University
of Ljubljana

Faculty
of Mechanical Engineering

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Slovenia

DOCTORAL PROGRAMME

in

MECHANICAL ENGINEERING

Ljubljana, February 2020

DOCTORAL PROGRAMME
in
MECHANICAL ENGINEERING
UNIVERSITY OF LJUBLJANA, FACULTY OF MECHANICAL ENGINEERING
Programme Presentation

1. Study Programme Details

Title:

Doctoral Programme in MECHANICAL ENGINEERING

Level:

Level 3

Duration:

4 years (8 semesters)

Number of ECTS credits:

240

Doctoral degree:

Doctor of Science
(abbreviated to **dr.** in front of the name)

Informative presentation of the *Doctoral Programme in **Mechanical Engineering*** is available on the internet address:
http://www.fs.uni-lj.si/educational_process/phd_study/

The duration of the *Doctoral Programme in **Mechanical Engineering*** is four years; it comprises 240 ECTS credits and is, according to the Bologna scheme, a programme of the 3rd level of higher education. Study obligations are evaluated by the European Credit Transfer System (ECTS), which provides the basis for international exchange of students in countries using the same or a comparable credit system.

Contents of the programme are a continuation and upgrade of the renovated study programmes of Level I. and Level II. in Mechanical engineering, and there considered contents on structural development and design, mechanics, energetic, environmental and manufacturing engineering, cybernetics and mechatronics. Organized study comprises 60 ECTS credits while the remaining 180 ECTS credits are awarded to individual research work and doctoral dissertation.

The goal of the programme is to educate outstanding students, who have finished Level II. programmes in engineering and natural sciences, and to train them for independent scientific and research work in mechanical engineering sciences. The programme gives priority to optional choice over compulsory forms of studies. In order to adequately cover the actual state of the art in modern mechanical engineering, the choice of study contents is wide and versatile. The possibility of choise gives students, provided they are supported by a chosen research mentor, the opportunity to plan their research careers carefully. Thus, they can follow specific needs of future employers to be later integrated readily when finishing the programme.

The *Doctoral Programme in **Mechanical Engineering*** inseparably connects the studies to scientific research and development work. In this regard the programme mainly focuses on independent creative research work of students, who are guided by their mentors. The key obligations of students include the proposal and preparation of the doctoral dissertation. The doctoral work demonstrates their capacity of thinking in a scientific manner and their aptitude for research work. Students present the subject of their dissertation and respective scientific results in public. The proof of original contributions to science is exposed when their work is published in international scientific publications. Two scientific papers are required.

2. The Fundamental Programme Objectives and General Competences

In accordance with clear orientations to increase competitiveness of the Slovenian economy, which depends on the ability to develop new products, process technologies and manufacture procedures all based on principles of a sustainable development and respecting environmental care, the main goal of the *Doctoral Programme in* ***Mechanical Engineering*** is to educate outstanding students, who have finished Level II. programmes in engineering and natural sciences, to perform independent scientific and research work in the fields of mechanical engineering. Following the above stated objectives those elements of the programme should be considered essential:

- Autonomous scientific-research and development oriented work, which originates from already achieved knowledge and results in new cognitions. The emphasis is put on:
    - Awareness, that a human being is learning from the observations of the nature, being at the same time a part of the nature himself. When interfering into the nature human beings must take care of the nature with great responsibility.
    - Establishing respect for the history of human race and its achievements, which are the reflection of the human restless mind and its creativeness.
    - Achieving deep understanding of fundamental physical science, which leads, when adequately technically implemented, to a new added value.
    - Developing a scientific way of thinking, supported by appropriate methodological research approaches.
    - Developing an appropriate and critical attitude in assessing the achievements of others, as well as the results of one's own work.
    - Developing communication skills for presentation of one's own ideas, hypotheses and results from scientific research to Professional public in the widest possible extent, i.e. in their own research fields, at Professional conferences at home and abroad, and in the Professional scientific publications.
- Education of doctors of science to meet the needs of creative scientific research and development work in the field of engineering sciences. Furthermore, the emphasis is put on:
    - Awareness of the necessity for ongoing monitoring of the development of science in the world.
    - Awareness of the necessity to perform the joint team work and inter-networking with intense exchange of research information.
    - Awareness of the importance of the transfer of new knowledge into economic environment (from the basic idea to its manifestation in the form of a manufactured product).

In this regard the doctoral programme gives superior knowledge both in specialized scientific areas of engineering and in engineering in general. Hence, employability and successful work is expected in engineering research and development departments of industrial companies, research laboratories and research institutes, educational institutions, strategic councils, etc.

3. Programme's Structure and Modes of Study

3.1 Curriculum with Credit Assessment of Study Requirements

The duration of the *Doctoral Programme in* ***Mechanical Engineering*** is four years; it comprises 240 ECTS credits and is, according to the Bologna scheme, a programme of Level 3 in higher education. The programme consists of organized forms of study and individual research work, both of which are evaluated with ECTS credits. The programme's structure is presented in Table 3.2.1-a, b, c, d. Year 1 focuses on organized studies in a form of lectures and seminar, while Year 2 Year 3 and Year 4 of the programme are entirely devoted to individual research work and preparation and presentation of the doctoral dissertation. One semester comprises 30 ECTS credits, one year 60 ECTS credits and the entire doctoral programme comprises 240 ECTS credits. Organized study comprises 60 ECTS credits while the remaining 180 ECTS credits are awarded to research work and doctoral dissertation.

The contents in a doctoral study of each candidate after Level 2 programme consists of obligations that fall within two groups:

1. Organized forms of study **(60 ECTS credits)**

a) *Theoretical and methodological content*
   - four (4) courses (4x10=40 ECTS credits)
   - one (1) seminar (1x5=5 ECTS credits).

b) *Presentation of doctoral dissertation thesis proposal, Presentation of the results of the research work before defending the doctoral dissertation and Doctoral dissertation defence*
   (3x5=15 ECTS credits).

Selection of four compulsory elective courses from the courses list (Table 3.3.2-a, b, c, d), chosen with regard to student's Professional interest by his/her mentor and in agreement with the student, is proposed to the Commission for doctoral studies for approval. The study obligations have to be approved both by the Commission for doctoral studies and by the Senate of UL ME in the end.

One compulsory seminar, which provide an overview of the results of outgoing research, have to be presented to the selected commission at the end of Year 1. On the commission comments basis the student is able to better define the topic of his doctoral dissertation.

The doctoral dissertation thesis proposal, as well as preparation of the dissertation and its defence is considered as organized study. Presentation of the doctoral thesis proposal with a scientific hypothesis included has to be performed and approved by the Senate of UL ME prior to the entry of the student in Year 3. The defence of the doctoral dissertation is allowed to the student only when he/she has published two scientific publications from the field of doctoral dissertations, the period of the doctoral thesis validity not being elapsed.

2. Research work for doctoral dissertation **(180 ECTS credits)**

Research work for doctoral dissertation has to be certified with a minimum of two scientific papers from the field of doctoral research published by the candidate. The papers, the candidate should be the first author of at least once, have to be published or accepted for publication in internationally recognized journals indexed by SCI prior to obtaining a PhD.

The focus of organized study forms (lectures, seminars and exercises) is in the first three semesters, thus allowing students the acquisition of relevant knowledge for the high quality research work on a doctoral dissertation in remaining semesters.

3.1.a Number and name of educational units

Elements of the programme are defined in accordance with the allocation of study commitments on the organized activities and research work.

3.1.a-1 Organized forms of study

Organized forms of study include: elective and generic courses, seminars and work for doctoral dissertation. All items are elective, but compulsory. The student along with his/her mentor chooses four courses (Semesters 1, 2 and 3), which have to be approved by the Commission for doctoral studies and by the Senate of UL ME. Seminar in Semesters 2 is compulsory and common to all doctoral students, which ensures strong interaction between doctoral students. Among the forms of organized study also the doctoral thesis proposal and its presentation (Semester 4), as well as presentation of the results of the research work before defending the doctoral dissertation (Semester 6) ang defence of the doctoral thesis (Semester 8) is considered.

Elective courses

All items in the programme are elective and evaluated with 10 ECTS credits. They can be classified as courses with relevant content to all students regardless of their orientation (Table 3.3.2-a) and courses that have specific expertise relevant to the selected course of study (Table 3.3.2-b, c, d). The student along with his/her mentor selects two to four subjects (any missing courses to the required four can be realized through the student's mobility (up to two) or by selecting generic content (not more than one)). Selected courses should be in accordance with the research work of the students; selection itself must be approved by the Commission for doctoral studies and by the Senate of UL ME. The double review of the selection for each candidate provides adequate quality of the program.

Generic courses

Generic and general courses provide transferable knowledge and skills. UL ME does not offer courses with generic content. Nevertheless, the student has the choice of a generic course or the generic content to the extent of 5 ECTS credits in the framework of doctoral programmes at UL or elsewhere. The missing 5 ECTS credits to the required 10 ECTS credits shall be replaced with the additional seminars in agreement with the mentor and approved by the Commission for doctoral studies and by the Senate of UL ME, or with additional articles published or accepted for publication in the journal indexed by SCI.

Seminar

Seminar are an organized form of study, which have to be performed by the student under the guidance of his/her mentor. The results of the work have to be presented in oral and written form in front of a committee set by the Senate of UL ME. Seminar, is evaluated with 5 ECTS credits, and it is compulsory for all PhD students. In the context of the seminar, the presentation of the work in the presence of other students and participation in the discussion is required. This ensures the extension of the study beyond the doctoral dissertation thesis and enables the interaction between doctoral students.

In the seminar (Semester 2) students prepare an overview of the field of their research work.

Doctoral dissertation thesis

By the end of Semester 4 students should prepare the proposal of their doctoral dissertation, which includes an appropriate breakdown of the topics, its incorporation into the field of the research work and indication of the expected contribution to science, which should be methodologically supported with initial results. Students present the doctoral thesis of their dissertation in public. The preparation and presentation of the thesis proposal is evaluated with 5 ECTS credits after the approval of the Senate of UL ME is obtained. Transition to Year 3 is possible only with an approved proposal of doctoral dissertation.

Presentation of the results of the research work before defending the doctoral dissertation

When the research work is in the final phase and when it is possible to give conclusions in accordance with the hypotheses or research questions, the doctoral student, members of the KSDŠ, the mentor and the co-mentor submit the draft of the doctoral dissertation and present the results of the research work with an emphasis on the main findings and the contribution to the field of science.

Doctoral dissertation

Doctoral work consists of research work (180 ECTS credits), work that is related to the preparation of doctoral dissertation topics proposal (5 ECTS credits), presentation of the results of the research work before defending the doctoral dissertation (5 ECTS credits) and work that is necessary for the preparation of doctoral thesis and its public defence (5 ECTS credits). The latter is ranked among the organized forms of study. Thesis is an original contribution to science, which has to be made in accordance with the Statute of UL and its rules regarding doctoral studies. Preparation and defence of doctoral dissertation are enabled when the candidate publishes at least two scientific papers in international scientific publications. Papers have to be published or accepted for publication in internationally recognized journals indexed by SCI prior to obtaining a doctorate. The candidate has to be the first author of at least one of the articles. Defence of the doctoral dissertation is possible within the period of validity of accepted dissertation proposal in accordance with the Statute of UL and the rules of doctoral studies.

3.1.a-2 Research work for doctoral dissertation

Research work in the overall extent of 180 ECTS credits is directed into the doctoral dissertation preparation. The work, which takes place in varying extends throughout all three years of doctoral study (25+45+55+55=180), is as a rule an individual scientific research work under the guidance of the student’s mentor. Research work requires active participation at Slovenian and international scientific and specialist meetings. The student is obligated to publish at least two scientific papers in international scientific publications indexed by SCI and has to be the first author of at least one of the articles.

Mentorship

An important role in the elaboration of the student's doctoral dissertation is attributed to his/her mentor. The mentor is a person with a corresponding academic title (Assistant Professor, Associate Professor and Professor) or a scientific worker with attested research activity and corresponding bibliography from the field of the doctoral dissertation. When the research is linked to the laboratory work the mentor has to ensure also the availability of research capacity and research infrastructure. Students choose their mentor at their discretion before or upon the enrolment. The responsibility of the mentor is to guide the student through his/her studies (selection of courses, seminars, proposal and composition of the doctoral dissertation thesis) and to ensure the working conditions for the work with research equipment, typically in the mentor's lab. Students can choose a different mentor up to the beginning of Semester 3. Only exceptionally the student can choose another mentor later, on a reasoned application. In case of mentor replacement the new mentor has to give his/her consent and the replacement has to be confirmed by the Commission for doctoral study. Co-mentorship is recommended in the case of interdisciplinary or multi-institutional researches. Co-mentorship is deliberated by the Commission for doctoral study.

Mobility

In agreement with the mentor the student with prescribed 40 ECTS credits of Professional contents, offered with a selection of courses from UL ME (Table 3.3.2-a, b, c, d), is allowed to choose up to 20 ECTS credits study contents from other programmes of UL or from comparable programmes of other universities. The student can study for two semesters at other university (60 ECTS credits), so one third of his/her study obligations can be done elsewhere.

3.2 Credit estimation of the whole programme and its particular learning units

Credit evaluation of the program is determined by the 5th of the Rules and regulations on doctoral study at the University of Ljubljana. They are available online at: https://www.uni-lj.si/study/doctoral/rules-regulation/

Thus, the *Doctoral Programme in* ***Mechanical Engineering*** is a four year doctoral programme with 240 ECTS credits of study commitments (Table 3.1.1). An obligation credit, evaluated by 1 ECTS credit, corresponds to 25 hours of the student's work. The total number of hours of study commitment is thus 750 hours (30 ECTS credits) per semester or 1500 hours (60 ECTS credits) per year. The entire programme thus requires 4500 hours (180 ECTS credits) of joint study commitments. The programme considering its detailed substructuring is shown in Tables 3.2.1-a, b, c, d.

Table 3.2.1-a: YEAR 1 Programme

YEAR 1		**Commitments in hours**			**Commitments in ECTS***		
	Type	**KU**	**SD**	**SO**	**E_{org}**	**E_{res}**	**ECTS**
Semester 1							
Course A	ORG	90	160	250	10		10
Course B	ORG	90	160	250	10		10
Research work	RES	25	225	250		10	10
Total Semester 1		**205**	**545**	**750**	**20**	**10**	**30**
Semester 2							
Course C	ORG	90	160	250	10		10
Research work	RES	50	325	375		15	15
Seminar I.	ORG	25	100	125	5		5
Total Semester 2		**165**	**585**	**750**	**15**	**15**	**30**
Total Semesters 1 & 2		**370**	**1130**	**1500**	**35**	**25**	**60**

Table 3.2.1-b: YEAR 2 Programme

YEAR 2		**Commitments in hours**			**Commitments in ECTS***		
	Type	**KU**	**SD**	**SO**	**E_{org}**	**E_{res}**	**ECTS**
Semester 3							
Course D	ORG	90	160	250	10		10
Research work	RES	60	440	500		20	20
Total Semester 3		**150**	**600**	**750**	**10**	**20**	**30**
Semester 4							
Research work	RES	75	550	625		25	25
Doctoral dissertation thesis	ORG	25	100	125	5		5
Total Semester 4		**100**	**650**	**750**	**5**	**25**	**30**
Total Semesters 3 & 4		**265**	**1300**	**1500**	**15**	**45**	**60**

Table 3.2.1-c: YEAR 3 Programme

YEAR 3	Type	Commitments in hours			Commitments in ECTS*		
		KU	SD	SO	E_{org}	E_{res}	ECTS
Semester 5							
Research work	RES	100	650	750		30	30
Total Semester 5		**100**	**650**	**750**	**0**	**30**	**30**
Semester 6							
Research work	RES	75	550	625		25	25
Presentation of the results of the research work	ORG	25	100	125	5		5
Total Semester 6		**100**	**650**	**750**	**5**	**25**	**30**
Total Semesters 5 & 6		**200**	**1300**	**1500**	**5**	**55**	**60**

YEAR 4	Type	Commitments in hours			Commitments in ECTS*		
		KU	SD	SO	E_{org}	E_{res}	ECTS
Semester 7							
Research work	RES	100	650	750		30	30
Total Semester 7		**100**	**650**	**750**	**0**	**30**	**30**
Semester 8							
Research work	RES	75	550	625		25	25
Doctoral dissertation	ORG	25	100	125	5		5
Total Semester 8		**100**	**650**	**750**	**5**	**25**	**30**
Total Semesters 7 & 8		**200**	**1300**	**1500**	**5**	**55**	**60**

KU - contact hours (KU = P + SV + LV + mentor)
SD - hours of independent student work
SO - total study obligation
P - lectures
SV - seminar exercises
LV - laboratory exercises

ORG - organized forms of study
RES - research work
E_{org} - credit evaluation of organized forms of study
E_{res} - credit evaluation of research work
ECTS - credit evaluation of study commitments

* Student commitment is equal to 60 ECTS credits / year, which is equivalent to 1500 hours / year; Hours include contact hours (KU) and independent student work (SD).

3.3 List of Elective Courses with Lecturers

Elective courses are arranged according to their content. Courses with general public content, relevant to all students regardless of their professional code definition, are specified by Selection Code 0, while courses with the content items specific to the selected professional fields of study in the programme are specified by Selection Codes 1, 2, 3, as shown in Table 3.3.1.

Table 3.3.1: Courses P/S (Programme/Module) classification

Selection	Module in the Programme	Selection Code	Course Code
P	Generally Applicable	0	0xx
S	Constructional and Mechanical Engineering Sciences	1	1xx
S	Energetical, Process and Environmental Engineering Sciences	2	2xx
S	Production Engineering Sciences, Cybernetics and Mechatronics	3	3xx

A list of all elective courses in the *Doctoral Programme in* ***Mechanical Engineering*** and the correspondent lecturers are in accordance with their contents and agreed classification presented in the following tables (Table 3.3.2-a, b, c, d).

