Module manual for
Smart Production
Engineering
SPE

SPO Version 2022
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Module manual for Smart Production Engineering (Master (1-Subject))

Module manual for
Smart Production
Engineering
SPE

RWTH AACHEN UNIVERSITY

Examination Regulation Field

Module offer

Examination offer

Teaching offer

CONTENT
Module manual for
Smart Production
Engineering
SPE

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Engineering
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Examination Regulation Title & Version:
Smart Production Engineering (SPO Version / 2022)

Title	Smart Production Engineering
Short title	SPE
Version	2022
Study/Qualification Objectives	The master's degree program in Smart Production Engineering qualifies graduates to apply the methods and concepts they have learned to future developments in production engineering and to work on production engineering problems under different technological, economic, and social circumstances. Graduates who have obtained this master's degree have the following qualifications: • They gain in-depth knowledge in the areas of production engineering, production management, quality management as well as mechatronics and control engineering of production plants. • They apply interdisciplinary and specialized analytical and methodological procedures to solve technical problems. • They have the competencies to rethink entire production creation and manufacturing processes through the responsible, social, and critical use of digital systems and the associated technological knowledge. • After graduation, they will have a broad fundamental knowledge of engineering and competencies in production technology, which will enable them to take on demanding tasks and challenges in the global transformation of the work environment.
Qualification Profile	
Additionnal information	

+ Mechatronics and Control Techniques for Production Plants ...

Module titel	Mechatronics and Control Techniques for Production Plants (Compulsory subject)
Identifier	4011451
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2013
Valid until	-
Module level	Master

Content	• Indroduction of Mechatronics and Control Techniques for Production Plants
	• Mechanical controls
	  • Machine elements of mechanical controls
	  • Application examples for mechanical controls
	• Information processing in mechatronic systems
	  • Theory and examples of embedded systems
	  • Programming of embedded systems and logical controls
	• Programmable Logic Control (PLC) and Motion Control (MC)
	  • Programming of programmable logic controllers
	  • Test methods of programmable logic controllers (HIL)
	• Numerical Control 1: Design, programming, CAM
	  • NC programming procedures (manual and workshop-oriented)
	  • NC programming of CAM systems
	• Numerical Control 2: Interpolation
	  • Structure of an NC control
	  • Tool offset, kinematic transformation and compensations, speed control and Interpolation
	• Position control of feed drives
	  • Control concept of a machine axis
	  • Accuracy and synchronous control of multi-axis systems
	• Measurement Systems and Sensors
	  • Measured variables in production systems
	  • Position, current acceleration, force, torque, temperature and angle measuring systems
	• Signal processing, process and condition monitoring
	  • Tasks of the process and condition monitoring
	  • Use of sensors and processing of sensor signals
	• Robots and handling systems, Robot Control (RC)
	  • Areas of application
	  • Construction and kinematics
	• Gripper technology
	  • Gripping principles
	• Mechatronic and system-oriented engineering
	  • Design and simulation software (drive design and behavior modeling)
	  • Virtual Commissioning

Learning Objectives/ Learning Outcomes	Subject-related: The students know in particular • Construction and design of mechatronic systems for production equipment • Characteristics of logical and mechanical numerical motion controls of machines • Special features of the behavior and the modeling of mechatronic components, especially for measuring and gripping technology • Concepts of machine control in various development systems, as well as machine and process monitoring • Fields of application, possibilities of an industrial engineering system and the design

+ Mechatronics and Control Techniques for Production Plants ...

	After this course, the students are able to understand the structure of mechatronic systems in the area of application of the means of production in its complexity and its context and overarching concepts of machine control systems to classify. Not subject-related: The Students can explain application areas and display the characteristics of motion controls required in machine and process monitoring. In addition, you can theoretically explain the design of an application-oriented problem and apply it to application-relevant questions. This allows the students to analyze theory-based mechatronic systems for production systems and industrial monitoring solutions and to evaluate their quality in the industrial environment. With this competence, they are able to use their own creative ideas and within the framework of the concepts known to you to develop solutions and to establish the set-up of concepts. In addition to the problem solving, they can also create control programs in various development systems and evaluate their quality.
(Study-Specific) Prerequisites	-
(recommended) Requirements	Recommended: Machine Tools
References	Skripte lecture and exercise for download as PDF
Language	English
Examination Terms	Written examination
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr.-Ing. Christian Brecher
ECTS Credits	6
Contact time (WSH)	-
Examination duration (min)	-
Total hours (h)	180,0
Contact hours (h)	-
Self-study hours (h)	-

● Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Mechatronics and Control Techniques for Production Plants (401145101)	1st semester	no semester recommended	6	0

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Mechatronics and Control Techniques for Production Plants	1st semester	no semester recommended	-	2

+ Mechatronics and Control Techniques for Production Plants ...

Exercise Mechatronics and Control Techniques for Production Plants	1st semester	no semester recommended	-	2

+ Manufacturing Technology I (4011458)

Module titel	Manufacturing Technology I (Compulsory subject)
Identifier	4011458
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2011
Valid until	-
Module level	Master
Content	- Introduction in manufacturing technology - Machining with geometrically defined cutting edge - Machining with geometrically undefined cutting edge I - Material removal manufacturing processes EDM - Material removal manufacturing processes ECM - Bulk forming - Sheet metal forming - Casting/Powder metallurgy - Additive manufacturing - Laser material processing and high-pressure water jet machining - Technology chain design and manufacturing-induced part characteristics - Closing-off lecture with contributions from the students
Learning Objectives/ Learning Outcomes	Overall goal: Extend prior knowledge about manufacturing technologies with scientific approaches, methods and models After successfully completing this course, the students will have acquired the following learning outcomes: Knowledge / Understanding Students: • know and understand the working principles of relevant manufacturing technologies. • know and understand the process parameters and the main effects on the part's quality, tool wear and processing time. • know and understand tool wear mechanisms and resulting errors. Abilities / Skills Students: • are able to assess manufacturing processes, machine tools and metrology methods with regard to workpiece characteristics. • Are able to evaluate the effects of parameter changes on thermo-mechanical loads, wear behaviour and risks. • are able to analyse, optimize and to question established manufacturing processes from a scientific point of view. Competencies

+ Manufacturing Technology I (4011458)

	Students: • critically analyse company decisions with a broad technological background and can communicate the assessments to non-specialist audiences. • elaborate manufacturing strategies for higher quality, more output and lower costs. • present alternatives for the production. At the end of the lecture series, students are given the opportunity to design a closing-off lecture. A few weeks before, topics will be offered, to which students can research independently, prepare a presentation and give a short lecture. The presentations can be done individually or in a small group and their contents can also be used for the exam. As an incentive, the chair offers the option to receive a letter of recommendation. The chair is enabled to do so by the personal commitment, the special interest in the subject, the cooperation during the preparation and by an impression of the quality of the presentation.
(Study-Specific) Prerequisites	-
(recommended) Requirements	-
References	-
Language	English
Examination Terms	Written exam or oral exam
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr.-Ing. Dr.-Ing. E. h. Dr. h. c. Dr. h. c. Fritz Klocke
ECTS Credits	5
Contact time (WSH)	-
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	-
Self-study hours (h)	-

● Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Manufacturing Technology I (401145801)	1st semester	no semester recommended	5	0

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Manufacturing Technology I	1st semester	no semester recommended	-	2

+ Manufacturing Technology I (4011458)

Tutorial Manufacturing Technology I	1st semester	no semester recommended	-	2

+ Production Management B (4011472)

Module titel	Production Management B (Compulsory subject)
Identifier	4011472
Version	-
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2014
Valid until	-
Module level	Master
Content	• IT in Production Management • Customer Relations Management • Enterprise Ressource Planning I • Enterprise Ressource Planning II • Enterprise Ressource Planning III • Supply Chain Management I • Supply Chain Management II • Product Lifecycle Managment I • Product Lifecycle Managment II • Product Lifecycle Managment III • Digitale Plant Planning and Simulation • Business Engineering - Method of selecting IT-Systems
Learning Objectives/ Learning Outcomes	On the basis of the lecture "Producion Management A" students will gain knowledge concerning particular aspects of the domains design, process planning, production as well as program planning and investment planning. They will understand the usefulness of modern planning methods, with emphasis on the application of computers (CAD, CAP, CAM etc.). Practical examples offer the possibility to understand the boundary conditions in daily business and give the students a comprehensive basis to reflect advantages and disadvantages of the discussed systems.
(Study-Specific) Prerequisites	-
(recommended) Requirements	-
References	-
Language	English
Examination Terms	Written exam or oral exam
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr.-Ing. Dipl.-Wirt. Ing. Günther Schuh
ECTS Credits	5
Contact time (WSH)	-
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	-

+ Production Management B (4011472)

Self-study hours (h)	-

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Production Management B (401147201)	2nd semester	no semester recommended	5	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Production Management B	2nd semester	no semester recommended	-	2
Exercise Production Management B	2nd semester	no semester recommended	-	2

+ Manufacturing Technology II (4011447)

Module titel	Manufacturing Technology II (Compulsory subject)
Identifier	4011447
Version	Angelegt über RWTH API als 1_neu
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2021
Valid until	-
Module level	Master
Content	Fundamentals: • Signatures of manufacturing processes • Tribology • Material specific challenges in cutting • High performance cutting • Forming technology • FEM-Simulation in manufacturing technology • Computer-aided technology planning • Process data • Productivity and profitability Branches: • Tool making • Propulsion technology • Gear making technologies • Optics
Learning Objectives/ Learning Outcomes	Wissen und Verstehen: Students acquire in-depth knowledge of desirable and undesirable manufacturing-related property modifications in the rim zone and in the interior of the component. They understand and model tribological effects and master material-specific challenges in cutting. They know: - Current developments in high-performance machining, - Latest trends in forming technology, - Fundamentals of FEM simulation of cutting and forming processes, - Possibilities for computer-aided design and optimization of manufacturing processes, - Current approaches to control manufacturing processes,

+ Manufacturing Technology II (4011447)

	- Key figures for the description of productivity and efficiency of manufacturing processes and basics of static test methodology, - Approaches of digitization in the addressed areas. They are familiar with the manufacturing technology challenges and current solution approaches in branches: - Tool making, - Optics, - Propulsion and gear making technology. This enables them to apply their knowledge to future development tasks. Fertigkeiten und Kompetenzen: Students can analyze and optimize manufacturing processes against a broad technological background. They are able to plan series of experiments based on hypotheses and take into account technological relationships of cause and effect. Moreover, they are able to further develop existing manufacturing processes and identify alternatives.
(Study-Specific) Prerequisites	-
(recommended) Requirements	Empfohlene Voraussetzungen: Manufacturing Technology I
References	-
Language	English
Examination Terms	A written or an oral exam
Miscellaneous	-
Module coordinator	Univ.-Prof. Dr.-Ing. Thomas Bergs
ECTS Credits	6
Contact time (WSH)	4
Examination duration (min)	-
Total hours (h)	180,0
Contact hours (h)	60,0
Self-study hours (h)	120,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Manufacturing Technology II (401144701)	2nd semester	no semester recommended	6	0

+ Manufacturing Technology II (4011447)

▲Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Manufacturing Technology II	2nd semester	no semester recommended	-	2
Tutorial Manufacturing Technology II	2nd semester	no semester recommended	-	2

+ Quality Management (4011453)

Module titel	Quality Management (Compulsory subject)
Identifier	4011453
Version	V2
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2022
Valid until	-
Module level	Master
Content	The digitalization and networking of production increases the availability of data over the entire product life cycle and changes the role of quality management in relation to systems, processes and products. With the shift in focus of data analysis from reactive and corrective to proactive and predictive, the principles of quality management remain, but actors acting in quality management need new tools, e.g. from the domain of machine learning, to deal with increased complexity. The lecture deals with the interweaving of quality-related methods with the needs of a rapid situation clarification of possibly deviating processes along value chains or the associated industrial services. The orientation towards the structure of the "Internet of Production" first builds on the principles of quality management (e.g. important standards, clarification of the terms system, process and product quality). The identification of quality relevant data sources (incl. social media) along the product life cycle leads to the modelling of the data-information-knowledge pyramid. The statistical/stochastic basics serve as a fundamental basis to understand methods of data analytics and machine learning and are applied situationally to typical problem classes from different areas of quality management (e.g. process control, risk management, fault management), which are typified with regard to their structure and thus made accessible for rationalization. The goal is to increase the action competence of actors by decision support (e.g. by the use of smart devices). Contributions from practice give insight into the implementation of quality management in industry.
Learning Objectives/ Learning Outcomes	Knowledge Students shall know • Important standards and guidelines in the knowledge domain "quality management" • structure of standards (high-level structure) • System, process and product quality • Quality relevant data and data sources along the product life cycle • Statistical and methodical basics of "lndustrial lntelligence" as a core task of QM • Legal implications Understanding Students shall understand • The "Internet of Production" • The importance of quality and machine learning methods in networked adaptive production • Importance of quality and quality management in networked, adaptive production • The Classification of typical problems • basic data analytics and machine learning methods Students shall be able to apply: • Data collection (e.g. customer insights in the product development process and during product usage, data-driven procurement management) • selected data analytics and machine learning methods (e.g. for risk quantification and prediction, process control) • Quality management for services • Decision support of the "Smart Quality Expert" (e.g. predictive quality, predictive maintenance) Skills and Competencies Students

+ Quality Management (4011453)

	• shall develop an understanding of the different forms of the quality concept that can be operationalized in the operational process and classify them in the sense of "Industrial Intelligence". • shall be able to identify and classify problems in the corporate context. • shall have basic knowledge in the field of machine learning, shall know corresponding advanced quality management methods and be able to describe their specific applicability and effectiveness. • shall be able to theoretically and practically penetrate applications in the quality management domain with the knowledge imparted to them as a 'tool'. • shall be able to build up the structure of an "lndustrial lntelllgence" by means of quality management methods in the corporate context, to evaluate it with regard to its effectiveness and to further develop and meaningfully link quality management methods based on an understanding of interrelationships and principles. • shall be able to intervene in value chains in an improving way based on their well-founded methodological and organizational knowledge. • shall be able to recognize and evaluate situations, strengths and weaknesses of an existing quality management system and to formulate suitable measures for a coherent further development. The contents are based on research of the Cluster of Excellence "Internet of Production". Considering this background, the participants should take the mental transformation from the application of tools (methodological competence) to the design of the underlying principles and cause-effect relationships in value chains (action competence).
(Study-Specific) Prerequisites	-
(recommended) Requirements	-none-
References	• Lecture Notes • Students also receive a list of relevant literature
Language	English
Examination Terms	Written (100 %)
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr.-Ing. Robert Schmitt
ECTS Credits	6
Contact time (WSH)	4
Examination duration (min)	-
Total hours (h)	180,0
Contact hours (h)	60,0
Self-study hours (h)	120,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Quality Managment (401145301)	3rd semester	no semester recommended	6	0

+ Quality Management (4011453)

▲Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture/Tutorial Quality Management	3rd semester	no semester recommended	-	4

Module titel	Welding and Joining Technologies (Compulsory subject)
Identifier	4011441
Version	-
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2012
Valid until	-
Module level	Master
Content	• Introduction • Welding of steel • Gas Fusion Welding • Manual Metal Arc Welding • Submerged Arc Welding • TIG Welding • Plasma Welding • MIG Welding • Electro Gas Welding • Electro Slag Welding • Pressure Welding • Resistance Welding • Electron Beam Welding • Laser Beam Welding • Special Processes • Mechanisation / • Automation • Sensor Technology • Brazing • Mechanical Joining / Adhesive Bonding • Essentials in Design and Calculation
Learning Objectives/ Learning Outcomes	After successfully completing this course, the students will have acquired the following learning outcomes: Knowledge / Understanding Students: • know and understand the main welding technologies. Abilities / Skills Students: • select the suitable welding technologies for a welding task and substantiate the selection by specifying the advantages and the disadvantages of the individual methods.
(Study-Specific) Prerequisites	-
(recommended) Requirements	-none-
References	-

Language	English
Examination Terms	Written exam
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr.-Ing. Uwe Reisgen
ECTS Credits	6
Contact time (WSH)	-
Examination duration (min)	0
Total hours (h)	180,0
Contact hours (h)	-
Self-study hours (h)	-

● Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Welding and Joining Technologies (401144101)	2nd semester	no semester recommended	6	0

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Tutorial Welding and Joining Technologies	2nd semester	no semester recommended	-	2
Lecture Welding and Joining Technologies	2nd semester	no semester recommended	-	2

Module titel	Additive Manufacturing 2 (Compulsory subject)
Identifier	4020490
Version	-
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2019
Valid until	-
Module level	Master
Content	1) Einführung: Motivation, Übersicht relevanter AM-Technologien 2) Produktentstehungsprozess (PEP) - Herkömmliche Ansätze: VDI2221, Lastenheft, Pflichtenheft, Projektplanung, Gantt-Chart 3) PEP - Neue Ansätze: Agile Produktentwicklung, SCRUM, Sprint, MVP, Design Thin-king 4) PEP - Agile Produktentwicklung: Grundlagen, Vorgehen, Rollen, Best Practice 5) Design for AM (DfAM): Restriktionen, Konstruktionsregeln, Stützstrukturen, Best Practice 6) DfAM-Methoden I: Geometrievariation (Modular vs. Integral, Methoden zur Funktionsintegration, Feature-Gestaltung), CAD-Software, Best Practice 7) DfAM-Methoden II: Topologieoptimierung (Grundlagen, sinnvolle Anwendungen, Vorgehen), CAD-Software, Best Practice 8) DfAM-Methoden III: Gitterstrukturen (Grundlagen, sinnvolle Anwendungen, Vorge-hen), CAD-Software, Best Practice 9) Business Case assessment I: Part Identification 10) Business Case assessment II: Reverse Engineering 11) Business Case assessment III: AM Costing, Kalkulationsmethoden Prozesskosten, Maschinensätze, Ressourcenorientiert) 12) Enterprise Environment I: PLM (Grundlagen, Costing, Projektmanagement), Work-flow und Änderungsmanagement 13) Enterprise Environment II: ERP
Learning Objectives/ Learning Outcomes	• Die Studierenden haben Kenntnis über die wesentlichen Methoden im Produktentstehungsprozess (PEP) und sind in der Lage, herkömmliche und neue Ansätze des PEP auf additiv zu fertigende Bauteile anzuwenden • Die Studierenden kennen die wesentlichen AM-spezifischen Konstruktionsregeln, simulationsgetriebenen Designprozessketten sowie die hierfür notwendigen Software-Programme und können verschiedene Design-Methoden anwenden • Die Studierenden sind in der Lage, potentielle AM-Bauteile als Business cases zu identifizieren und über verschiedene Kalkulationsmethoden wirtschaftlich einzuordnen • Die Studierenden haben Kenntnis über die wesentlichen anagementmethoden zur Einbindung der AMTechnologie in PEP, Prouktion und Geschäftsprozesse. • Die Studierenden sind in der Lage, Lösungen zu vorgegebenen Fragestellungen selbstständig zu erarbeiten.
(Study-Specific) Prerequisites	-

(recommended) Requirements	AM 1, Fertigungstechnik, Produktionssystematik, Konstruktionslehre
References	Vorlesungsskript, Übungsaufgaben
Language	German
Examination Terms	Die Note ergibt sich zu 100% aus der schriftlichen Klausur.
Miscellaneous	-
Module coordinator	Univ.-Prof. Dr.-Ing. Dipl.-Wirt.-Ing. Johannes Schleifenbaum
ECTS Credits	6
Contact time (WSH)	-
Examination duration (min)	-
Total hours (h)	180,0
Contact hours (h)	-
Self-study hours (h)	-

● Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Additive Manufacturing 2 (402049001)	2nd semester	no semester recommended	6	-

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Additive Manufacturing 2	2nd semester	no semester recommended	-	2
Exercise Additive Manufacturing 2	2nd semester	no semester recommended	-	2

Module titel	Materials for Additive Manufacturing (Compulsory subject)
Identifier	4022684
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2021
Valid until	-
Module level	Master
Content	• Introduction: Motivation, additive manufacturing processes and material classes • Input materials for additive manufacturing process, their properties, determination and evaluation of these properties • Material defects, their causes and effects • General microstructure and texture development during the additive manufacturing and post-treatment process, influencing factors on the microstructures formed and textures in materials manufactured using additives • Correlation between microstructure, texture and properties of additive materials • Production, properties, finishing, applications of additive steels • Production, properties, finishing, fields of application of additive aluminium alloys • Production, properties, finishing, fields of application of additive titanium alloys • Production, properties, post-processing, fields of application of additive nickel-based alloys • Production, properties, post-processing, fields of application of additive manufactured other metallic alloys • Failure behaviour of additive materials • Simulation of material behaviour during and after additive manufacturing
Learning Objectives/ Learning Outcomes	After successfully completing this course, the students will have acquired the following learning outcomes: Knowledge / Understanding Students • understand the correlation between the AM process, microstructure development and properties of materials for additive manufacturing. In addition to the actual additive manufacturing processes, post-treatment processes are also considered • learn about the causes of material defects and their effect on their properties • learn the relevant properties of the input materials, e.g. powder, and understand their influence on the material behaviour along the additive manufacturing process chain. Abilities / Skills Students • describe the differences between additive and conventionally manufactured materials and parts. Competencies Students • independently work out solutions to given problems.
(Study-Specific) Prerequisites	-
(recommended) Requirements	none
References	Lecture Notes

	Students also receive a list of relevant literature
Language	English
Examination Terms	-
Miscellaneous	-
Module coordinator	Univ.-Prof. Dr.-Ing. Johannes Schleifenbaum
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

● Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Materials for Additive Manufacturing (402268401)	3rd semester	no semester recommended	5	-

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Materials for Additive Manufacturing	3rd semester	no semester recommended	-	2
Exercise Materials for Additive Manufacturing	3rd semester	no semester recommended	-	1

Module titel	Laser Applications (Compulsory subject)
Identifier	4022685
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2020
Valid until	-
Module level	Master
Content	• The laser principle • Properties of laser radiation (spectral, temporal and spatial) • Laser types and systems • Reflection, absorption, transmission • Temperature, heat conduction, mass diffusion and melt pool dynamics • Laser-based surface treatment • Additive Manufacturing • Joining • Cutting • Ablation • Measurement technology
Learning Objectives/ Learning Outcomes	Overall goal: Students gain basic knowledge about the generation, characteristics and applications of laser radiation. After successfully completing this course, the students will have acquired the following learning outcomes: Knowledge / Understanding: Students • understand the generation and properties of laser radiation • know the fundamentals of light-matter interaction, heat transport and phase transitions • gain knowledge about laser-based processing and manufacturing (like hardening, joining, drilling, cutting and additive manufacturing) and further fields of laser application (like measurement technology). Abilities / Skills: Students • are able to evaluate manufacturing processes in order to identify those that benefit from the use of laser radiation • can apply mathematical techniques to identify and optimise process-specific laser beam parameters. Competencies: Students • are able to identify suitable laser parameters for specific tasks in materials processing • can identify a laser source providing the desired parameters for a given process • are able to work on current research problems, e.g. within a Master’s thesis
(Study-Specific) Prerequisites	-

(recommended) Requirements	none
References	Lecture notes R. Poprawe, K. Boucke, D. Hoffmann: Tailored Light 1 (Springer Verlag, 2018) R. Poprawe: Tailored Light 2 (Springer Verlag, 2011) Students receive a list of relevant literature
Language	English
Examination Terms	A written or an oral exam
Miscellaneous	-
Module coordinator	Univ.-Prof. Dr. rer. nat. Constantin Leon Häfner
ECTS Credits	6
Contact time (WSH)	4
Examination duration (min)	-
Total hours (h)	180,0
Contact hours (h)	60,0
Self-study hours (h)	120,0

● Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Laser Applications (402268501)	1st semester	no semester recommended	6	-

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Laser Applications	1st semester	no semester recommended	-	2
Exercise Laser Applications	1st semester	no semester recommended	-	2

Module titel	Additive Manufacturing: Technologies and Processes (Compulsory subject)
Identifier	4017421
Version	Angelegt über RWTH API als 1_neu
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2021
Valid until	-
Module level	Master
Content	1) lntroduction: motivation, market relevance, overview of relevant technologies 2) selective laser melting: process principle, develpoment of process strategies, quality and cost optimization, high power slm 3) laser metal deposition: process princlple, workflow and productivity, best practice examples 4) selective laser sintering & stereolithography: process principle, workflow and productivity, best practice examples 5) thin film processing: process principle, workflow and productivity, best practice examples 6) material & process control: material classes, properties and applications, material production and quality assurance, quality aspects within additve manufacturing, system technology and sensor technology, controlling and monitoring of laser manufacturing processes 7) design for additive manufacturing I: agil project management within additive manufacturing, extension of the CAE process chain, AM software, AM confirm product development 8) design for additive manufacturing II: simulation driven design process (topology optimization, integration of lattice structures, function integration) 9) production planning I: job preperation (data control and mesh repair, CAM (SLM vs. LMD), part placement & material handling, work safety and environment 10) production planning II: simulation (mold dynamics, heat transfer, structure, tension, protective atmosphere and gas flow, und nozzle design) 11) subsequent processes: heat treatment, surface finishing, hybrid application, automatization concepts. 12) application and market: present applications & expectet developments, efficiency, intellectual property 13) summary and future trends: key properties of AM technologie, overview of the physical and digital processchain, outlook
Learning Objectives/ Learning Outcomes	Knowledge and comprehension: - the students have knowledge of significant AM - technologies and their fundamental properties and applications - the students are in the position to differentiale AM - technotogies from conventional production processes - the students have knowledge of AM - specific construction rules and simulation driven design processes - the studends know essential pre- and post processes and interdependencies along the digital and physical process chain

	- the students know major factors of key determinants on the economic application of AM - technology - the students have knowledge of content-related aspects which correspond to present applications and expected developments Skills and competencies: - the students are able to develop own strategies and solutions to prescribed scientific issues
(Study-Specific) Prerequisites	-
(recommended) Requirements	Recommended: - knowledge in production technology - knowledge in heat and mass transfer - knowledge in laser technology
References	Vorlesungsskript, Übungsaufgaben
Language	German/English
Examination Terms	Exam
Miscellaneous	-
Module coordinator	Modulverantworlicher: Universitätsprofessor Dr.-Ing. Dipl.-Wirt.-Ing. Johannes Schleifenbaum
ECTS Credits	6
Contact time (WSH)	4
Examination duration (min)	-
Total hours (h)	180,0
Contact hours (h)	60,0
Self-study hours (h)	120,0

● Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Additive Manufacturing: Technologies and Processes (401742101)	1st semester	no semester recommended	6	0

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exercise Additive Manufacturing: Technologies and Processes	1st semester	no semester recommended	-	2

Lecture Additive Manufacturing: Technologies and Processes	1st semester	no semester recommended	-	2

Module titel	Gear and Transmission Technology (Compulsory elective subject)
Identifier	4011427
Version	V2
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2019
Valid until	-
Module level	-
Content	L01: Transmission in application L02: Gear geometry L03: Gear damages L04: Gear design I - Macro geometry L05: Gear design II - Micro geometry L06: Load Carrying and Efficiency L07: Acoustics L08: Process chains L09: Manufacturing I - Defined cutting edge L10: Manufacturing II - Undefined cutting edge L11: Crossing axes I - Bevel gears L12: Crossing axes II - Special gears L13: Planetary gears
Learning Objectives/ Learning Outcomes	L01: Transmission in application L02: Gear geometry L03: Gear damages L04: Gear design I - Macro geometry L05: Gear design II - Micro geometry L06: Load Carrying and Efficiency L07: Acoustics L08: Process chains L09: Manufacturing I - Defined cutting edge L10: Manufacturing II - Undefined cutting edge L11: Crossing axes I - Bevel gears L12: Crossing axes II - Special gears L13: Planetary gears
(Study-Specific) Prerequisites	-
(recommended) Requirements	Manufacturing Technology I Machine Tools
References	Lecture and exercise notes for download Recommended literature: • Zahnrad- und Getriebetechnik, Fritz Klocke, Christian Brecher • Werkzeugmaschinen Bd. 1, Christian Brecher • Fertigungstechnik Bd. 1-5, Fritz Klocke
Language	English
Examination Terms	Eine schriftliche oder eine mündliche Prüfung
Miscellaneous	-

Module coordinator	Universitätsprofessor Dr.-Ing. Christian Brecher Universitätsprofessor Dr.-Ing. Dr.-Ing. E. h. Dr. h. c. Dr. h. c. Fritz Klocke
ECTS Credits	6
Contact time (WSH)	-
Examination duration (min)	-
Total hours (h)	180,0
Contact hours (h)	-
Self-study hours (h)	-

● Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Gear and Transmission Technology (401142701)	1st semester	no semester recommended	6	0

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exercise Gear and Transmission Technology	1st semester	no semester recommended	-	2
Lecture Gear and Transmission Technology	1st semester	no semester recommended	-	2

Module titel	Production Metrology (Compulsory elective subject)
Identifier	4011467
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2012
Valid until	-
Module level	Master
Content	Introduction • Relevance of metrology for quality assurance and its integration in production processes. Metrological Basics • Metrological concepts and definitions (Calibration, Uncertainty etc.) Tolerancing • Form and positional tolerances, tolerancing principles and basics Inspection Planning • Tasks and workflow of inspection planning, Procedure for creation of inspection plans Shop floor measuring devices/ Measuring sensors • Commonly used manual inspection devices for the shop floor, Function and application of inductive, capacitive and pneumatical sensors Optoelectronic inspection devices • Optical inspection systems for geometry testing and applications Form and surface inspection devices • Tactile and optical system for the characterisation of forms and surfaces, surfaces parameters Coordinate measurement technology • Principles, types and applications of coordinate measuring machines Gauging inspection • Form and positional gauging, Gauging Procedures Statistical basics • Statistical parameters for the description of production and measuring processes, tests on normal distribution SPC, Process Capability • Statistical analysis and control of processes, Process capability indices Inspection device management • Tasks and procedures of inspection device management, Calculation of measuring device capability, Calibration chain
Learning Objectives/ Learning Outcomes	First of all, the elements of the application of the means of measurement concerning the production are pointed out. The theoretical fundamentals which have to be taken into consideration while the measuring process is planned, controlled, analysed, are discussed. Thereby, current measuring principles and devices in the field of industrial production will be considered and new measuring techniques and trends will be presented In this context the characteristics of the measured quantities and their fringe conditions are explained. A further subject of the lecture will be the statistical analysis of the measured values.

	The aim of this lecture is to create the awareness, that “measuring” comprehends a lot more than plain data acquisition and metrology is a vital part of modern production processes.
(Study-Specific) Prerequisites	-
(recommended) Requirements	-
References	-
Language	English
Examination Terms	Written exam or oral exam
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr.-Ing. Robert Schmitt
ECTS Credits	5
Contact time (WSH)	-
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	-
Self-study hours (h)	-

● Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Production Metrology (401146701)	2nd semester	no semester recommended	5	0

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture/Exercise Production Metrology	2nd semester	no semester recommended	-	4

Module titel	Industrial Logistics (Compulsory elective subject)
Identifier	4011473
Version	-
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2014
Valid until	-
Module level	Master
Content	• Objectives and tasks of logistics • Organisational involvement of logistics • Exercise: Prozess optimisation • Material flow design • Recitation by an external • Information logistics • Exercise: "Beergame" • Development and Procurement • Exercise: Development and Procurement • Material and finished goods disposition • Exercise: Workshop on the Enhancement of Disposition Quality • Distribution logistics • Exercise: Opening proceedings for tour planning • Spare part logistics • Recitation by an external • Logistics controlling • Exercise: ABC, XYZ Analysis
Learning Objectives/ Learning Outcomes	Students know objectives and tasks of industrial logistics as well as main aspects of industrial logistics from organisational involvement to logistics controlling. Students understand the meaning and the effects of individual aspects of industrial logistics and can place them in the overall context.They can apply the knowledge acquired to practical problems.
(Study-Specific) Prerequisites	-
(recommended) Requirements	-
References	-
Language	English
Examination Terms	Written exam or oral exam
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr.-Ing. Dipl.-Wirt. Ing. Günther Schuh apl. Professor Dr.-Ing. Volker Stich
ECTS Credits	5
Contact time (WSH)	-
Examination duration (min)	-

Total hours (h)	150,0
Contact hours (h)	-
Self-study hours (h)	-

● Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Industrial Logistics (401147301)	2nd semester	no semester recommended	5	0

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exercise Industrial Logistics	2nd semester	no semester recommended	-	1
Lecture Industrial Logistics	2nd semester	no semester recommended	-	2

Module titel	Tribology (Compulsory elective subject)
Identifier	4011475
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2013
Valid until	-
Module level	Master
Content	Basics of Tribology: • The Tribosystem in general and its analysis, its wear and friction processes and their test methods, also reasonable test and substitute systems Interactions between base and contact Bodies: • Contact processes and geometries, material strain, Hertzian theory, contact mechanics Interactions between base and contact Bodies: • Frictional processes and the results and influence on the tribosystem, wear processes and methods to avoid wear and losses Properties of base and contact Bodies: • Tribomaterials and the analysis of technical surfaces, roughness, hardness definitions and test methods Properties of base and contact Bodies: • Coating types and methods and their technical application, systematical methods and examples for the correct choice of material Properties of intermediate medium: • Basic properties, dependencies and test methods for the viscosity Properties of intermediate medium: • Classification, properties and application examples for different lubricants (oils, greases and solid lubricants) Basics of hydrodynamics and elastohydrodynamics: • Fundamentals and principles of flow mechanisms, derivation of Navier-Stokes and Reynolds equations and continuity equation Basics of hydrodynamics and elastohydrodynamics: • Application of the hydrodynamic equations regarding the calculation of bearings, Basics of the elastohydrodynamics Triboystem Journal Bearings: • Functionality and calculation of hydrodynamic axial and radial journal bearings, different occurring damages and failures and the choice of suitable lubricants Triboystem Journal Bearings: • Functionality and calculation of hydrostatical axial and radial journal bearings, different occurring damages and failures and the choice of suitable lubricants Tribosystem gear wheels: • Lubricants and materials for gears and their influence and application, application of the EHD-theory for gear stages Tribosystem gear wheels: • Damages and failures on gear wheels and suitable test methods for the analysis of gear stages Tribosystem roller bearings:

	• Design, materials, friction and lubrication of roler bearings, damages and failures and test methods for the analysis of roller bearings Tribosystem seals: • Different types and designs, specialties and application of different seals and materials for seals
Learning Objectives/ Learning Outcomes	The students are able to find and localize and systematically analyze tribo systems in general mechanical systems. They are theoretically capable of choosing and applying different suitable measuring- and test systems for journal bearings, roller bearings and gear wheels and they are capable of estimating the quality of the Tribosystem according to the test results and to optimize it with the background knowledge of a considerably large action catalogue. The students know the basic theories of hydrodynamics and of elastic material deformations and are able to use them in the calculation and analysis of tribological issues in a reasonable way.
(Study-Specific) Prerequisites	-
(recommended) Requirements	-
References	-
Language	English
Examination Terms	Written exam or oral exam
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr.-Ing. Georg Jacobs
ECTS Credits	5
Contact time (WSH)	-
Examination duration (min)	0
Total hours (h)	150,0
Contact hours (h)	-
Self-study hours (h)	-

● Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Tribology (401147501)	1st semester	no semester recommended	5	0

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
ExerciseTribology	1st semester	no semester recommended	-	2

Lecture Tribology	1st semester	no semester recommended	-	2

Module titel	Simulation Techniques in Manufacturing Technology (STMT) (Compulsory elective subject)
Identifier	4012413
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2011
Valid until	-
Module level	Master
Content	1 - In der ersten Vorlesung wird eine Einführung in das Thema „Simulationsverfahren in der Fertigungstechnik“ gegeben. 2 - Die Inhalte der zweiten Vorlesung sind die grundlegenden Aspekte und Prozesse der Umformtechnik. 3 - Nachdem der Student die Grundlagen der Umformtechnik erlernt hat, konzentriert sich diese Vorlesung auf aktuelle Simulationsverfahren beim Umformen. 4 - Die vierte Vorlesung befasst sich mit grundlegenden Aspekten und der Simulation der Massivumformung. 5 - Die fünfte Vorlesung gibt eine Einführung in die Grundlagen und Simulationsverfahren bei Blechumformung und Trennen. 6 - Inhalt der sechsten Vorlesung sind die Grundsätze der Zerspanung. 7 - Vorlesung 7 gibt einen generellen Überblick der verschiedenen Zerpanprozesse. 8 - Eine Möglichkeit Zerspanprozesse ganzheitlich zu modellieren ist die Finite-Elemente-Methode (FEM). Diese Vorlesung vermittelt die Vorgehensweise und Modellierungsansätze der FE-Zerspansimulation sowie zeigt verschiedene und aktuelle Beispiele für die FE-Simulation von Zerspanprozessen. 9 - Die neunte Vorlesung gibt eine Einführung in das Zerspanen mit undefinierter Schneide. 10 - Vorlesung 10 stellt aktuelle Modellierungsmethoden beim Schleifen vor. 11 - In Vorlesung 11 wird besonders auf die Methoden der Validierungs- und Optimierungstechniken eingegangen. 12 - Inhalt der letzten Veranstaltung ist es, in kleinen Gruppen die Aufstellung und Auswertung von FE-Simulation mit den FE-Codes DEFORM und ABAQUS zu erlernen.
Learning Objectives/ Learning Outcomes	Fachbezogene Lernziele: - Einführung in die grundsätzlichen Methoden der Modellierung und Simulation von Fertigungsverfahren - Revision der Grundlagen der Werkstoffkunde und Fertigungstechnik - Darstellung des Potentials der Modellierung und Simulation: Erhöhung des Prozessverständnisses, Verbesserung der Prozesssicherheit und Optimierung des Arbeitsergebnisses - Vorgehensweise und Einsatz der Finite-Elemente-Methode zur Simulation von Fertigungsprozessen - Möglichkeiten und Grenzen der Modellierung und Simulation zeigen - Anwendung der Simulationssoftware DEFORM und ABAQUS zur Simulation unterschiedlicher Fertigungsverfahren Nicht fachbezogene Lernziele: - Im Rahmen von Forschung und Entwicklung eigenständig passende Simulationsverfahren für Fertigungsprozesse auswählen und wissenschaftlich fundiert begründen - Eigene Ansätze zur Modellierung der Fertigungsprozesse entwickeln und in Forschungsfragen formulieren sowie in Entwicklungstätigkeiten einfließen lassen
(Study-Specific) Prerequisites	-
(recommended) Requirements	Empfohlene Voraussetzungen: - Grundkenntnisse der Werkstoffkunde - Grundlagen der Vektor- und Tensorrechnung - EDV-Grundlagen

	Empfohlene Voraussetzungen - Englisch in Wort und Schrift - Fertigungstechnik I
References	S. Kobayashi, T. Altan, S. Kobayashi: Metal Forming and the Finite-Element Method, Oxford Series on Advanced Manufacturing, Oxford University Press, 1989 - T. Childs: Metal Machining (Theory and Applications), ISBN-13: 978-0340691595 - K. Cheng: Machining Dynamics (Fundamentals, Applications and Practices), ISBN: 978-1-84628-367-3
Language	English
Examination Terms	Eine mündliche oder eine schriftliche Prüfung
Miscellaneous	-
Module coordinator	Univ.-Prof. Dr.-Ing. Thomas Bergs
ECTS Credits	6
Contact time (WSH)	-
Examination duration (min)	-
Total hours (h)	180,0
Contact hours (h)	-
Self-study hours (h)	-

● Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam STMT (401241301)	1st semester	no semester recommended	6	0

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exercise STMT	1st semester	no semester recommended	-	2
Lecture STMT	1st semester	no semester recommended	-	2

Module titel	Modeling, Model Reduction and Simulation in Laser Processing - Laser (Compulsory elective subject)
Identifier	4013863
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Winter semester 2016
Valid until	-
Module level	Master
Content	• overview of contents, definition of the 10 learning targets • the constribution of the engineer to the interactive cooperation of scientific disciplines • main features of the theory of cognition (Karl Popper) • laser radiation, Helmholtz equation, reduced model: SVE-approximation • Learning target 1:gaussian beam, beam guiding and forming • reflection, transmission and absorption of light • Learning target 2:reduced model of the Fresnel Formulae for the limiting case of small discplacemant current, optical parameters • technical task and examples: cutting with laser radiation • Learning target 3:quality features of the high quality cut • physical task of cutting and identification of quality defined processing domains • Learning target 4:relation of physicl phenomena to built up of quality degradations • technical task and examples: drilling with laser radiation • physical task and 5 dominant phenomena • Learning target 5: quality features of the drilled hole • mathematical modelling Ia: time scales • degrees of freedom in phase space of dependent variables • separation of time scales in simple dynamical systems • Learning target 6a: separation of time scales • mathematical modelling Ib:length scales • thermal boundary layer in heat conduction with moving boundaries • Learning target 6b: separation of length scales • mathematical modelling IIa: Free Boundary Problems (FBP) for the solid phase • reduced model for the FBP: motion of the melting front, integral methods, variational formulation • Learning target 7: heating and melting phase of ablation • mathematical modelling IIb: FBP for the liquid phase • Navier-Stokes equations, material equations and boundary values • mathematical model reduction: melt flow • reduced model for thin film flow • Learning target 8: boundary character, integral and spectral methods • model reduction and solution with controlled error: melt flow at low Reynolds-number • structural stability of the reduced model: lubrication approximation, fingering and droplet formation • Learning target 9: creeping flow and expansion with respect to the Reynolds-number, exact solution of a model problem for arbitrary Reynolds-number • global properties of the solution of balance equations for mass, momentum and thermal energy • Learning target 10: scales for the choice of processing parameters in cutting and drilling • concluding discussion of the learning targets • actual research and development of laser processing
Learning Objectives/ Learning Outcomes	The students obtain scientific skills for the application of: 1. Free Boundary Problems and integral methods of solution, 2. non-linear stability analysis using spectral methods, 3. analysis of the structural stability of model equations and • know the least 3 types of laser systems, temporal and spatial distribution of laser radiation, Fresnel-number, invariant quantity of light propagation

	• understand the structure of solution for the Helmholtz-equation, diffraction, 5 parameter pairs of optical material equations, transmission, reflection, absorption, Fresnel Formulae, polarisation of matter and radiation • know and understand the 5 different, dominant phenomena of drilling, welding and cutting with laser radiation • know the physical meaning of the terms contained in the Navier-Stokes equations for mass, momentum and energy balance • know the main properties of the solution in the asymptotic case of thin film flow (boundary layer) and can explain the relation between dynamical properties of the solution and quality features of the product as well as productivity of the process for drilling and cutting • know the effect of dissipation in disctributed dynamical systems (inertial manifold) and know examples for the application of methods for the reduction of the dimension in dissipative systems, understand and perform the separation of length and time scales in simple systems The students get to know non-scientific tasks: • understand the interactive cooperation of scientists from engineering, physics and mathematics for application of model based methods for diagnosis in laser processing • Application of model based methods for solving practical tasks from discussion of project examples
(Study-Specific) Prerequisites	-
(recommended) Requirements	-
References	-
Language	English
Examination Terms	Written exam or oral exam
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr. rer. nat. Wolfgang Schulz
ECTS Credits	5
Contact time (WSH)	-
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	-
Self-study hours (h)	-

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Modeling, Model Reduction and Simulation in Laser Processing - Laser (401386301)	2nd semester	no semester recommended	5	0

▲Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Modeling, Model Reduction and Simulation in Laser Processing - Laser	2nd semester	no semester recommended	-	2
Exercise Modeling, Model Reduction and Simulation in Laser Processing - Laser	2nd semester	no semester recommended	-	2

Module titel	Modeling, Model Reduction and Simulation in Laser Processing - Applications (Compulsory elective subject)
Identifier	4013864
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2016
Valid until	-
Module level	Master

Content	• overview of contents, definition of the learning targets
	• ecapitulation of the 10 learning targets from part I of the course
	• derivation and consolidation of the application of integral methods for treating heat conduction with Stefan-type boundary conditions
	• Learning target 1: variational formulation compared with direct integration for one space variable, spectral methods for error control of integral methods: spatial one-dimensional model problem, Eigenfunctions of differential operators, spectral decomposition of non-linear problems, discrete and continuous spectra
	• Learning target 2: separation of variables and relation to spectral methods, applications of spectral methods, asymptotic expansion of partial differential equations and their solution applied to a model problem of heat conduction
	• Learning target 3: identification of characteristic dynamical variables, degrees of freedom of an inertial manifold, determination of dimensionless groups, Buckingham's Pi-theorem, definition and physical meaning of Peclet-, Reynolds-, Marangoni- and Stefannumber.
	• Learning target 4: physical interpretation of dimensionless groups of system parameters and the dimension in phase space of processing parameters, optical modes in passive fibers, numerical aperture, total reflection, maximum mode-number, coupling of modes, optical excitation in active fibers and dissipation
	• Learning target 5: Slow surfaces in dynamical systems, Application of time scale separation
	• Learning target 6: thermal effects of large and small Peclet-number, model problems in thin film flow, applications of spectral methods:
	  • formation of pores in welding, closure of the drill hole
	• Learning target 7: relation of time scales and the onset of quality features, modelling evaporation and recondensation of metals I, comparison of models from Aden and Aoki &; Sone
	• Learning target 8: liquid-vapor phase transition in drilling and welding, modelling evaporation and recondensation of metals, Laplacepressure, evaporation and recondensation as driving forces for momentum of the liquid by pressure gradients
	• Learning target 9: boundary conditions for momentum at ideal surfaces,
	• technical examples:
	  • drilling with laser radiation, welding with laser radiation, concluding discussion of learning targets
	• actual research and development of laser processing

Learning Objectives/ Learning Outcomes	In this course, students shall acquire the following: Knowledge / Understanding: Students shall obtain understanding about the applications of: 1. Free Boundary Problems and integral methods of solution, 2. analysis of dynamical stability, non-linear stability analysis using spectral methods, 3. analysis of the structural stability of model equations. Abilities / Skills: Students

	• shall obtain scientific skills for the application of free Boundary Problems and integral methods of solution, non-linear stability analysis using spectral methods and for the analysis of the structural stability of model equations. • shall be able to determine the maximum number of dimensionsless groups of Boundary Value Problems. • shall understand the relation of boundary conditions, boundary values and the structure of solution for the Navier-Stokes equations. • shall know and understand the 5 different, dominant phenomena of drilling, welding and cutting with laser radiation. • shall know and be able to explain the physical meaning of the Navier-Stokes equations. • shall know the main properties of the solution in the asymptotic case of thin film flow (boundary layer) and shall be able to explain the relation between dynamical properties of the solution and quality features of the product as well as productivity of the process for drilling and cutting. • shall know the effect of dissipation in distributed dynamical systems (inertial manifold) and shall know examples for the application of methods for the reduction of the dimension in dissipative systems. • shall understand and perform the separation of length and time scales in simple systems. • shall understand the interactive cooperation of scientists from engineering, physics and mathematics for application of model based methods for diagnosis in laser processing.
(Study-Specific) Prerequisites	-
(recommended) Requirements	Recommended: • Modeling, Model Reduction and Simulation in Laser Processing - Laser
References	• Lecture Notes • Students also receive a list of relevant literature
Language	English
Examination Terms	Oral exam
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr. rer. nat. Wolfgang Schulz
ECTS Credits	5
Contact time (WSH)	-
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	-
Self-study hours (h)	-

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Modeling, Model Reduction and Simulation in Laser Processing - Applications (401386401)	1st semester	no semester recommended	5	0

▲Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exercise Modeling, Model Reduction and Simulation in Laser Processing - Applications	1st semester	no semester recommended	-	2
Lecture Modeling, Model Reduction and Simulation in Laser Processing - Applications	1st semester	no semester recommended	-	2

Module titel	Multibody Dynamics (Compulsory elective subject)
Identifier	4011462
Version	V1
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2020
Valid until	-
Module level	Master
Content	• Introduction • Fundamentals • Fields of application • Model Building • Methods of Approach for Equivalent Models • Multi-body Systems • General mathematical description • Kinematics of Multi Body Systems • Position and Orientation of Bodies • Translational Kinematics • Rotational Kinematics • Equations of Motion • Lagrangian Equations of 2nd Kind • Newton-Euler equations • Lagrangian Equations of 1st Kind • Eigen Value Approach • Undamped non-gyroscopic systems • Damped gyroscopic systems • Eigen Value Stability Criteria Linear Systems with Harmonic Excitation • Real Frequency Matrix • Complex Frequency Matrix • State Equation • System Matrix • Eigen Value Approach • Fundamental Matrix • Modal Matrix • Theorem of Cayley-Hamilton • Analytical Solution • Numerical Solution • Step Excitation • Harmonic Excitation • Periodical Excitation Example • Modelling • Calculation • Evaluation
Learning Objectives/ Learning Outcomes	In this course, students shall acquire the following: <u>Knowledge / Understanding:</u> Students: • shall have a profound knowledge of theory of vibrations. • shall be capable of comprehending, describing and analyzing vibratory systems.

