**
(Test og validering)

Prerequisites: The module adds to the knowledge obtained in Applied Statistics and Probability Theory.

Goal: Students who complete the module are expected to:

Knowledge

- Understand methodology for design of experiments and test series and for reduction of ambiguity of experimental results, and for comparability with model predictions
- Explain elementary and advanced quantification tools, and their application to validation between model and experiment data
- Account for common contemporary methods and relevant specific industry standards
- Understand processing methods for analog and digital data (continuous vs. discrete)

Skills

- scrutinize a non-trivial physical systems for appropriate experimental study
- isolate principal measurable parameters
- design an experiment matrix for systematic variation of parameters
- perform a probabilistic study of the experimental data in order to quantify the influence of individual parameters
- scrutinize a model (analytical or numerical) for comparison with an appropriate experimental study
- isolate principal input parameters and their known or assumed statistical variations
- perform a probabilistic study of the model in order to quantify the level of confidence
- account for the level of coherence between test results and model predictions
- Identify invalid data (outliers)
- account for common errors and limitations in the processing of model data or experimentally obtained data

Competences

- undertake experiment planning and execution for refinement and validation (or rejection) of model-based predictions of phenomena within their principal line of study..

Form of examination: Oral examination based on submitted written assignment

Evaluation criteria: As stated in the Joint Programme Regulations

3.6 Design of Mechanical Systems, 4th Semester

3.6.1 Design of Mechanical Systems (30, 50, 60 ECTS)

Title: **Master's Thesis**
Kandidatspeciale
The master thesis can be conducted as a long master thesis using both the 3rd and 4th semester. If choosing to do a long master thesis, it has to include experimental work and has to be approved by the study board. The amount of experimental work must reflect the allotted ECTS.

Goal: Students who complete the module are expected to:

Knowledge

- Have attained thorough understanding of a broad range of theoretical, numerical and experimental techniques within the area of design of mechanical systems.

Skills

- Be able to apply scientific methodology to solve a wide variety of problems within the field of specialization.
- Be able to perform scientific work in relevant topics within the field of specialization.
- Be able to apply a wide range of engineering methods in research and development projects in the field of specialization.
- Be able to participate or lead projects in mechanical system design, product development, modeling and analysis of mechanical systems, materials technology, production technology, structural mechanics and design of lightweight structures.

Competences

- Be able to work independently with a project on a specific problem within their field of interest on the highest possible level within their specialization.
- Be able to take part in technical development and research
- Be able to direct the technical management of development projects within the industry.
- Be competent to solve new and complicated technical problems by the use of advanced mathematics, scientific and technological knowledge.

Teaching Method: In this module, the Master's project is carried out. The module constitutes independent project work and concludes the program. Within the approved topic, the Master's project must document that the level for the program has been attained.

Form of examination: Oral examination with participation of an external examiner.

Evaluation criteria: As stated in the Joint Programme Regulations

Chapter 4: Entry into Force, Interim Provisions and Revision

The curriculum is approved by the Dean of the Faculty of Engineering and Science and enters into force as of September 2017.

Students who wish to complete their studies under the previous curriculum from 2014 must conclude their education by the summer examination period 2018 at the latest, since examinations under the previous curriculum are not offered after this time.

In accordance with the Joint Programme Regulations for the Faculty of Engineering and Science at Aalborg University, the curriculum must be revised no later than 5 years after its entry into force.

Chapter 5: Other Provisions

5.1 Rules concerning written work, including the Master's thesis
In the assessment of all written work, regardless of the language it is written in, weight is also given to the student's spelling and formulation ability, in addition to the academic content. Orthographic and grammatical correctness as well as stylistic proficiency are taken as a basis for the evaluation of language performance. Language performance must always be included as an independent dimension of the total evaluation. However, no examination can be assessed as 'Pass' on the basis of good language performance alone; similarly, an examination normally cannot be assessed as 'Fail' on the basis of poor language performance alone.
The Board of Studies can grant exemption from this in special cases (e.g., dyslexia or a native language other than Danish).
The Master's thesis must include an English summary.[3] If the project is written in English, the summary must be in Danish.[4] The summary must be at least 1 page and not more than 2 pages. The summary is included in the evaluation of the project as a whole.

5.2 Rules concerning credit transfer (*merit*), including the possibility for choice of modules that are part of another programme at a university in Denmark or abroad
In the individual case, the Board of Studies can approve successfully completed (passed) programme elements from other Master's programmes in lieu of programme elements in this programme (credit transfer). The Board of Studies can also approve successfully completed (passed) programme elements from another Danish programme or a programme outside of Denmark at the same level in lieu of programme elements within this curriculum. Decisions on credit transfer are made by the Board of Studies based on an academic assessment. See the Joint Programme Regulations for the rules on credit transfer.

5.3 Rules for examinations
The rules for examinations are stated in the Examination Policies and Procedures published by The Technical Faculty of IT and Design, The Faculty of Engineering and Science, and the Faculty of Medicine on their website.

5.4 Exemption
In exceptional circumstances, the Board of Studies study can grant exemption from those parts of the curriculum that are not stipulated by law or ministerial order. Exemption regarding an examination applies to the immediate examination.

5.5 Rules and requirements for the reading of texts
At programmes taught in Danish, it is assumed that the student can read academic texts in modern Danish, Norwegian, Swedish and English and use reference works, etc., in other European

[3] Or another foreign language (upon approval from the Board of Studies.
[4] The Board of Studies can grant exemption from this.

languages At programmes taught in English, it is assumed that the student can read academic text and use reference works, etc., in English.

5.6 Additional information
The current version of the curriculum is published on the Board of Studies' website, including more detailed information about the programme, including exams.