Table 3.3.2-a: List of General Elective Courses in the Programme

Code	Course	Operator	Title	Performers	Title	ECTS
7001	Acoustics and ultrasound	Jurij Prezelj	Assoc.Prof.	Jurij Prezej Tomaž Kek	Asosc.Prof. Assist.Prof.	10
7002	Differential equations	Aljoša Peperko	Assist.Prof	Aljoša Peperko	Assist.Prof.	10
7003	Experimental methods in research work	Jože Kutin Drago Bračun	Assoc.Prof. Assist.Prof.	Jože Kutin Drago Bračun	Assoc.Prof. Assist.Prof.	10
7005	Chaotic dynamics	Edvard Govekar	Prof.	Edvard Govekar	Prof.	10
7006	Linear algebra	Janez Žerovnik	Prof.	Janez Žerovnik	Prof.	10
7007	Finite element and boundary element methods	Nikolaj Mole	Assist.Prof.	Nikolaj Mole	Assist.Prof.	10
7008	Nonlinear mechanics of materials	Miha Brojan	Assist.Prof	Miha Brojan	Assist.Prof	10
7009	Neural networks	Edvard Govekar	Prof.	Edvard Govekar Primož Potočnik	Prof. Assist.Prof.	10
7010	Numerical methods	Janko Slavič	Assoc.Prof	Janko Slavič	Assoc.Prof.	10
7011	Computational methods for fluid dynamics	Božidar Šarler	Prof.	Božidar Šarler	Prof.	10
7012	Numerical modelling of coupled systems	Nikolaj Mole Božidar Šarler	Assist.Prof. Prof.	Nikolaj Mole Božidar Šarler	Assist.Prof. Prof.	10
7013	Optimization methods	Janez Žerovnik	Prof.	Janez Žerovnik	Prof.	10
7014	Synergetics	Edvard Govekar	Prof.	Edvard Govekar	Prof.	10
7015	Materials science	Roman Šturm	Prof.	Roman Šturm	Prof.	10
7016	Turbomachinery theory	Mihael Sekavčnik Marko Hočevar	Prof. Prof.	Mihael Sekavčnik Marko Hočevar Matevž Dular	Prof. Prof. Prof.	10
7018	Probability and mathematical statistics	Peperko Aljoša	Assist.Prof	Peperko Aljoša	Assist.Prof	10
7019	Applied statistics for engineers	Edvard Govekar	Prof.	Edvard Govekar	Prof.	10

Table 3.3.2-b: List of Elective Courses in the Module: Constructional and Mechanical Engineering Sciences

Code	Course	Operator	Title	Performers	Title	ECTS
7101	Acoustical emission and noise	Jurij Prezelj	Assoc. Prof.	Jurij Prezelj	Assoc. Prof.	10
7102	Dynamics and vibrations	Miha Boltežar	Prof.	Miha Boltežar	Prof.	10
7103	Dynamics of multibody systems	Miha Boltežar	Prof.	Miha Boltežar	Prof.	10
7104	Advanced experimental mechanics	Janko Slavič	Assoc.Prof.	Janko Slavič	Assoc.Prof.	10
7105	Engineering of contact surfaces	Mitjan Kalin Roman Šturm	Prof. Prof.	Mitjan Kalin Roman Šturm	Prof. Prof.	10
7106	Characterization of polymers	Lidija Slemenik Perše	Assist.Prof.	Lidija Slemenik Perše	Assist.Prof.	10
7108	Mechanics of flight	Tadej Kosel	Assoc.Prof.	Tadej Kosel	Assoc.Prof	10
7109	Mechanisms	Robert Kunc	Assoc.Prof.	Robert Kunc	Assoc.Prof.	10
7110	Nonlinear structural dynamics	Miha Boltežar	Prof.	Miha Boltežar	Prof.	10
7111	Operational strength	Marko Nagode Jernej Klemenc	Prof. Prof.	Marko Nagode Jernej Klemenc	Prof. Assoc.Prof.	10
7112	Design and development principles in aviation engineering	Tadej Kosel	Assoc.Prof.	Tadej Kosel	Assoc.Prof.	10
7114	Buckling	Miha Brojan	Assist.Prof.	Miha Brojan	Assist.Prof	10

7115	Technical diagnostics	Mitjan Kalin	Prof.	Mitjan Kalin	Prof.	10
7116	Product data management system	/		/		10
7117	Engineering design theory	Roman Žavbi	Prof.	Roman Žavbi	Prof.	10
7118	Thermoplasticity	Miroslav Halilovič	Assist.Prof.	Miroslav Halilovič	Assist.Prof.	10
7119	Theory of viscoelasticity	Lidija Slemenik Perše	Assist.Prof.	Lidija Slemenik Perše	Assist.Prof.	10
7120	Transportation systems and logistic	Boris Jerman	Assist. Prof.	Boris Jerman	Assist. Prof.	10
7121	Tribology	Mitjan Kalin	Prof.	Mitjan Kalin	Prof.	10

Table 3.3.2-c: List of Elective Courses in the Module:
Energetical, Process and Environmental Engineering Sciences

Code	Course	Operator	Title	Performers	Title	ECTS
7201	Ecology of working and living environment	Matjaž Prek Uroš Stritih	Assist.Prof. Assoc.Prof.	Matjaž Prek Uroš Stritih	Assist.Prof. Assoc.Prof.	10
7202	Experimental modelling in power engineering	Marko Hočevar	Prof.	Marko Hočevar Matevž Dular	Prof. Prof.	10
7203	Enhanced heat transfer	Iztok Golobič	Prof.	Iztok Golobič	Prof.	10
7204	Numerical simulations of processes in internal combustion engines	Tomaž Katrašnik	Prof	Tomaž Katrašnik	Prof.	10
7205	Heating and cooling	Alojz Poredoš Andrej Kitanovski	Prof. Prof.	Alojz Poredoš Andrej Kitanovski	Prof. Prof.	10
7206	Heat and mass transfer	Alojz Poredoš Andrej Kitanovski	Prof. Prof.	Alojz Poredoš Andrej Kitanovski Iztok Golobič	Prof. Prof. Prof.	10
7207	Combustion theory	Andrej Senegačnik Tomaž Katrašnik	Assoc.Prof Prof.	Andrej Senegačnik Tomaž Katrašnik	Assoc.Prof. Prof.	10
7208	Thermal energetic analysis of processes	Andrej Senegačnik Tomaž Katrašnik	Assoc.Prof. Prof.	Andrej Senegačnik Tomaž Katrašnik	Assoc.Prof. Prof.	10
7209	Thermal power system	Mihael Sekavčnik	Prof	Mihael Sekavčnik	Prof.	10
7210	Multiphase flow	Božidar Šarler	Prof.	Božidar Šarler Andrej Bombač Matjaž Perpar	Prof. Assist.Prof. Assist.Prof.	10

Table 3.3.2-d: List of Elective Courses in the Module:
Production Engineering Sciences, Cybernetics and Mechatronics

Code	Course	Operator	Title	Performers	Title	ECTS
7301	Selected topics of the production systems	Janez Kušar	Assoc.Prof.	Janez Kušar	Assoc.Prof.	10
7302	Selected topics in technical cybernetics	Primož Podržaj	Assoc.Prof.	Primož Podržaj	Assoc.Prof.	10
7303	Complex mechatronic systems	Janez Diaci	Prof.	Janez Diaci	Prof.	10
7304	Lasers and laser applications	Janez Diaci Matija Jezeršek	Prof. Assoc.Prof.	Janez Diaci Matija Jezeršek	Prof. Assoc.Prof.	10
7305	Non destructive testing of materials and constructions	Tomaž Kek	Assist.Prof.	Tomaž Kek	Assist.Prof.	10
7306	Machine tools	Franci Pušavec	Assoc.Prof.	Franci Pušavec	Assoc.Prof.	10

				Tomaž Pepelnjak	Assoc.Prof	
7307	Operations research	Janez Žerovnik	Prof.	Janez Žerovnik Janez Povh	Prof. Assoc.Prof.	10
7308	Optimization of machining technologies	Franci Pušavec	Assoc.Prof.	Franci Pušavec Davorin Kramar	Assoc.Prof. Assoc.Prof	10
7309	Nonconventional machining processes	Joško Valentinčič	Assoc.Prof.	Joško Valentinčič	Assoc.Prof.	10
7310	Machining processes	Franci Pušavec	Assoc.Prof.	Franci Pušavec	Assoc.Prof.	10
7311	Material forming processes	Tomaž Pepelnjak	Assoc.Prof.	Tomaž Pepelnjak	Assoc.Prof.	10
7312	Welding processes	Damijan Klobčar	Assist.Prof.	Damjan Klobčar	Assist.Prof	10
7313	Computer integrated manufacturing and work systems CIM/FMS	Rok Vrabič	Assist.Prof.	Drago Bračun Rok Vrabič	Assist.Prof. Assist.Prof.	10
7314	Quality systems	Drago Bračun	Assist.Prof.	Drago Bračun Davorin Kramar	Assist.Prof. Assoc.Prof.	10
7315	Systems of production planning and control	Janez Kušar	Assoc.Prof.	Janez Kušar	Assoc.Prof.	10
7316	Concurrent engineering	Janez Kušar	Assoc.Prof.	Janez Kušar	Assoc.Prof.	10
7317	Intelligent handling and assembly systems	Niko Herakovič	Prof.	Niko Herakovič	Prof.	10
7318	Heat treatment and surface treatment of materials	Roman Šturm	Prof.	Roman Šturm	Prof.	10
7319	Welding, cutting and surfacing with high energy density	Damijan Klobčar	Assist.Prof.	Damijan Klobčar	Assist.Prof.	10

Curricula of individual courses are presented in Chapter 5.

4. Admission Requirements and Enrolment Criteria

4.1 Enrolment criteria

In accordance with Article 38.a of the ZViS and Article 16. of the Transitional and final provisions to the ZViS-E (Ur.l. RS št. 119/20.11.2006), the following candidates with completed:

- second-degree of study (Bologna Master's degree)
- study programmes for university degree (old programme)
- specialization study programmes in the field of natural science and engineering, after having previously completed Higher-Professional programme. To offset the input of knowledge to candidates prior to the entry in the doctoral programme, UL ME specifies additional obligations to the extent of 30 to 60 ECTS credits.
- study programes to obtain the Master of Science (old programmes). These candidates are in the doctoral programme of study recognized to have finished the obligations of 60 ECTS credits in total

can enrol in the *Doctoral Programme in* ***Mechanical Engineering***.

University graduates from elsewhere may also enter the *Doctoral Programme in* ***Mechanical Engineering***. Equivalence of previously acquired education shall be determined in the process of recognition of foreign education for continuing education, in accordance with the Statute of UL.

Forms of documents from the Article 9. *Criteria for credit evaluation of courses by ECTS*: student application/registration, report of the obligations of the study, and the contract of study are available online at http://www.uni-lj.si/bolonjski_proces/dokumenti.aspx .

4.2 Selection criteria when enrolment is restricted

The number of entry places is 50. When exceeding that number, the selection of candidates will be based on performance in previous studies and achievements in scientific and Professional field. Candidates with a higher total number of collected points will be chosen. On the list of chosen candidates, candidates with the same number of points, as reached by the last candidate will be added, regardless of the number of tender places.

Individual elements for the selections will be evaluated as shown in Table 4.2.1.

Table 4.2.1: Elements of income competences evaluation

Average grade (without degree) in undergraduate studies (old programme)	grade x 10
Average grade (without degree) I. and II. degree (Bologna programme)	grade x 10
Degree and defence with grade equal to 8 or more	(grade – 8) x 3
Research paper assessed by the criteria of the habilitation commission of the UL from the field which the candidate is applying	points x 3
Prešeren Prize at the UL	6 points
Prešeren Prize at the Faculty (if the same work is submitted as the Bachelor Thesis only half points) or other Prizes at the discretion of the Commission	5 points
Specialisation or other degree at a higher education programme	6 points
Other Professional graduate courses with a valid document (one month up to 10 credits, one semester up to 30 credits)	credits devided by 10
Completed current programme of Master's degree	10 points

4.3 Criteria for recognising knowledge and skills acquired before enrolment in the programme

Knowledge and skills acquired by formal, informal or experiential learning, prior to enrolment in the doctoral programme, will be in accordance with Criteria for accreditation of courses, recognized in the enrolment when having the restriction of entry (Table 4.2.1). Recognition of knowledge and skills which the candidate has acquired prior to entry into the programme, on the basis of candidate's written applications and supporting documents (certificates and other papers), that showing the acquired knowledge and the content of these skills, decided by the Commission of doctoral studies.

The scope and content of such knowledge and skills will be valued for the candidate at the time of enrolment in the doctoral programme by the ECTS system and by the discretion of the Commission for doctoral studies, and will be recognized as a liability study conducted in the programme.

In recognition of these skills and knowledge the following is taken into account:

- professional specialization,
- another diploma of higher education institution, which is thematically linked to the field of doctoral study
- published scientific papers, patents, etc..., from the field of application,
- specializations which can be creditably evaluated.

4.4 Methods of assessment

In accordance with Article 120 of the Statute of UL the performance at examinations is assessed with grades form 1 to 10, positive grades being from 6 to 10. Details about the assessment of knowledge are regulated by the Examination rules of the Faculty of Mechanical Engineering at the UL.

The programme includes written and oral exams. The grade can be fully acquired to by seminars or projects, where preparation and presentation will be assessed. Methods of assessment are described in detail under individual course syllabi.

Candidates receive the proposed number of ECTS credits for a course if they perform at the required knowledge assessment for that particular course successfully.

4.5 Requirements for progression through the programme

Requirements for progression from Year 1 to Year 2 in the *Doctoral Programme in **Mechanical Engineering*** are the completed study requirements worth a total of at least 50 ECTS credits.

For progression to Year 3 of the doctoral study students have to have all study obligations of organized forms of studies from the first two years completed and the proposal of the subject of doctoral dissertation approved by the Senat of the Faculty of Mechanical Engineering.

For progression to Year 4 of the doctoral study students have to have consent of the UL Senate on the topic of the doctoral dissertation.

The last year, Year 4, is totally intended for research work and the preparation and defence of the doctoral dissertation.

In the case when the student does not fulfil the study obligations due to legitimate reasons, he can file an application for the suspension status. The request has to be accompanied by documented proof of the reasons.

4.6 Provisions on changing programmes

Termination of the student's education in the programme in which he/she was enrolled and the continuation of the studies in the *Doctoral Programme in* ***Mechanical Engineering*** is regarded as transfer between programmes. Students' applications for the transfer to the *Doctoral Programme in* ***Mechanical Engineering*** will be, in accordance with Articles 129 of the Statute of the University of Ljubljana, separately dealt with by the Commission for doctoral studies.

4.7 Requirements for completion of the programme

Requirements for completion of the study programme and for acquisition of the academic title of Doctor of Science are: all study obligations determined by the programme successfully completed and doctoral dissertation successfully defended, which is worth 240 ECTS credits all together.

Student has to publish at least two scientific papers from the field of his/her doctoral dissertation. Papers has to be published or accepted for publication in internationally recognized journals indexed by SCI prior to obtaining a PhD, the candidate being the first author at least once.

4.8 Requirements for completion of individual parts of the programme
Completing individual parts of the programme is not possible.

4.9 Indication of Professional or academic qualification
Students completing the *Doctoral Programme in* ***Mechanical Engineering*** obtain the academic title of Doctor of Science (PhD).