	• shall be familiar with the most important matrix based procedures for the calculation of eigenmotions and the behaviour of linear systems under forced excitations. Abilities / Skills: Students • shall have the ability of describing mathematically any mechanical system with its inherent physical effects like elasticity, damping and friction. • shall be able to properly interpret simulation results especially under consideration of simplifications within the model compared to the real system. Competencies: Students • shall be able to derive from their knowledge the necessary methods and proceedings for the analysis and synthesis of the systems in regard. • shall be capable to solve - accessing their acquired theoretical knowledge - complex problems concerning the choice and design of industrial vibratory systems.
(Study-Specific) Prerequisites	-
(recommended) Requirements	-none-
References	• Lecture Notes • Students also receive a list of relevant literature
Language	English
Examination Terms	Written/Oral Examination (Depending on registration numbers)
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr.-Ing. Dr. h. c. Burkhard Corves
ECTS Credits	6
Contact time (WSH)	-
Examination duration (min)	-
Total hours (h)	180,0
Contact hours (h)	-
Self-study hours (h)	-

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Multibody Dynamics (401146201)	2nd semester	no semester recommended	6	0

▲Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Tutorial Multibody Dynamics	2nd semester	no semester recommended	-	2
Lecture Multibody Dynamics	2nd semester	no semester recommended	-	2

Module titel	Internship (Compulsory elective subject)
Identifier	4023100
Version	-
Duration (Semester)	one semester
Cycle (Semester)	-
Valid from	Winter semester 2020
Valid until	-
Module level	Master
Content	Internships in companies are necessary to ensure the correct choice of the course of studies, a sufficient understanding of the technical and economic courses as well as in preparation for the professional life (also in Germany) in the future. The students should acquire knowledge about technical materials and processes used in practice corresponding economic considerations and procedures, and gain insights into social processes and structures in the companies. See guidelines for practical training in the examination regulations
Learning Objectives/ Learning Outcomes	After successfully completing this course, the students will have acquired the following learning outcomes: Knowledge / Understanding Students: • know different fields of activity in the desired occupational field • understand theoretical concepts during implementation Abilities / Skills Students: • put theory and practice in relation to each other • test their own abilities and knowledge on the basis of practical experience • follow and participate in production engineering team meetings • eliminate misconceptions about the chosen profession Competencies Students: • assess their competences correctly • discern individual learning fields with regard to a professional activity • assess social processes and structures of companies and organisations • establish contacts with potential colleagues and employers For more see guidelines for practical training in the examination regulations
(Study-Specific) Prerequisites	-

(recommended) Requirements	none
References	-
Language	-
Examination Terms	Internship Report (100%)
Miscellaneous	-
Module coordinator	-
ECTS Credits	12
Contact time (WSH)	1
Examination duration (min)	-
Total hours (h)	360,0
Contact hours (h)	15,0
Self-study hours (h)	345,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Internship (402310001)	3rd semester	no semester recommended	12	-

Module titel	International Factory Planning (Compulsory elective subject)
Identifier	4011481
Version	V2_neu
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2021
Valid until	-
Module level	Master
Content	L1 - Introduction to Factory Planning & Project Management: • basic glossary, different viewpoints, challenges and requirements of factory planning L2 - Target Definition & Product/Process Planning: • definition of objectives with the involvement of different stakeholders and requirements • challenges and approaches of product and process planning within the framework of factory design L3 - Location Planning & Site Structure Planning: • current trends in site structure planning and methods for evaluating different plant structure alternatives in order to create a basis for one of the most essential decisions within the factory planning process L4 - Industrial Building & Building Planning: • factory planning on the building side, i.e. advantages and disadvantages of different bearing structures, roof constructions and facade types L5 - Production Structure Planning & Capacity Planning: • production structure within the plant according to the site structure planning • challenges and approaches of capacity planning L6 - Layout Planning & Workplace Design: • overview of the goals and challenges of layout planning and the even more detailed workplace design L7 - Highlight lecture: • state-of-art application of modern factory planning methods
Learning Objectives/ Learning Outcomes	Within the framework of the lecture Factory Planning, the state-of-the-art of the respective subject areas will be introduced, relevant methods and procedures will be explained and reference solutions will be presented. The contents will be deepened in the exercises and in the case study. In this way, future production managers will be able to comprehensively plan and develop individual production sites as well as entire production networks of internationally active companies. The lectures and exercises as weil as the case studies are only held in summer semesters. The case studies are conducted in group work. A successful registration for the module Factory Planning already at the very beginning of each summer semester is therefore vital in order to be integrated within the allocation to groups. Each group then collaborates as a planning team to work on the case study, but members are graded individually. However, the exam can be written each semester, which means that the requirement of the case study has to be fulfilled (passed with a grade of 4.0 or better) to take the exam. lf an exam is failed, but the case study has already been completed, the grade of the case study is credited in the following semester. The aim of these case studies is to deepen the contents conveyed in the lecture in a practical application. The students are presented with a real-world-oriented factory planning problem. In order to successfully perform an extensive analysis covering multiple planning levels and give decision-targeted recommendations, the concepts and methods learned from the lectures and excercises need to be rigorously applied. By emulating a real factory planning project, students are prompted to work together and transfer their knowledge into practice. In addition, the developed solutions are to be validated using

	simulation tools provided by the chair, e.g. for verifying material flows. Finally, the used procedures and achieved results are compiled into a case study report. The case study work is expected to run from May to June in the summer semester and must therefore be submitted before the written exam phase. Knowledge / Understanding - describe the characteristics and challenges of factory planning and with regard to the global environment - formulate the object precisely and in a detailed way - have an extended understanding of state of the art planning process of factories - know and understand the definition of the own value adding scope, the choice and allocation of suitable production locations, the conception of production systems and the usage of suitable planning tools. - understand the procedures and methods in factory planning Abilities / Skills - apply the acquired methods to design a factory - apply this knowledge to analyse organizational structures and forms of production Competencies - analyse the initial situation of a factory planning project, draft and classify possible solutions - define and develop single production plants as well as production networks of globalized companies and explain them to different target groups
(Study-Specific) Prerequisites	-
(recommended) Requirements	-
References	Lecture reprint Exercise reprint Sample solution reprint
Language	English
Examination Terms	The final grade is composed to 2/3 of the exam grade and to 1/3 of the case study grade (individual grading). Both parts have to be passed in order to pass the whole module. Bonus points are awarded for the e-Test in L2P: Tests with 5-6 questions per lecture unit; time limited to 30 minutes activation from the day of the lecture to the day before the following lecture or max. 1 week > 50% of questions correct (i.e. 3 questions) - > test passed! 1 bonus point per test-> Max. 6 bonus points reachable (5% of all points reachable in the exam)
Miscellaneous	-
Module coordinator	Univ.-Prof. Dr.-Ing.Günther Schuh
ECTS Credits	6
Contact time (WSH)	4
Examination duration (min)	-
Total hours (h)	180,0
Contact hours (h)	60,0
Self-study hours (h)	120,0

● Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam International Factory Planning (401148101)	2nd semester	no semester recommended	4	0
Case Study International Factory Planning (401148102)	2nd semester	no semester recommended	2	-

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exercise International Factory Planning	2nd semester	no semester recommended	-	2
Lecture International Factory Planning	2nd semester	no semester recommended	-	2

Module titel	Process Analysis in Manufacturing Technology (Compulsory elective subject)
Identifier	4026065
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2021
Valid until	-
Module level	Master
Content	• Introduction on the scope of the course to go for the elective or not Fundamentals: • Technical sensors: Strain, force, acceleration, acoustic emission, temperature, pressure, viscosity, clouding, moisture • Measuring chain : Components, setup, signal conditioning, analog-to-digital, parameterization, measuring deviation, application software LabView • Signal analysis: Time and frequency domain, bandwidth, spectral resolution, aliasing, analysis of stationary and instationary processes, application software Diadem Applications: • Turning: Force, acceleration, temperature and wear measurement, force and wear modelling, self-induced and forced vibrations, residual stress measurement, thin film integrated sensors • Drilling: Force, acceleration, temperature and wear measurement, telemetry, force and wear modelling, short and deep hole drilling, monitoring of the chip removal, scaling of force and torque at small diameters • Milling: Interrupted cut, dynamical system analysis, transfer function, stability theory , force and acceleration measurement • Grinding: Grinding burn, nital etching, Barkhausen noise, adaptive grinding, sensor assisted dressing and balancing • Powder metallurgy: Powder classification, analysis of the porosity distribution, non- destructive testing methods • Laser material processing: Beam quality and caustic measurement, power measurement in the continuous and pulsed wave mode, weld seam tracing and triangulation • Forming and blank cutting: Integration of force and distance sensors in forming and cutting tools, tribological effects, measurement of pressure, temperature, viscosity and clouding of hydraulic oils • Material removal technologies: Measurement of high-frequency voltage and current impulses, application of measurement systems in electromagnetically polluted environments, force and distance measurement in micro EDM sinking, passivation layer thickness measurement in ELID grinding
Learning Objectives/ Learning Outcomes	Overall goal: Ability to analyse manufacturing processes Students understand how process and workpiece properties can be measured and analysed. They get to know metrology as an essential part of modern production processes. After successfully completing this course, the students will have acquired the following learning outcomes: <u>Knowledge / Understanding</u> • Setup, functionality and application of technical sensors for the analysis of manufacturing processes • Components of a measuring chain, functionality, connection of the elements and estimation of the measuring deviation • Options on signal analysis of stationary and instationary processes in time and frequency domain • Characteristics of manufacturing technologies which require a scientific analysis

	Abilities / Skills Students are able to choose suitable measurement systems, to integrate them into manufacturing processes, to acquire and analyse the signals. In the laboratory, they gain the practical experience, which is required to apply the theoretical knowledge. Students are able to arrange the setup of a measuring chain, data acquisition in LabView and data analysis in the software Diadem. Competencies The students recognize correlations between process and part characteristics and can make conclusions on the part's quality. Furthermore, they recognize the impact of metrology on manufacturing processes, which results from the integration of certain measurement systems. They are able to describe changes of dynamical systems and critically evaluate these changes.
(Study-Specific) Prerequisites	-
(recommended) Requirements	Recommended: Manufacturing Technology I
References	Klocke, F.; König, W.: Manufacturing Processes 1, 1st Ed., 2011 Klocke, F.; König, W.: Manufacturing Processes 2, 1st Ed., 2009 Klocke, F.; König, W.: Manufacturing Processes 4, 1st Ed., 2013
Language	English
Examination Terms	A written or an oral exam
Miscellaneous	-
Module coordinator	Univ.-Prof. Dr.-Ing. Thomas Bergs
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Process Analysis in Manufacturing Technology (402606501)	3rd semester	no semester recommended	5	-

▲Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Process Analysis in Manufacturing Technology	3rd semester	no semester recommended	-	2
Exercise Process Analysis in Manufacturing Technology	3rd semester	no semester recommended	-	1

Module titel	Intelligent Monitoring of Engineering Systems (Compulsory elective subject)
Identifier	4021494
Version	V1_neu
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Winter semester 2022
Valid until	-
Module level	Master
Content	The course curriculum consists of seminar lectures followed by a semester project. During the seminar lectures, the students will receive the necessary theoretical background to independently plan and execute the project in small groups. Consultation hours are offered to discuss challenges and problems arising during the course of the project. Finally, each group presents their achievements and results live and in form of a written report. The following topics are covered: • Sensing • Signal processing • Machine learning • Non-Destructive Testing (NDT) • Structural Health Monitoring (SHM) • Data pre- and postprocessing using MATLAB
Learning Objectives/ Learning Outcomes	In this course, students shall acquire the following: Knowledge / Understanding The students will understand • the theoretical foundations of structural health monitoring approaches in engineering • state-of-the-art and current trends in structural health monitoring • the fundamentals of sensors, filtering methods, and computational Intelligence Abilities / Skills The students are able to • describe and analyse mechanical engineering systems • extract and monitor relevant system parameters • apply fundamental methods of structural health monitoring • transfer their knowledge to new engineering applications in science and industry • independently plan, advance and complete projects
(Study-Specific) Prerequisites	-
(recommended) Requirements	Recommended: Programming experience, particularly in MATLAB (Python)
References	Farrar, C.R. and Worden, K., 2012. Structural Health Monitoring: A Machine Learning Perspective. Wiley.
Language	English
Examination Terms	Written or Oral Examination (100 %)
Miscellaneous	-

Module coordinator	Univ.-Prof. Dr.-Ing. Bernd Markert
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

● Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Intelligent Monitoring of Engineering Sys-tems (402149401)	2nd semester	no semester recommended	5	-

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Intelligent Monitoring of Engineering Systems	2nd semester	no semester recommended	-	2
Exercise Intelligent Monitoring of Engineering Systems	2nd semester	no semester recommended	-	1

Module titel	Linear Control Systems (Compulsory elective subject)
Identifier	4011476
Version	Angelegt über RWTH API als 1_neu
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2022
Valid until	-
Module level	Master
Content	Significance of control theory, examples of biological and biomedical control loops, functional diagrams, linearization, set up and solving of differential equations, stability, features in time domain of dynamical systems, Laplace transform, transfer function, frequency response, functional diagram algebra, features in frequency domain of dynamical systems, bode diagram, Nyquist plot, Linear control loop elements, principle and goals of controller design, algebraic stability criteria, steady state analysis and transient performance of a control loop, controller setting rules, Nyquist stability criterion, phase margin, gain margin, controller design in bode diagram.
Learning Objectives/ Learning Outcomes	After successfully completing this course, the student will have acquired the following learning outcomes: Knowledge / Understanding: • know, recognize and classify the most common linear control loop elements • the effects of feedback and apply different methods to set up feedback elements (controllers) such that predefined control goals are met Abilities / Skills: • to analyze dynamical, biological and biomedical systems and identify the relevant causalities • to employ different mathematical descriptions of dynamical systems • solve differential equations by means of Laplace transform • assess of the stability of dynamical systems using different methods • obtain, interpret and employ the frequency response of dynamical systems
(Study-Specific) Prerequisites	-
(recommended) Requirements	Basic knowledge in mathematics as defined in the examination regulations.
References	-
Language	English
Examination Terms	The module grading is weighted according to the CP-allocation • Written Exam (schriftliche Prüfung) or • Oral Exam (mündliche Prüfung)
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr.-Ing. Dirk Abel
ECTS Credits	4
Contact time (WSH)	2

Examination duration (min)	-
Total hours (h)	120,0
Contact hours (h)	30,0
Self-study hours (h)	90,0

● Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Linear Control Systems (401147601)	1st semester	no semester recommended	4	0

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Linear Control Systems	1st semester	no semester recommended	-	1
Tutorial Linear Control Systems	1st semester	no semester recommended	-	1

Module titel	Embedded Systems (Compulsory subject)
Identifier	1215690
Version	Angelegt über RWTH API als 1_neu
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Winter semester 2018
Valid until	-
Module level	Bachelor/Master
Content	Embedded systems control many things in our daily life. Energy-efficient refrigerators, elevator controls, and advanced driver assistance systems are just some examples. Embedded systems also control processes in industrial environments and are used to detect and prevent system failures. This lecture gives a general introduction to the topic of embedded systems. It introduces basic concepts and points out important differences to “normal” computer systems. This lecture prepares students for advanced lectures of the Embedded Software Laboratory that cover safety, reliability, formal methods and dynamic systems in detail. This lecture is targeted at all students that do not want to limit themselves to understanding PCs but also want to know how, for example, engine control units and production control systems work. Topics covered in this lecture are: Microcontroller, Programmable logic controllers (PLCs, PLC programming languages, Real-time requirements, Real-time operating systems, Characteristics of embedded software design, Intra vehicle communication (e.g., CAN bus), Teasers of advanced lectures of the embedded software laboratory, The lecture will be held in German with English slides.
Learning Objectives/ Learning Outcomes	Knowledge: Knowledge and confidence in modern software techniques for embedded systems | Skills: Ability to apply a model-based quality-oriented approach for the design of embedded software | Competences: Sensibility for special qualitative requirements for the design of embedded software
(Study-Specific) Prerequisites	-
(recommended) Requirements	Knowledge of “Foundations of Technical Computer Science”.
References	Slides of the lecture, script and the following books: Marwedel: Eingebettete Systeme. 2003 | Bass, Clements: Software Architecture in Practice. | Douglass: Real-time UML
Language	English
Examination Terms	Written exam or oral examination (100 %). Students must pass written homework to be admitted to the module examination.
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr.-Ing. Stefan Kowalewski
ECTS Credits	6
Contact time (WSH)	-
Examination duration (min)	15-45 (mündlich/oral) | 90-120 (schriftlich/written)
Total hours (h)	180,0
Contact hours (h)	-

Self-study hours (h)	-

● Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exercise Embedded Systems (121569002)	2nd semester	no semester recommended	0	1
Exam Embedded Systems (121569001)	2nd semester	no semester recommended	6	0

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Embedded Systems	2nd semester	no semester recommended	-	3

Module titel	Model-based Systems Engineering (Compulsory subject)
Identifier	1222882
Version	V1
Duration (Semester)	one semester
Cycle (Semester)	winter/summer semester
Valid from	Winter semester 2020
Valid until	-
Module level	Master
Content	After a thorough and detailed introduction of SysML and UML, the possibilities of using models in system development processes are discussed. These include simulation, code and test case generation, analysis, modeling and evolution of systems by refactoring of models.
Learning Objectives/ Learning Outcomes	Knowledge: • SysML, UML • MontiArc • Architecture and behavior models • Statecharts, finite automata • Object diagrams and class diagrams • Geometrical models and their connection to software controlling models • Use of models in the software and systems engineering process • Simulation, code, and test generation • Analysis of models • Evolution of models and systems Skills: • Application of models in the development process • Ability to read and write own models in appropriate languages Competences: • Understanding of the use of models • Application of models in software and systems engineering • Knowledge and practice of SysML and UML • Designing systems with a strong software impact by using model-based development techniques
(Study-Specific) Prerequisites	-
(recommended) Requirements	Introduction to software engineering or comparable courses.
References	[Rum17] B. Rumpe: Agile Modeling with UML: Code Generation, Testing, Refactoring. Springer International, May 2017. [CFJ+16] B. Combemale, R. France, J. Jézéquel, B. Rumpe, J. Steel, D. Vojtisek: Engineering Modeling Languages: Turning Domain Knowledge into Tools. Chapman &; Hall/CRC Innovations in Software Engineering and Software Development Series, November 2016.
Language	English
Examination Terms	Written exam or oral examination (100%). Students must pass written homework to be admitted to the examination.
Miscellaneous	-

Module coordinator	-
ECTS Credits	6
Contact time (WSH)	5
Examination duration (min)	-
Total hours (h)	180,0
Contact hours (h)	75,0
Self-study hours (h)	105,0

● Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Model-based Systems Engineering (122288201)	1st semester	no semester recommended	6	0
Exercise Model-based Systems Engineering (122288202)	1st semester	no semester recommended	0	3

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Model-based Systems Engineering	1st semester	no semester recommended	-	2

Module titel	International Factory Planning (Compulsory subject)
Identifier	4011481
Version	V2_neu
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2021
Valid until	-
Module level	Master
Content	L1 - Introduction to Factory Planning & Project Management: • basic glossary, different viewpoints, challenges and requirements of factory planning L2 - Target Definition & Product/Process Planning: • definition of objectives with the involvement of different stakeholders and requirements • challenges and approaches of product and process planning within the framework of factory design L3 - Location Planning & Site Structure Planning: • current trends in site structure planning and methods for evaluating different plant structure alternatives in order to create a basis for one of the most essential decisions within the factory planning process L4 - Industrial Building & Building Planning: • factory planning on the building side, i.e. advantages and disadvantages of different bearing structures, roof constructions and facade types L5 - Production Structure Planning & Capacity Planning: • production structure within the plant according to the site structure planning • challenges and approaches of capacity planning L6 - Layout Planning & Workplace Design: • overview of the goals and challenges of layout planning and the even more detailed workplace design L7 - Highlight lecture: • state-of-art application of modern factory planning methods
Learning Objectives/ Learning Outcomes	Within the framework of the lecture Factory Planning, the state-of-the-art of the respective subject areas will be introduced, relevant methods and procedures will be explained and reference solutions will be presented. The contents will be deepened in the exercises and in the case study. In this way, future production managers will be able to comprehensively plan and develop individual production sites as well as entire production networks of internationally active companies. The lectures and exercises as weil as the case studies are only held in summer semesters. The case studies are conducted in group work. A successful registration for the module Factory Planning already at the very beginning of each summer semester is therefore vital in order to be integrated within the allocation to groups. Each group then collaborates as a planning team to work on the case study, but members are graded individually. However, the exam can be written each semester, which means that the requirement of the case study has to be fulfilled (passed with a grade of 4.0 or better) to take the exam. lf an exam is failed, but the case study has already been completed, the grade of the case study is credited in the following semester. The aim of these case studies is to deepen the contents conveyed in the lecture in a practical application. The students are presented with a real-world-oriented factory planning problem. In order to successfully perform an extensive analysis covering multiple planning levels and give decision-targeted recommendations, the concepts and methods learned from the lectures and excercises need to be rigorously applied. By emulating a real factory planning project, students are prompted to work together and transfer their knowledge into practice. In addition, the developed solutions are to be validated using

	simulation tools provided by the chair, e.g. for verifying material flows. Finally, the used procedures and achieved results are compiled into a case study report. The case study work is expected to run from May to June in the summer semester and must therefore be submitted before the written exam phase. Knowledge / Understanding - describe the characteristics and challenges of factory planning and with regard to the global environment - formulate the object precisely and in a detailed way - have an extended understanding of state of the art planning process of factories - know and understand the definition of the own value adding scope, the choice and allocation of suitable production locations, the conception of production systems and the usage of suitable planning tools. - understand the procedures and methods in factory planning Abilities / Skills - apply the acquired methods to design a factory - apply this knowledge to analyse organizational structures and forms of production Competencies - analyse the initial situation of a factory planning project, draft and classify possible solutions - define and develop single production plants as well as production networks of globalized companies and explain them to different target groups
(Study-Specific) Prerequisites	-
(recommended) Requirements	-
References	Lecture reprint Exercise reprint Sample solution reprint
Language	English
Examination Terms	The final grade is composed to 2/3 of the exam grade and to 1/3 of the case study grade (individual grading). Both parts have to be passed in order to pass the whole module. Bonus points are awarded for the e-Test in L2P: Tests with 5-6 questions per lecture unit; time limited to 30 minutes activation from the day of the lecture to the day before the following lecture or max. 1 week > 50% of questions correct (i.e. 3 questions) - > test passed! 1 bonus point per test-> Max. 6 bonus points reachable (5% of all points reachable in the exam)
Miscellaneous	-
Module coordinator	Univ.-Prof. Dr.-Ing.Günther Schuh
ECTS Credits	6
Contact time (WSH)	4
Examination duration (min)	-
Total hours (h)	180,0
Contact hours (h)	60,0
Self-study hours (h)	120,0

● Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam International Factory Planning (401148101)	2nd semester	no semester recommended	4	0
Case Study International Factory Planning (401148102)	2nd semester	no semester recommended	2	-

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exercise International Factory Planning	2nd semester	no semester recommended	-	2
Lecture International Factory Planning	2nd semester	no semester recommended	-	2

Module titel	Process Analysis in Manufacturing Technology (Compulsory subject)
Identifier	4026065
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2021
Valid until	-
Module level	Master
Content	• Introduction on the scope of the course to go for the elective or not Fundamentals: • Technical sensors: Strain, force, acceleration, acoustic emission, temperature, pressure, viscosity, clouding, moisture • Measuring chain : Components, setup, signal conditioning, analog-to-digital, parameterization, measuring deviation, application software LabView • Signal analysis: Time and frequency domain, bandwidth, spectral resolution, aliasing, analysis of stationary and instationary processes, application software Diadem Applications: • Turning: Force, acceleration, temperature and wear measurement, force and wear modelling, self-induced and forced vibrations, residual stress measurement, thin film integrated sensors • Drilling: Force, acceleration, temperature and wear measurement, telemetry, force and wear modelling, short and deep hole drilling, monitoring of the chip removal, scaling of force and torque at small diameters • Milling: Interrupted cut, dynamical system analysis, transfer function, stability theory , force and acceleration measurement • Grinding: Grinding burn, nital etching, Barkhausen noise, adaptive grinding, sensor assisted dressing and balancing • Powder metallurgy: Powder classification, analysis of the porosity distribution, non- destructive testing methods • Laser material processing: Beam quality and caustic measurement, power measurement in the continuous and pulsed wave mode, weld seam tracing and triangulation • Forming and blank cutting: Integration of force and distance sensors in forming and cutting tools, tribological effects, measurement of pressure, temperature, viscosity and clouding of hydraulic oils • Material removal technologies: Measurement of high-frequency voltage and current impulses, application of measurement systems in electromagnetically polluted environments, force and distance measurement in micro EDM sinking, passivation layer thickness measurement in ELID grinding
Learning Objectives/ Learning Outcomes	Overall goal: Ability to analyse manufacturing processes Students understand how process and workpiece properties can be measured and analysed. They get to know metrology as an essential part of modern production processes. After successfully completing this course, the students will have acquired the following learning outcomes: <u>Knowledge / Understanding</u> • Setup, functionality and application of technical sensors for the analysis of manufacturing processes • Components of a measuring chain, functionality, connection of the elements and estimation of the measuring deviation • Options on signal analysis of stationary and instationary processes in time and frequency domain • Characteristics of manufacturing technologies which require a scientific analysis

	Abilities / Skills Students are able to choose suitable measurement systems, to integrate them into manufacturing processes, to acquire and analyse the signals. In the laboratory, they gain the practical experience, which is required to apply the theoretical knowledge. Students are able to arrange the setup of a measuring chain, data acquisition in LabView and data analysis in the software Diadem. Competencies The students recognize correlations between process and part characteristics and can make conclusions on the part's quality. Furthermore, they recognize the impact of metrology on manufacturing processes, which results from the integration of certain measurement systems. They are able to describe changes of dynamical systems and critically evaluate these changes.
(Study-Specific) Prerequisites	-
(recommended) Requirements	Recommended: Manufacturing Technology I
References	Klocke, F.; König, W.: Manufacturing Processes 1, 1st Ed., 2011 Klocke, F.; König, W.: Manufacturing Processes 2, 1st Ed., 2009 Klocke, F.; König, W.: Manufacturing Processes 4, 1st Ed., 2013
Language	English
Examination Terms	A written or an oral exam
Miscellaneous	-
Module coordinator	Univ.-Prof. Dr.-Ing. Thomas Bergs
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Process Analysis in Manufacturing Technology (402606501)	3rd semester	no semester recommended	5	-

▲Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Process Analysis in Manufacturing Technology	3rd semester	no semester recommended	-	2
Exercise Process Analysis in Manufacturing Technology	3rd semester	no semester recommended	-	1

Module titel	Gear and Transmission Technology (Compulsory elective subject)
Identifier	4011427
Version	V2
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2019
Valid until	-
Module level	-
Content	L01: Transmission in application L02: Gear geometry L03: Gear damages L04: Gear design I - Macro geometry L05: Gear design II - Micro geometry L06: Load Carrying and Efficiency L07: Acoustics L08: Process chains L09: Manufacturing I - Defined cutting edge L10: Manufacturing II - Undefined cutting edge L11: Crossing axes I - Bevel gears L12: Crossing axes II - Special gears L13: Planetary gears
Learning Objectives/ Learning Outcomes	L01: Transmission in application L02: Gear geometry L03: Gear damages L04: Gear design I - Macro geometry L05: Gear design II - Micro geometry L06: Load Carrying and Efficiency L07: Acoustics L08: Process chains L09: Manufacturing I - Defined cutting edge L10: Manufacturing II - Undefined cutting edge L11: Crossing axes I - Bevel gears L12: Crossing axes II - Special gears L13: Planetary gears
(Study-Specific) Prerequisites	-
(recommended) Requirements	Manufacturing Technology I Machine Tools
References	Lecture and exercise notes for download Recommended literature: • Zahnrad- und Getriebetechnik, Fritz Klocke, Christian Brecher • Werkzeugmaschinen Bd. 1, Christian Brecher • Fertigungstechnik Bd. 1-5, Fritz Klocke
Language	English
Examination Terms	Eine schriftliche oder eine mündliche Prüfung
Miscellaneous	-

Module coordinator	Universitätsprofessor Dr.-Ing. Christian Brecher Universitätsprofessor Dr.-Ing. Dr.-Ing. E. h. Dr. h. c. Dr. h. c. Fritz Klocke
ECTS Credits	6
Contact time (WSH)	-
Examination duration (min)	-
Total hours (h)	180,0
Contact hours (h)	-
Self-study hours (h)	-

● Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Gear and Transmission Technology (401142701)	1st semester	no semester recommended	6	0

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exercise Gear and Transmission Technology	1st semester	no semester recommended	-	2
Lecture Gear and Transmission Technology	1st semester	no semester recommended	-	2

Module titel	Welding and Joining Technologies (Compulsory elective subject)
Identifier	4011441
Version	-
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2012
Valid until	-
Module level	Master
Content	• Introduction • Welding of steel • Gas Fusion Welding • Manual Metal Arc Welding • Submerged Arc Welding • TIG Welding • Plasma Welding • MIG Welding • Electro Gas Welding • Electro Slag Welding • Pressure Welding • Resistance Welding • Electron Beam Welding • Laser Beam Welding • Special Processes • Mechanisation / • Automation • Sensor Technology • Brazing • Mechanical Joining / Adhesive Bonding • Essentials in Design and Calculation
Learning Objectives/ Learning Outcomes	After successfully completing this course, the students will have acquired the following learning outcomes: Knowledge / Understanding Students: • know and understand the main welding technologies. Abilities / Skills Students: • select the suitable welding technologies for a welding task and substantiate the selection by specifying the advantages and the disadvantages of the individual methods.
(Study-Specific) Prerequisites	-
(recommended) Requirements	-none-
References	-

Language	English
Examination Terms	Written exam
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr.-Ing. Uwe Reisgen
ECTS Credits	6
Contact time (WSH)	-
Examination duration (min)	0
Total hours (h)	180,0
Contact hours (h)	-
Self-study hours (h)	-

● Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Welding and Joining Technologies (401144101)	2nd semester	no semester recommended	6	0

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Tutorial Welding and Joining Technologies	2nd semester	no semester recommended	-	2
Lecture Welding and Joining Technologies	2nd semester	no semester recommended	-	2

Module titel	Production Metrology (Compulsory elective subject)
Identifier	4011467
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2012
Valid until	-
Module level	Master
Content	Introduction • Relevance of metrology for quality assurance and its integration in production processes. Metrological Basics • Metrological concepts and definitions (Calibration, Uncertainty etc.) Tolerancing • Form and positional tolerances, tolerancing principles and basics Inspection Planning • Tasks and workflow of inspection planning, Procedure for creation of inspection plans Shop floor measuring devices/ Measuring sensors • Commonly used manual inspection devices for the shop floor, Function and application of inductive, capacitive and pneumatical sensors Optoelectronic inspection devices • Optical inspection systems for geometry testing and applications Form and surface inspection devices • Tactile and optical system for the characterisation of forms and surfaces, surfaces parameters Coordinate measurement technology • Principles, types and applications of coordinate measuring machines Gauging inspection • Form and positional gauging, Gauging Procedures Statistical basics • Statistical parameters for the description of production and measuring processes, tests on normal distribution SPC, Process Capability • Statistical analysis and control of processes, Process capability indices Inspection device management • Tasks and procedures of inspection device management, Calculation of measuring device capability, Calibration chain
Learning Objectives/ Learning Outcomes	First of all, the elements of the application of the means of measurement concerning the production are pointed out. The theoretical fundamentals which have to be taken into consideration while the measuring process is planned, controlled, analysed, are discussed. Thereby, current measuring principles and devices in the field of industrial production will be considered and new measuring techniques and trends will be presented In this context the characteristics of the measured quantities and their fringe conditions are explained. A further subject of the lecture will be the statistical analysis of the measured values.

	The aim of this lecture is to create the awareness, that “measuring” comprehends a lot more than plain data acquisition and metrology is a vital part of modern production processes.
(Study-Specific) Prerequisites	-
(recommended) Requirements	-
References	-
Language	English
Examination Terms	Written exam or oral exam
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr.-Ing. Robert Schmitt
ECTS Credits	5
Contact time (WSH)	-
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	-
Self-study hours (h)	-

● Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Production Metrology (401146701)	2nd semester	no semester recommended	5	0

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture/Exercise Production Metrology	2nd semester	no semester recommended	-	4

Module titel	Industrial Logistics (Compulsory elective subject)
Identifier	4011473
Version	-
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2014
Valid until	-
Module level	Master
Content	• Objectives and tasks of logistics • Organisational involvement of logistics • Exercise: Prozess optimisation • Material flow design • Recitation by an external • Information logistics • Exercise: "Beergame" • Development and Procurement • Exercise: Development and Procurement • Material and finished goods disposition • Exercise: Workshop on the Enhancement of Disposition Quality • Distribution logistics • Exercise: Opening proceedings for tour planning • Spare part logistics • Recitation by an external • Logistics controlling • Exercise: ABC, XYZ Analysis
Learning Objectives/ Learning Outcomes	Students know objectives and tasks of industrial logistics as well as main aspects of industrial logistics from organisational involvement to logistics controlling. Students understand the meaning and the effects of individual aspects of industrial logistics and can place them in the overall context.They can apply the knowledge acquired to practical problems.
(Study-Specific) Prerequisites	-
(recommended) Requirements	-
References	-
Language	English
Examination Terms	Written exam or oral exam
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr.-Ing. Dipl.-Wirt. Ing. Günther Schuh apl. Professor Dr.-Ing. Volker Stich
ECTS Credits	5
Contact time (WSH)	-
Examination duration (min)	-

Total hours (h)	150,0
Contact hours (h)	-
Self-study hours (h)	-

● Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Industrial Logistics (401147301)	2nd semester	no semester recommended	5	0

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exercise Industrial Logistics	2nd semester	no semester recommended	-	1
Lecture Industrial Logistics	2nd semester	no semester recommended	-	2

Module titel	Tribology (Compulsory elective subject)
Identifier	4011475
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2013
Valid until	-
Module level	Master
Content	Basics of Tribology: • The Tribosystem in general and its analysis, its wear and friction processes and their test methods, also reasonable test and substitute systems Interactions between base and contact Bodies: • Contact processes and geometries, material strain, Hertzian theory, contact mechanics Interactions between base and contact Bodies: • Frictional processes and the results and influence on the tribosystem, wear processes and methods to avoid wear and losses Properties of base and contact Bodies: • Tribomaterials and the analysis of technical surfaces, roughness, hardness definitions and test methods Properties of base and contact Bodies: • Coating types and methods and their technical application, systematical methods and examples for the correct choice of material Properties of intermediate medium: • Basic properties, dependencies and test methods for the viscosity Properties of intermediate medium: • Classification, properties and application examples for different lubricants (oils, greases and solid lubricants) Basics of hydrodynamics and elastohydrodynamics: • Fundamentals and principles of flow mechanisms, derivation of Navier-Stokes and Reynolds equations and continuity equation Basics of hydrodynamics and elastohydrodynamics: • Application of the hydrodynamic equations regarding the calculation of bearings, Basics of the elastohydrodynamics Triboystem Journal Bearings: • Functionality and calculation of hydrodynamic axial and radial journal bearings, different occurring damages and failures and the choice of suitable lubricants Triboystem Journal Bearings: • Functionality and calculation of hydrostatical axial and radial journal bearings, different occurring damages and failures and the choice of suitable lubricants Tribosystem gear wheels: • Lubricants and materials for gears and their influence and application, application of the EHD-theory for gear stages Tribosystem gear wheels: • Damages and failures on gear wheels and suitable test methods for the analysis of gear stages Tribosystem roller bearings:

	• Design, materials, friction and lubrication of roler bearings, damages and failures and test methods for the analysis of roller bearings Tribosystem seals: • Different types and designs, specialties and application of different seals and materials for seals
Learning Objectives/ Learning Outcomes	The students are able to find and localize and systematically analyze tribo systems in general mechanical systems. They are theoretically capable of choosing and applying different suitable measuring- and test systems for journal bearings, roller bearings and gear wheels and they are capable of estimating the quality of the Tribosystem according to the test results and to optimize it with the background knowledge of a considerably large action catalogue. The students know the basic theories of hydrodynamics and of elastic material deformations and are able to use them in the calculation and analysis of tribological issues in a reasonable way.
(Study-Specific) Prerequisites	-
(recommended) Requirements	-
References	-
Language	English
Examination Terms	Written exam or oral exam
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr.-Ing. Georg Jacobs
ECTS Credits	5
Contact time (WSH)	-
Examination duration (min)	0
Total hours (h)	150,0
Contact hours (h)	-
Self-study hours (h)	-

● Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Tribology (401147501)	1st semester	no semester recommended	5	0

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
ExerciseTribology	1st semester	no semester recommended	-	2

Lecture Tribology	1st semester	no semester recommended	-	2

Module titel	Simulation Techniques in Manufacturing Technology (STMT) (Compulsory elective subject)
Identifier	4012413
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2011
Valid until	-
Module level	Master
Content	1 - In der ersten Vorlesung wird eine Einführung in das Thema „Simulationsverfahren in der Fertigungstechnik“ gegeben. 2 - Die Inhalte der zweiten Vorlesung sind die grundlegenden Aspekte und Prozesse der Umformtechnik. 3 - Nachdem der Student die Grundlagen der Umformtechnik erlernt hat, konzentriert sich diese Vorlesung auf aktuelle Simulationsverfahren beim Umformen. 4 - Die vierte Vorlesung befasst sich mit grundlegenden Aspekten und der Simulation der Massivumformung. 5 - Die fünfte Vorlesung gibt eine Einführung in die Grundlagen und Simulationsverfahren bei Blechumformung und Trennen. 6 - Inhalt der sechsten Vorlesung sind die Grundsätze der Zerspanung. 7 - Vorlesung 7 gibt einen generellen Überblick der verschiedenen Zerpanprozesse. 8 - Eine Möglichkeit Zerspanprozesse ganzheitlich zu modellieren ist die Finite-Elemente-Methode (FEM). Diese Vorlesung vermittelt die Vorgehensweise und Modellierungsansätze der FE-Zerspansimulation sowie zeigt verschiedene und aktuelle Beispiele für die FE-Simulation von Zerspanprozessen. 9 - Die neunte Vorlesung gibt eine Einführung in das Zerspanen mit undefinierter Schneide. 10 - Vorlesung 10 stellt aktuelle Modellierungsmethoden beim Schleifen vor. 11 - In Vorlesung 11 wird besonders auf die Methoden der Validierungs- und Optimierungstechniken eingegangen. 12 - Inhalt der letzten Veranstaltung ist es, in kleinen Gruppen die Aufstellung und Auswertung von FE-Simulation mit den FE-Codes DEFORM und ABAQUS zu erlernen.
Learning Objectives/ Learning Outcomes	Fachbezogene Lernziele: - Einführung in die grundsätzlichen Methoden der Modellierung und Simulation von Fertigungsverfahren - Revision der Grundlagen der Werkstoffkunde und Fertigungstechnik - Darstellung des Potentials der Modellierung und Simulation: Erhöhung des Prozessverständnisses, Verbesserung der Prozesssicherheit und Optimierung des Arbeitsergebnisses - Vorgehensweise und Einsatz der Finite-Elemente-Methode zur Simulation von Fertigungsprozessen - Möglichkeiten und Grenzen der Modellierung und Simulation zeigen - Anwendung der Simulationssoftware DEFORM und ABAQUS zur Simulation unterschiedlicher Fertigungsverfahren Nicht fachbezogene Lernziele: - Im Rahmen von Forschung und Entwicklung eigenständig passende Simulationsverfahren für Fertigungsprozesse auswählen und wissenschaftlich fundiert begründen - Eigene Ansätze zur Modellierung der Fertigungsprozesse entwickeln und in Forschungsfragen formulieren sowie in Entwicklungstätigkeiten einfließen lassen
(Study-Specific) Prerequisites	-
(recommended) Requirements	Empfohlene Voraussetzungen: - Grundkenntnisse der Werkstoffkunde - Grundlagen der Vektor- und Tensorrechnung - EDV-Grundlagen

	Empfohlene Voraussetzungen - Englisch in Wort und Schrift - Fertigungstechnik I
References	S. Kobayashi, T. Altan, S. Kobayashi: Metal Forming and the Finite-Element Method, Oxford Series on Advanced Manufacturing, Oxford University Press, 1989 - T. Childs: Metal Machining (Theory and Applications), ISBN-13: 978-0340691595 - K. Cheng: Machining Dynamics (Fundamentals, Applications and Practices), ISBN: 978-1-84628-367-3
Language	English
Examination Terms	Eine mündliche oder eine schriftliche Prüfung
Miscellaneous	-
Module coordinator	Univ.-Prof. Dr.-Ing. Thomas Bergs
ECTS Credits	6
Contact time (WSH)	-
Examination duration (min)	-
Total hours (h)	180,0
Contact hours (h)	-
Self-study hours (h)	-

● Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam STMT (401241301)	1st semester	no semester recommended	6	0

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exercise STMT	1st semester	no semester recommended	-	2
Lecture STMT	1st semester	no semester recommended	-	2

Module titel	Modeling, Model Reduction and Simulation in Laser Processing - Design (Compulsory elective subject)
Identifier	4013860
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2017
Valid until	-
Module level	Master

Content	Learning target M1
	• Cooperation Engineering: the contribution of the engineer to the interactive cooperation of scientific disciplines (“FlowChart” approach)
	Learning target M2
	• Meta-Modelling: main features of the theories for “design thinking” by “meta-modelling” are
	  • model reduction methods MRM: mathematical, empirical and ; ;numerical approaches
	  • global approximation and optimization methods
	  • sensitivity analysis and hierarchical models
	Learning target M3
	• model reduction methods MRM:
	  • Buckingham’s Pi-Theorem(mathematical MRM)
	  • Model hierarchy threshold (empirical MRM))
	  • Kriging global approximation versus response surface (numerical ; ;MRM)
	  • Proper orthogonal decomposition POD(numerical MRM)
	Learning target M4
	• mathematical MRM:
	  • Analysis of dissipative distributed systems applied to standard examples
	  • Time scale separation (Inertial manifolds)
	  • Singular perturbation
	Learning target L1
	• heating and melting ;phenomena
	  • Laser Polishing (Marangoni effect, evaporation)
	Learning target L2
	• evaporation phenomena
	  • Laser induced thermal stress analysis
	  • Laser driven EUV-Sources (Extreme Ultra-Violet EUV)
	  • Laser Propulsion
	• Light Engine
	Learning target L3
	• linear ;excitation phenomena
	  • Laser Induced Fluorescence (LIF): biological carrier for TNT detection
	Learning target L4
	• nonlinear Multi-Photon phenomena
	  • Laser Filamentation
	  • Kerr effect, Multi-photon absorption
	  • Multi-Photon Lithography
	Learning target L5

	• Coherence phenomena
	  • Optical Coherence Tomography (OCT)
	  • Particle detection (PIV, LDV, DGV, FRS)
	  • Laser Interferometer Space Antenna (LISA)
	  • Laser Time Measurement
	• Frequency Comb Physical Limits related to energy manipulation (Laser Fusion, Laser Cooling)
	Concluding discussion of the learning targets and Actual research ;and development of laser processing

Learning Objectives/ Learning Outcomes	After successfully completing this course, the student will have acquired the following learning outcomes: Knowledge / Understanding Students: • Design of Research is based on formulation of a research question followed by research hypothesis, state of the art, contributions of theory and experiment • Design Thinking for laser specification and laser processes by formulating specific research hypothesis leading to Reduced Models using the methods: 1. Dimensional Analysis, 2. Dimensionless groups, 3. Inertial Manifolds and Central Manifolds, 4. Length scale analysis and time scale separation • know how to adapt laser properties to high performance processing • understand the interactive cooperation of scientists from engineering, physics and mathematics for application of model based methods for diagnosis in laser processing. Abilities / Skills Students: • apply model based methods for solving practical tasks of laser design.
(Study-Specific) Prerequisites	-
(recommended) Requirements	-
References	Lecture Notes, List of relevant literature
Language	English
Examination Terms	An oral exam
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr. rer. nat. Wolfgang Schulz
ECTS Credits	5
Contact time (WSH)	-
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	-
Self-study hours (h)	-

● Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Modeling, Model Reduction and Simulation in Laser Processing - Design (401386001)	2nd semester	no semester recommended	5	0

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Modeling, Model Reduction and Simulation in Laser Processing - Design	2nd semester	no semester recommended	-	2
Exercise Modeling, Model Reduction and Simulation in Laser Processing - Design	2nd semester	no semester recommended	-	2