5. Programme Courses Presentation

	Course Course Syllabus Basic Literature
001	**ACOUSTICS AND ULTRASOUND** Introduction. Theoretical fundamentals and main characteristics of audible sound and ultrasound. List of recommended literature. Propagation of acoustic waves in unlimited liquid without damping. Characteristics of wave equations, energy of acoustic waves. Acoustical impedance. Acoustics quantities and levels. Acoustic wave propagation in unlimited elastic media without damping. Different type of waves. Reflection of sound. Reflection and refraction of one-dimensional plane wave on a surface boundary in liquid and elastic media, reflection on a sphere. Particularities of spherical and cylindrical waves. Sound radiation from point-, line- and surface sources. General methods for description of sound sources, simplified general formulas, characteristics of sound field, different examples. Acoustical environment. Sound scattering on a barrier. General method for description of sound scattering, different examples for liquids and rigid materials, link with defectoscopy. Sound waves as a result of excitation of structure by a force and by a sound wave. Sound in media with damping. Damping in gaseous and liquid media, and in rigid structure, effect of different physical parameters. Sound in limited media and wave conductors. Solution of wave equations for one- and two-dimensional example. Standing waves and dispersivity of waves. Density of energy spectrum. Nonlinear effects. Use of powerful sound and ultrasound in techniques and medicine. Introduction in ultrasound defectoscopy and analyse of acoustic emission. Sensors and actuators, instruments for analyse of audible and ultrasound phenomena. [1] Čudina M.: Tehnična akustika, Fakulteta za strojništvo, Ljubljana, 2001. [2] Čudina M.: Pumps and pumping system noise and vibration prediction and control. Handbook of noise and vibration control. Edited by M.J. Crocker. John Wiley & Sons. 2007. [3] Möser M.: Technical Acoustics, Springer, Berlin, 2004. [4] Kuttruff H.: Akustik, Eine Einführung, Hirzel Stuttgart, 2004. [5] Hylton B., Farrant M.P.: Basic Ultrasound. John Wiley & Sons, 1995. [6] Schömerr L., Song S.J.: Ultrasonic Nondestructive Evaluation Systems: Models and Measurements, 2007. Springer; 1 edition, 2007. [7] Abramov O.V.: High-Intensity Ultrasonics: Theory and Industrial Applications by O V Abramov. CRC; 1 edition, 1999. [8] Rose J. L.: Ultrasonic Waves in Solid Media, Cambridge University Press, 2004. [9] Subramanian C.V.: Practical Ultrasonics, Alpha Science International, Ltd, 2006. [10] Cheeke J.D.N.: Fundamentals and Applications of Ultrasonic Waves (Pure and Applied Physics), CRC; 1 edition, 2002. [11] Miller R.K., McIntire P.: Nondestructive Testing Handbook, Third edition, Vol. 6, Acoustic Emission Testing, American Society for Nondestructive Testing, Inc., 2005. [12] Birks A.S., Green R.E., McIntire P.: Nondestructive Testing Handbook, 3rd edition, Vol. 7, Ultrasonic Testing, American Society for Nondestructive Testing, Inc., 2007.
002	**DIFFERENTIAL EQUATIONS** Linear differential equations: structure of solutions, differential equations in the complex domain, special functions. Boundary value problems: definition, examples for second order linear differential equations,

	eigenvalues and eigenfunctions, orthonormal systems, Legendre polynomials, Chebishev polynomials of first and second order, cylindric functions, spherical functions. Partial differential equations: definitions, second order partial differential equations from physics, elliptical, hyperbolic and parabolic partial differential equations, wave equation in mechanics and electromagnetism, heat equation, Poisson formula and the Fourier method, Dirichlet and Neumann problems. [1] E. Zakrajšek, **Analiza III**, Društvo matematikov, fizikov in mehanikov, 1998. [2] W. Walter, **Ordinary differential equations**, Springer, 1998. [3] L. C. Evans, **Partial Differential Equations**, American Mathematical Society, 1998. [4] E. Zakrajšek, **Analiza IV**, , Društvo matematikov, fizikov in mehanikov, 1998. [5] S. J. Farlow, **Partial Differential Equations for Scientists and Engineers**, Dover, 1993.
003	**EXPERIMENTAL METHODS IN RESEARCH WORK** Structure and functional description of measurement systems. Basic elements of measurement systems. Working characteristics of instruments. Manipulation, transfer and record of measured quantities. Systems for recording and displaying measurement quantities. Large systems for acquisition and evaluation of measurement quantities. Automatisation of experimental work. Approach to experimental work. Methods and importance of experiment planning. Metrological analysis of measured quantities and display of results. [1] Montgomery, D.C.: Design and analysis of experiments.- 5th ed., J. Wiley,. 2001. [2] Barney, George C.: Intelligent instrumentation: microprocessor applications in measurement and control.- 2nd ed.- New York: Prentice Hall, 1988 [3] Holman, J.P.: Experimental methods for engineers.- 7th ed.- Boston etc.: McGraw-Hill, cop. 2001.- (McGraw-Hill series in mechanical engineering). [4] Boyes, W.: Instrumentation Reference Book, 3rd ed., Elsevier, 2003. [5] Dietrich, C.F.: Uncertainty, calibration and probability: the statistics of scientific and industrial measurement.- 2nd ed.- Bristol [etc.]: Adam Hilger, 1991.
005	**CHAOTIC DYNAMICS** **General introduction:** Introduction of concept of chaos and properties of chaotic systems , Brief history o fchaos theory Importance and applications of chaotic dynamics in engineering **Basics of nonlinear dynamic systems:** Phase space and system attractors, Phase space flows of one and two dimensional dynamic systems, Fixed points, centers, stability and bifurcations, Cylindrical phase space, quasi-periodic motion and flow on a torus, Nonlinear limit cycles. **Chaotic systems:** Basic properties of chaotic systems. Necessary conditions for chaos and sensitivity to initial conditions, Strange attractors, Fractal structure, Routes to chaos: logistic map, period doubling. Universality of chaos, intermittency route, quasi-periodic route **Characterisation of chaotic systems:** Time series of a phase variable, Autocorrelation Fourier-spectra, Poincare section, Dynamic characteristics; Liapunov specter, Kolmogorov entropy, Fractal concepts and fractal dimension of attractor, Measures of fractal dimension **Overview of chaotic systems:** Mathematical model of chaotic systems, Convection phenomena, Impact systems, Chaos in periodically forced systems, Instability and chaos of cutting processes, Other chaotic experimental systems. **Nonlinear time series analysis:** Stationarity, Phase space and attractor reconstruction; Embedding dimension and attractor dimensionality, Modeling and prediction of chaotic time series. **Advanced topics:** Advanced embedding methods, Chaos and noise, Space temporal chaos, Chaos control. [1] Strogatz, S. H.: Nonlinear dynamics and chaos: with applications to physics, biology, chemistry and engineering.- Reading [etc.]: Addison-Wesley, 1994.- [2] Anastasios A. Tsonis: Chaos: From Theory to Applications, Plenum Press, NY, 1992

	[2] Moon, F.: Chaotic and fractal dynamics, an introduction for applied scientists and engineers.- New York [etc.]: J. Wiley & Sons, 1992.) [3] Paul S Addison: Fractals and Chaos an Illustrated Course, IOP Publishing 1997 [4] Kantz, H., Schreiber, T.: Nonlinear time series analysis.- New York: Cambridge University Press, 1997.- (Cambridge nonlinear science series; 7) [5] H. D. I. Abarbanel: Analysis of Observed Chaotic Data, Springer, 1996 [6] Heiger R, Kantz, H., Schreiber, TISEAN-Nonlinear time series analysis,- software package http://www.mpipks-dresden.mpg.de/~tisean/
006	**LINEAR ALGEBRA** Real and complex numbers. Linear space. Basis and dimension. Dual space. Bilinear forms. Linear transformations. Matrix representation. Change of basis. Similar matrices. Eigenvalues and eigenvectors. Jordan form. Euclidean and unitary linear space. Scalar product in real and complex linear space. Orthogonal and orthonormal basis. Gram-Schmidt orthogonalization. Linear functionals. Self adjoint transformations. Positivity. Unitary, normal, orthogonal transofrmations. Projections. Sprectral theorem. [1] S. Lipschutz, M.L. Lipson, Schaum's outline of theory and problems of linear algebra, 4th ed., New York [etc.] : McGraw-Hill, 2009. [2] Meyer, Carl D. (February 15, 2001), *Matrix Analysis and Applied Linear Algebra*, Society for Industrial and Applied Mathematics (SIAM). Available online at http://www.matrixanalysis.com/DownloadChapters.htm [3] I.Vidav in soavtorji, Višja Matematika II, DZS 1975. [4] P.R. Halmos: Finite-dimensional vector spaces.- New York: Springer, 1974.
007	**FINITE ELEMENT AND BOUNDARY ELEMENT METHODS** • **Mathematical basics:** Definition of Hilbert space: metrics in Hilbert space. Orthogonality and orthonormal systems of functions in the space of quadratic integrable functions. Properties of linear operator. • **Mathematical modelling:** Definition of boundary and initial value problem in physics. Physical and mathematical relations between primary and secondary variables. Dirichlet, Neumann, Robin etc. boundary conditions. Feasibility of analytical solution. • **Integral formulations:** Boundary value problem in integral form. Principal, weak and inverse form of integral formulation. Theorem of stationary value of quadratic functional. • **Approximate solution:** Procedures for approximating solution of equation A.u=f based on variational formulation (method of orthonormal series, Rayleigh-Ritz procedure, method of weighted residuals, Courant method). Local based approximation functions. • **Advanced methods of approximate solutions:** Variational approach of treating boundary value problems expressed by integral formulation. Space discretization, locally confined approximation of principal variable. Influence of the chosen variational functions on effectiveness of the problem solution. • **Finite element method:** Basics, domain discretization – finite element, interpolation functions on finite element domain, finite element equation, assembled finite element equation of the problem. Specificity of solving problems with FEM. **Boundary element method:** Basics, boundary discretization – boundary element, interpolation functions on boundary element domain, boundary element equation, assembled boundary element equation of the problem. Specificity of solving problems with BEM. [1] K. Rektorys: Variationsmethoden in Mathematik, Physik und Technik, C. Hanser Verlag, 1984

	[2] O.C. Zienkiewicz, R.L. Taylor, J.Z. Zhu: The Finite Element Method: Its Basis and Fundamentals, Sixth Edition, Elsevier, 2006. [3] O.C. Zienkiewicz, R.L. Taylor: The Finite Element Method for Solid and Structural Mechanics, Sixth Edition, Elsevier, 2006. [4] J.N. Reddy: An Introduction to the Finite Element Method, 3rd edition, McGraw Hill Series in Mechanical Engineering, 2006. [5] J. Fish, T. Belytschko: A First Course in Finite Elements, John Wiley & Sons, 2007. [6] G. Beer, J.O. Watson: Introduction to Finite and Boundary Element Methods for Engineers, John Wiley & Sons, 1992. [7] F. Hartmann: Introduction to Boundary Elements: Theory and Applications, John Springer-Verlag, 1989, 1990.
008	**NONLINEAR MECHANICS OF MATERIALS** Deformation gradient. Line, area and volume elements. Material and spatial coordinates. Motion equations of a continuum. Constitutive equations. Material symmetries and their influence. Rheology of shape memory materials. Rheology of multi-phase materials. Introduction to mechanics of composites. Structural-phenomenological model. Mechanical properties of the macroscopical model of composite material. Analysis of rheological properties of materials using theory of dislocations. Boundary value problems in thermoplasticity of materials with periodical structure. Stochastic model of stress-strain state in materials with chaotic structure. Load carrying capacity of elements and structures made of composites. Particle reinforced composites. [1] Kunin, I.A.: **Elastic Media with Microstructure. I,II**, Springer, Berlin, 1982. [2] Bhattacharya, K.: **Microstructure of Martensite. Why it Forms and How it Gives Rise to the Shape-Memory Effect**, Oxford University Press, New York, 2004. [3] Šermergor, T.D.: **Teorija Uprugosti Mikroneodnorodnih Sred**, Nauka,Moskva 1977. [4] Lurje, A.I.: **Nelinejnaja Teorija Uprugosti**, Nauka; FML, Moskva, 1980. [5] Navožilov, U.U., Kadaševič, J.I.: **Mikro Naprjaženija v Konstrukcionih Materialah**, Mašinostrojenije, Leningrad, 1990. [6] Christian, J.W.: **The Theory of Transformations in Metal and Alloys**, 2nd ed.,Oxford, Pergamon, (International Series on Materials Science and Technology; Vol. 15), 1975. [7] Mura, T.: **Micromechanics of Defects in Solids**, Martinus Nijhoff Publishers, 1987.
009	**NEURAL NETWORKS** **(i) General Introduction** What is a neural network?, Biological neural networks, Human nervous system, Artificial neural networks, Benefits of neural networks, Brief history of neural networks, Applications of neural networks **(ii) Neuron Model, Network Architectures and Learning** Neuron model, Activation functions, Network architectures, Learning algorithms, Learning paradigms, Learning tasks, Knowledge representation, Neural networks vs. statistical methods **(iii) Perceptrons and Linear Filters** Perceptron neuron, Perceptron learning rule, Adaline, LMS learning rule, Adaptive filtering, XOR problem **(iv) Backpropagation** Multilayer feedforward networks, Backpropagation algorithm, Working with backpropagation, Advanced algorithms, Performance of multilayer perceptrons **(v) Dynamic Networks** Historical dynamic networks, Focused time-delay neural network, Distributed time-delay neural network, NARX network, Layer recurrent network, Computational power of dynamic networks, Learning algorithms, System identification, Model reference adaptive control **(vi) Radial Basis Function Networks** RBFN structure, Exact interpolation, Radial basis functions, Radial basis function networks, RBFN training, RBFN for pattern recognition, Comparison with multilayer perceptron, Probabilistic networks, Generalized regression networks **(vii) Self-organizing maps** Self-organization, Self-organizing maps, SOM algorithm, Properties of the feature map, Learning vector quantization

	(viii) Practical Considerations Preparing data, Selection of inputs, Data encoding, Principal component analysis, Invariances and prior knowledge, Generalization, General guidelines **(ix) Advanced topics** Optimal network architectures, Evolution of neural networks, Support vector machines, Committee machines, Stochastic machines, Principal component networks, Bayesian neural networks [1] S. Haykin: **Neural Networks: A Comprehensive Foundation**, 2/E, Prentice Hall, 1999. [2] C.M. Bishop: **Neural Networks for Pattern Recognition**, Oxford University Press, 1995. [3] I. Grabec, W. Sachse: **Synergetics of measurement, prediction and control**, Berlin; Heidelberg; New York: Springer, 1997. [4] W. Sarle: **Neural FAQ**, ftp://ftp.sas.com/pub/neural/FAQ.html, 2002. [5] **MATLAB Neural Networks Toolbox** (User's Guide), http://www.mathworks.com/access/helpdesk/help/toolbox/nnet/
010	**NUMERICAL METHODS** Errors in numerical computation, well and ill conditioned problems, convergence and stability of numerical methods. Solutions of nonlinear equations of one variable, methods for solving linear systems and special linear systems. Direct, iterative and gradient methods. Solutions of nonlinear systems of equations. Linear and nonlinear approximation theory. Polynomial and rational function approximation and interpolation. Interpolation with splines, cubic natural splines, parametric, Akima, Bézier and B-splines. Two-dimensional interpolation and approximation. Fourier series, integral and transforms, fast Fourier transforms, Laplace transforms, orthogonal polynomials. Advance methods of numerical differentiation and integration. Multiple and improper integrals. Numerical solution of initial-value and boundary-value problems for ordinary differential equations. Methods for solution of system of ordinary differential equations. Numerical methods for solution of elliptic, parabolic and hyperbolic partial differential equations with different boundary conditions, difference method and method of characteristics. Eigenvalue problems, the power method, the inverse power method, the Jacobi method for a symmetric matrix, QD, LR, and QR methods. Method of penalty functions. Spectral methods, meshless methods and Monte-Carlo methods. Numerical optimization. [1] R. L. Burden, J. D. Faires: **Numerical analysis,** -7th ed., BROOKS/COLE, 2001. [2] A. Quarteroni, R. Sacco, F. Saleri: **Numerical Mathematics**, Springer, 2000. [3] H. M. Antia: **Numerical Methods for Scientists and Engineers,** Birkhäuser Verlag, 2002. [4] J. Petrišič: **Reševanje enačb,** Univerza v Ljubljani, Fakulteta za strojništvo, Ljubljana, 2005. [5] J. Nocedal, S.J. Wright: **Numerical Optimization**, Springer Verlag, 1999.
012	**NUMERICAL MODELLING OF COUPLED SYSTEMS** • **Introduction to multiphysic problems:** On the analysis of technical systems composed from different materials or media considering simultaneous interaction between different physical phenomena. Identification of space subdomains, time scales and physical phenomena; determination of their mutual influence. Classification of problems to multiphysics and multidomain problems. Examples of coupled problems from the fields of continuum mechanics, fluid mechanics, heat transfer and electromagnetism. • **Mathematical models and their properties:** Governing equations of several physical problems and their properties. One-domain and multidomain problems, multiphysics problems. Boundary conditions and interface conditions, characterization of interdependence between physical variables of coupled systems. Approaches to modelling of multiphysics problems regarding degree of coupling, nonlinearity of response and time simultaneity. About choosing an adequate model regarding the prescribed analysis criteria; validation of the model. • **Advanced numerical solution methods:** On the choice of adequate numerical method (FEM, FDM, BEM, FVM) regarding nature of the problem. Space and time discretization in a view of their mutual interaction; strategies used for time integration regarding the degree of physical coupling and problem nonlinearity. Computer simulations of problems in view of time consumption and possible simplifications of numerical models. Parallel computations and computational process synchronization. Modern computation

technologies and programs.

- **Simulations of manufacturing processes:** Analyses of mechanical interactions between systems (contact between deformable bodies, fluid-structure interactions) and analyses of physical coupling (electromagnetism, heat transfer, mechanical deformation) occur. Case studies: simulation of processes of metal forming, continuous casting and rolling, welding, inductive heating, heat treatment...

[1] M.C.S. Arriaga, J. Bundschuh, F.J.Dominguez-Mota: **Numerical modelling of coupled phenomena in science and engineering (Multiphysics modeling)**, Routledge, Taylor & Francis, 2008.
[2] B.J. Zimmerman: **Multiphysics modelling with finite element methods**, World Scientific Publishing Co. Pte. Ltd., 2006.
[3] S.K. Chakrabarti (Editor): **Numerical Models in Fluid-Structure Interaction, Advances in Fluid Mechanics**, WIT press, 2007.
[4] A. J. KASSAB, M. H. ALIABADI (Editors), **Coupled Field Problems, Advances in Boundary Elements**, WIT press, 2001.
[5] Radaj D.: **Heat Effects of Welding. Temperature Field, Residual Stress, Distortion**; Springer-Verlag, Heidelberg, 1992.

013 **OPTIMIZATION METHODS**

Graphs and digraphs. Shortest paths. Breadth first search. Algorithm of Dijkstra. Depth first search. Critical paths. Minimal spanning tree. Algorithms of Prim and Kruskal. Network flows. Ford-Fulkersonov algorithm.
Basic problems of combinatorial optimization: traveling salesman problem, chinese postman problem, knapsack. Goal function, feasible and optimal solutions. NP-hard and tractable problems.
Applications: transportation, location, scheduling, warehousing.
Hevristics and metaheuristics for NP-hard problems: Local search, Tabu search, Simulated annealing, Genetic algorithms…

[1] J.Žerovnik: Osnove teorije grafov in diskretne optimizacije, (druga izdaja), Fakulteta za strojništvo, Maribor 2005.
[2] E. Zakrajšek: Matematično modeliranje, DMFA, Ljubljana 2004.
[3] E. Kreyszig: Advanced Engineering Mathematics, (9th edition), Wiley, New York 2006.
[4] B.Korte, J.Vygen: Combinatorial Optimization, Theory and algorithms, Springer, Berlin 2000.
[5] J.Hromkovič: Algorithmics for Hard Problems, Introduction to Combinatorial Optimization, Randomization, Approximation, and Heuristics, 2nd ed., Springer, Berlin 2004.