Module titel	Modeling, Model Reduction and Simulation in Laser Processing - Laser (Compulsory elective subject)
Identifier	4013863
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Winter semester 2016
Valid until	-
Module level	Master
Content	• overview of contents, definition of the 10 learning targets • the constribution of the engineer to the interactive cooperation of scientific disciplines • main features of the theory of cognition (Karl Popper) • laser radiation, Helmholtz equation, reduced model: SVE-approximation • Learning target 1:gaussian beam, beam guiding and forming • reflection, transmission and absorption of light • Learning target 2:reduced model of the Fresnel Formulae for the limiting case of small discplacemant current, optical parameters • technical task and examples: cutting with laser radiation • Learning target 3:quality features of the high quality cut • physical task of cutting and identification of quality defined processing domains • Learning target 4:relation of physicl phenomena to built up of quality degradations • technical task and examples: drilling with laser radiation • physical task and 5 dominant phenomena • Learning target 5: quality features of the drilled hole • mathematical modelling Ia: time scales • degrees of freedom in phase space of dependent variables • separation of time scales in simple dynamical systems • Learning target 6a: separation of time scales • mathematical modelling Ib:length scales • thermal boundary layer in heat conduction with moving boundaries • Learning target 6b: separation of length scales • mathematical modelling IIa: Free Boundary Problems (FBP) for the solid phase • reduced model for the FBP: motion of the melting front, integral methods, variational formulation • Learning target 7: heating and melting phase of ablation • mathematical modelling IIb: FBP for the liquid phase • Navier-Stokes equations, material equations and boundary values • mathematical model reduction: melt flow • reduced model for thin film flow • Learning target 8: boundary character, integral and spectral methods • model reduction and solution with controlled error: melt flow at low Reynolds-number • structural stability of the reduced model: lubrication approximation, fingering and droplet formation • Learning target 9: creeping flow and expansion with respect to the Reynolds-number, exact solution of a model problem for arbitrary Reynolds-number • global properties of the solution of balance equations for mass, momentum and thermal energy • Learning target 10: scales for the choice of processing parameters in cutting and drilling • concluding discussion of the learning targets • actual research and development of laser processing
Learning Objectives/ Learning Outcomes	The students obtain scientific skills for the application of: 1. Free Boundary Problems and integral methods of solution, 2. non-linear stability analysis using spectral methods, 3. analysis of the structural stability of model equations and • know the least 3 types of laser systems, temporal and spatial distribution of laser radiation, Fresnel-number, invariant quantity of light propagation

	• understand the structure of solution for the Helmholtz-equation, diffraction, 5 parameter pairs of optical material equations, transmission, reflection, absorption, Fresnel Formulae, polarisation of matter and radiation • know and understand the 5 different, dominant phenomena of drilling, welding and cutting with laser radiation • know the physical meaning of the terms contained in the Navier-Stokes equations for mass, momentum and energy balance • know the main properties of the solution in the asymptotic case of thin film flow (boundary layer) and can explain the relation between dynamical properties of the solution and quality features of the product as well as productivity of the process for drilling and cutting • know the effect of dissipation in disctributed dynamical systems (inertial manifold) and know examples for the application of methods for the reduction of the dimension in dissipative systems, understand and perform the separation of length and time scales in simple systems The students get to know non-scientific tasks: • understand the interactive cooperation of scientists from engineering, physics and mathematics for application of model based methods for diagnosis in laser processing • Application of model based methods for solving practical tasks from discussion of project examples
(Study-Specific) Prerequisites	-
(recommended) Requirements	-
References	-
Language	English
Examination Terms	Written exam or oral exam
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr. rer. nat. Wolfgang Schulz
ECTS Credits	5
Contact time (WSH)	-
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	-
Self-study hours (h)	-

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Modeling, Model Reduction and Simulation in Laser Processing - Laser (401386301)	2nd semester	no semester recommended	5	0

▲Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Modeling, Model Reduction and Simulation in Laser Processing - Laser	2nd semester	no semester recommended	-	2
Exercise Modeling, Model Reduction and Simulation in Laser Processing - Laser	2nd semester	no semester recommended	-	2

Module titel	Modeling, Model Reduction and Simulation in Laser Processing - Applications (Compulsory elective subject)
Identifier	4013864
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2016
Valid until	-
Module level	Master

Content	• overview of contents, definition of the learning targets
	• ecapitulation of the 10 learning targets from part I of the course
	• derivation and consolidation of the application of integral methods for treating heat conduction with Stefan-type boundary conditions
	• Learning target 1: variational formulation compared with direct integration for one space variable, spectral methods for error control of integral methods: spatial one-dimensional model problem, Eigenfunctions of differential operators, spectral decomposition of non-linear problems, discrete and continuous spectra
	• Learning target 2: separation of variables and relation to spectral methods, applications of spectral methods, asymptotic expansion of partial differential equations and their solution applied to a model problem of heat conduction
	• Learning target 3: identification of characteristic dynamical variables, degrees of freedom of an inertial manifold, determination of dimensionless groups, Buckingham's Pi-theorem, definition and physical meaning of Peclet-, Reynolds-, Marangoni- and Stefannumber.
	• Learning target 4: physical interpretation of dimensionless groups of system parameters and the dimension in phase space of processing parameters, optical modes in passive fibers, numerical aperture, total reflection, maximum mode-number, coupling of modes, optical excitation in active fibers and dissipation
	• Learning target 5: Slow surfaces in dynamical systems, Application of time scale separation
	• Learning target 6: thermal effects of large and small Peclet-number, model problems in thin film flow, applications of spectral methods:
	  • formation of pores in welding, closure of the drill hole
	• Learning target 7: relation of time scales and the onset of quality features, modelling evaporation and recondensation of metals I, comparison of models from Aden and Aoki &; Sone
	• Learning target 8: liquid-vapor phase transition in drilling and welding, modelling evaporation and recondensation of metals, Laplacepressure, evaporation and recondensation as driving forces for momentum of the liquid by pressure gradients
	• Learning target 9: boundary conditions for momentum at ideal surfaces,
	• technical examples:
	  • drilling with laser radiation, welding with laser radiation, concluding discussion of learning targets
	• actual research and development of laser processing

Learning Objectives/ Learning Outcomes	In this course, students shall acquire the following: Knowledge / Understanding: Students shall obtain understanding about the applications of: 1. Free Boundary Problems and integral methods of solution, 2. analysis of dynamical stability, non-linear stability analysis using spectral methods, 3. analysis of the structural stability of model equations. Abilities / Skills: Students

	• shall obtain scientific skills for the application of free Boundary Problems and integral methods of solution, non-linear stability analysis using spectral methods and for the analysis of the structural stability of model equations. • shall be able to determine the maximum number of dimensionsless groups of Boundary Value Problems. • shall understand the relation of boundary conditions, boundary values and the structure of solution for the Navier-Stokes equations. • shall know and understand the 5 different, dominant phenomena of drilling, welding and cutting with laser radiation. • shall know and be able to explain the physical meaning of the Navier-Stokes equations. • shall know the main properties of the solution in the asymptotic case of thin film flow (boundary layer) and shall be able to explain the relation between dynamical properties of the solution and quality features of the product as well as productivity of the process for drilling and cutting. • shall know the effect of dissipation in distributed dynamical systems (inertial manifold) and shall know examples for the application of methods for the reduction of the dimension in dissipative systems. • shall understand and perform the separation of length and time scales in simple systems. • shall understand the interactive cooperation of scientists from engineering, physics and mathematics for application of model based methods for diagnosis in laser processing.
(Study-Specific) Prerequisites	-
(recommended) Requirements	Recommended: • Modeling, Model Reduction and Simulation in Laser Processing - Laser
References	• Lecture Notes • Students also receive a list of relevant literature
Language	English
Examination Terms	Oral exam
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr. rer. nat. Wolfgang Schulz
ECTS Credits	5
Contact time (WSH)	-
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	-
Self-study hours (h)	-

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Modeling, Model Reduction and Simulation in Laser Processing - Applications (401386401)	1st semester	no semester recommended	5	0

▲Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exercise Modeling, Model Reduction and Simulation in Laser Processing - Applications	1st semester	no semester recommended	-	2
Lecture Modeling, Model Reduction and Simulation in Laser Processing - Applications	1st semester	no semester recommended	-	2

Module titel	High Precision Glass Optics Manufacturing (Compulsory elective subject)
Identifier	4017864
Version	V1
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2018
Valid until	-
Module level	Master
Content	LE 1 (Introduction): Clear overview on the topic and the following courses, Application cases, Awareness for the need of high precision optics LE 2 (Machine Aspects): Awareness of requirements on UP machines in comparison to non-UP machines, tribological aspects, error origins/impacts/compensation strategies LE 3 (Grinding I): Awareness of the needs of grinding, machining, distinction between brittle and ductile machining, rendition of ELID sequencesLE 4 (Grinding II): Classification of different materials regarding their machinability by grinding, grinding wheel indications, assign wheel composition to the application LE 5 (Polishing of glass optics I): Distinction between grinding, polishing, lapping and honing, working principle, influence on the removal rate LE 6 (Polishing of glass optics II): Full-aperture, sub-aperture and corrective polishing, corrective polishing principles, mechanical and chemo-mechanical polishing LE 7 (Diamond Turning): Distinction between grinding/polishing and diamond turning, achievable accuracy, impossibility of direct steel SPDT, wear mechanisms and prevention LE 8 (Coatings): Coatings and their applications, optical and wear protective coatings, differences between coating technologies, AR-coatings, wear mechanisms and prevention LE 9 (Modeling): Simulation assistance in molding processes, concepts/mathematics, chances and limits, critical interpretation of simulation results LE 10 (Non-isothermal Glass Molding): Precision and efficiency, working principle, heat transfer mechanisms, knowledge of wear phenomena and influence sources LE 11 (Precision Glass Molding): Classifying PGM regarding precision and efficiency, understanding of the working principle (temperatures, motions, etc.) esp. in comparison to NGM, Knowledge of wear phenomena and influence sources LE 12 (Metrology): Measuring principles and application, complex shape measurements, tactile and non-tactile shape qualification, interferometry, validity of measuring results LE 13 (Application Case): Recapitulation of the »big picture«, approaching manufacturing problems systematically, evaluation of direct or replicative manufacturing depending on applications and markets
Learning Objectives/ Learning Outcomes	Knowledge and understanding: After successfully completing this course, the student will have acquired the following learning outcomes: Students • Know and understand the demands on precision components. • Know and understand the specialities of glass in comparison to other materials. • Know and understand direct machining and replication methods for complex optical lens production. • Know and understand the characteristics of ultra-precision machine tools for machining optical components. • Understand the measurement methods that are established in ultra-precision shape, surface and rim zone characterization. Skills and competencies: Students • Apply this knowledge and are able to assess manufacturing processes, machine tools and metrology methods with regard to the demands of optical components. • Are able to evaluate production strategies for higher quality, higher output, higher complexity and lower costs. • Critically analyze company decisions with a technological background and communicate the assessments to non-specialist audiences. • Are familiar with the latest production trends in the seminal optics branch.

(Study-Specific) Prerequisites	-
(recommended) Requirements	Fertigungstechnik I
References	Lecture: Klocke, F.; König, W. Fertigungsverfahren 2 – Zerspanung mit geometrisch unbestimmter Schneide, Springer Vieweg, 5. Auflage, 2018; Klocke, F.; König, W. Fertigungsverfahren 4 – Umformen, Springer Vieweg, 6. Auflage, 2018; Recommended literature: Bliedtner, J.; Gräfe, G. Optiktechnologie. Grundlagen – Verfahren – Anwendungen – Beispiele. München, Fachbuchverl. Leipzig (Carl-Hanser-Verl.), 2008; Weck, M., Brecher, C. (Hrsg.) Werkzeugmaschinen. Vol. 1 – 4, Berlin Heidelberg, Springer Press, 2005; Bach, H.; Neuroth, N. (Hrsg.) The Properties of Optical Glass. Berlin/Heidelberg, Springer-Verlag, 1995
Language	English
Examination Terms	Written or oral exam
Miscellaneous	-
Module coordinator	Univ.-Prof. Dr.-Ing. Thomas Bergs
ECTS Credits	6
Contact time (WSH)	1
Examination duration (min)	-
Total hours (h)	180,0
Contact hours (h)	15,0
Self-study hours (h)	165,0

● Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam High Precision Glass Optics Manufacturing	1st semester	no semester recommended	6	-

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture High Precision Glass Optics Manufacturing	1st semester	no semester recommended	-	2
Exercise High Precision Glass Optics Manufacturing	1st semester	no semester recommended	-	2

Module titel	Robotic Systems (Compulsory elective subject)
Identifier	4018563
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Summer semester 2018
Valid until	-
Module level	Bachelor/Master
Content	1st Lecture Introduction to Industrial Robots (History of Robotics, Definition of Robotics, World Robotic Market, Requirements and application scenario, Essential construction elements of an industry robot, Category of robotics, Robotic Companies and StartUps, Future smart and intelligent Robots) 2nd Lecture Introduction to Advanced Robots (Advanced, Space, Food, Medical, Home Cleaning Robots, Mobile Manipulators, Intelligent Vehicles, World Robotic market: Service Robotics) 3rd Lecture General Robot Structures (Joints and Motion, Degree of Freedom, Workspaces, Different Classifications) 4th Lecture Structural Synthesis (Selection of robotic structures / quantitative optimization) 5th Lecture Robot End-effector Technology (Types and function of different End-effector technologies) 6th Lecture Gripper Technology (Characteristics of Objects, The Grasp, Gripper Mechanisms, Merit Indices, Design) 7th Lecture Components of Robotic Systems (Gears) 8th Lecture Components of Robotic Systems (Actuators) 9th Lecture Components of Robotic Systems (Sensors and Vision Systems) 10th Lecture Components of Robotic Systems (Control and Safety Architecture) 11th Lecture Properties and Benchmarking (Performance evaluation) 12th Lecture Mobile Manipulators (Types of Wheels, Kinematic Constrains, Robot Configuration Variables, Characterization of robot mobility, Wheeled Robot Structures) 13th Lecture Control and Path Planning (Artificial Intelligence)
Learning Objectives/ Learning Outcomes	Knowledge and understanding: The students have a profound comprehension of the fundamentals of robotic systems as well as the components used to build and run a robotic system. Thus, they are capable of comprehending, describing and analyzing robotic systems and components. Skills and competencies: The students got a brief overview about existing and future robotic systems. The students are capable of running through the development and implementation process of a mechatronic robotic gripper. They have the ability to analyse the kinematic structure of robots as well as grippers. Furthermore, they have the knowledge and the ability to launch and use general robotic components (stepper motor, sensors) and control (via microcontroller) the kinematic structures to complete it to a full mechatronic system. For the development of the gripper during the project, the students use general methods of structural synthesis and follow the development guidance for mechatronic systems (VDI 2206).
(Study-Specific) Prerequisites	-
(recommended) Requirements	Recommended requirements: - mechanic (kinematic, dynamic) - mathemaitc I,II,III
References	- Lecture slides - Exercise slides Recommended literatur: - Siciliano, B.: Robotics; Modelling, Planning and Control, Springer International Publishing, 2009, eBook ISBN 978-1-84628-642-1, DOI 10.1007/978-1-84628-642-1

	- Siciliano, B. (Hrsg.): Springer Handbook of Robotics, Springer International Publishing, 2016, eBook ISBN 978-3-319-32552-1, DOI 10.1007/978-3-319-32552-1
Language	English
Examination Terms	A written or an oral exam
Miscellaneous	-
Module coordinator	Modulverantworlicher: apl. Professor Dr.-Ing. Mathias Hüsing
ECTS Credits	5
Contact time (WSH)	-
Examination duration (min)	0
Total hours (h)	150,0
Contact hours (h)	-
Self-study hours (h)	-

● Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Robotic Systems (401856301)	1st semester	no semester recommended	5	0

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Robotic Systems	1st semester	no semester recommended	-	2
Exercise Robotic Systems	1st semester	no semester recommended	-	2

Module titel	Multibody Dynamics (Compulsory elective subject)
Identifier	4011462
Version	V1
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2020
Valid until	-
Module level	Master
Content	• Introduction • Fundamentals • Fields of application • Model Building • Methods of Approach for Equivalent Models • Multi-body Systems • General mathematical description • Kinematics of Multi Body Systems • Position and Orientation of Bodies • Translational Kinematics • Rotational Kinematics • Equations of Motion • Lagrangian Equations of 2nd Kind • Newton-Euler equations • Lagrangian Equations of 1st Kind • Eigen Value Approach • Undamped non-gyroscopic systems • Damped gyroscopic systems • Eigen Value Stability Criteria Linear Systems with Harmonic Excitation • Real Frequency Matrix • Complex Frequency Matrix • State Equation • System Matrix • Eigen Value Approach • Fundamental Matrix • Modal Matrix • Theorem of Cayley-Hamilton • Analytical Solution • Numerical Solution • Step Excitation • Harmonic Excitation • Periodical Excitation Example • Modelling • Calculation • Evaluation
Learning Objectives/ Learning Outcomes	In this course, students shall acquire the following: <u>Knowledge / Understanding:</u> Students: • shall have a profound knowledge of theory of vibrations. • shall be capable of comprehending, describing and analyzing vibratory systems.

	• shall be familiar with the most important matrix based procedures for the calculation of eigenmotions and the behaviour of linear systems under forced excitations. Abilities / Skills: Students • shall have the ability of describing mathematically any mechanical system with its inherent physical effects like elasticity, damping and friction. • shall be able to properly interpret simulation results especially under consideration of simplifications within the model compared to the real system. Competencies: Students • shall be able to derive from their knowledge the necessary methods and proceedings for the analysis and synthesis of the systems in regard. • shall be capable to solve - accessing their acquired theoretical knowledge - complex problems concerning the choice and design of industrial vibratory systems.
(Study-Specific) Prerequisites	-
(recommended) Requirements	-none-
References	• Lecture Notes • Students also receive a list of relevant literature
Language	English
Examination Terms	Written/Oral Examination (Depending on registration numbers)
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr.-Ing. Dr. h. c. Burkhard Corves
ECTS Credits	6
Contact time (WSH)	-
Examination duration (min)	-
Total hours (h)	180,0
Contact hours (h)	-
Self-study hours (h)	-

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Multibody Dynamics (401146201)	2nd semester	no semester recommended	6	0

▲Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Tutorial Multibody Dynamics	2nd semester	no semester recommended	-	2
Lecture Multibody Dynamics	2nd semester	no semester recommended	-	2

Module titel	Industrial product development process - battery systems for hybrid and electric vehicles (Compulsory elective subject)
Identifier	6022858
Version	v1
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2021
Valid until	-
Module level	Master
Content	Formulation of the requirements for vehicle batteries (among others package, weight, safety, costs, development time); development of specifications from these require-ments, taking into account the standards and safety regulations relevant to the market; definition of key performance indicators for the development of vehicle batteries. Measures and procedures for quality assurance and maintaining safety standards (e.g. ASIL – all levels) together with methods and processes for achieving these standards (including the V-model, concepts for developing secure software and its evaluation, etc.) Fundamentals of costing and cost efficiency analyses on the basis of the parts lists, taking into account purchasing processes in the automotive industry and the production process. Procedures for systematic competition and market analysis, patent and license re-search procedures, preparation of a dedicated portfolio of proprietary rights. Product development of high voltage battery packs with full functionality incl. battery management system, thermal management and active/passive safety measures. Development and optimization of the production process, definition of the machines and the level of automation, establishment of the logistic chains with vendors and semi-finished products. Program of tests and trials to ensure functionality, the fulfilment of guarantee periods and all safety requirements. Product Design • Requirement • Preparation of Specification Development • PDP • A,B,C,D samples • Testing and simulation ;;Production planning • Tolerance management • Process FMEA • Requirements of the production facilities Production start-up • Test bench technology – ensuring a zero defect product • Ramp-up of a production line and its optimization Series production support • Quality and vendor management • Diagnosis • Quality control loops

Learning Objectives/ Learning Outcomes	The students learn how to assimilate and process complex system interrelationships. The development and production of high voltage battery packs for hybrid and electric vehicles is used as an example of the product development process. They learn how to deal with vaguely formulated questions, how to use the freedoms this opens up and how to find creative ways of solving problems. During complex assignments they learn how to structure a complex issue, how to split up the overall problem and then bring it together again into a joint solution. After successfully completing this course, the students will have acquired the following learning outcomes: Knowledge / Understanding Students • have an understanding of the industrial product development process • understand the complete process chain Abilities / Skills Students • apply basic procedures in development, quality assurance, product qualification and production • set up market analyses and cost efficiency analyses • prepare specifications for battery packs and develop them taking into account the safety standards, industrial quality assurance procedures and the required production engineering Competencies Students • independently build a complete process chain • independently manage a complete industrial product development process in a practical setting ;
(Study-Specific) Prerequisites	-
(recommended) Requirements	Bachelor degree should be completed
References	-
Language	English
Examination Terms	oral or written examination
Miscellaneous	-
Module coordinator	**Professor Sauer**
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	30 or 90
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

● Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Industrial product development process - battery systems for hybrid and electric vehicles (602285801)	2nd semester	no semester recommended	5	-

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture and Exercise Industrial product development process - battery systems for hybrid and electric vehicles	2nd semester	no semester recommended	-	3

Module titel	Internship (Compulsory elective subject)
Identifier	4023100
Version	-
Duration (Semester)	one semester
Cycle (Semester)	-
Valid from	Winter semester 2020
Valid until	-
Module level	Master
Content	Internships in companies are necessary to ensure the correct choice of the course of studies, a sufficient understanding of the technical and economic courses as well as in preparation for the professional life (also in Germany) in the future. The students should acquire knowledge about technical materials and processes used in practice corresponding economic considerations and procedures, and gain insights into social processes and structures in the companies. See guidelines for practical training in the examination regulations
Learning Objectives/ Learning Outcomes	After successfully completing this course, the students will have acquired the following learning outcomes: Knowledge / Understanding Students: • know different fields of activity in the desired occupational field • understand theoretical concepts during implementation Abilities / Skills Students: • put theory and practice in relation to each other • test their own abilities and knowledge on the basis of practical experience • follow and participate in production engineering team meetings • eliminate misconceptions about the chosen profession Competencies Students: • assess their competences correctly • discern individual learning fields with regard to a professional activity • assess social processes and structures of companies and organisations • establish contacts with potential colleagues and employers For more see guidelines for practical training in the examination regulations
(Study-Specific) Prerequisites	-

(recommended) Requirements	none
References	-
Language	-
Examination Terms	Internship Report (100%)
Miscellaneous	-
Module coordinator	-
ECTS Credits	12
Contact time (WSH)	1
Examination duration (min)	-
Total hours (h)	360,0
Contact hours (h)	15,0
Self-study hours (h)	345,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Internship (402310001)	3rd semester	no semester recommended	12	-

Module titel	Advanced Software Engineering (Compulsory elective subject)
Identifier	4011468
Version	V2_neu
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2022
Valid until	-
Module level	Master
Content	The aim of the course is to explain students for what purposes, under which conditions and with which consequences computer systems are used for the solution of problems related to Mechanical Engineering.Within the first part of the course the steps from problem description to the final software solution are illustrated. This covers the topics modelling, problem elicitation and analysis, program design and an introduction to UML (Unified Modelling Language) and implementation in C++ Java. Then the course goes on with a closer examination of the various aspects which comprise software development, concerning topics like design patterns, agile software processes and project management. Parallel to the lecture the students are given the chance to employ the theoretical input from the course in small software projects. After an introduction to Java and object-oriented programming, the students stepwise pass through the particular stages of a software development process.
Learning Objectives/ Learning Outcomes	In this course, students shall acquire the following: Knowledge / Understanding: Students • are to gain solid knowledge in the Software Development Life Cycle and also the main activities and core concepts in different software development phases. Abilities / Skills: Students • shall have the ability to transfer the acquired knowledge in object - oriented design to different engineering problems and understand the general structure and the functionality of software.
(Study-Specific) Prerequisites	-
(recommended) Requirements	Recommended: • Basic knowledge in a programming language (e.g. C, C++, Java, Python)
References	• Bruegge, B.; Dutoit, A. (2009): Object-Oriented Software Engineering • Using UML, Patterns and Java. Boston: Pearson. • Sommerville, I. (2010): Software engineering. Boston: Pearson
Language	English
Examination Terms	Written or oral Examination (100 %)
Miscellaneous	-
Module coordinator	Dipl.-Inform Daniel Lütticke
ECTS Credits	5