014 **SYNERGETICS**

Introduction: goals of course, typical examples, problems.
Basis of probability theory: random variables, probability, probability distribution, mean values, random processes, empirical estimation, modeling of natural laws.
Information: definition of information entropy, principle of maximal entropy, derivation of probability distribution from empirical data.
Random events: model of Brownian motion, basic equation of probability, Markov processes, fluctuations.
Laws: dynamical processes, critical points, limit cycles, stability and bifurcation.
Randomness and laws: Langevin equation, Fokker-Planck equation, similarity with phase transitions.
Self-organization: organization and self-organization, significance of order parameters, appearance of structures and patterns.
Physical systems: cooperative phenomena in lasers, instability in fluid dynamics, elastic stability, instability in treatment processes, population instabilities.
Foundations of deterministic chaos: basic properties of non-linear dynamical systems, phase space and classification of attractors, Fourier spectrum, Poincare imaging, duplication of periods, bifurcation diagrams, crisis and transitional chaos, conservative chaos, Ljapunovi exponents and fractal dimensions, modeling and prediction of chaotic phenomena.
Automatic modelling of natural phenomena: intelligent self-organizational information

	system, connection with neural networks, optimal retrieval, prediction and optimal control of processes. [1] I. Grabec, J. Gradišek: Opis naključnih pojavov, Fakulteta za strojništvo, 2000. [2] H. Haken: Synergetics, Springer Verlag, 1983. [3] F. Moon: Chaotic and fractal dynamics: an introduction for applied scientists and engineers, J. Wiley & Sons, 1992.
015	**MATERIALS SCIENCE** Atomic bonding and crystal structure. Imperfections in crystals and experimental methods for imperfection characterizations, diffusion, model of atomic diffusion, Fick's laws, temperature dependence of diffusion coefficient, diffusion mechanisms and activation energy, diffusion influence factors, Kirkendall's effect, diffusive experiments. Dislocation mechanisms at cold deformation, slip, strengthening, recrystallization, nucleation and recovery mechanisms. Metal strengthening with heat treatment, phase transformations, nucleation, precipitation strengthening. Creep, creep types and mechanisms. Fracture and strengthening of metals. Griffith's fracture theory, models of fracture for ductile to brittle metals, crack mechanisms, fatigue, morphology of fatigue fracture. Corrosion, mechanisms of different types of corrosion, corrosion failures, corrosion protection, corrosion resistant materials. Surface integrity after mechanical and thermal treatment, experimental methods for surface integrity characterization. Polymers: kinetic reactions, configuration of polymer chains, amorphous and crystallinity, polymer reactions, types of polymers, additives, thermodynamic phases, properties, methods for polymer characterization, polymer pre-processing preparation. Technical ceramics: physical – chemical basis, phase diagrams, phase and surface mechanisms, powder preparation, shaping and sintering, powder characterization, thermo – mechanical applications. Composites: classification, composites with metal, polymer and ceramic matrix, composition of composites, matrix, fibres and viskers, bonding phase, composite micro-mechanics, mechanical properties, fracture mechanics, composite characterization methods, production technology of composites, non-destructive testing, dynamical and fatigue properties. Wear resistance, wear types and mechanisms, wear resistant metals, ceramics, polymers and composites, procedures to increase wear resistance, surface strengthening with mechanical and heat energy, with electron and laser beam. Theoretical background of mechanical tests, theoretical background of non-destructive tests, quantitative material analysis with failure evaluation, materials reliability during operation, planning and material selection. [1] Physical metallurgy. Vol. 1, 2, 3 / edited by R.W. Cahn, P. Haasen.- Amsterdam [etc.]: North-Holland, 1996 [2] Kumar, S.A.: Ferrous physical metalurgy.- Boston: Butterworth, 1989 [3] Sinha A.K.: Physical Metallurgy Handbook, McGraw Hill Handbooks, New York, 2003 [4] Guy A.G.: Introduction to Materials Science, McGraw-Hill, Kogakusha, Tokyo, New York 1972 [5] Tilley R.I.D.: Understanding Solids, The Science of Materials, John Wiley & sons, Chichester 2004 [6] Solidification Science and Processing, eds.: I.Ohnaka, D.M.Stefanescu, TMS, 1995 [7] Handbook of residual stress and deformation of steel / edited by G. Totten, M. Howes, T. Inoue.- Materials Park, Ohio: ASM International, 2001 cop. 2002 [8] Grum J.: Laser surface hardening. V: TOTTEN, George E. (ur.), FUNATANI, Kiyoshi (ur.), XIE, Lin (ur.). *Handbook of metallurgical process design*, (Materials engineering, 24). New York; Basel: M. Dekker, cop. 2004, str. 641-731. [9] Grum J.: Laser surface hardening. V: TOTTEN, George E. (ur.). *Steel heat treatment : equipment and process design*. 2nd ed. Boca Raton: Taylor & Francis, cop. 2007, str. 435-566.
016	**TURBOMACHINERY THEORY** • Classification of turbomachinery and fundaments of turbomachinery fluid dynamics;

	• Basic principles, analyses and performance characteristics of turbomachinery;
	• In-viscid fluid flow through the turbomachinery cascade;
	• 3-D in-viscid and quasi-viscid fluid flow within turbomachinery flow channel;
	• Calculation of flow dynamics within the turbomachinery flow channels;
	• Cooling and heat transfer in trubomachinery;
	• Cavitation in turbomachinery;
	• Off-design operation of turbo-compressors (rotating stall and surge);
	• Supersonic flow in turbomachinery;
	• Determination and analysis of typical physical phenomena and relevant research activities in the field of:
	    ○ water turbines
	    ○ pumps
	    ○ steam and gas turbines
	    ○ turbo-compressors
	
	[1] Pfleiderer, C., Petermann, N.: **Strömungsmaschinen**.- 7. Aufl.- Berlin [etc.]: Springer, 2004
	[2] Raabe, J.: **Hydro power**: the design, use and function of hydromechanical, hydraulic and electrical equipment.- Düsseldorf: VDI, 1985
	[3] Lakshminarayana, B.: **Fluid dynamics and heat transfer of turbomachinery**.- New York [etc.]: J. Wiley & Sons, 1996
	[4] B.Širok, M.Dular, B.Stoffel. **Kavitacija**. 1. natis. Ljubljana: i2, 2006. 164 str., ilustr., graf. prikazi.
	[5] Saravanamuttoo H., Rogers G., Cohen H.: Gas turbine theory, 5th Edition, Prentice Hall, 2001

018	**PROBABILITY AND MATHEMATICAL STATISTICS** Probability: events, probability, independence, conditional probability, random variables, standard distributions, normal distribution, central limit theorem, distributions related to normal distribution, stable distributions and the generalized central limit theorem. Mathematical statistics: sampling, standard error, confidence intervals, evaluation of parameters, method of maximum likelihood, hypothesis testing, Wald theorem, variance analysis, discrete data analysis, linear regression, Gauss-Markov the**orem.** [1] M. A. Rice, Mathematical Statistics and Data Analysis, 3rd edition, Duxburry Press, 1995. [2] S. Weisberg, Applied Linear Regression, 2 nd Ed., John Wiley & Sons, 1985. [3] J.P. Nolan, Stable Distributions: Models for Heavy Tailed Data, verzija 13. 5. 2009, [ogled 21. 8. 2012], dostopno na http://academic2.american.edu/~jpnolan/stable/chap1.pdf. [4] B. Rugelj, Stabilne porazdelitve: delo diplomskega seminarja, Fakulteta za matematiko in fiziko, Univerza v Ljubljani, 2012. [5] G. Samorodnitsky in M.S. Taqqu, Stable non-Gaussian random processes: stochastic models with infinite variance, Stocharstic modeling, Chapman & Hall/CRC, Boca Raton, 1994. [6] B.V. Gnedenko in A.N. Kolmogorov, Limit distributions for sums of independent random variables, Addison-Wesley Publ., Cambridge, 1954. [7] G.G. Roussas, A course in mathematical statistics, 2 nd edition, Academic Press, 1997. [8] NIST/SEMATECH, Engineering Statistical Handbook, e-Handbook of Statistical Methods, http:/ www.itl.nist.gov/div898/handbook
019	**APPLIED STATISTICS FOR ENGINEERS** Introduction to engineering statistics: importance and role of statistical analysis in engineering, important statistics, probability distributions of statistics; point estimators; methods of determining estimators; confidence intervals; statistical hypothesis, tests and inference; inference errors; goodness of fit tests, independence and homogeneity test; analysis of variance. Alternative statistical methods: nonparametric statistics, bootstrap statistical methods, methods of robust statistics. Function estimatiors and empirical modeling: parametric regression, simple and multiple linear regression, nonlinear regression, nonparametric regression.

	Stohastic processes: stationarity and ergodicity, moments and processes characteristics, autocorrelation function, spectral density, non-linear and advanced methods of analysis and characterization of stochastic processes, ARMA and ARIMA processes, empirical modeling and forecasting of processes. [1] I. Grabec, J. Gradišek: Naključni pojavi; Fakulteta za strojništvo, 2000; [2] E. Govekar. Naključni pojavi: elektronski zapiski in interaktivni učbenik. Ljubljana: Fakulteta za strojništvo, 2005. http://lab.fs.uni-lj.si/lasin/www/teaching/np/predavanja.htm [3] L. Wasserman; All of Statistics, A concise Course in Statistical Inference, Springer, 2004 [3] D. C. Montgomery in G. C. Runger: Applied Statistics and Probability for Engineers, John Wiley & Sons, Inc., New York, 1994. [4] P.J.Huber, E. M. Ronchetti; Robust Statistics, Second Edition, John Wiley, 2009 [5] A.C. Davison, D.V.Hinkley: Bootsrap Methods and their Applications. Cambridge University Press 2009. [4] P. J. Brockwell: Introduction to Time Series and Forecasting, Second Edition, Springer, 2002 [5] T. Masters; Advanced algorithms for neural networks, John Willey & Sons (1991)
101	**ACOUSTICAL EMISSION AND NOISE** Theoretical background. Definition of sound and noise. Types of sound waves (plane, spherical, cylindrical, complex wave) and their analytical description. Definition of sound pressure, sound intensity and sound power, and their levels. Wave equation. Interference, resonance, acoustics impedance and standing waves. Fourier's transformation (FFT) and spectra of sound. Types of sound spectra. Total sound pressure level. Noise sources: definition of sound sources and their forms of appearances. Noise generation mechanisms. Aero-, hydro-, mechanical and electromagnetic sound sources. Structural noise. Noise of machinery and equipment. Particularity of HVAC and pneumatic transport systems. Measurement and analysis of noise Components of test rigs. Standards and directives for measurement of sound pressure and sound intensity. Spectral analysis - octave, third octave, narrowband. Noise measurement uncertainty. Analytical and numerical methods for description and prediction of noise sources and their transmission: basic integral equation, method of singularity, FEM/REM, SEA, MA methods, etc. Methods for noise reduction. Active and passive noise reduction: at the source, on transmission path and at the receiver. Principle of active noise control. [1] ČUDINA M.: Tehnična akustika, Fakulteta za strojništvo, Ljubljana, 2001. [2] ČUDINA M.: Pumps and pumping system noise and vibration prediction and control. Handbook of noise and vibration control. Edited by M.J. Crocker. John Wiley & Sons. 2007. [3] MÖSER M.: Technical Acoustics, Springer, Berlin, 2004. [4] BERANEK L. L.: Noise and Vibration Control, Institute of Noise Control Engineering, McGrow-Hill, Inc. Washington, 1999. [5] BELL, L.H., Bell, D.H.: Industrial noise control.- 2nd ed.- New York [etc.]: Marcel Dekker, 1994.- (Mechanical engineering; 88) [6] WALKER J.G.. Noise and vibration / edited by R.G. White, -Chichester: Ellis Horwood; New York [etc.]: Halsted Press, 1986. [7] CREMER, L., HECKL, M.: Structure - borne sound.- 2nd ed. - Berlin [etc.]: Springer, 1988 [8] FAHY, F.J.: Sound intensity.- London; New York: Elsevier Applied Science, 1989 [9] KOLLMAN, F.G.: Maschinenakustik, Grundlagen, Messtechnik, Berechnung, Beeinflussung.- Springer Verlag, 2000. [10] Encyclopedia of acoustics / Malcolm J. Crocker, editor – in – chief.- New York [etc.]: J.Wiley & Sons, 1997- 4. zv. [11] SCOTT S.D.: Active Noise Control Primer, Series : Modern Acoustics and Signal Processing, SPRINGER, BERLIN, 2000. [12] DANIEL R. The Science and Applications of Acoustics, Series: Modern Acoustics and Signal Processing, Raichel, 2000. [13] LIPS , W.: Strömungsakustik in Theorie und Praxis, Anleitungen zur lärmarmen Projektierung von Maschinen und Anlagen, Kontakt & Studium Bd.474, 2001. [14] AUREGAN Y., MAUREL A., PAGNEUX V.: Sound-Flow Interactions, SPRINGER, Berlin, 2002.
102	**DYNAMICS AND VIBRATIONS**

	Vibrations of linear systems with several degrees-of-freedom. Modal transformation. The response of the system in modal coordinates. Vibrations of continuous systems, analytical and approximate methods. The basic principles of nonlinear vibrations. Vibration testing. Experimental work in vibrations. Analysis of measured variables in the time and frequency domains. Dynamic stability. Rotor dynamics, determination of critical speed of rigid and flexible rotors. Mass balancing of rotors. Dynamics of reciprocating engines. Vibroisolations of elastically mounted engines. Torsional vibrations of shafts. Basics of vibrations of plates, vibrations or rotating bars. Random vibrations, theoretical and experimental aspects. Human response to vibrations. [1] Rao, S.S.: **Mechanical vibrations**.- 3rd ed.- Reading [etc.]: Addison-Wesley Publishing Company, cop. 1995. [2] Rao, J.S.: **Dynamics of plates**.- New York; Basel; Hong Kong: M. Dekker; New Delhi [etc.]: Narosa, cop. 1999. [3] Frolov, K.V., Furman, F.A.: **Applied theory of vibration isolation systems**.- New York [etc.]: Hemisphere, 1990. [4] McConnell, K.G.: **Vibration testing: theory and practice.**- New York [etc.]: John Wiley & Sons, cop. 1995. [5] Lee, Chong-Won: **Vibration analysis of rotors**.- Dordrecht; Boston; London: Kluwer Academic, cop. 1993.- (Solid mechanics and its applications; vol. 21) [6] Newland, D.E.: **An introduction to random vibrations: spectral and wavelet analysis**, 3rd ed.- Longman, 1997. - Izbrana poglavja [7] Griffin, M.J.: **Handbook of human vibration** – 2nd ed.- London [etc.]: Academic Press, 1994, cop. 1990. - Izbrana poglavja
103	**DYNAMICS OF MULTIBODY SYSTEMS** Introduction, kinematics in the fixed and moving reference frame, rotational matrices. Analytic approach: generalised coordinates and kinematical constraints, Lagrangian dynamics, Euler equations in the case of several variables. Dynamic equations in the moving reference frame: kinematics, inertia of deformable bodies, generalised forces, the use of generalised coordinates, dynamic equations with multiplicators. Dynamic equations in the case of big deformations, absolute nodal coordinate system, determination of stiffness matrix. Application to computational dynamics of systems of rigid and flexible bodies. Applications in modern engineering. Dynamics of rigid bodies with unilateral contacts: contact kinematics, several simultaneous impacts, simultaneous description of friction and impact. Linear complementarity problem. Numerical aspects. Application in mechanical engineering. [1] A. A. Shabana: **Computational Dynamics**, John Wiley & Sons, 1994. – izbrana poglavja [2] F. Pfeiffer, C. Glocker: **Multibody Dynamics with Unilateral Contacts**, John Wiley & Sons, 1996. [3] A. A. Shabana: **Dynamics of Multibody Systems**, 3rd ed., Cambridge university press, 1994. – izbrana poglavja [4] A. A. Shabana: **Computational Continuum Mechanics**, Cambridge University Press, 2008.
104	**ADVANCED EXPERIMENTAL MECHANICS** For single student the priority list of topics for laboratory work. Characterization of material static properties: tension, compression and bending test, material hardness measurements. Load velocity influence on measurements. Procedures for strain measurements. Bausching fatigue effect. Creeping, relaxation and retardation. Specialty of anisotropic materials (composites, partially crystallized materials and blends)