Contact time (WSH)	-
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	-
Self-study hours (h)	-

● Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Advanced Software Engineering (401146801)	1st semester	no semester recommended	5	0

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Advanced Software Engineering	1st semester	no semester recommended	-	2
Tutorial Advanced Software Engineering	1st semester	no semester recommended	-	2

Module titel	Intelligent Monitoring of Engineering Systems (Compulsory elective subject)
Identifier	4021494
Version	V1_neu
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Winter semester 2022
Valid until	-
Module level	Master
Content	The course curriculum consists of seminar lectures followed by a semester project. During the seminar lectures, the students will receive the necessary theoretical background to independently plan and execute the project in small groups. Consultation hours are offered to discuss challenges and problems arising during the course of the project. Finally, each group presents their achievements and results live and in form of a written report. The following topics are covered: • Sensing • Signal processing • Machine learning • Non-Destructive Testing (NDT) • Structural Health Monitoring (SHM) • Data pre- and postprocessing using MATLAB
Learning Objectives/ Learning Outcomes	In this course, students shall acquire the following: Knowledge / Understanding The students will understand • the theoretical foundations of structural health monitoring approaches in engineering • state-of-the-art and current trends in structural health monitoring • the fundamentals of sensors, filtering methods, and computational Intelligence Abilities / Skills The students are able to • describe and analyse mechanical engineering systems • extract and monitor relevant system parameters • apply fundamental methods of structural health monitoring • transfer their knowledge to new engineering applications in science and industry • independently plan, advance and complete projects
(Study-Specific) Prerequisites	-
(recommended) Requirements	Recommended: Programming experience, particularly in MATLAB (Python)
References	Farrar, C.R. and Worden, K., 2012. Structural Health Monitoring: A Machine Learning Perspective. Wiley.
Language	English
Examination Terms	Written or Oral Examination (100 %)
Miscellaneous	-

− Track Smart Factory
− Elective Courses
+ Intelligent Monitoring of Engineering Systems (4021494)

Module coordinator	Univ.-Prof. Dr.-Ing. Bernd Markert
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

● Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Intelligent Monitoring of Engineering Sys-tems (402149401)	2nd semester	no semester recommended	5	-

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Intelligent Monitoring of Engineering Systems	2nd semester	no semester recommended	-	2
Exercise Intelligent Monitoring of Engineering Systems	2nd semester	no semester recommended	-	1

Module titel	Linear Control Systems (Compulsory elective subject)
Identifier	4011476
Version	Angelegt über RWTH API als 1_neu
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2022
Valid until	-
Module level	Master
Content	Significance of control theory, examples of biological and biomedical control loops, functional diagrams, linearization, set up and solving of differential equations, stability, features in time domain of dynamical systems, Laplace transform, transfer function, frequency response, functional diagram algebra, features in frequency domain of dynamical systems, bode diagram, Nyquist plot, Linear control loop elements, principle and goals of controller design, algebraic stability criteria, steady state analysis and transient performance of a control loop, controller setting rules, Nyquist stability criterion, phase margin, gain margin, controller design in bode diagram.
Learning Objectives/ Learning Outcomes	After successfully completing this course, the student will have acquired the following learning outcomes: Knowledge / Understanding: • know, recognize and classify the most common linear control loop elements • the effects of feedback and apply different methods to set up feedback elements (controllers) such that predefined control goals are met Abilities / Skills: • to analyze dynamical, biological and biomedical systems and identify the relevant causalities • to employ different mathematical descriptions of dynamical systems • solve differential equations by means of Laplace transform • assess of the stability of dynamical systems using different methods • obtain, interpret and employ the frequency response of dynamical systems
(Study-Specific) Prerequisites	-
(recommended) Requirements	Basic knowledge in mathematics as defined in the examination regulations.
References	-
Language	English
Examination Terms	The module grading is weighted according to the CP-allocation • Written Exam (schriftliche Prüfung) or • Oral Exam (mündliche Prüfung)
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr.-Ing. Dirk Abel
ECTS Credits	4
Contact time (WSH)	2

Examination duration (min)	-
Total hours (h)	120,0
Contact hours (h)	30,0
Self-study hours (h)	90,0

● Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Linear Control Systems (401147601)	1st semester	no semester recommended	4	0

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Linear Control Systems	1st semester	no semester recommended	-	1
Tutorial Linear Control Systems	1st semester	no semester recommended	-	1

Module titel	Gear and Transmission Technology (Compulsory subject)
Identifier	4011427
Version	V2
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2019
Valid until	-
Module level	-
Content	L01: Transmission in application L02: Gear geometry L03: Gear damages L04: Gear design I - Macro geometry L05: Gear design II - Micro geometry L06: Load Carrying and Efficiency L07: Acoustics L08: Process chains L09: Manufacturing I - Defined cutting edge L10: Manufacturing II - Undefined cutting edge L11: Crossing axes I - Bevel gears L12: Crossing axes II - Special gears L13: Planetary gears
Learning Objectives/ Learning Outcomes	L01: Transmission in application L02: Gear geometry L03: Gear damages L04: Gear design I - Macro geometry L05: Gear design II - Micro geometry L06: Load Carrying and Efficiency L07: Acoustics L08: Process chains L09: Manufacturing I - Defined cutting edge L10: Manufacturing II - Undefined cutting edge L11: Crossing axes I - Bevel gears L12: Crossing axes II - Special gears L13: Planetary gears
(Study-Specific) Prerequisites	-
(recommended) Requirements	Manufacturing Technology I Machine Tools
References	Lecture and exercise notes for download Recommended literature: • Zahnrad- und Getriebetechnik, Fritz Klocke, Christian Brecher • Werkzeugmaschinen Bd. 1, Christian Brecher • Fertigungstechnik Bd. 1-5, Fritz Klocke
Language	English
Examination Terms	Eine schriftliche oder eine mündliche Prüfung
Miscellaneous	-

Smart Production Engineering SPE
−
Tracks

− Track Electric Mobility Production
− Compulsory Courses
+ Gear and Transmission Technology (4011427)

Module coordinator	Universitätsprofessor Dr.-Ing. Christian Brecher Universitätsprofessor Dr.-Ing. Dr.-Ing. E. h. Dr. h. c. Dr. h. c. Fritz Klocke
ECTS Credits	6
Contact time (WSH)	-
Examination duration (min)	-
Total hours (h)	180,0
Contact hours (h)	-
Self-study hours (h)	-

● Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Gear and Transmission Technology (401142701)	1st semester	no semester recommended	6	0

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exercise Gear and Transmission Technology	1st semester	no semester recommended	-	2
Lecture Gear and Transmission Technology	1st semester	no semester recommended	-	2

Module titel	Welding and Joining Technologies (Compulsory subject)
Identifier	4011441
Version	-
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2012
Valid until	-
Module level	Master
Content	• Introduction • Welding of steel • Gas Fusion Welding • Manual Metal Arc Welding • Submerged Arc Welding • TIG Welding • Plasma Welding • MIG Welding • Electro Gas Welding • Electro Slag Welding • Pressure Welding • Resistance Welding • Electron Beam Welding • Laser Beam Welding • Special Processes • Mechanisation / • Automation • Sensor Technology • Brazing • Mechanical Joining / Adhesive Bonding • Essentials in Design and Calculation
Learning Objectives/ Learning Outcomes	After successfully completing this course, the students will have acquired the following learning outcomes: Knowledge / Understanding Students: • know and understand the main welding technologies. Abilities / Skills Students: • select the suitable welding technologies for a welding task and substantiate the selection by specifying the advantages and the disadvantages of the individual methods.
(Study-Specific) Prerequisites	-
(recommended) Requirements	-none-
References	-

Language	English
Examination Terms	Written exam
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr.-Ing. Uwe Reisgen
ECTS Credits	6
Contact time (WSH)	-
Examination duration (min)	0
Total hours (h)	180,0
Contact hours (h)	-
Self-study hours (h)	-

● Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Welding and Joining Technologies (401144101)	2nd semester	no semester recommended	6	0

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Tutorial Welding and Joining Technologies	2nd semester	no semester recommended	-	2
Lecture Welding and Joining Technologies	2nd semester	no semester recommended	-	2

Module titel	Electric Mobility - Battery systems production for a sustainable mobility (Compulsory subject)
Identifier	4027153
Version	-
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2022
Valid until	-
Module level	Master
Content	• Formulation of requirements for vehicle batteries, development of specifications from these requirements, taking into account the standards and safety regulations relevant to the market; definition of key performance indicators for the development of vehicle batteries. • Measures and procedures for quality assurance and maintaining safety standards together with methods and processes for achieving these standards including concepts for developing secure software and its evaluation • Specifics of costing and cost efficiency analyses on the basis of the parts lists, purchasing processes and basic production processes. • Procedures for systematic competition and market analysis, patent and license research procedures. • Product development of high voltage battery packs incl. Battery management system, thermal management and active/passive safety measures. • Overview of the production processes, automation and logistics chains with suppliers and semi-finished products. • Testing and validation of battery systems. • E-mobility challenges and projects of the air and maritime sectors.
Learning Objectives/ Learning Outcomes	*Overall goal: The students acquire advanced knowledge of methods, processes and technology in the area of the development of energy storage systems, battery product evaluation processes and battery production. They will get a deep insight into practical realisation within a battery supplier in automotive industry. Electrification will play an important role in transformation of the mobility and offers great opportunities not only for electrically powered vehicles, but also for electric transport by air and sea. In addition, students will get an outlook on the context, the challenges and current projects of marine and aviation E-Mobility.* In this course, students shall acquire the following: <u>Knowledge / Understanding</u> • The students will understand the need, motivation and current status of sustainable E-mobility. • The students shall learn about an industrial product development process and how to apply it. • Students shall learn about the product development process by means of an example, namely the development and production of high voltage battery packs for hybrid and electric vehicles <u>Abilities / Skills</u> • The students shall obtain skills to understand the complete process chain and shall learn to apply it independently. This includes dealing with basic procedures for development, quality assurance, product qualification and production overview. • The students will be able to prepare specifications for battery packs and develop them, taking into account the safety standards, industrial quality assurance procedures and the required production engineering. <u>Competencies</u> • The students shall be able to assimilate and process complex system interrelationships. • Students shall learn how to deal with vaguely formulated questions, how to use the freedoms this opens up and how to find creative ways of solving problems.

	• During complex assignments students shall learn how to structure a complex issue, how to split up the overall problem and then bring it together again into a joint solution. • Additionally students shall acquire technological competences and evaluation skills with regard to sustainable e-mobility solutions.
(Study-Specific) Prerequisites	-
(recommended) Requirements	-None-
References	Lecture Notes Students also receive a list of relevant literature.
Language	English
Examination Terms	Written or oral examination
Miscellaneous	-
Module coordinator	Univ.-Prof. Dr.-Ing. Thomas Bergs
ECTS Credits	3
Contact time (WSH)	3
Examination duration (min)	-
Total hours (h)	90,0
Contact hours (h)	45,0
Self-study hours (h)	45,0

● Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Electric Mobility - Battery systems production for a sustainable mo-bility (402715301)	2nd semester	no semester recommended	3	-

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Electric Mobility - Battery systems production for a sustainable mobility	2nd semester	no semester recommended	-	2
Exercise Electric Mobility - Battery systems production for a sustainable mobility	2nd semester	no semester recommended	-	1

Module titel	Electric Mobility - Li-Ion Cell Production (Compulsory subject)
Identifier	4027154
Version	-
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2022
Valid until	-
Module level	Master
Content	The module focuses on… • Relevant steps of the production process of different Li-Ion cells (pouch, cylindrical, prismatic) • In-depth description of the relevant manufacturing technologies for Li-Ion cells • Methods to secure the quality of each production steps and traceability along the value stream • Concept of the digital factory and application of a digital twin in Li-Ion cell production and aftermarket • Environmental aspects in Li-Ion cell production and supply chain • Relevant standards and certifications and required testing
Learning Objectives/ Learning Outcomes	*Overall objective: The basis of the lithium-ion battery was already used in the 1970s. In recent decades, the technology of lithium-ion batteries has been applied for more and more products. Today, the technology and its further development play an essential role in the e-mobility revolution. The Cell production takes place in so-called giga factories, which are characterised by high efficiency. The students will get a general overview of lithium-ion cells technology with focus on the production. The students will gain a deep insight into the production rocesses, quality assurance, supply chain and sustainability.* In this course, students shall acquire the following: <u>Knowledge / Understanding</u> • The students shall gain knowledge of different Li-Ion cell chemistries (NMC, NCA, LFP) and cell formats (pouch, cylindrical, prismatic) and will understand the main components of Li-Ion cells. • The students shall understand the production of Li-Ion cells and core processes and production steps (slurry mixing, coating, pressing, cell assembly, filling, formation and aging, EOL Test). • The students will understand the complexity and interdependencies between cell design, material development and production process. • The students shall understand the environmental impact of the production process and supply chain and how it can be influenced to achieve a sustainable production set-up. • The students will gain knowledge in relevant international standards and certifications for Li-Ion cells and required testing to enable high quality in mass production. • The students will understand the main production technologies for Li-Ion cells. <u>Abilities / Skills</u> • The students will be able to break down a Li-Ion cell into its main components and can establish an efficient production concept. • The students will be able to establish the production cost with consideration of equipment/ building investment, energy and workforce. • The students will understand how production parameters impact the characteristics of Li-Ion cells. • The students will understand relevant quality assurance methods during Li-Ion cell production and can establish a high level control plan. • Students shall understand typical quality defects and required analysis methods. • Students can establish a test plan based on product requirements to ensure that the product meets target specification and quality.

(Study-Specific) Prerequisites	-
(recommended) Requirements	-None-
References	Lecture Notes Students also receive a list of relevant literature.
Language	English
Examination Terms	Written or oral examination
Miscellaneous	-
Module coordinator	Univ.-Prof. Dr.-Ing. Thomas Bergs
ECTS Credits	3
Contact time (WSH)	3
Examination duration (min)	-
Total hours (h)	90,0
Contact hours (h)	45,0
Self-study hours (h)	45,0

● Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Electric Mobility - Li-Ion Cell Production (402715401)	2nd semester	no semester recommended	3	-

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Electric Mobility - Li-Ion Cell Production	2nd semester	no semester recommended	-	2
Exercise Electric Mobility - Li-Ion Cell Production	2nd semester	no semester recommended	-	1

Module titel	Electric Mobility - Battery Production (Compulsory subject)
Identifier	4027152
Version	-
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2022
Valid until	-
Module level	Master
Content	The module focuses on… • Relevant steps of the production process of cell modules for round, prismatic, pouch cells and battery packs with the required production equipment. • Methods to secure the quality of the single production steps in each project phase, • Requirements-based design of the production concept depending on product, production location and production quantity, • Application of the digital factory and other methods for planning and realization of production lines, • In-depth description of the most important manufacturing technologies for battery systems, • Methods how a serial production is organized, • Factors influencing production conditions, such as ergonomics, occupational safety, staff training, building requirement, • Calculation and tracking of costs for the project, launch and serial phase.
Learning Objectives/ Learning Outcomes	*Overall objective: Using real examples from company practice, students gain insights into the production of electrical energy storage devices. The focus is also on the analysis and optimisation of the application, the production-related design of the battery and the production process design of components and systems.* In this course, students shall acquire the following: Knowledge / Understanding • The students shall understand the main components of battery systems and their production, the relevant core processes and production steps, including quality assurance aspects. • The students shall have a comprehensive understanding of established and innovative production technologies and their interlinking in battery production. • The students shall understand the complexity and interdependencies that product technology innovations have on the production set-up and the challenges that need to be solved for successful industrialization. • The students will understand the influence of the quantity requirements on the production technologies. • The students will understand the main production technologies for battery systems. Abilities / Skills • The students shall be able to break down a product into single process steps and elaborate a production concept. • The students shall know the systematics of planning a battery production from the first production concepts through their implementation to the end of production (EOP). • The students will know how to calculate the costs according to each project phase. Competencis • The students shall be able to further deepen the topic independently, using digital information and communication technologies. • Students shall be able to analyse current technological possibilities and evaluate "ideal" and "real" conditions for

(Study-Specific) Prerequisites	-
(recommended) Requirements	-None-
References	Lecture Notes Students also receive a list of relevant literature.
Language	English
Examination Terms	Written or oral examination
Miscellaneous	-
Module coordinator	Univ.-Prof. Dr.-Ing. Thomas Bergs
ECTS Credits	3
Contact time (WSH)	3
Examination duration (min)	-
Total hours (h)	90,0
Contact hours (h)	45,0
Self-study hours (h)	45,0

● Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Electric Mobility - Battery Production (402715201)	2nd semester	no semester recommended	3	-

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Electric Mobility - Battery Production	2nd semester	no semester recommended	-	2
Exercise Electric Mobility - Battery Production	2nd semester	no semester recommended	-	1

Module titel	Tribology (Compulsory elective subject)
Identifier	4011475
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2013
Valid until	-
Module level	Master
Content	Basics of Tribology: • The Tribosystem in general and its analysis, its wear and friction processes and their test methods, also reasonable test and substitute systems Interactions between base and contact Bodies: • Contact processes and geometries, material strain, Hertzian theory, contact mechanics Interactions between base and contact Bodies: • Frictional processes and the results and influence on the tribosystem, wear processes and methods to avoid wear and losses Properties of base and contact Bodies: • Tribomaterials and the analysis of technical surfaces, roughness, hardness definitions and test methods Properties of base and contact Bodies: • Coating types and methods and their technical application, systematical methods and examples for the correct choice of material Properties of intermediate medium: • Basic properties, dependencies and test methods for the viscosity Properties of intermediate medium: • Classification, properties and application examples for different lubricants (oils, greases and solid lubricants) Basics of hydrodynamics and elastohydrodynamics: • Fundamentals and principles of flow mechanisms, derivation of Navier-Stokes and Reynolds equations and continuity equation Basics of hydrodynamics and elastohydrodynamics: • Application of the hydrodynamic equations regarding the calculation of bearings, Basics of the elastohydrodynamics Triboystem Journal Bearings: • Functionality and calculation of hydrodynamic axial and radial journal bearings, different occurring damages and failures and the choice of suitable lubricants Triboystem Journal Bearings: • Functionality and calculation of hydrostatical axial and radial journal bearings, different occurring damages and failures and the choice of suitable lubricants Tribosystem gear wheels: • Lubricants and materials for gears and their influence and application, application of the EHD-theory for gear stages Tribosystem gear wheels: • Damages and failures on gear wheels and suitable test methods for the analysis of gear stages Tribosystem roller bearings:

	• Design, materials, friction and lubrication of roler bearings, damages and failures and test methods for the analysis of roller bearings Tribosystem seals: • Different types and designs, specialties and application of different seals and materials for seals
Learning Objectives/ Learning Outcomes	The students are able to find and localize and systematically analyze tribo systems in general mechanical systems. They are theoretically capable of choosing and applying different suitable measuring- and test systems for journal bearings, roller bearings and gear wheels and they are capable of estimating the quality of the Tribosystem according to the test results and to optimize it with the background knowledge of a considerably large action catalogue. The students know the basic theories of hydrodynamics and of elastic material deformations and are able to use them in the calculation and analysis of tribological issues in a reasonable way.
(Study-Specific) Prerequisites	-
(recommended) Requirements	-
References	-
Language	English
Examination Terms	Written exam or oral exam
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr.-Ing. Georg Jacobs
ECTS Credits	5
Contact time (WSH)	-
Examination duration (min)	0
Total hours (h)	150,0
Contact hours (h)	-
Self-study hours (h)	-

● Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Tribology (401147501)	1st semester	no semester recommended	5	0

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
ExerciseTribology	1st semester	no semester recommended	-	2

Lecture Tribology	1st semester	no semester recommended	-	2

Module titel	Simulation Techniques in Manufacturing Technology (STMT) (Compulsory elective subject)
Identifier	4012413
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2011
Valid until	-
Module level	Master
Content	1 - In der ersten Vorlesung wird eine Einführung in das Thema „Simulationsverfahren in der Fertigungstechnik“ gegeben. 2 - Die Inhalte der zweiten Vorlesung sind die grundlegenden Aspekte und Prozesse der Umformtechnik. 3 - Nachdem der Student die Grundlagen der Umformtechnik erlernt hat, konzentriert sich diese Vorlesung auf aktuelle Simulationsverfahren beim Umformen. 4 - Die vierte Vorlesung befasst sich mit grundlegenden Aspekten und der Simulation der Massivumformung. 5 - Die fünfte Vorlesung gibt eine Einführung in die Grundlagen und Simulationsverfahren bei Blechumformung und Trennen. 6 - Inhalt der sechsten Vorlesung sind die Grundsätze der Zerspanung. 7 - Vorlesung 7 gibt einen generellen Überblick der verschiedenen Zerpanprozesse. 8 - Eine Möglichkeit Zerspanprozesse ganzheitlich zu modellieren ist die Finite-Elemente-Methode (FEM). Diese Vorlesung vermittelt die Vorgehensweise und Modellierungsansätze der FE-Zerspansimulation sowie zeigt verschiedene und aktuelle Beispiele für die FE-Simulation von Zerspanprozessen. 9 - Die neunte Vorlesung gibt eine Einführung in das Zerspanen mit undefinierter Schneide. 10 - Vorlesung 10 stellt aktuelle Modellierungsmethoden beim Schleifen vor. 11 - In Vorlesung 11 wird besonders auf die Methoden der Validierungs- und Optimierungstechniken eingegangen. 12 - Inhalt der letzten Veranstaltung ist es, in kleinen Gruppen die Aufstellung und Auswertung von FE-Simulation mit den FE-Codes DEFORM und ABAQUS zu erlernen.
Learning Objectives/ Learning Outcomes	Fachbezogene Lernziele: - Einführung in die grundsätzlichen Methoden der Modellierung und Simulation von Fertigungsverfahren - Revision der Grundlagen der Werkstoffkunde und Fertigungstechnik - Darstellung des Potentials der Modellierung und Simulation: Erhöhung des Prozessverständnisses, Verbesserung der Prozesssicherheit und Optimierung des Arbeitsergebnisses - Vorgehensweise und Einsatz der Finite-Elemente-Methode zur Simulation von Fertigungsprozessen - Möglichkeiten und Grenzen der Modellierung und Simulation zeigen - Anwendung der Simulationssoftware DEFORM und ABAQUS zur Simulation unterschiedlicher Fertigungsverfahren Nicht fachbezogene Lernziele: - Im Rahmen von Forschung und Entwicklung eigenständig passende Simulationsverfahren für Fertigungsprozesse auswählen und wissenschaftlich fundiert begründen - Eigene Ansätze zur Modellierung der Fertigungsprozesse entwickeln und in Forschungsfragen formulieren sowie in Entwicklungstätigkeiten einfließen lassen
(Study-Specific) Prerequisites	-
(recommended) Requirements	Empfohlene Voraussetzungen: - Grundkenntnisse der Werkstoffkunde - Grundlagen der Vektor- und Tensorrechnung - EDV-Grundlagen

	Empfohlene Voraussetzungen - Englisch in Wort und Schrift - Fertigungstechnik I
References	S. Kobayashi, T. Altan, S. Kobayashi: Metal Forming and the Finite-Element Method, Oxford Series on Advanced Manufacturing, Oxford University Press, 1989 - T. Childs: Metal Machining (Theory and Applications), ISBN-13: 978-0340691595 - K. Cheng: Machining Dynamics (Fundamentals, Applications and Practices), ISBN: 978-1-84628-367-3
Language	English
Examination Terms	Eine mündliche oder eine schriftliche Prüfung
Miscellaneous	-
Module coordinator	Univ.-Prof. Dr.-Ing. Thomas Bergs
ECTS Credits	6
Contact time (WSH)	-
Examination duration (min)	-
Total hours (h)	180,0
Contact hours (h)	-
Self-study hours (h)	-

● Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam STMT (401241301)	1st semester	no semester recommended	6	0

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exercise STMT	1st semester	no semester recommended	-	2
Lecture STMT	1st semester	no semester recommended	-	2

Module titel	Modeling, Model Reduction and Simulation in Laser Processing - Design (Compulsory elective subject)
Identifier	4013860
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2017
Valid until	-
Module level	Master

Content	Learning target M1
	• Cooperation Engineering: the contribution of the engineer to the interactive cooperation of scientific disciplines (“FlowChart” approach)
	Learning target M2
	• Meta-Modelling: main features of the theories for “design thinking” by “meta-modelling” are
	  • model reduction methods MRM: mathematical, empirical and ; ;numerical approaches
	  • global approximation and optimization methods
	  • sensitivity analysis and hierarchical models
	Learning target M3
	• model reduction methods MRM:
	  • Buckingham’s Pi-Theorem(mathematical MRM)
	  • Model hierarchy threshold (empirical MRM))
	  • Kriging global approximation versus response surface (numerical ; ;MRM)
	  • Proper orthogonal decomposition POD(numerical MRM)
	Learning target M4
	• mathematical MRM:
	  • Analysis of dissipative distributed systems applied to standard examples
	  • Time scale separation (Inertial manifolds)
	  • Singular perturbation
	Learning target L1
	• heating and melting ;phenomena
	  • Laser Polishing (Marangoni effect, evaporation)
	Learning target L2
	• evaporation phenomena
	  • Laser induced thermal stress analysis
	  • Laser driven EUV-Sources (Extreme Ultra-Violet EUV)
	  • Laser Propulsion
	• Light Engine
	Learning target L3
	• linear ;excitation phenomena
	  • Laser Induced Fluorescence (LIF): biological carrier for TNT detection
	Learning target L4
	• nonlinear Multi-Photon phenomena
	  • Laser Filamentation
	  • Kerr effect, Multi-photon absorption
	  • Multi-Photon Lithography
	Learning target L5

	• Coherence phenomena
	  • Optical Coherence Tomography (OCT)
	  • Particle detection (PIV, LDV, DGV, FRS)
	  • Laser Interferometer Space Antenna (LISA)
	  • Laser Time Measurement
	• Frequency Comb Physical Limits related to energy manipulation (Laser Fusion, Laser Cooling)
	Concluding discussion of the learning targets and Actual research ;and development of laser processing

Learning Objectives/ Learning Outcomes	After successfully completing this course, the student will have acquired the following learning outcomes: Knowledge / Understanding Students: • Design of Research is based on formulation of a research question followed by research hypothesis, state of the art, contributions of theory and experiment • Design Thinking for laser specification and laser processes by formulating specific research hypothesis leading to Reduced Models using the methods: 1. Dimensional Analysis, 2. Dimensionless groups, 3. Inertial Manifolds and Central Manifolds, 4. Length scale analysis and time scale separation • know how to adapt laser properties to high performance processing • understand the interactive cooperation of scientists from engineering, physics and mathematics for application of model based methods for diagnosis in laser processing. Abilities / Skills Students: • apply model based methods for solving practical tasks of laser design.
(Study-Specific) Prerequisites	-
(recommended) Requirements	-
References	Lecture Notes, List of relevant literature
Language	English
Examination Terms	An oral exam
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr. rer. nat. Wolfgang Schulz
ECTS Credits	5
Contact time (WSH)	-
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	-
Self-study hours (h)	-

● Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Modeling, Model Reduction and Simulation in Laser Processing - Design (401386001)	2nd semester	no semester recommended	5	0

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Modeling, Model Reduction and Simulation in Laser Processing - Design	2nd semester	no semester recommended	-	2
Exercise Modeling, Model Reduction and Simulation in Laser Processing - Design	2nd semester	no semester recommended	-	2

Module titel	Modeling, Model Reduction and Simulation in Laser Processing - Laser (Compulsory elective subject)
Identifier	4013863
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Winter semester 2016
Valid until	-
Module level	Master
Content	• overview of contents, definition of the 10 learning targets • the constribution of the engineer to the interactive cooperation of scientific disciplines • main features of the theory of cognition (Karl Popper) • laser radiation, Helmholtz equation, reduced model: SVE-approximation • Learning target 1:gaussian beam, beam guiding and forming • reflection, transmission and absorption of light • Learning target 2:reduced model of the Fresnel Formulae for the limiting case of small discplacemant current, optical parameters • technical task and examples: cutting with laser radiation • Learning target 3:quality features of the high quality cut • physical task of cutting and identification of quality defined processing domains • Learning target 4:relation of physicl phenomena to built up of quality degradations • technical task and examples: drilling with laser radiation • physical task and 5 dominant phenomena • Learning target 5: quality features of the drilled hole • mathematical modelling Ia: time scales • degrees of freedom in phase space of dependent variables • separation of time scales in simple dynamical systems • Learning target 6a: separation of time scales • mathematical modelling Ib:length scales • thermal boundary layer in heat conduction with moving boundaries • Learning target 6b: separation of length scales • mathematical modelling IIa: Free Boundary Problems (FBP) for the solid phase • reduced model for the FBP: motion of the melting front, integral methods, variational formulation • Learning target 7: heating and melting phase of ablation • mathematical modelling IIb: FBP for the liquid phase • Navier-Stokes equations, material equations and boundary values • mathematical model reduction: melt flow • reduced model for thin film flow • Learning target 8: boundary character, integral and spectral methods • model reduction and solution with controlled error: melt flow at low Reynolds-number • structural stability of the reduced model: lubrication approximation, fingering and droplet formation • Learning target 9: creeping flow and expansion with respect to the Reynolds-number, exact solution of a model problem for arbitrary Reynolds-number • global properties of the solution of balance equations for mass, momentum and thermal energy • Learning target 10: scales for the choice of processing parameters in cutting and drilling • concluding discussion of the learning targets • actual research and development of laser processing
Learning Objectives/ Learning Outcomes	The students obtain scientific skills for the application of: 1. Free Boundary Problems and integral methods of solution, 2. non-linear stability analysis using spectral methods, 3. analysis of the structural stability of model equations and • know the least 3 types of laser systems, temporal and spatial distribution of laser radiation, Fresnel-number, invariant quantity of light propagation

	• understand the structure of solution for the Helmholtz-equation, diffraction, 5 parameter pairs of optical material equations, transmission, reflection, absorption, Fresnel Formulae, polarisation of matter and radiation • know and understand the 5 different, dominant phenomena of drilling, welding and cutting with laser radiation • know the physical meaning of the terms contained in the Navier-Stokes equations for mass, momentum and energy balance • know the main properties of the solution in the asymptotic case of thin film flow (boundary layer) and can explain the relation between dynamical properties of the solution and quality features of the product as well as productivity of the process for drilling and cutting • know the effect of dissipation in disctributed dynamical systems (inertial manifold) and know examples for the application of methods for the reduction of the dimension in dissipative systems, understand and perform the separation of length and time scales in simple systems The students get to know non-scientific tasks: • understand the interactive cooperation of scientists from engineering, physics and mathematics for application of model based methods for diagnosis in laser processing • Application of model based methods for solving practical tasks from discussion of project examples
(Study-Specific) Prerequisites	-
(recommended) Requirements	-
References	-
Language	English
Examination Terms	Written exam or oral exam
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr. rer. nat. Wolfgang Schulz
ECTS Credits	5
Contact time (WSH)	-
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	-
Self-study hours (h)	-

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Modeling, Model Reduction and Simulation in Laser Processing - Laser (401386301)	2nd semester	no semester recommended	5	0

▲Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Modeling, Model Reduction and Simulation in Laser Processing - Laser	2nd semester	no semester recommended	-	2
Exercise Modeling, Model Reduction and Simulation in Laser Processing - Laser	2nd semester	no semester recommended	-	2

Module titel	Modeling, Model Reduction and Simulation in Laser Processing - Applications (Compulsory elective subject)
Identifier	4013864
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2016
Valid until	-
Module level	Master

Content	• overview of contents, definition of the learning targets
	• ecapitulation of the 10 learning targets from part I of the course
	• derivation and consolidation of the application of integral methods for treating heat conduction with Stefan-type boundary conditions
	• Learning target 1: variational formulation compared with direct integration for one space variable, spectral methods for error control of integral methods: spatial one-dimensional model problem, Eigenfunctions of differential operators, spectral decomposition of non-linear problems, discrete and continuous spectra
	• Learning target 2: separation of variables and relation to spectral methods, applications of spectral methods, asymptotic expansion of partial differential equations and their solution applied to a model problem of heat conduction
	• Learning target 3: identification of characteristic dynamical variables, degrees of freedom of an inertial manifold, determination of dimensionless groups, Buckingham's Pi-theorem, definition and physical meaning of Peclet-, Reynolds-, Marangoni- and Stefannumber.
	• Learning target 4: physical interpretation of dimensionless groups of system parameters and the dimension in phase space of processing parameters, optical modes in passive fibers, numerical aperture, total reflection, maximum mode-number, coupling of modes, optical excitation in active fibers and dissipation
	• Learning target 5: Slow surfaces in dynamical systems, Application of time scale separation
	• Learning target 6: thermal effects of large and small Peclet-number, model problems in thin film flow, applications of spectral methods:
	  • formation of pores in welding, closure of the drill hole
	• Learning target 7: relation of time scales and the onset of quality features, modelling evaporation and recondensation of metals I, comparison of models from Aden and Aoki &; Sone
	• Learning target 8: liquid-vapor phase transition in drilling and welding, modelling evaporation and recondensation of metals, Laplacepressure, evaporation and recondensation as driving forces for momentum of the liquid by pressure gradients
	• Learning target 9: boundary conditions for momentum at ideal surfaces,
	• technical examples:
	  • drilling with laser radiation, welding with laser radiation, concluding discussion of learning targets
	• actual research and development of laser processing

Learning Objectives/ Learning Outcomes	In this course, students shall acquire the following: <u>Knowledge / Understanding:</u> Students shall obtain understanding about the applications of: 1. Free Boundary Problems and integral methods of solution, 2. analysis of dynamical stability, non-linear stability analysis using spectral methods, 3. analysis of the structural stability of model equations. <u>Abilities / Skills:</u> Students

	• shall obtain scientific skills for the application of free Boundary Problems and integral methods of solution, non-linear stability analysis using spectral methods and for the analysis of the structural stability of model equations. • shall be able to determine the maximum number of dimensionsless groups of Boundary Value Problems. • shall understand the relation of boundary conditions, boundary values and the structure of solution for the Navier-Stokes equations. • shall know and understand the 5 different, dominant phenomena of drilling, welding and cutting with laser radiation. • shall know and be able to explain the physical meaning of the Navier-Stokes equations. • shall know the main properties of the solution in the asymptotic case of thin film flow (boundary layer) and shall be able to explain the relation between dynamical properties of the solution and quality features of the product as well as productivity of the process for drilling and cutting. • shall know the effect of dissipation in distributed dynamical systems (inertial manifold) and shall know examples for the application of methods for the reduction of the dimension in dissipative systems. • shall understand and perform the separation of length and time scales in simple systems. • shall understand the interactive cooperation of scientists from engineering, physics and mathematics for application of model based methods for diagnosis in laser processing.
(Study-Specific) Prerequisites	-
(recommended) Requirements	Recommended: • Modeling, Model Reduction and Simulation in Laser Processing - Laser
References	• Lecture Notes • Students also receive a list of relevant literature
Language	English
Examination Terms	Oral exam
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr. rer. nat. Wolfgang Schulz
ECTS Credits	5
Contact time (WSH)	-
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	-
Self-study hours (h)	-

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Modeling, Model Reduction and Simulation in Laser Processing - Applications (401386401)	1st semester	no semester recommended	5	0

▲Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exercise Modeling, Model Reduction and Simulation in Laser Processing - Applications	1st semester	no semester recommended	-	2
Lecture Modeling, Model Reduction and Simulation in Laser Processing - Applications	1st semester	no semester recommended	-	2

Module titel	High Precision Glass Optics Manufacturing (Compulsory elective subject)
Identifier	4017864
Version	V1
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2018
Valid until	-
Module level	Master
Content	LE 1 (Introduction): Clear overview on the topic and the following courses, Application cases, Awareness for the need of high precision optics LE 2 (Machine Aspects): Awareness of requirements on UP machines in comparison to non-UP machines, tribological aspects, error origins/impacts/compensation strategies LE 3 (Grinding I): Awareness of the needs of grinding, machining, distinction between brittle and ductile machining, rendition of ELID sequencesLE 4 (Grinding II): Classification of different materials regarding their machinability by grinding, grinding wheel indications, assign wheel composition to the application LE 5 (Polishing of glass optics I): Distinction between grinding, polishing, lapping and honing, working principle, influence on the removal rate LE 6 (Polishing of glass optics II): Full-aperture, sub-aperture and corrective polishing, corrective polishing principles, mechanical and chemo-mechanical polishing LE 7 (Diamond Turning): Distinction between grinding/polishing and diamond turning, achievable accuracy, impossibility of direct steel SPDT, wear mechanisms and prevention LE 8 (Coatings): Coatings and their applications, optical and wear protective coatings, differences between coating technologies, AR-coatings, wear mechanisms and prevention LE 9 (Modeling): Simulation assistance in molding processes, concepts/mathematics, chances and limits, critical interpretation of simulation results LE 10 (Non-isothermal Glass Molding): Precision and efficiency, working principle, heat transfer mechanisms, knowledge of wear phenomena and influence sources LE 11 (Precision Glass Molding): Classifying PGM regarding precision and efficiency, understanding of the working principle (temperatures, motions, etc.) esp. in comparison to NGM, Knowledge of wear phenomena and influence sources LE 12 (Metrology): Measuring principles and application, complex shape measurements, tactile and non-tactile shape qualification, interferometry, validity of measuring results LE 13 (Application Case): Recapitulation of the »big picture«, approaching manufacturing problems systematically, evaluation of direct or replicative manufacturing depending on applications and markets
Learning Objectives/ Learning Outcomes	Knowledge and understanding: After successfully completing this course, the student will have acquired the following learning outcomes: Students • Know and understand the demands on precision components. • Know and understand the specialities of glass in comparison to other materials. • Know and understand direct machining and replication methods for complex optical lens production. • Know and understand the characteristics of ultra-precision machine tools for machining optical components. • Understand the measurement methods that are established in ultra-precision shape, surface and rim zone characterization. Skills and competencies: Students • Apply this knowledge and are able to assess manufacturing processes, machine tools and metrology methods with regard to the demands of optical components. • Are able to evaluate production strategies for higher quality, higher output, higher complexity and lower costs. • Critically analyze company decisions with a technological background and communicate the assessments to non-specialist audiences. • Are familiar with the latest production trends in the seminal optics branch.

(Study-Specific) Prerequisites	-
(recommended) Requirements	Fertigungstechnik I
References	Lecture: Klocke, F.; König, W. Fertigungsverfahren 2 – Zerspanung mit geometrisch unbestimmter Schneide, Springer Vieweg, 5. Auflage, 2018; Klocke, F.; König, W. Fertigungsverfahren 4 – Umformen, Springer Vieweg, 6. Auflage, 2018; Recommended literature: Bliedtner, J.; Gräfe, G. Optiktechnologie. Grundlagen – Verfahren – Anwendungen – Beispiele. München, Fachbuchverl. Leipzig (Carl-Hanser-Verl.), 2008; Weck, M., Brecher, C. (Hrsg.) Werkzeugmaschinen. Vol. 1 – 4, Berlin Heidelberg, Springer Press, 2005; Bach, H.; Neuroth, N. (Hrsg.) The Properties of Optical Glass. Berlin/Heidelberg, Springer-Verlag, 1995
Language	English
Examination Terms	Written or oral exam
Miscellaneous	-
Module coordinator	Univ.-Prof. Dr.-Ing. Thomas Bergs
ECTS Credits	6
Contact time (WSH)	1
Examination duration (min)	-
Total hours (h)	180,0
Contact hours (h)	15,0
Self-study hours (h)	165,0

● Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam High Precision Glass Optics Manufacturing	1st semester	no semester recommended	6	-

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture High Precision Glass Optics Manufacturing	no semester recommended	no semester recommended	-	2
Exercise High Precision Glass Optics Manufacturing	1st semester	no semester recommended	-	2

Module titel	Laser Applications (Compulsory elective subject)
Identifier	4022685
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2020
Valid until	-
Module level	Master
Content	• The laser principle • Properties of laser radiation (spectral, temporal and spatial) • Laser types and systems • Reflection, absorption, transmission • Temperature, heat conduction, mass diffusion and melt pool dynamics • Laser-based surface treatment • Additive Manufacturing • Joining • Cutting • Ablation • Measurement technology
Learning Objectives/ Learning Outcomes	Overall goal: Students gain basic knowledge about the generation, characteristics and applications of laser radiation. After successfully completing this course, the students will have acquired the following learning outcomes: Knowledge / Understanding: Students • understand the generation and properties of laser radiation • know the fundamentals of light-matter interaction, heat transport and phase transitions • gain knowledge about laser-based processing and manufacturing (like hardening, joining, drilling, cutting and additive manufacturing) and further fields of laser application (like measurement technology). Abilities / Skills: Students • are able to evaluate manufacturing processes in order to identify those that benefit from the use of laser radiation • can apply mathematical techniques to identify and optimise process-specific laser beam parameters. Competencies: Students • are able to identify suitable laser parameters for specific tasks in materials processing • can identify a laser source providing the desired parameters for a given process • are able to work on current research problems, e.g. within a Master’s thesis
(Study-Specific) Prerequisites	-

(recommended) Requirements	none
References	Lecture notes R. Poprawe, K. Boucke, D. Hoffmann: Tailored Light 1 (Springer Verlag, 2018) R. Poprawe: Tailored Light 2 (Springer Verlag, 2011) Students receive a list of relevant literature
Language	English
Examination Terms	A written or an oral exam
Miscellaneous	-
Module coordinator	Univ.-Prof. Dr. rer. nat. Constantin Leon Häfner
ECTS Credits	6
Contact time (WSH)	4
Examination duration (min)	-
Total hours (h)	180,0
Contact hours (h)	60,0
Self-study hours (h)	120,0

● Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Laser Applications (402268501)	1st semester	no semester recommended	6	-

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Laser Applications	1st semester	no semester recommended	-	2
Exercise Laser Applications	1st semester	no semester recommended	-	2

Module titel	Multibody Dynamics (Compulsory elective subject)
Identifier	4011462
Version	V1
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2020
Valid until	-
Module level	Master
Content	• Introduction • Fundamentals • Fields of application • Model Building • Methods of Approach for Equivalent Models • Multi-body Systems • General mathematical description • Kinematics of Multi Body Systems • Position and Orientation of Bodies • Translational Kinematics • Rotational Kinematics • Equations of Motion • Lagrangian Equations of 2nd Kind • Newton-Euler equations • Lagrangian Equations of 1st Kind • Eigen Value Approach • Undamped non-gyroscopic systems • Damped gyroscopic systems • Eigen Value Stability Criteria Linear Systems with Harmonic Excitation • Real Frequency Matrix • Complex Frequency Matrix • State Equation • System Matrix • Eigen Value Approach • Fundamental Matrix • Modal Matrix • Theorem of Cayley-Hamilton • Analytical Solution • Numerical Solution • Step Excitation • Harmonic Excitation • Periodical Excitation Example • Modelling • Calculation • Evaluation
Learning Objectives/ Learning Outcomes	In this course, students shall acquire the following: <u>Knowledge / Understanding:</u> Students: • shall have a profound knowledge of theory of vibrations. • shall be capable of comprehending, describing and analyzing vibratory systems.