	and micro mechanical and nano fibers. Characterization of dynamical material properties: high velocity tension test, load velocity influence. Mechanical stroke tests. Cycling force tests. Cycling test with constant frequency, resonance tests, measurement of deformation hysteresis, coincidental loading. Specialty in measurements of polymers, composites and micro mechanical and nano fibers. Thermal analysis of materials, termogravimetry. Differential thermal analisis (DTA,DCS), thermo mechanical analysis. (TMA, DMA). Analysis of plain stress-strain: theoretical approach. Strain-gages for strain measurements. Special fragile and photo-elastic coating. Basics of optical methods in mechanical properties measurements. Speckle methods and laser interferometry. Specialty in measurements of time dependent materials and composites. Dynamical analysis of machines and construction: acceleration, velocity and movement measurements. Analysis of machines and constructions vibrational state. Usage of visco-elastic materials for vibrations and noise damping. Passive and active isolation. Fatigue of material. Experimental modal analysis: basic theory. Appropriate sensor and measuring location selection Mechanical and electrical response. Calibration. Results interpretation. Expert systems: linear system (transfer function). Data base and logical algorithm forming. Multi-channel computer added measurements (CAM) in Windows® operating system (Visual Basic, Visual C, LabView). Methods for measurements geometrical parameter influence on stress peek. Experimental methods for unstable branching state determination and system hoping in line, plane, and shell constructions. [1] Cloud, G.L.: **Optical methods of engineering analysis**.- New York; Cambridge: Cambridge University Press, 1998 [2] KNAUSS, W. G., EMRI, I., LU, H., **Mechanics of polymers : viscoelasticity**. V: SHARPE, W. N. (ur.). *Handbook of experimental solid mechanics*. New York: Springer, cop. 2008, str. 49-95. [3] Dally, J.W., Riley, W.F.: **Experimental stress analysis**.- 3rd ed.- New York [etc.]: McGraw-Hill, cop. 1991 [4] Cheremisinoff, N.P.: **Product design and testing of polymeric materials**.- New York; Basel: Marcel Dekker, 1990 [5] Whitney, J.M., Daniel, I.M., Pipes, R.B.: **Experimental mechanics od fiber reinforced composite materials**, Society for Experimental mechanics, 1980 [6] **Thermal characterization of polymeric materials** / edited by Edith A Turi.- 2nd ed.- San Diego [etc.]: Academic Press, 1997.- 2 zv. [7] Nashif, A.D., Jones, D.I.G., Henderson, J.P.: **Vibration damping**.- New York [etc.]: John Wiley & Sons, 1985 [8] Grabec, I., Sachse, W.: **Synergetics of measurement, prediction and control**.- Berlin: Heidelberg; New York: Springer Verlag, 1997
105	**ENGINEERING OF CONTACT SURFACES** Contact of two surfaces; contact geometry, line, point and Hertz's contact, contact of two bended surfaces, forces, velocity and contact stresses, line, point and surface load, Hertz+s theory, tangential load, combination of tangential and normal load – sliding, micro and macro sliding, rolling, elasto-plastic contact, elastic deformation, plastic deformation, plasticity index, contact of rough surfaces, surface roughness, influence of roughness on stress distribution, temperature in contact, still and moving source of heat, temperature field, thermo-elastic contact. Practical applications: sliding washers, rolling bearings, gear wheels…. Characterization of contact surfaces, microscopy, optical and electron microscopy, sample preparation. Composition and structure of the surface: EDS, X-ray, IR, XPS, Auger… Topography, surface roughness, analysis of roughness parameters, surface load capacity, surface hardness and elasticity, hardness measurements, Young's modulus, residual stresses, measurement methods and analysis, surface coating adhesion, slicing test, acoustic methods, press in method, wear and friction properties, model tests, simulation, real tests. Refinement of contact surfaces, technological procedures: thermal and chemo-thermal processes, processes of hard coating deposition, surface preparation, criteria for coating deposition selection, different kinds and properties of surface coatings; diffusion layers, metal coatings, ceramic coatings, diamante and like-diamante coatings, multi-component

	and multi-layer coatings, tribological properties of surface layers, influence of thickness, hardness, residual stresses and elasticity of surface layer, mechanics of layered surface, composite stress field, maps of local yielding. Practical applications: sliding washers, rolling bearings, gear wheels…. [1] Modern Surface Technology, eds.: F.W. Bach, A. Laarmann, T. Wenz, Wiley-VCH, Weinheim 2004 [2] V. Schulze: Modern Mechanical Surface Treatment, Wiley-VCH, Weinheim 2006 [3] Johnson, K.L.: Contact mechanics.- Cambridge: Cambridge University Press,1994 [4] Stachowiak, G.W., Batchelor, A.W.: Engineering tribology.- [2nd ed.].- Amsterdam: Elsevier, 1993 [5] Bhushan, B., Gupta, B.K.: Handbook of tribology, New York [etc.]: McGraw-Hill, 1991 [6] Holmberg, K. , Matthews, A.: Coatings tribology: properties, techniques and applications in surface engineering.- Amsterdam [etc.]: Elsevier, cop. 1994 [7] Dowson, D., Taylor, C.M., Childs, T.H.C., Godet, M.,Dalmaz, G.: Thin films in tribology.- Amsterdam: Elsevier, 1993 (Tribology series; 25) [8] Surface engineering practice /ed. by K.N. Strafford, P.K. Datta, J.S. Gray.- New York: Ellis Horwood, 1990 [9] Grum J.: Laser surface hardening. V: TOTTEN, George E. (ur.). *Steel heat treatment: equipment and process design*. 2nd ed. Boca Raton: Taylor & Francis, cop. 2007, str. 435-566. [10] Grum J.: Modelling of Laser Surface Hardening,, C. H. Gür, J. Pan: Handbook of Thermal Process Modeling of Steels, CRC Press, Taylor & Francis Group, USA, 499 – 626, 2009. [11] Grum J.: Failure Analysis of Heat Treated Steel Component ASM Int., Metals Park Ohio, USA, 417 – 502, 2008.
106	**CHARACTERIZATION OF POLYMERS** Linear-viscoelastic behavior of polymers and composites. Non-linear behavior (multiple-integral representation, determination of model parameters from experimental data). Examples (relaxation of PS and PE under shear loading, creep of PA in torsion, creep of PMMA in torsion and uniaxial extension). Periodic tooth-like loading, behavior of time-dependent materials under spring loading. Generalization to other modes of loading. Fatigue of polymers and composites. Strain accumulation. Deviatoric and isotropic deformation energy. Stored and dissipated deformation energy. Limit of linear viscoelasticity. Crazing (deformation energy in creep and relaxation, examples, simplified relations). Failure and flow of polymers. Time-dependent behavior of composites and nano-composites. Micro-, and nano-mechanical properties, Strength of orthotropic composites, methods of testing, and mechanisms of failure. Behavior of polymers and composites under high rate-loading. Discussion and summary. [1] Brostow, W., Corneliussen, R. D.: **Failure of plastics**.- München: Hanser Publisher, 1986 [2] Cheremisinoff, N. P.: **Product design and testing of polymeric materials**.- New York: Marcel Dekker, Inc., 1990 [3] Brüller, O.: **Linear and nonlinear characterisation of the behaviour and failure of polymeric materials**, Lecture Notes.- Udine: CISM Centre International des sciences mechaniques, 1991 [4] KNAUSS, W. G., EMRI, I., LU, H., **Mechanics of polymers : viscoelasticity**. V: SHARPE, William N. (ur.). *Handbook of experimental solid mechanics*. New York: Springer, cop. 2008, str. 49-95. [5] Hyer, M. W. , **Stress Analysis of Fiber-Reinforced Composite Materials**, McGraw-Hill, 1998
108	**MECHANICS OF FLIGHT** ▪ Aircraft aerodynamics ▪ Propellers and rotors ▪ Aircraft performance ▪ Dinamics of flight ▪ Aircraft stabilty (longitudinal, lateral, directional), static and dynamic stability ▪ Stability coefficients ▪ Aircraft control ▪ Restrictions and limitations

	▪ Influence of the powerplant, structure elastisity, mass distribution and speed of flight ▪ Aeroelasticity, static and dynamic ▪ Active and passive methods of reducing aeroelastic phenomena ▪ Regulations for airworthness ▪ Static and dynamic tests of structure elements and airframe ▪ Aircraft tests on ground and in the air ▪ Aerodynamic tests of structure elements and airframe during flight [1] Barnard R. H. and Philpott D. R.: Aircraft Flight, Longman 1989 [2] Coyle S.: The Arte and Science of Flying Helicopters, Iowa State University Press, 1997 [3] Etkin B.: Dynamics of Flight, stability and Control, John Wiley & Sons, inc. 1996 [4] Kermode A.C.: Mechanics of Flight, Longman 1996 [5] Khoury G.A., Gillett J.D.: Airship Technology, Cambridge University Press 1999 [6] Leishman J.G.: Principles of Helicopter Aerodynamics, Cambridge University Press 2000 [7] Nelson C.R.: Flight Stability and Automatic Control, Longman 1989 [8] Padfield G.D.: Helicopter Flight Dynamics, Blackweel Science 1996 [9] Pallett E.H.J., Coyle S.: Automatic Flight Control, Blackwell Science 1995 [10] Russell, J.B.: Performance and Stability of Aircraft, Arnold 1996 [11] Roskam, J.: Airplane design. Part VII, Determination of stability, control and performance characteristics, 1991 [12] Kimberlin R.D.: Flight Testing of Fixed Wing Aircraft, AIAA 2003 [13] Ward D.T.: Introduction to flight test engineering, Elsevier 1993
109	**MECHANISMS** Modeling of rigid and/or flexible multibody systems. Methods of mechanism design. Mechanism characteristics. Analysis of kinematics and dynamics of broadly used types of mechanisms. Mechanism modification and optimization. Role of elasticity and clearance in mechanism joints. Role of cam design. Computer-aided synthesis and analysis of mechanism in development process. [1] Uicker, J. J., Pennock, R. R., Shigley, E. J.: Theory of Machines and Mechanisms; Third Edition; Oxford University Press, 2003: ISBN 0-19-515598-X [2] Norton, L. R.: Design of Machinery (Synthesis and Analysis of Mechanisms and Machines), Second Edition; McGraw-Hill: ISBN 0-07-237960-X [3] Chironis, P. N.: Mechanisms and Mechanical Devices Sourcebook, Fourth Edition McGraw-Hill, 2006: ISBN-13 978-0071467612 [4] Howel, L. L.: Compliant Mechanisms; Wiley-Interscience, 2001: ISBN-13 978-0471384786 [5] Mabie, H. H., Reinholtz, C. F.: Mechanisms and Dynamics of Machinery, Fourth Edition; Wiley, 1987: ISBN-13 978-0471802372 [6] Tsai, L.-W.: Mechanism Design: Enumeration of kinematic Structures According to Function (Advanced Topics in Mechanical Engineering Series), First Edition; CRC, 2000: ISBN-13 978-0849309014 [7] Hahn, H.: Rigid Body Dynamics of Mechanisms, 1 Theoretical Basis; Springer, 2002: ISBN 978-3-540-42373-7 [8] Hahn, H.: Rigid Body Dynamics of Mechanisms, 2 Applications; Springer, 2003: ISBN 978-3-540-02237-4 [9] *Mechanism and Machine Theory*; Elsevier, ISSN 0094-114X
110	**NONLINEAR STRUCTURAL DYNAMICS** Experimental modal analysis, operational modal analysis. Identification and modelling of localised nonlinearities in complex structures and their valid modelling. Spectral analysis at experimental work in structural dynamics. Non-parametric and parametric methods. Fourier decomposition of signals, discrete Fourier transform. Higher order spectral analyses to detect nonlinearities in the time series. Bispectral and bicoherence analyses. The quality of estimates. Continuous wavelet transform in nonstationary dynamics. Modal parameters estimation using continuous wavelet transform. Identification and modelling of structural damping.

	Boundary and intermediate conditions, identification and modelling. Nonlinear dynamics in the phase space, real and reconstructed. Nonlinear normal modes. Nonlinear structural dynamics in order to detect faults in products. The design aspects of end-of-line control devices. [1] N.M.M.Maia, J.M.M.Silva: **Theoretical and Experimental Modal Analysis**, Research Studies Press, 1997 – izbrana poglavja [2] K. Worden, G.R. Tomlinson: **Nonlinearity in Structural Dynamics: Detection, Identificationand Modelling**, IoP Publishing, 2001 [3] S. Braun: **Discover Signal Processing, An Interactive Guide for Engineers**, John Wiley & Sons, 2008 [4] K Shin, J.K.Hammond: **Fundamentals of Signal Processing for Sound and Vibration Engineers**, John Wiley & Sons, 2008 [5] A.H. Nayfeh, D. Mook: **Nonlinear Oscillations**, John Wiley & Sons, 1995– izbrana poglavja [6] S. Mallat: **A Wavelet Tour of Signal Processing**, 2nd ed., Academic Press, 2001– izbrana poglavja [7] Nikias C.L. , A. Petropulu: **Higher order spectra analysis, a nonlinear signal processing framework**, Prentice Hall, 1993
111	**OPERATIONAL STRENGTH** • Operational strength in R&D, production, operational, maintenance and recycling technical systems. • Operational condition (structure, loads, environmental influences, durability, reliability). • R&D process (design, evaluation) • Loads (mechanical, thermo-mechanical, thermal, neutron radiation, chemical). • Loads in time and frequency domain (deterministic, random, stationary, ergodic, spectra etc.). • Evaluation of loads (counting methods, loading spectra, power spectrum density, probability of realisation, extreme-value theory, period of return). • Damage (mechanical, thermo-mechanical, thermal etc.). • Instantaneous damage and fatigue damage. • Damage phenomena and criteria. • Instantaneous damage (rupture, crash, extreme events). • Fatigue damage (low-cycle, medium-cycle fatigue, high-cycle fatigue and durability). • Damage accumulation hypotheses. • Fatigue damage (until the technical crack, crack growth). • Low-cycle and medium-cycle fatigue (stress-based and strain-based approach, fatigue damage models, parametric and non-parametric description of states and influential parameters). • High-cycle fatigue and durability (methods for evaluating durability, Palmgreen-Miner hypotheses: original, modified, Haibach's etc.). • Operational strength (scatter of load states and durability, probability of fault). • Criteria for evaluation of R&D solutions (RMS criteria). • Effectiveness of products and systems (readiness for operation, reliability, elasticity). • Reliability (cross-section of probability spaces, methods for definition, determination and measurement). • Reliability models (influence of structure, models). • Computer aided reliability modelling (standard, specific and commercial software equipment). • Methods for validation of models. • Experiments in operational strength (test for determination of loading and operating conditions, test of materials, test for supporting modelling and simulations, fatigue damage tests). • Test stands (standard, specific). • Experimental techniques in operational strength. [1] O. Buxbaum: **Betriebsfestigkeit**, Verlag Stahleisen, 1992. [2] E. Haibach: **Betriebsfestigkeit: Verfahren und Daten zur Bauteilberechnung**, VDI, 1989. [3] J.D. Andrews, T.R. Moss: **Reliability and risk assessment**, Longman Scientific &

	Technical, 1993. [4] A. Birolini: **Quality and reliability of technical systems: theory, practice, management**, Springer Verlag, 1994. [5] C.E. Ebeling: **An introduction to reliability and maintainability engineering**, McGraw-Hill, 1997. [6] D.J. Smith: **Reliability, maintainability, and risk: practical methods for engineers**, Butterworth-Heinemann; Woburn, 2001. [7] J. Lemaitre, J.L. Chaboche: **Mechanics of solid materials**, Cambridge University Press, 2000. – Izbrana poglavja [8] S. Suresh: **Fatigue of Materials**, Cambridge University Press, 2004. [9] N.E. Dowling: **Mechanical behaviour of materials**, Prentice Hall, 1999. [10] Farahmand: **Fatigue and fracture mechanics of high risk parts**, Chapman & Hall, 1997.
112	**DESIGN AND DEVELOPMENT PRINCIPLES IN AVIATION ENGINEERING** • Evolution of aircraft structures (materials, tehnology, performance) • Tipology and systematic of aircraft (usage, geometry, components) • Design principles of aircraft (principles, specifications, requirements) • Loads (air loads, ground loads) • Stresses in airframe (shear, normal, torsional) • Deformations • Stability of constructional elements • Aircraft parts and systems • Airplane concepts (tailed, flying wing, canard, tandem wing) • Materials in aircraft design (characteristics, tehnology, tests) • Usage of composite materials (laminates, honeycomb, fibers) • Design of aircraft parts • Inspection of airframe • Tehnical publications in aviation engineering • Repair of airframe • Standard parts in aircraft design [1] Bruhn, E.F.: Analysis and Design of Flight Vehicle Structures, Jacobs Publishing, 1973 [2] Charles J.A., Crane F.A.A. and Furness: Selection and use of engineering materials, Butterworth Heinemann 1997 [3] Dowell,E.H.: A Modern Course in Aeroelasticity, Kluwer Academic Publishers, 1995 [4] Nicolai,L.M.: Fundamentals of Aircraft Design, METS, Inc., 1975 [5] Niu, M.C.Y.: Airframe Structural Design, Hong Kong Conmilit Press, 1997 [6] Niu M.C.Y.: Composite airframe structures, Hong Kong Conmilit Press ltd, 1996 [7] Perry D.J. & Azar J.J.: Aircraft Structures, McGraw-Hill, 1982 [8] Raymer, D.P.: Aircraft Design: A Conceptual Approach, AIAA, 1992. [9] Roskam J.: Airplane Design, Part I/II/III/IV/V/VI/VII, Roskam Aviation and Engineering Corporation 1997 [10] Stinton D.: The Design of the Airplane, Blackwell Science, 1995 [11] Torenbeek E.: Synthesis of Subsonic Airplane Design, Kluwer Academic Press,1982 [12] Wilkinson R.: Aircraft Structures & Systems, Longman 1996 [13] Atluri S.N., Sampath S.G., Tong P.: Structural Integrity of Aging Airplanes, Springer-Verlag 1990 [14] Baker A.A., Jones R.: Bonded Repair of Aircraft Structures, Martinus Nijhoff Publishers 1988 [15] Bifolchi : Aircraft Maintanence and Repair, 1987 [16] Douglas C. L.: Nondestructive Testing for Aircraft, Jeppesen Sanderson 1994 [17] Jeppesen: Advisory Circular – Acceptable Methods, Techniques, and Practices-Aircraft Inspection and Repair, 1998 [18] Jeppesen: Standard Aviation Maintenance Handbook, Jeppesen Sanderson 1985
114	**BUCKLING** • Equilibrium and energy method for exact solution of buckling of beams and plates in elastic and plastic domain.

	• Special cases of snap-through. • Validity of classical solutions obtained via theory of the second and the third order and aplicability of solutions in elastic and elasto-plastic domain. • Stability of structural elements made from viscoelastic material. • Special cases of lateral buckling of beams and systems. • Influence of complex loading on buckling. • Load carrying capacity of plates in post-critical domain. • Local stability of multilayered plates. • Kinetic stability. • Theory of large deformations. • General bending-torsional problem of slender beam. • Experimental methods: Southwell method, method of dynamical stability, method of inflection point. • Methods of model mechanics. [1] Timošenko, S.: Theory of elastic stability.- New York: McGraw-Hill, 1985 [2] Pflüger, A.: Stabilitätsprobleme der Elastostatik,- Berlin: Springer, 1964 [3] Volmir, A.S.: Ustojčivost deformiruemyh sistem.- Moskva: Nauka, 1967 [4] Drozdov, A.D.: Stability in viscoelasticity.- Amsterdam: Elsevier, 1994 [5] Iyengar, N. G. R.: Structural stability of columns and plates.- New York: Ellis Horwood, 1987
115	**TECHNICAL DIAGNOSTICS** Maintenance technology; Theory of damages; reliability, maintainability, availability; Damage and damage analyses; Damage indicators, Techniques for data acquisition; vibration, acoustics, oil and particles analysis, thermography. Non-destructive techniques; penetration acoustic emission, magnetic flux, ultrasound, endoscopies. Data acquisition, Data processing, Diagnostics and prognostics methods; Diagnostic system design. [1] Cornelius Scheffer, Paresh Girdhar: **Machinery Vibration Analaysis- predictive maintenance.** Elsevier, 2004 [2] Donald E. Bently, Charles T. Hatch: **Fundamentals of Rotating machinery Diagnostics. Bently pressurized bearing press**, 2002 [3] Bolotin, V.V.: **Prediction of service life for machines and structures**.- New York: ASME, 1989 [4] Grosch, J.: **Schadenskunde im Maschinenbau: charakteristische Schaden-** sursachen- Analyse und Aussagen von Schadensfällen / Johann Grosch und Mitautoren.- 2., völling neuberbeitete Aufl.- Renningen-Malmsheim: Expert, 1995 [5] **Handbook of condition monitoring** / ed. by B.K.N. Rao.- Oxford: Elsevier, 1996
116	**PRODUCT DATA MANAGEMENT SYSTEM** An overview of building blocks and a structure of product data management systems (PDM/PLM), the role in a manufacturing company and virtual project team. Production information system. Product or service as a carrier of the process. Methods to analyse information flows: function diagrams IDEF0, ARIS model, organisation structure model, document flow, department – time diagram, model of communication, simulation of processes, Petri nets. Modelling of an enterprise, product data and processes with E/R diagrams, EXPRESS language, object models. Data models for engineering: STEP standard for exchange of product data from conceptual design to manufacturing and maintenance. Product data model or service through the whole life-cycle. Product and process data identification and generation in the manufacturing process. Functionality of production information systems (ERP). Functionality of product data management systems (PDM/PLM). Overview of the modules in the PDM/PLM systems: documents management, natural classification, development phases of building blocks and documents, information and documents flow, bill of materials: variant, structural, modular, integration with CAD/CAM tools, integration with project management.

	Data security background: backups, access control, security in the Internet, user identification. Long-term data archiving, legislation requests, standards (EDI, SGML). PDM/PLM systems as knowledge database and as backbone for virtual product development teams. Reference examples for different type of production: mass, serial or individual. Reference models for key processes: engineering change management, technical documentation management, system documentation. Procedure of applying of product data management systems to manufacturing enterprise or to support virtual product development teams. [1] Rude S.: **Wissenbasiertes Konstruieren, Shaker Verlag, Aachen, 1998** [2] Prasad B.: **Concurrent Engineering Fundamentals, Vol. I Integrated product and process, Prentice Hall 1996** [3] Stefan Brandner, Markus Kelch, Helmut Stengele, Martin Eigner, Alexander Suhm, Gunther Reinhart,: **EDM Engineering Data Management, Seminarberichte, IWB, 1996** [4] August- Wilhelm Scheer: **ARIS - Architecture and Reference Models for Business Process Management, Springer 2000** [5] Stark, J.: **Engineering information management systems: beyond CAD/CAM to concurrent engineering support.- New York: Van Nostrand Reinhold, 1992.- (Automation in manufacturing series)**
117	**ENGINEERING DESIGN THEORY** Descriptive and prescriptive models of conceptualisation; Search for opportunities for new products; Problem analysis and abstraction; Synthesis of technical processes; Formation of design requirements and benchmarkig; Function/Means law; Synthesis of function structure and synthesis of Function/Means Tree; Systematics of physical laws; Chaining of physical laws; Synthesis of basic schemata based on function carriers (wirk elements); Synthesis of elementary technical systems based on chains of physical laws and complementary basic schemata; Methods for evaluation and selection of concepts; Definition of research and development tasks in various phases of design process; Methods of CAD; Model of collaborative product development; 2D and 3D modeling; Relations between 2D and 3D space; Characteristics of model representation, Geometry database; Requirements for graphical languages. [1] Hubka, V., Eder, W.E. **Theory of Technical Systems: A Total Concept Theory for Engineering Design**, Springer-Verlag, Berlin. [2] Suh, Nam P. **Axiomatic design: advances and applications**, New York: Oxford University Press, 2001 [3] Roozenburg, N.F.M., Eekels, J. **Product design: fundamentals and methods**, Chichester: John Wiley & Sons, 1995 [4] Chakrabarti, A. **Engineering design synthesis: understanding, approaches, and tools,** London : Springer, cop. 2002 [5] Nachtigall, W., **Bionik : Grundlagen und Beispiele für Ingenieure und Naturwissenschaftler**, 2., vollständig neu bearbeitet Aufl., Berlin [etc.] : Springer, 2002 [6] Pahl, G., Beitz, W., Feldhusen, J., Grote, K-H**. Konstruktionslehre : Grundlagen erfolgreicher Produktentwicklung Methoden und Anwendung**, 7. Aufl., Berlin, Heidelberg: Springer, 2007 (selected chapters) [7] Eris, O. **Effective inquiry for innovative engineering design**, Boston: Kluwer Academic Publishers, cop. 2004 [8] Farin, G. **Curves and surfaces for CAGD** : a practical guide, 5th ed., San Francisco: M. Kaufmann, 2002
118	**THERMOPLASTICITY** • Definition of a representative volume and a material point. Fundamentals of rheological models. Constitutive equations of thermoplasticity. Yield criteria. Approaches to modelling of the plastic flow direction. • Irreversibility of the plastic response and its consequences. Hardening, elastic and plastic anisotropy. Cyclic loading. • Influence of the temperature on the plastic response. • Definition of boundary value problem in thermoplasticity and its solution. General

	theorems in thermoplasticity, energy theorems. • Elastoplastic torsion and bending. Plane and axisymmetric elastoplastic problems. Stability of elastoplastic equilibrium. Limit stress analysis. • Slip-line theory and its characteristics. • Experimental determination of material properties during elastoplastic yielding. • Mechanics of forming and cutting technological processes. [1] W.F. Hosford, R.M. Caddell: **Metal Forming: Mechanics and Mettallurgy**, Cambridge University Press, 2007 [2] H_C.Wu: **Continuum Mechanics and Plasticity**, Chapman&Hall/CRC, 2005. [3] **Thermal stresses 1** (Mechanics and mathematical methods; a series of handbooks; 1), North-Holland, 1986. [4] A.Mendelson: **Plasticity: theory and application**, McMillan Comp., 1986. [5] R.Hill: **The mathematical theory of plasticity**, 6th edition, The Clarendon Press, 1971.
119	**THEORY OF VISCOELASTICITY** The behavior of polymer materials and related composites and nano-composites changes over time. This time-dependence is strongly influenced by temperature, pressure, humidity, as well as the size and shape of mechanical loading. The analysis of these dependencies constitutes the content of this course. Basic definitions and concepts. Characteristics of nonlinear time-dependent behaviour of polymers, composites, nano-composites and hybrid materials. Structural differences between materials and their effect on time-dependent mechanical properties. Interface issue. Critical nano-dimension of fillers and fibers. Material functions in time and frequency domain. Problems relating to the solving of the inverse problem of the Fredholm integrals of the first kind. Mechanical spectrum. The Emri-Tschoegl algorithm. Effects of temperature, pressure and humidity. Energy absorption at dynamic loading. Physical ageing. The Knauss-Emri nonlinear viscoelastic model. [1] Emri, I.: **Viscoelasticity and Applications**,- Lecture Notes on AE 221.- Pasadena, CA: California Institute of Technology, 2001 [2] Ferry, J.D.: **Viscoelastic Properties of Polymers**.- 3rd ed.- New York: J. Wiley & Sons, 1980 [3] Schwarzl: **Mechanische Eigenschaften von Polymeren**.- Springer-Verlag, 1990 [4] Tschoegl, N.W.: **The Phenomenological Theory of Linear Viscoelastic Behavior**.- Springer-Verlag, 1989 [5] Emri, I.: **Rheology of Solid Polymers**; *Rheology reviews 2005*. [S.l.]: British Society of Rheology, 2005, str. 49-100. [3] Wineman, A.S., Rajagopal, K.R.: **Mechanical Response of Polymers, an Introduction**; Cambridge University Press, 2000
120	**TRANSPORTATION SYSTEMS AND LOGISTIC** Transport systems and specific problems by existing equipments. The problem definition methods. Modern crane design and specialty of their functions, load dynamics on the ropes, dynamics and dimensioning of elements and construction carrying of it. Transport systems for continuously transport, conveyer's dynamics and deformability of their elements, operation mode and specific problems by rope lifting systems. Pneumatic transport systems and actual specific in environment. Logistic and transport systems inside the complexity of environment. Theoretical basis by technical logistic. Presentation of the models and systems at logistic. Production logistic, chain management and supply logistics. Stock and distribution logistic. Logistic in the production systems of technical systems at all. Logistic of technical systems refection; [1] C. Seeßelberg: Kranbahnen, Bemessung und konstruktive Gestaltung; Bauwerk Verlag GmbH, Berlin 2005 [2] Verschoof J.: Cranes - Design, Practice, and Maintenance; Second edition, Professional Engineering Publishing, 2002 [3] H.Buhrke, H.J.Kecke, H.Richter: Strömungsförderer; VEB Verlag Technik, Berlin, 1988

	[4] Dieter Arnold: Materialflusslehre, 2. verbesserte Auflage, Vieweg 1998 [5] Heinrich Martin: Transport- und Lagerlogistik; Planung, Aufbau und Steuerung von Transport- und Lagersystemen; Friedr. Vieweg & Sohn Verlagsgesellschaft mbH, Braunschweig, 1995 [6] Carlos F. Daganzo: Logistic Systems Analysis; Springer Verlag, 1999 [7] Martin Christopher :Logistics & Supply Chain Management: creating value-adding networks (3rd Edition) (Financial Times Series), 2005 [8] Roger Stough: Intelligent Transport Systems: Cases and Policies (Hardcover), 2001
121	**TRIBOLOGY** Introduction: relevance for industrial environment and economy. Fundamental properties of contacting surfaces: real contact area, Greenwood-Williamson model, roughness parameters and effect on tribological performance, topography, measurements, plasticity index Tribological contacts: types of contacts, Hertzian contact contacts with and without friction Lubrication: base oils, additives, their functionality, lubrication regimes, Reynolds equation, HL and EHL lubrication, pressure distribution in lubricant film, viscosity and deformation effects, mixed lubrication, boundary lubrication, influences of lubrication regime on component life Friction: components of friction, basic models, effects Wear: mechanisms and forms of wear Characterization of surfaces and damages: typical damage forms – examples, solutions, techniques for surface characterization (topography, SEM, EDS; XPS; AES, AFM, STM, TEM.) Tribological aspects of mechanical components: sliding and rolling bearings, gears, seals. [1] Williams, J.A.: **Engineering tribology**.- Oxford [etc.]: Oxford University Press, 1994.- (Oxford science publications) [2] Suh, N.P.: **Tribophysics.**- Englewood Cliffs: Prentice-Hall, 1986 [3] Stachowiak, G.W., Batchelor, A.W.: **Engineering tribology.**- Amsterdam [etc.]: Elsevier, 1993.- (Tribology series; 24) [4] Stolarski, T.A.: **Tribology in machine design.**- Reprinted.- Oxford [etc.]: Butterworth-Heinemann, BH, 2000 [5] Blau, P.J.: **Friction science and technology**.- Marcel Dekker, inc., 1995 [6] **CRC handbook of lubrication** / edited by E. Richard Booser.- 7th ed.- Boca Raton: CRC Press, 1990 [7] Hutchings, I.M.: **Tribology: friction and wear of engineering materials**.- London … [etc.]: Edward Arnold, cop. 1992.- (Metallurgy & materials science series)
201	**ECOLOGY OF WORKING AND LIVING ENVIRONMENT** Lectures: Introduction in contents, purpose of subject and program, competence. Human being and environmental ecology. Environment systems influence on working and residence environment in correlation with human being. Thermoregulation of human being. Atmosphere parameters influence on working and residence environment. Parameters and criteria of working and residence indoor environment, occupied zone. Models, methods and criteria for determine analysis and valuate (indoor) environment. Thermal environment and influence on comfort and health of human being and/or on exhibits. Air quality (hygiene) and influence on comfort and health of human being and/or on exhibits. Hygiene requirements for ventilation and air-conditioning. Harmful and typical contaminants in air. Contaminant distribution in ventilated rooms. Contaminant removal effectiveness, conservative and non-conservative systems. Influence of building substances and building installations on human being ecology and/or exhibit. Sick Building Syndrome (SBS), causes, consequences and salvations. Engineering's request for heating, cooling, ventilation, moisten and drying, and air-conditioning. Olfactometry. Odour dispersion modeling. Physical mechanism of contaminant transportation. Ventilation, ventilation effectiveness, age of air. Industrial ventilation. Cleans spaces. Computational fluid dynamics in ventilation design. Mathematical background. Turbulence models. Numerical methods. Boundary conditions. Quality control. CFD combined with other predictions

	models, applications of CFD codes in building design. Indoor climate and productivity. Quantitative relationships between indoor environmental quality (IEQ), effects of IEQ on performance of work. Sick leave and influence on exhibits. Prediction of air quality by computational fluid dynamics. Advanced indoor environment – productivity – costs – health. Seminars (such as example): Low energy buildings and indoor environment ecology. Low pollutant environment (buildings). Productivity and working environment. Influence of air movement and turbulence on comfort and health of human being. Engineer's design requirements at specific working or residence environments. Influence of fresh air supply on productivity. How to integrate productivity in life-cycle costs analysis of building services? Working and residence environment on correlation with sick person's absent. Individual chosen themes. [1] C. Streffer all: **Environmental standards. Combined exposures and their effects on human beings and their environment**. Springer – Verlag, Berlin, 2003.–Izbrana poglavja. [2] R.N. Reeve: **Introduction to environmental analysis. Analytical techniques in the sciences**. John Wiley & Sons, Chichester, 2002. – Izbrana poglavja. [3] de N. Nevers: **Air pollution control engineering**. McGraw-Hill, New York, 1995. [4] E. Mundt and all: **Ventilation effectiveness**, REHVA Guidebook 2, Brussels 2004. [5] Wargocki P. and all. **Indoor climate and productivity in offices**, REHVA Guidebook 6, Brussels, 2006. [6] R. Reeve: **Introduction to Environmental analysis**. John Willey & sons, LTD., Chichester, 2002. - Izbrana poglavja. [7] P. Pasanen et all: **Cleanless of ventilation system**. REHVA Guidebook 8, Brussels, 2007.
202	**EXPERIMENTAL MODELLING IN POWER ENGINEERING** - Basic concepts of measurement methods; - Measurement uncertainty of combined measurement systems. - Measurement signal acquisition and digitization in combined measurement systems. - Frequent measurement errors and how to avoid them; - Introduction to experimental modelling; - Simple linear regression models; - Other regression models; - Measurement techiques and tools in power engineering; - Behaviour of measurement systems in power engineering; - Experimental design and analysis of selected examples; - Analysis of regression models; [1] B. Širok , B. Blagojević, P. Bullen: **Mineral wool : production and properties**. Cambridge: Woodhead, 2008. X, 185 str., ilustr. [2] B.Širok, M.Dular, B.Stoffel: **Kavitacija.** 1. natis. Ljubljana: i2, 2006. 164 str. [3] Douglas C. Montgomery: **Design and analysis of experiments.** John Wiley & Sons, INC, 5th Edition, 2001, 684 str. [4] Richard S. Figliola, Donald E. Beasley: **Theory and Design for Mechanical Measurements.** John Wiley & Sons, Inc., 4th Edition, 2005, 560 str.
203	**ENHANCED HEAT TRANSFER** The lectures begin with introduction to enhancements of heat transfer. They give many techniques, which were developed for convective heat transfer enhancements. The techniques are classified and a wider range of literature is introduced. Application of different heat transfer modes is presented: single phase natural convection, single phase forced convection, integral roughness, pool boiling and thin film evaporation, convective vaporization, vapor space condensation and convective condensation. Passive techniques of heat transfer enhancements (no external energy source is needed) as well as active techniques (external energy is required) and combined techniques (simultaneous application of two techniques or more) are included. Determination of characteristics of single phase as well as two-phase heat transfer, fouling, additives for liquids and gases, nanofluids, microchannels and electronic cooling heat transfer are presented. Students learn how to choose an appropriate enhancement technique for