	• shall be familiar with the most important matrix based procedures for the calculation of eigenmotions and the behaviour of linear systems under forced excitations. Abilities / Skills: Students • shall have the ability of describing mathematically any mechanical system with its inherent physical effects like elasticity, damping and friction. • shall be able to properly interpret simulation results especially under consideration of simplifications within the model compared to the real system. Competencies: Students • shall be able to derive from their knowledge the necessary methods and proceedings for the analysis and synthesis of the systems in regard. • shall be capable to solve - accessing their acquired theoretical knowledge - complex problems concerning the choice and design of industrial vibratory systems.
(Study-Specific) Prerequisites	-
(recommended) Requirements	-none-
References	• Lecture Notes • Students also receive a list of relevant literature
Language	English
Examination Terms	Written/Oral Examination (Depending on registration numbers)
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr.-Ing. Dr. h. c. Burkhard Corves
ECTS Credits	6
Contact time (WSH)	-
Examination duration (min)	-
Total hours (h)	180,0
Contact hours (h)	-
Self-study hours (h)	-

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Multibody Dynamics (401146201)	2nd semester	no semester recommended	6	0

▲Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Tutorial Multibody Dynamics	2nd semester	no semester recommended	-	2
Lecture Multibody Dynamics	2nd semester	no semester recommended	-	2

Module titel	Industrial product development process - battery systems for hybrid and electric vehicles (Compulsory elective subject)
Identifier	6022858
Version	v1
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2021
Valid until	-
Module level	Master
Content	Formulation of the requirements for vehicle batteries (among others package, weight, safety, costs, development time); development of specifications from these require-ments, taking into account the standards and safety regulations relevant to the market; definition of key performance indicators for the development of vehicle batteries. Measures and procedures for quality assurance and maintaining safety standards (e.g. ASIL – all levels) together with methods and processes for achieving these standards (including the V-model, concepts for developing secure software and its evaluation, etc.) Fundamentals of costing and cost efficiency analyses on the basis of the parts lists, taking into account purchasing processes in the automotive industry and the production process. Procedures for systematic competition and market analysis, patent and license re-search procedures, preparation of a dedicated portfolio of proprietary rights. Product development of high voltage battery packs with full functionality incl. battery management system, thermal management and active/passive safety measures. Development and optimization of the production process, definition of the machines and the level of automation, establishment of the logistic chains with vendors and semi-finished products. Program of tests and trials to ensure functionality, the fulfilment of guarantee periods and all safety requirements. Product Design • Requirement • Preparation of Specification Development • PDP • A,B,C,D samples • Testing and simulation ;;Production planning • Tolerance management • Process FMEA • Requirements of the production facilities Production start-up • Test bench technology – ensuring a zero defect product • Ramp-up of a production line and its optimization Series production support • Quality and vendor management • Diagnosis • Quality control loops

Learning Objectives/ Learning Outcomes	The students learn how to assimilate and process complex system interrelationships. The development and production of high voltage battery packs for hybrid and electric vehicles is used as an example of the product development process. They learn how to deal with vaguely formulated questions, how to use the freedoms this opens up and how to find creative ways of solving problems. During complex assignments they learn how to structure a complex issue, how to split up the overall problem and then bring it together again into a joint solution. After successfully completing this course, the students will have acquired the following learning outcomes: Knowledge / Understanding Students • have an understanding of the industrial product development process • understand the complete process chain Abilities / Skills Students • apply basic procedures in development, quality assurance, product qualification and production • set up market analyses and cost efficiency analyses • prepare specifications for battery packs and develop them taking into account the safety standards, industrial quality assurance procedures and the required production engineering Competencies Students • independently build a complete process chain • independently manage a complete industrial product development process in a practical setting ;
(Study-Specific) Prerequisites	-
(recommended) Requirements	Bachelor degree should be completed
References	-
Language	English
Examination Terms	oral or written examination
Miscellaneous	-
Module coordinator	**Professor Sauer**
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	30 or 90
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

● Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Industrial product development process - battery systems for hybrid and electric vehicles (602285801)	2nd semester	no semester recommended	5	-

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture and Exercise Industrial product development process - battery systems for hybrid and electric vehicles	2nd semester	no semester recommended	-	3

Module titel	Principles of Power Electronics (Compulsory elective subject)
Identifier	6019099
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	winter/summer semester
Valid from	Winter semester 2017
Valid until	-
Module level	Master
Content	• Semiconductors and analysis • Line-Commutated converters • Inductor and transformer analysis • Design, control and modulation of dc-dc converters • Self-commutated converters • Pulse width modulation • Operation principle of a buck converter • Simulation of a line-commutated B6C converter and a buck converter • Practical design and construction of a buck converter and converter inductance • Validation through measurement
Learning Objectives/ Learning Outcomes	After successfully completing this course, the students will have acquired the following learning outcomes: **Knowledge / Understanding** Students: • understand topologies for power electronic applications; • understand the working principle of different power converters. **Abilities / Skills** Students: • design/ size main components in a power conversion system; • analyse the dynamic behaviour of components and circuits, and their basic control concepts; • transform their theoretical knowledge on power electronics • buck converter into an experimental set-up; • design, simulate and construct dc-dc converters; • perform tests of power electronic converters and assess the performance; • analyse the operational characteristics of power electronic converters considering real-life phenomena. **Competencies** Students: • accurately describe the findings from simulations and measurements in a brief scientific report.
(Study-Specific) Prerequisites	-
(recommended) Requirements	none
References	Lecture Notes Students also receive a list of relevant literature
Language	English
Examination Terms	Written or oral examination (100%) Written homework (not graded)
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr. ir. Dr. h. c. (RTU) Rik W. De Doncker
ECTS Credits	4

Contact time (WSH)	4
Examination duration (min)	90
Total hours (h)	120,0
Contact hours (h)	60,0
Self-study hours (h)	60,0

● Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Examination: Principles of Power Electronics	1st semester	no semester recommended	4	0

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Practical Session: Principles of Power Electronics	1st semester	no semester recommended	-	1
Lecture and Exercise: Principles of Power Electronics	1st semester	no semester recommended	-	3

Module titel	Internship (Compulsory elective subject)
Identifier	4023100
Version	-
Duration (Semester)	one semester
Cycle (Semester)	-
Valid from	Winter semester 2020
Valid until	-
Module level	Master
Content	Internships in companies are necessary to ensure the correct choice of the course of studies, a sufficient understanding of the technical and economic courses as well as in preparation for the professional life (also in Germany) in the future. The students should acquire knowledge about technical materials and processes used in practice corresponding economic considerations and procedures, and gain insights into social processes and structures in the companies. See guidelines for practical training in the examination regulations
Learning Objectives/ Learning Outcomes	After successfully completing this course, the students will have acquired the following learning outcomes: Knowledge / Understanding Students: • know different fields of activity in the desired occupational field • understand theoretical concepts during implementation Abilities / Skills Students: • put theory and practice in relation to each other • test their own abilities and knowledge on the basis of practical experience • follow and participate in production engineering team meetings • eliminate misconceptions about the chosen profession Competencies Students: • assess their competences correctly • discern individual learning fields with regard to a professional activity • assess social processes and structures of companies and organisations • establish contacts with potential colleagues and employers For more see guidelines for practical training in the examination regulations
(Study-Specific) Prerequisites	-

(recommended) Requirements	none
References	-
Language	-
Examination Terms	Internship Report (100%)
Miscellaneous	-
Module coordinator	-
ECTS Credits	12
Contact time (WSH)	1
Examination duration (min)	-
Total hours (h)	360,0
Contact hours (h)	15,0
Self-study hours (h)	345,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Internship (402310001)	3rd semester	no semester recommended	12	-

Module titel	International Factory Planning (Compulsory elective subject)
Identifier	4011481
Version	V2_neu
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2021
Valid until	-
Module level	Master
Content	L1 - Introduction to Factory Planning & Project Management: • basic glossary, different viewpoints, challenges and requirements of factory planning L2 - Target Definition & Product/Process Planning: • definition of objectives with the involvement of different stakeholders and requirements • challenges and approaches of product and process planning within the framework of factory design L3 - Location Planning & Site Structure Planning: • current trends in site structure planning and methods for evaluating different plant structure alternatives in order to create a basis for one of the most essential decisions within the factory planning process L4 - Industrial Building & Building Planning: • factory planning on the building side, i.e. advantages and disadvantages of different bearing structures, roof constructions and facade types L5 - Production Structure Planning & Capacity Planning: • production structure within the plant according to the site structure planning • challenges and approaches of capacity planning L6 - Layout Planning & Workplace Design: • overview of the goals and challenges of layout planning and the even more detailed workplace design L7 - Highlight lecture: • state-of-art application of modern factory planning methods
Learning Objectives/ Learning Outcomes	Within the framework of the lecture Factory Planning, the state-of-the-art of the respective subject areas will be introduced, relevant methods and procedures will be explained and reference solutions will be presented. The contents will be deepened in the exercises and in the case study. In this way, future production managers will be able to comprehensively plan and develop individual production sites as well as entire production networks of internationally active companies. The lectures and exercises as weil as the case studies are only held in summer semesters. The case studies are conducted in group work. A successful registration for the module Factory Planning already at the very beginning of each summer semester is therefore vital in order to be integrated within the allocation to groups. Each group then collaborates as a planning team to work on the case study, but members are graded individually. However, the exam can be written each semester, which means that the requirement of the case study has to be fulfilled (passed with a grade of 4.0 or better) to take the exam. lf an exam is failed, but the case study has already been completed, the grade of the case study is credited in the following semester. The aim of these case studies is to deepen the contents conveyed in the lecture in a practical application. The students are presented with a real-world-oriented factory planning problem. In order to successfully perform an extensive analysis covering multiple planning levels and give decision-targeted recommendations, the concepts and methods learned from the lectures and excercises need to be rigorously applied. By emulating a real factory planning project, students are prompted to work together and transfer their knowledge into practice. In addition, the developed solutions are to be validated using

	simulation tools provided by the chair, e.g. for verifying material flows. Finally, the used procedures and achieved results are compiled into a case study report. The case study work is expected to run from May to June in the summer semester and must therefore be submitted before the written exam phase. Knowledge / Understanding - describe the characteristics and challenges of factory planning and with regard to the global environment - formulate the object precisely and in a detailed way - have an extended understanding of state of the art planning process of factories - know and understand the definition of the own value adding scope, the choice and allocation of suitable production locations, the conception of production systems and the usage of suitable planning tools. - understand the procedures and methods in factory planning Abilities / Skills - apply the acquired methods to design a factory - apply this knowledge to analyse organizational structures and forms of production Competencies - analyse the initial situation of a factory planning project, draft and classify possible solutions - define and develop single production plants as well as production networks of globalized companies and explain them to different target groups
(Study-Specific) Prerequisites	-
(recommended) Requirements	-
References	Lecture reprint Exercise reprint Sample solution reprint
Language	English
Examination Terms	The final grade is composed to 2/3 of the exam grade and to 1/3 of the case study grade (individual grading). Both parts have to be passed in order to pass the whole module. Bonus points are awarded for the e-Test in L2P: Tests with 5-6 questions per lecture unit; time limited to 30 minutes activation from the day of the lecture to the day before the following lecture or max. 1 week > 50% of questions correct (i.e. 3 questions) - > test passed! 1 bonus point per test-> Max. 6 bonus points reachable (5% of all points reachable in the exam)
Miscellaneous	-
Module coordinator	Univ.-Prof. Dr.-Ing.Günther Schuh
ECTS Credits	6
Contact time (WSH)	4
Examination duration (min)	-
Total hours (h)	180,0
Contact hours (h)	60,0
Self-study hours (h)	120,0

● Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam International Factory Planning (401148101)	2nd semester	no semester recommended	4	0
Case Study International Factory Planning (401148102)	2nd semester	no semester recommended	2	-

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exercise International Factory Planning	2nd semester	no semester recommended	-	2
Lecture International Factory Planning	2nd semester	no semester recommended	-	2

Module titel	Process Analysis in Manufacturing Technology (Compulsory elective subject)
Identifier	4026065
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2021
Valid until	-
Module level	Master
Content	• Introduction on the scope of the course to go for the elective or not Fundamentals: • Technical sensors: Strain, force, acceleration, acoustic emission, temperature, pressure, viscosity, clouding, moisture • Measuring chain : Components, setup, signal conditioning, analog-to-digital, parameterization, measuring deviation, application software LabView • Signal analysis: Time and frequency domain, bandwidth, spectral resolution, aliasing, analysis of stationary and instationary processes, application software Diadem Applications: • Turning: Force, acceleration, temperature and wear measurement, force and wear modelling, self-induced and forced vibrations, residual stress measurement, thin film integrated sensors • Drilling: Force, acceleration, temperature and wear measurement, telemetry, force and wear modelling, short and deep hole drilling, monitoring of the chip removal, scaling of force and torque at small diameters • Milling: Interrupted cut, dynamical system analysis, transfer function, stability theory , force and acceleration measurement • Grinding: Grinding burn, nital etching, Barkhausen noise, adaptive grinding, sensor assisted dressing and balancing • Powder metallurgy: Powder classification, analysis of the porosity distribution, non- destructive testing methods • Laser material processing: Beam quality and caustic measurement, power measurement in the continuous and pulsed wave mode, weld seam tracing and triangulation • Forming and blank cutting: Integration of force and distance sensors in forming and cutting tools, tribological effects, measurement of pressure, temperature, viscosity and clouding of hydraulic oils • Material removal technologies: Measurement of high-frequency voltage and current impulses, application of measurement systems in electromagnetically polluted environments, force and distance measurement in micro EDM sinking, passivation layer thickness measurement in ELID grinding
Learning Objectives/ Learning Outcomes	Overall goal: Ability to analyse manufacturing processes Students understand how process and workpiece properties can be measured and analysed. They get to know metrology as an essential part of modern production processes. After successfully completing this course, the students will have acquired the following learning outcomes: <u>Knowledge / Understanding</u> • Setup, functionality and application of technical sensors for the analysis of manufacturing processes • Components of a measuring chain, functionality, connection of the elements and estimation of the measuring deviation • Options on signal analysis of stationary and instationary processes in time and frequency domain • Characteristics of manufacturing technologies which require a scientific analysis

	Abilities / Skills Students are able to choose suitable measurement systems, to integrate them into manufacturing processes, to acquire and analyse the signals. In the laboratory, they gain the practical experience, which is required to apply the theoretical knowledge. Students are able to arrange the setup of a measuring chain, data acquisition in LabView and data analysis in the software Diadem. Competencies The students recognize correlations between process and part characteristics and can make conclusions on the part's quality. Furthermore, they recognize the impact of metrology on manufacturing processes, which results from the integration of certain measurement systems. They are able to describe changes of dynamical systems and critically evaluate these changes.
(Study-Specific) Prerequisites	-
(recommended) Requirements	Recommended: Manufacturing Technology I
References	Klocke, F.; König, W.: Manufacturing Processes 1, 1st Ed., 2011 Klocke, F.; König, W.: Manufacturing Processes 2, 1st Ed., 2009 Klocke, F.; König, W.: Manufacturing Processes 4, 1st Ed., 2013
Language	English
Examination Terms	A written or an oral exam
Miscellaneous	-
Module coordinator	Univ.-Prof. Dr.-Ing. Thomas Bergs
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Process Analysis in Manufacturing Technology (402606501)	1st semester	no semester recommended	5	-

▲Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Process Analysis in Manufacturing Technology	1st semester	no semester recommended	-	2
Exercise Process Analysis in Manufacturing Technology	1st semester	no semester recommended	-	1

Module titel	Advanced Software Engineering (Compulsory elective subject)
Identifier	4011468
Version	V2_neu
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2022
Valid until	-
Module level	Master
Content	The aim of the course is to explain students for what purposes, under which conditions and with which consequences computer systems are used for the solution of problems related to Mechanical Engineering.Within the first part of the course the steps from problem description to the final software solution are illustrated. This covers the topics modelling, problem elicitation and analysis, program design and an introduction to UML (Unified Modelling Language) and implementation in C++ Java. Then the course goes on with a closer examination of the various aspects which comprise software development, concerning topics like design patterns, agile software processes and project management. Parallel to the lecture the students are given the chance to employ the theoretical input from the course in small software projects. After an introduction to Java and object-oriented programming, the students stepwise pass through the particular stages of a software development process.
Learning Objectives/ Learning Outcomes	In this course, students shall acquire the following: Knowledge / Understanding: Students • are to gain solid knowledge in the Software Development Life Cycle and also the main activities and core concepts in different software development phases. Abilities / Skills: Students • shall have the ability to transfer the acquired knowledge in object - oriented design to different engineering problems and understand the general structure and the functionality of software.
(Study-Specific) Prerequisites	-
(recommended) Requirements	Recommended: • Basic knowledge in a programming language (e.g. C, C++, Java, Python)
References	• Bruegge, B.; Dutoit, A. (2009): Object-Oriented Software Engineering • Using UML, Patterns and Java. Boston: Pearson. • Sommerville, I. (2010): Software engineering. Boston: Pearson
Language	English
Examination Terms	Written or oral Examination (100 %)
Miscellaneous	-
Module coordinator	Dipl.-Inform Daniel Lütticke
ECTS Credits	5

Contact time (WSH)	-
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	-
Self-study hours (h)	-

● Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Advanced Software Engineering (401146801)	1st semester	no semester recommended	5	0

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Advanced Software Engineering	1st semester	no semester recommended	-	2
Tutorial Advanced Software Engineering	1st semester	no semester recommended	-	2

Module titel	Intelligent Monitoring of Engineering Systems (Compulsory elective subject)
Identifier	4021494
Version	V1_neu
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Winter semester 2022
Valid until	-
Module level	Master
Content	The course curriculum consists of seminar lectures followed by a semester project. During the seminar lectures, the students will receive the necessary theoretical background to independently plan and execute the project in small groups. Consultation hours are offered to discuss challenges and problems arising during the course of the project. Finally, each group presents their achievements and results live and in form of a written report. The following topics are covered: • Sensing • Signal processing • Machine learning • Non-Destructive Testing (NDT) • Structural Health Monitoring (SHM) • Data pre- and postprocessing using MATLAB
Learning Objectives/ Learning Outcomes	In this course, students shall acquire the following: Knowledge / Understanding The students will understand • the theoretical foundations of structural health monitoring approaches in engineering • state-of-the-art and current trends in structural health monitoring • the fundamentals of sensors, filtering methods, and computational Intelligence Abilities / Skills The students are able to • describe and analyse mechanical engineering systems • extract and monitor relevant system parameters • apply fundamental methods of structural health monitoring • transfer their knowledge to new engineering applications in science and industry • independently plan, advance and complete projects
(Study-Specific) Prerequisites	-
(recommended) Requirements	Recommended: Programming experience, particularly in MATLAB (Python)
References	Farrar, C.R. and Worden, K., 2012. Structural Health Monitoring: A Machine Learning Perspective. Wiley.
Language	English
Examination Terms	Written or Oral Examination (100 %)
Miscellaneous	-

− Track Electric Mobility Production
− Elective Courses
+ Intelligent Monitoring of Engineering Systems (4021494)

Module coordinator	Univ.-Prof. Dr.-Ing. Bernd Markert
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

● Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Intelligent Monitoring of Engineering Sys-tems (402149401)	2nd semester	no semester recommended	5	-

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Intelligent Monitoring of Engineering Systems	2nd semester	no semester recommended	-	2
Exercise Intelligent Monitoring of Engineering Systems	2nd semester	no semester recommended	-	1

Module titel	Linear Control Systems (Compulsory elective subject)
Identifier	4011476
Version	Angelegt über RWTH API als 1_neu
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2022
Valid until	-
Module level	Master
Content	Significance of control theory, examples of biological and biomedical control loops, functional diagrams, linearization, set up and solving of differential equations, stability, features in time domain of dynamical systems, Laplace transform, transfer function, frequency response, functional diagram algebra, features in frequency domain of dynamical systems, bode diagram, Nyquist plot, Linear control loop elements, principle and goals of controller design, algebraic stability criteria, steady state analysis and transient performance of a control loop, controller setting rules, Nyquist stability criterion, phase margin, gain margin, controller design in bode diagram.
Learning Objectives/ Learning Outcomes	After successfully completing this course, the student will have acquired the following learning outcomes: Knowledge / Understanding: • know, recognize and classify the most common linear control loop elements • the effects of feedback and apply different methods to set up feedback elements (controllers) such that predefined control goals are met Abilities / Skills: • to analyze dynamical, biological and biomedical systems and identify the relevant causalities • to employ different mathematical descriptions of dynamical systems • solve differential equations by means of Laplace transform • assess of the stability of dynamical systems using different methods • obtain, interpret and employ the frequency response of dynamical systems
(Study-Specific) Prerequisites	-
(recommended) Requirements	Basic knowledge in mathematics as defined in the examination regulations.
References	-
Language	English
Examination Terms	The module grading is weighted according to the CP-allocation • Written Exam (schriftliche Prüfung) or • Oral Exam (mündliche Prüfung)
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr.-Ing. Dirk Abel
ECTS Credits	4
Contact time (WSH)	2

Examination duration (min)	-
Total hours (h)	120,0
Contact hours (h)	30,0
Self-study hours (h)	90,0

● Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Linear Control Systems (401147601)	1st semester	no semester recommended	4	0

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Linear Control Systems	1st semester	no semester recommended	-	1
Tutorial Linear Control Systems	1st semester	no semester recommended	-	1

+ Language Course I (4021266)

Module titel	Language Course I (Compulsory subject)
Identifier	4021266
Version	V1
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2019
Valid until	-
Module level	Master
Content	The course is aimed at students who are looking for a university-specific foreign lan-guage education, who need a foreign language for their studies and/or are planning a stay abroad (study, internship, project). Depending on the level, the range of foreign languages on offer takes into account the training of language skills specific to the profession. In the course you will learn the essential elements of grammar and vocabulary of the respective language, depending on your level, so that you can assert yourself both in writing and orally in everyday communication situations. In addition, you will learn to extract the essential information from authentic and university-specific reading and lis-tening texts as well as from various types of texts such as: Write e-mails, letters, messages and notes.
Learning Objectives/ Learning Outcomes	To learn the basics of the respective language or to deepen and expand already existing skills for active participation in everyday and working life.
(Study-Specific) Prerequisites	-
(recommended) Requirements	none
References	-
Language	German/English
Examination Terms	100% written examination in reading, listening, writing and grammar
Miscellaneous	-
Module coordinator	-
ECTS Credits	2
Contact time (WSH)	2
Examination duration (min)	-
Total hours (h)	60,0
Contact hours (h)	30,0
Self-study hours (h)	30,0

+ Language Course I (4021266)

● Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Examination Language Course I (402126601)	1st semester	no semester recommended	2	-

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Language Course I	1st semester	no semester recommended	-	1
Exercise Language Course I	1st semester	no semester recommended	-	1

+ Language Course II (4021267)

Module titel	Language Course II (Compulsory subject)
Identifier	4021267
Version	V1
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Winter semester 2019
Valid until	-
Module level	Master
Content	The course is aimed at students who are looking for a university-specific foreign lan-guage education, who need a foreign language for their studies and/or are planning a stay abroad (study, internship, project). Depending on the level, the range of foreign languages on offer takes into account the training of language skills specific to the profession. In the course you will learn the essential elements of grammar and vocabulary of the respective language, depending on your level, so that you can assert yourself both in writing and orally in everyday communication situations. In addition, you will learn to extract the essential information from authentic and university-specific reading and lis-tening texts as well as from various types of texts such as: Write e-mails, letters, messages and notes.
Learning Objectives/ Learning Outcomes	To learn the basics of the respective language or to deepen and expand already existing skills for active participation in everyday and working life.
(Study-Specific) Prerequisites	-
(recommended) Requirements	none
References	-
Language	German/English
Examination Terms	100% written examination in reading, listening, writing and grammar
Miscellaneous	-
Module coordinator	-
ECTS Credits	2
Contact time (WSH)	2
Examination duration (min)	-
Total hours (h)	60,0
Contact hours (h)	30,0
Self-study hours (h)	30,0

+ Language Course II (4021267)

● Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Examination Language Course II (402126701)	2nd semester	no semester recommended	2	-

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Language Course II	2nd semester	no semester recommended	-	1
Exercise Language Course II	2nd semester	no semester recommended	-	1

RWTH AACHEN UNIVERSITY

+ Linguistic Elective (4024418)

Module titel	Linguistic Elective (Compulsory subject)
Identifier	4024418
Version	V1
Duration (Semester)	one semester
Cycle (Semester)	winter/summer semester
Valid from	Winter semester 2021
Valid until	-
Module level	Master
Content	The course is aimed at students who are looking for a university-specific foreign lan-guage education, who need a foreign language for their studies and/or are planning a stay abroad (study, internship, project). Depending on the level, the range of foreign languages on offer takes into account the training of language skills specific to the profession. In the course you will learn the essential elements of grammar and vocabulary of the respective language, depending on your level, so that you can assert yourself both in writing and orally in everyday communication situations. In addition, you will learn to extract the essential information from authentic and university-specific reading and listening texts as well as from various types of texts such as: Write e-mails, letters, messages and notes. *Recommended language: Technical English*
Learning Objectives/ Learning Outcomes	To learn the basics of the respective language or to deepen and expand already existing skills for active participation in everyday and working life.
(Study-Specific) Prerequisites	-
(recommended) Requirements	-
References	-
Language	-
Examination Terms	100% written examination
Miscellaneous	-
Module coordinator	-
ECTS Credits	2
Contact time (WSH)	2
Examination duration (min)	-
Total hours (h)	60,0
Contact hours (h)	30,0
Self-study hours (h)	30,0

+ Linguistic Elective (4024418)

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Examination Linguistic Elective (402441801)	3rd semester	no semester recommended	2	2

+ Master Thesis (4023099)

Module titel	Master Thesis (Compulsory subject)
Identifier	4023099
Version	-
Duration (Semester)	one semester
Cycle (Semester)	-
Valid from	Winter semester 2020
Valid until	-
Module level	Master
Content	The students learn the independent approach and processing of academic themes, their documentation and written interpretation within a set deadline. They acquire systematic academic research.
Learning Objectives/ Learning Outcomes	Completed academic paper which shall show that the students are capable of independently processing a problem related to their subject according to academic methods within a set deadline.
(Study-Specific) Prerequisites	-
(recommended) Requirements	The topic of the Master's thesis cannot be assigned until 80 CPs have been achieved.
References	-
Language	English
Examination Terms	100% Master Thesis, to pass the Master Thesis, the participation at the colloquium is mandatory
Miscellaneous	-
Module coordinator	-
ECTS Credits	30
Contact time (WSH)	1
Examination duration (min)	-
Total hours (h)	900,0
Contact hours (h)	15,0
Self-study hours (h)	885,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Master Thesis and Colloqium (402309901)	4th semester	no semester recommended	30	-