	single- and multi-phase flow and how to determine performance evaluation criteria for enhancements. Advanced enhancements belong to the third generation of heat transfer technology and to the fourth generation, when combined with different active techniques. [1] Webb R.L.: **Principles of enhanced heat transfer**. Second edition, Taylor& Francis, Boca Raton, 2005. [2] Bergles A.E., Jensen M.K., Shome B.: **Bibliography on enhancement of convective heat and mass transfer: Heat transfer laboratory report, HTL-23**, Rensselaer Polytechnic Institute, Troy, 1995. [3] Thome J.R.: **Enhanced boiling heat transfer.** Hemisphere, New York,1990. [4] Sobhan C.B., Peterson G.P.: **Microscale and nanoscale heat transfer.** Fundamentals and engineering applications. CRC Press, Boca Raton, 2008.
204	**NUMERICAL SIMULATIONS OF PROCESSES IN INTERNAL COMBUSTION ENGINES** - Clasification of the models for simulating internal combustion engines (ICEs) - Governing equations - Determination of adequate computational domain - Selection of adequate simulation models - Numerical methods to solve systems of governig equations - Accuracy and computational speed of simulation models - Gas property models - Heat transfer models in ICEs - Chemical kinetics models applied to ICEs - Control strategies and thermal management of ICEs - Coupling of ICE and vehicle model to simulate real-world drive cycles - Coupling of the ICE and hybrid powertrain model - Modeling of energy conversion efficiency and exhaust emissions of ICEs [1] J.B.Heywood: **Internal combustion engine fundamentals**, McGraw-Hill, N.York,1988, izbrana poglavja [2] C.F.Taylor: **The Internal combustion engine in theory and praxis, Vol.1 – thermodynamics, fluid flow, performance**, The MIT Pres, Massachusetts, 1986 [3] D.E. Winterbone and R.J. Pearson: **Theory of Engine Manifold Design.** Professional Engineering Publishing Limited, UK, 2000, izbrana poglavja [4] R.S. Benson: **The Thermodynamics and gas dynamics of Internal Combustion Engines**,Volume I, Clarendon Press, Oxford, 1982, Izbrana poglavja [1] M.B. Allen, I. Herrera, G.F. Pinder: **Numerical Modeling in Science and Engineering**, John Wiley & Sons, 1988. - Izbrana poglavja
205	**HEATING AND COOLING** Importance of heating and cooling for health of human being and working capability in buildings. Thermodynamic analysis of heating, cooling and air-conditioning processes. Usage of primary energy for heating, cooling and air-conditioning. Energy and exergy process analysis. Methods and measures for low-energy achievement of heating and cooling processes. Environment reduction influence with alternative sources of energy. Static and dynamic modeling of transformation processes and energy usage. Simulation of heating, cooling and air-conditioning systems operating due to the technical suitability and economical effectiveness. Combined systems with renewable energy sources exploitations. Classical and sorption's refrigerators impelled by thermal compressors. Reversible heat pumps impelled by electrical energy or by waste heat from industrial processes. Fasten together heating cooling systems with condensers redundant heat for contemporary cooling and heating of buildings. Economic analysis of operating regimes and optimal operating due to the minimal annual costs. Advanced systems for heating and cooling energy supply. Cogeneration and tri-generation. District energy systems. District heating and district cooling. Advanced heating, cooling and air-conditioning device and systems. Costs evaluation of heating, cooling and air-conditioning installations in life cycle cost assessment (LCCA). Life cycle cost management, methods and tools. Energy study of individual systems, relationship and environment impact. Building operating and management. Commissioning. Industrial

	applications. Energy related applications (geothermal, solar energy usage, thermal storage …). Hybrid systems using phase change materials (PCM). [1] Kotas, T.J.: **The Exergy methods of thermal plant analyses**.- London: Butterworths, 1985. [2] Stoecker, W.F.: **Design of thermal systems**.- 3rd ed.- New York /etc.): McGraw-Hill, 1989. [3] Gosney, W.B.: **Principles of refrigeration**.- Cambridge /etc./: Cambridge University Press, 1982. [4] A. Vadrot, J. Delbes: **District cooling handbook**, European Marketing Group, October 2001. [5] ASHRAE Handbook: **HVAC Systems** and Equipment, Atlanta, 2008, izbrana poglavja. [6] ASHRAE Handbook: **HVAC Application**, Atlanta, 2007, izbrana poglavja.
206	**HEAT AND MASS TRANSFER** Upgrading knowledge of steady-state heat conduction in one and multi-dimensional systems with and without a heat source. Enhanced surfaces to augmentation of heat transfer. Extended surfaces. Transient heat conduction. Heat conduction by using Green's functions. Convective heat transfer (analytical and empirical approach) with and without a phase change. Stefan's problem. The radiation heat transfer. Micro and nano heat transfer. Analogy between the heat and mass transfer. Fick's equimolar and non-equimolar diffusion in binary and multicomponent mixture in one- and multi-dimensional sistem. Mass diffusion with homogeneous chemical reactions. Convective mass transfer. Mass transfer in porous media. Mass transfer through the boundary layer of drops and bubbles. Transient mass transfer. Simultaneous heat and mass transfer. [1] Incropera F.P., DeWitt P.D., Bergman, T.L, Lavine, A.S.: **Fundamentals of Heat and Mass Transfer**, Sixth Edition, John Wiley and Sons, New York, 2007. [2] Baehr H.D., Stephan K.: **Heat and Mass Transfer**, Springer Verlag, Berlin, 1998. [3] Lienhard IV J.H., Lienhard V J.H.: **A Heat Transfer Textbook**, Third Edition, Phlogison Press, Cambridge, Massachusetts, 2003. [4] Gašperšič B.: **Prenos toplote**, Univerza v Ljubljani, Fakulteta za strojništvo, Ljubljana, 2001. [5] Basmadjian D.: **Mass Transfer and Separation Processes**, CRC Press, Boca Raton, 2007. [6] Greene G., Cho Y., Hartnett J., Bar-Cohen A.: **Advances in Heat Transfer**, 39 / serial publications, Elsevier, Oxford, 2006.
207	**COMBUSTION THEORY** Physical processes in flame, thermodynamical rudiments, chemical processes and the kinetics of reactions. Transport phenomena and dynamics of combustion in stationary combustion chambers and in internal combustion engines (ICE). Physical interpretation of combustion of various fuels and various combustion systems. Combustion processes in fixed and variable geometry combustion chambers. Providing quality of combustion processes. Chemical energy potential of fuels and transformation. Gasification and liquefaction of fuels and biomass. Hydrogen production. Advanced technologies of coal usage, alternative synthetic fuels. Process of fuel-air mixture preparation in internal combustion engines. Technologies of carbon dioxide capturing and storing. Formation of pollutants at combustion processes and measures for its reduction, cleaning of combustion products. [1] C. K. Law, **Combustion Physics**, Cambridge University Press, 2006. [2] T. Poinsot, D. Veynante, **Theoretical and Numerical Combustion**, Second Edition, R.T. Edwards, Inc, 2005. [3] C. Higman, M. Burgt. **Gasification**, Second Edition, Gulf Professional Publishing, 2008.
208	**THERMAL ENERGETIC ANALYSIS OF PROCESSES** The topic of the course is related to the individual goals of the candidates study. Therefore the basic aim of the candidate study is to improve their knowledge of optimising the energy systems from the point of energetic, environmental and economic view. In general the content of the subject includes overviews of special theoretical methods, principals of applications for analysing the individual processes for optimisation of thermo energetic systems in practice. Moreover, the content of this course includes, methods for entropy generation minimization,

	exergy analysis, thermo economic analysis and evaluation, pinch point methods, advance design of thermal systems and studies of (BAT) and their applications in general systems and power plants. Emphasis is also on current developing tendencies in energetic branch. The course also treats the method of complex testing of thermal-systems, usable models, on-line data acquisition and calculation, study of influence of unstable parameters of reliable results transit phenomena in largest thermo energetic systems. [1] A.Bejan; **Thermal Design and Optimization**, John Wiley and Sons, INC. 1996. [2] J. Szargut; **Exergy Method**, WIT Press, 2005. [3] Yehia M. El – Sayed;**The Thermoeconomics of Energy Conversions**, Elsevier, 2003.
209	**THERMAL POWER SYSTEMS** • Introduction: content, subjects, demanded pre-knowledge level, teaching method • Classification of thermal power systems • Contemporary solid-to-gas fuel technologies • Techniques of reducing global warming gas emissions and their impact on thermal power system performance (CCS) • Approaches to model of thermal power systems • Modeling of components of thermal power systems (boilers, heat exchangers, steam and gas turbine, gasification units, fuel cells, etc.) • Modeling of complex thermal power systems and simulation of stationary operation conditions at best efficiency point and at off-design operation • Experimental approaches to determine quality of operation thermal power plants • Life Cycle Assessment method and its application to thermal power plants • Modeling and optimization algorithms of broader network operation with thermal power systems [1] R. Bachmann, H. Nielsen, J. Warner, R. Kehlhofer: **Combined - Cycle Gas & Steam Turbine Power Plants**, Penn Well, 1999 [2] L. Drbal, K. Westra, P. Boston**: Power Plant Engineering**, Champman & Hall, 1995. [3] J. Larminie, A. Dicks: **Fuel Cell Systems Explained**, John Willey & Sons, 2003 [4] P. Kiameh: **Power Generation Handbook**, McGraw – Hill, 2002 [5] R. Bove, S. Ubertini: **Modeling Solid Oxide Fuel Cells**, Springer 2008
210	**MULTIPHASE FLOW** **General complex system:** imposed, engineered or created hierarchy, variable structure two-phase system; aim: to learn how to choose scale separation and how to define objective function in multi-scale multi-functional systems. **Two phase flow emergent properties:** Macro scale, mesoscale, microscale; aim: to learn about the nature of system properties that escalate depending upon the reference scale, to learn about the role of flow patterns, flow regimes and structural function, also to learn about possible experimental techniques in two-phase flow. **Two-phase flow design parameters**: primary design parameters, secondary design parameters; aim: to learn how to distinguish between system and process parameters. **Modeling:** conservation principles, topological laws, constitutive laws, transfer laws, theoretical and practical constraints. 1D modeling, 3D modeling; aim: to learn how to model two-phase flow using channel averaging or to model two-phase flow using local instant formulation. **Practical applications:** students are encouraged to submit their own applications of interest that may cover all possible solid-gas–liquid flow combinations relevant to large- or micro-scale devices; aim: to promote independent studies of multiphase systems and to learn how to design, implement and present research work. [1] C. E. Brennen: **Fundamentals of Multiphase Flow**, Cambridge University Press, 2005– Selected chapters. [2] S. Levy: **Two-phase Flow in Complex Systems**, John Wiley & Sons, 1999– Selected chapters. [3] A. Faghri, Z. Zhang: **Transport Phenomena in Multiphase Systems**, Academic Press, 2006 Selected chapters [4] M. Ishii, T. Hibiki: **Thermo-fluid Dynamics of Two-phase Flow**, Springer 2006

	Selected chapters. [5] G. Hetsroni, **Handbook of Multiphase Systems**, Hemisphere, 1982– Selected chapters.
301	**SELECTED TOPICS OF THE PRODUCTION SYSTEMS** The definition, structure, function, production function, investment, management and objectives of the production system. Analysis to ensure the economy of the production system: analysis of usefulness, analysis of the value, analysis of break-even point. Seven types of waste in the organization of work of the production system and methods of eliminating them. Planning needs for equipment, personnel and supply of production storage and administration. The planning of the material flow and workflow- shop and product workflow principle and Schmigalla's determination diagram of the workflow principle. The creation of the ideal and detailed Layout of production, storage and administrative elements of production systems. Computer-aided design of the production system. [1] Jingshan Li: **Production Systems Engineering**, Springer, 2008. [2] Claus-Gerold Grunding: **Fabrikplanung**, Fachbuchverlag Leipzig, 2008 [3] **Aggteleky B.:** Fabrikplanung – Betriebsanalyse und Feasibility – Studie**, Fachbuchverlag Leipzig, 2001** [4] J Frey, S.R.: **Plant Layout,** Carl Hanser Verlag, 1990. [5] Hans Schmigalla: **Fabrikplanung**, Carl Hanser Verlag, 1995**.**
302	**SELECTED TOPICS IN TECHNICAL CYBERNETICS** Computerized methods of modelling and simulation of analog and digital control systems, analysis of control systems in time, frequency and phase space, root analysis, methods of synthesis, bond graphs (especially for mechatronics), methods of analysis and synthesis of nonlinear control systems, methods of discrete control of dynamic systems, discrete signal procession and communication, usage of fuzzy logics when synthesizing control systems, etc. [1] H. Chesnut: **Systems engineering tools**, Wiley, 1966 [2] A.W. Wymore: **Systems engineering methodology for interdisciplinary teams**, Wiley, 1976 [3] D. Karnopp, R. Rosenberg: **System dynamics: a unified approach**, Wiley, 1975. [4] P.E. Wellstead: **Introduction to physical system modelling**, Academic Press, 1979. [5] J.J. DiStefano, A.R. Stubberud, I.J. Williams: **Schaum's outline of theory and problems of feedback and control systems - 2nd ed.**, McGraw-Hill, 1995. [6] К. А. Пупков (red.): **Методы современной теории автоматического управления**, Издательство МГТУ имени Н.Э. Баумана, 2004 [7] S.A. Tretter: **Introduction to discrete-time signal processing**, Wiley, 1976. [8] R. Isermann: **Digitale Regelsysteme. Bd.2: Stochastische Regelungen**, Springer-Verlag, 1987 [9] E. Cox: **The fuzzy systems handbook**, Academic Press, 1994 [10] W. Pedrycz: **Fuzzy sets engineering**, CRC Press, 1995
303	**COMPLEX MECHATRONIC SYSTEMS** Advanced data-processing technologies for CMS Embedded system hardware: processors, chip-sets, interfaces, converters, displays, communication interfaces, networks, microcontrollers. Field-programmable gate arrays as platforms for high-performance data processing in CMS. Embedded system software: programming languages and methods, operation systems, real-time operation, simultaneous tasks. Design and implementation methodologies for embedded systems in CMS: hardware and software. Selected topics in agorithms for signal and image processing. Processing of 3D data sets (clouds of points acquired during 3D shape measurements); analysis of 3D data sets and

	extraction of characteristic dimensions / features. Multi-sensor data fusion algorithms. Selected topics in modeling and simulation of CMS. Opto-mechatronic systems. Opto-mechatronic technologies. Components: optical, opto-electronic in electro-optic, mechatronic. Optomehatronic integration. Basic optomechatronic functional units. Design and implementation methodologies. Micro-scale implementations: micro-opto-mechatronic syistems. Selected examples of opto-mechatronic systems. [1] T. Scheurer: **Foundations of computing: system development with set theory and logic**, Addison-Wesley, 1994. [2] K. Edwards: **Real-time structured methods: systems analysis**, Wiley, 1993. [3] A. Burns, G. Davies: **Concurrent programming**, Addison-Wesley, 1993. [4] C.A.R. Hoare: **Communicating sequential processes**, Prentice-Hall, 1985. [5] D.R. Martinez, R.A. Bond, and M.M. Vai, **High Performance Embedded Computing Handbook: A Systems Perspective**, CRC, 2008. – izbrana poglavja [6] P. Marwedel, **Embedded System Design**, Springer, 2003. [7] R. Zurawski, **Embedded Systems Handbook**, CRC, 2005. – izbrana poglavja [8] J. Wikander and B. Svensson, **Real-Time Systems in Mechatronic Applications**, Springer, 1998. [9] D.C. Karnopp, D.L. Margolis, and R.C. Rosenberg, **System Dynamics: Modeling and Simulation of Mechatronic Systems,** Wiley, 2006. [10] F. Caccavale and L. Villani, **Fault Diagnosis and Fault Tolerance for Mechatronic Systems**, Springer, 2002. [11] D. Auslander, J. Ridgely, and J. Ringgenberg, **Control Software for Mechanical Systems: Object-Oriented Design in a Real-Time World**, Prentice Hall PTR, 2002. [12] R.H. Bishop, **The Mechatronics Handbook, Second ed.**,CRC, 2007. [13] C.W.D. Silva, **Mechatronic Systems: Devices, Design, Control, Operation and Monitoring**, CRC, 2007. – izbrana poglavja [14] H. Cho: **Optomechatronics: Fusion of Optical and Mechatronic Engineering**, CRC Press, 2005. – izbrana poglavja [15] H. Ukita, **Micromechanical Photonics**, Springer, 2006. [16] H. Mitchell, **Multi-Sensor Data Fusion: An Introduction**, Springer, 2007. [17] J.W. Gardner, V. Varadan, and O.O. Awadelkarim, **Microsensors, MEMS and Smart Devices**, Wiley, 2001. – izbrana poglavja
304	**LASERS AND LASER APPLICATIONS** **Fundamentals of laser physics** Selected topics in classical optics. Non-linear optics, harmonic frequency generation. Novel laser sources: active media, pumping techniques, resonators and beam quality, beam shaping, methods for generation of short and ultra-short laser pulses. Theoretical description of light propagation in optical waveguides. Single-mode and multi-mode optical fibers. High power optical fibers. Non-linear effects in optical fibers. **Laser light – matter interaction** Interaction processes. Material properties (optical, thermodynamic, mechanical). Basic mechanisms of thermal laser processing. Athermal processing. Gas assistance. Optodynamics. **Laser processing** Laser cutting and welding. Laser ablation. Laser drilling. Laser cleaning. Laser marking and engraving. Laser scribing. Laser micro-processing in electronics and in manufacturing of micromechanical components. Laser forming. Laser-based technologies for rapid prototyping. Laser processing diagnostics. Modeling of laser manufacturing processes. **Laser based measurements** Laser measurement of distance, displacement, angle, Profile, and 3D shape of objects. Laser triangulation. Laser interferometry. Laser Doppler anemometry and velocimetry. **Optical fiber sensors** Intensity sensors. Sensors based on phase detection. **Fiber lasers** Physical properties of doped optical fibers. High power fiber lasers. Structure and operation. Methods for generation of (ultra-) short laser pulses and high average power beams. Novel wavelengths in IR, visible and UV spectral ranges. Advantages and limitations – comparison

	to classical solid-state and gas lasers. Beam shaping and delivery. [1] Das, P: Lasers and Optical Engineering, Springer-Verlag, Berlin, 1991. [2] Smith, F.G., King, T.A., Wilkins, D.: Optics and photonics, Chichester, John Wiley&Sons, 2007 [3] Allmen, M. von: Laser-beam interactions with materials.- Berlin [etc.]: Springer, 1987 [4] Schuoecker, D.: High power lasers in production engineering, London, Imperial College Press, 1999 [5] Steen, W.M.: Laser material processing, London, Springer Verlag, 2003 [6] Ion, J.C.: Laser processing of engineering materials, Oxford, Elsevier Butterworth-Heinemann, 2005 [7] Gasvik, K.J.: Optical metrology, Chichester, John Wiley &Sons, 1995 [8] J.A. Buck, Fundamentals of Optical Fibers, 2nd edition, Wiley 2004 [9] D.A. Krohn, Fiber optic sensors, Instrument society of America, 1988 [10] L.N. Durvasula, Fiber Lasers: Technology, Systems, And Applications, SPIE-International Society for Optical Engine 2005
305	**NON DESTRUCTIVE TESTING OF MATERIALS AND CONSTRUCTIONS** Visual testing: basic physical concepts, observations without and with optical instruments, criteria for visual assessment. Borescopy: basic physical concepts, illumination systems, optical systems for distant image processing, surface and flaw evaluation, criteria for surface assesment. Optical microscopy: basic physical concepts, preparing of replicas and impresses, microscopy of replicas, assessment of surface and microstructure. Liquid penetrant inspection: basic physical concepts, methods, instruments for surface observation, surface evaluation and ways of recording of surface states, types of liquid penetrant inspections. Magnetic methods in surface testing: basic physical concepts, magnetizing and demagnetizing of the sample, magnetic particle types, control and data display systems, surface evaluation, establishment of procedures. Eddy current inspection: basic physical concepts, inspection methods, establishment of criteria for testing of different materials, assessment of surface and surface layers, testing of corrosion damage, testing with regard on material properties, chemical content etc., establishment of procedures. Ultrasonic inspection: basic physical concepts, ultrasound generation, ultrasonic inspection methods, ultrasonic devices, ultrasonic transducers, special ultrasonic methods for material evaluation, establishment of procedures. Acoustic emission: basic physical concepts, methods of testing, methods of signal evaluation and signal classification. [1] Conf. Proceedings of the 8th Int. Conf. of the Slovenian Society for Non-destructive Testing. Portorož, Slovenia, 2005. [2] ASM handbook. Vol. 17, Nondestructive evaluation and quality control / prepared under the direction of the ASM International Handbook Committee.- 5th printing, 1997.- [Metal Park]: ASM International, cop. 1989. [3] Krautkraemer, J., Krautkraemer. H.: Ultrasonic testing of materials.- 3rd ed.- Berlin: Springer-Verlag, 1983. [4] Proceedings of the World Conferences on Non-destructive Testing. [5] Journals on Non-Destructive Testing, e.g.: Nondestructive Testing and Evaluation, Materials Testing, Research in Nondestructive Evaluation.
306	**MACHINE TOOLS** Optimum ways in machine tool construction according to 3 E methodology (economical, ergonomic, esthetical). Defining and calculation of machine tool bases, machine tool housing in correlation to the machine tool requirements. The ways to find the solution for decreasing the noise in the stage of machine tool construction. Defining the slide ways and bearing system with their realization in correlation to machine tool requirements (rough machining, fine machining, and high precision machining). Sorts of drives and their usage in state of the art machine tools (AC, linear motors, etc.). Control of geometrical requirements

	and taking them into account when developing machine tool – product, statical and dynamical stiffness. Upgrade of basic theory of machine tool development with theory of sustainable development, and so in development of machine tool in parallel include ecology, safety, etc. Literature selection is in close correlation to the project research theme that is representing the core part of graduate study of the student and has to be therefore decided on an individual level. [1] J. Kopac, Obdelovalni stroji, orodja in naprave: modulna gradnja obdelovalnih strojev, Ljubljana: Fakulteta za strojništvo, 2005 [2] P. H. Joshi Machine Tools Handbook, McGraw-Hill Handbooks, 2007 [3] L.N. López de Lacalle and A. Lamikiz, Machine Tools for High Performance Machining, Springer, 2008 [4] Weck, M.: Werkzeugmaschinen, Fertigungssysteme.- Band 1,2.- Düsseldorf: VDI-Verlag, 1991 [5] Muren, H.: Elementi odrezovalnih strojev I+II.- Ljubljana: Fakulteta za strojništvo, 1991 [6] Šmarčan, P.: Obdelovalni stroji I.+II.- Maribor: Tehniška fakulteta, 1990 [7] Umformtechnik. Bd. 1, Grundlagen /ed. K. Lange.- 2., völlig neubearbeitete Aufl.- Berlin [etc.]: Springer, 1984 [8] Wagener, H.W.: Mechanische und Hydraulische Pressen.- Düsseldorf: VDI- Verlag,1992 [9] Milberg, J.: Werkzeugmaschinen – Grundlagen: Zerspantechnik, Dynamik, Baugruppen und Steuerungen.- Berlin [etc.]: Springer-Verlag, 1992 [10] Kalpakjian, S.: Manufacturing engineering and technology.- 3rd ed.- Reading [etc.]: Addison Wesley, cop. 1995 [11] Wright, P. K.: 21st century manufacturing.- Upper Saddle River: Prentice Hall, cop. 2001, Manufacturing excellence: the competitive edge / ed. by T. Pfeifer, W. Eversheim, W. Konig, M. Weck.- London [etc.]: Chapman & Hall, 1997 [12] Machine tool practices / Richard R. Kibbe, John E. Neely, Rolando O. Meyer, Warren T. White.- 6th ed.- Upper Saddle River, New Jersey: Prentice Hall, 1999, cop. 1979 [13] Lange, K.: Handbook on metal forming.- New York: McGraw- Hill, 1991 [14] CIRP Annals – Manufacturing Technology - Papers / SC Forming
307	**OPERATIONS RESEARCH** Basic notions. Real world problem, mathematical model, goal function, feasible and optimal solutions. Tractable and hard optimization problems. Linear programing. Dual program. Simplex method. Interior point methods. Applications. Relation with integer programing. Generalizations of linear programing. Stochastic programing. Dynamical programing. Optimization of nonlinear problems. Multicriterial optimization. Basic notions, goal function, optimality criteria. Additional chapters: desicison making with uncertainty and risk, matrix games, fuzzy logic… [1] Winston, W. L., 1994. Operations Research: Applications and algorithms, Duxbury, Belmont. [2] Figueira, J., Greco, S., Ehrgott, M., 2005. Multiple criteria decision analysis., Springer. [3] L. Zadnik-Stirn, Metode operacijskih raziskav za poslovno odločanje. Novo mesto: Visoka šola za upravljanje in poslovanje, 2001. [4] Bohanec, M., 2006. Odločanje in modeli. DMFA, Ljubljana. [5] Omladič, V., 2002, matematika in odločanje, DMFA, Ljubljana. [6] E. Kreyszig: Advanced Engineering Mathematics, (9th edition), Wiley, New York 2006. [7] J.Hromkovič: Algorithmics for Hard Problems, Introduction to Combinatorial Optimization, Randomization, Approximation, and Heuristics, 2nd ed., Springer, Berlin 2004.
308	**OPTIMIZATION OF MACHINING TECHNOLOGIES** Review, introduction and detailed analysis of different possible machining technologies, with their pros and cons, offering manufacturing/machining of different final products/parts. Analysis of significant input parameters in correspondence to requested part/product shape, workpiece material, extent of production series, demanded part/product quality, etc. Technological evaluation of chosen procedures and corresponding optimization of machining parameters. Determination of

	the optimization procedure, based on the optimization objectives and constraints (costs, time, sustainability, etc.) that are following from the final product specification. Presentation of global optimization procedure flow and its implementation in the sense of novel management technologies (available machine tool or possibilities investments into new equipment, assuring quality control (ISO 9000), sustainable development, etc. with the aim to increase the value of the final product and still minimize the influences on the environment and society. [1] A. Ravindran, K. M. Ragsdell, and G. V. Reklaitis, Engineering Optimization: methods and applications, Wiley, 2006 [2] D.C. Montgomery, Design and Analysis of Experiments, John Wiley & Sons, 2006 [3] Enrique del Castillo, Process Optimization: A Statistical Approach (International Series in Operations Research & Management Science), Springer, 2007 [4] Kopač, J.: Odrezavanje.- Ljubljana: Fakulteta za strojništvo, 1991 [5] Dolinšek, S., Kopač, J.: Odrezavanje: dopolnilno gradivo za predavanja in vaje.- Ljubljana: Fakulteta za strojništvo, 1992 [6] Kuzman, K., Pipan, J., Kampuš, Z.: Priporočila za načrtovanje tehnologij preoblikovanja.- Ponatis.- Ljubljana: Fakulteta za strojništvo, 2000 [7] Flexible manufacturing systems: past-present-future / ed. by J. Peklenik.- Ljubljana: Faculty of Mechanical Engineering, 1993 [8] Machine tool practices / Richard R. Kibbe, John E. Neely, Rolando O. Meyer, Warren T. White.- 6th ed.- Upper Saddle River, New Jersey: Prentice Hall, 1999, cop. 1979 [9] Manufacturing excellence: the competitive edge /ed. by T. Pfeifer … [et al.].- London [etc.]: Chapman & Hall, 1994 [10] Weck, M. and oth.: Wettberbsfaktor Produktionstechnik.- Düsseldorf: VDI Verlag, 1990 [11] König, W., Klocke, F.: Fertigungsverfahren. 1, Drehen, Fräsen, Bohren.- 5., überarb. Aufl.- Berlin [etc.]: Springer, cop.1997 [12] König, W., Klocke, F.: Fertigungsverfahren. Bd 2, Schleifen, Honen, Läppen.- 3., grundlegend neu bearb. und erw. Aufl. – Düsseldorf: VDI, cop. 1996 (Studium und Praxis) [13] König, W., Klocke, F.: Fertigungsverfahren. 3, Abtragen und Generieren.- 3., überarbeitete Aufl.- Berlin [etc.]: Springer, 1997
309	**NONCONVENTIONAL MACHINING PROCESSES** Development of combined and special machining processes with emphasis on micro-technologies. State and development of special machining technologies and corresponding machining systems in the world and the local environment. Determination of processes regarding the type of cutting energy. Analysis of energy models for mechanical, electrochemical, chemical and electrothermal machining processes. Influence on machining material due to processes of cutting and deposition. Study of specific events in micro and macro machining of products. Analysis of physical and chemical properties and technologic characteristics of special machining processes. Grinding in magnetic field, electrochemical grinding, ultrasonic machining, abrasive water jet machining, cutting with CO_2 laser, electron and ion beam machining, electro-discharge machining, chemical and electrochemical machining and lithography. Measuring methods and methods of identification of special machining processes, attributive description of process characteristics, methods of process parameters acquisition. Alternative technological design methods and optimization of technology in view of quality, economy, ecology and sustainable development. Application of acquired knowledge: in the context of the seminar work and practical exercises the student will apply acquired knowledge on an example with reference to his Ph.D. thesis. [1] Taniguchi, N.: Energy - beam processing of materials:advanced manufacturing using various energy sources.- Oxford: Clarendon Press (Oxford University Press), 1989 [2] Blatt, F.J.: Modern physics.- New York [etc.]: McGraw-Hill, Inc., 1992 [3] Han, M.Y.: The secret life of quanta.- Blue Ridge Summit, Pa: TAB Books, 1990 [4] Nanotechnology: research and perspectives: papers from the first foresight conference on nanotechnology, [held in Palo Alto, California in October 1989] / ed. by B.C. Crandall and J. Lewis.- Cambridge, Mass.; London, England: The MIT Press, 1992 [5] Reichl: Micro-system technologies 92.- Vde Verlag, 1992 [6] Condition - based maintenance and machine diagnostics / ed. John H. Williams, Alan Davies and Paul R. Drake.- London [etc.]: Chapman & Hall, 1994

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[8] Handbook of micro/nanotribology / ed. by B. Bhushan.- Boca Raton [etc.]: CRC Press, cop. 1995.- (Mechanical and materials science series; 1)
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[10] De Callatay, A.M.: Natural and artificial intelligence: misconceptions about brains and neural networks.- Amsterdam [etc.]: North-Holland: Elsevier Science Publ., 1992
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[12] Junkar, M; Nekonvencionalni postopki obdelave (skripta)

310 MACHINING PROCESSES

Theory and detailed analysis of machining process mechanisms and technologies. Mechanisms of chip formation in case of defined and undefined cutting tool geometry. Phenomena on the cutting tool edge and machined surface in accordance to cutting force trends, covering statical and dynamical states and influence of vibration on the machining process. Theory and analysis of machined surface integrity.
Research work on tool wear mechanisms, directions for cutting tool developments, cutting tool materials and machining performances of novel workpiece materials. Machining processes in combination (upgrade) with other technologies; fine/micro machining, high speed machining and sustainable machining.
Control of machining process based of process models (tool wear, machined surface integrity, cutting forces, chip formation and their shape, etc.) Sustainable development theory and its application on the machining processes with usage of novel technologies (cryogenic machining, high pressure assisted machining, etc.) Literature selection is in close correlation to the project research theme that is representing the core part of graduate study of the student and has to be therefore decided on an individual level.

[1] J. Kopac, Odrezavanje : teoretične osnove in tehnološki napotki, Ljubljana: Fakulteta za strojništvo, 2008
[2] W. Grzesik, Advanced Machining Processes of Metallic Materials: Theory, Modelling and Applications, Elsevier Science, 2008
[3] H. El-Hofy, Fundamentals of Machining Processes: Conventional and Nonconventional Processes, CRC, 2006
[4] Opitz, H.: Moderne Produktionstechnik.- 3.Aufl.- Essen: Verlag W.Girardet, 1971
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[7] Shaw, M. C.: Metal cutting principles.- [1st published].- Oxford: University Press, 1989. (Oxford series on advanced manufacturing;
[8] Kopač, J.: Odrezavanje.- Ljubljana: Fakulteta za strojništvo, 1991
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311 MATERIAL FORMING PROCESSES

Based on knowledge of materials and the mechanics of their forming, the study will upgraded into the direction of integral analysis and understanding of process and material parameters interrelations. The acquired knowledge will later enable technological improvements, definition of all needed parameters for tool design and forming production systems definition.
The study will be focused also on forming process design considering changes of specific characteristics of worked materials, impacts of heat flows and elastic system responses

	which could affect the quality of the final product. During studies students will utilize up to date commercially available tools for numerical modelling and forming process simulations. They will also have a possibility to perform laboratory experimental work on modern machines equipped with all needed sensors to control and monitor forming process. Finally they will have a possibility of getting additional information from partner industrial companies. Systematic evaluations and analyses of potential differences between experimental and numerically obtained results will be an excellent basis for deeper forming process understanding. [1] Gologranc, F.: **Preoblikovanje - I.del: Osnove**.- Ljubljana: Fakulteta za strojništvo, 1991 [2] Gologranc, F.: **Preoblikovanje – II. del: Masivno preoblikovanje**.- Ljubljana: Fakulteta za strojništvo, 1999 [3] Lange, K.: **Handbook on metal forming**.- New York: McGraw- Hill, 1991 [4] Hosford, E.,W., Cadell, R.,M.: **Metal Forming – Mechanics and Metalurgy**, Cambridge University Press, 2007 [5] CIRP Annals – **Manufacturing Technology - Papers / SC Forming** [6] Campbell, F.C.: **Manufacturing Processes For Advanced Composites**. Elsevier Advanced Technology, Oxford 2004 [7] Rosato, D., V., Rosato, V., Rosato, M., G.: **Injection Molding Handbook**. Kluwer Academic Publisher Boston 2000.
312	**WELDING PROCESSES** Physical, chemical, and metallurgical phenomena of welding and welding related processes and processes of joining and thermal cutting. Analysis of welding arc, plasma arc, electron beam and beam of light, thermal, mechanical and chemical energy. Thermal phenomena of welding and welding related processes and processes of thermal cutting of metals and nonmetals. Overview of the arc welding processes, processes of welding with a chemical and mechanical energy, the energy of light, and the other processes of the material joining. Consumable materials and the compatibility of consumable and base material. The formation of weld or welding joint. Weldability and welding of metals and alloys, the relationships between composition and material properties of weld or welding joint, thermal welding cycle in connection with properties of welded construction. Shielding medium of arc and weld bead (gasses, gas mixtures and powders). Key-hole effect, Marangony effect. The analysis of residual stresses and deformations and their suppress in welding joints and in all the constriction. Mathematical modeling of processes during welding. Quality assurance and control of welding joints, attesting of welding personnel, certification of processes, products and systems. [1] Brazing handbook / prepared by AWS Committee on Brazing and Soldering.- 4th ed.- Miami: American Welding Society, 1991 [2] Welding handbook. Vol. 3, Materials and applications. Part 1 / editor William R. Oates.- 8th ed.- Miami: American welding society, 1996 [3] Ninth Edition, Volumen 1, Welding Science and Technology; Welding Handbook AWS 550 N. W. Lejeeune road Miami FL 33126, 2006 [4] Ninth Edition, Volumen 2, Welding Processes Part 1; Welding Handbook AWS 550 N. W. Lejeeune road Miami FL 33126, 2006 [5] N. N.: Ninth Edition, Volumen 3, Welding Processes Part 2; Welding Handbook AWS 550 N. W. Lejeeune road Miami FL 33126, 2008 [6] Mohler, R.: Practical Welding Technology, Industrial pressinc, 200 Madison Avenue, New York, 2006 [7] Steen, W.M.: Laser material welding.- 2nd ed.- London, 1998 [8] Marfels, W.: Der Lichtbogenschweißer: Leitfaden für Ausbildung und Praxis / Marfels, Orth.- 9.- überarbeitete und erweiterte Aufl.- Düsseldorf: DVS-Verlag, 1997 (Die schwiesstechnische Praxis; Band 2, [9] Ceramic to metal joining: 250 references from the METADEX database / prepared by the editors of Materials Information in cooperation with ASM Information; Bethesda, MD: Cambridge Scientific Abstracts, [2000].- (Search-in-print report; C 501) [10] Welding of aluminium: 250 references from the METADEX database / prepared by the editors of Materials Information in cooperation with ASM International & the Institute of Materials.- London: Materials Information; Bethesda, MD: Cambridge

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313	**COMPUTER INTEGRATED MANUFACTURING AND WORK SYSTEMS CIM/FMS** Development of manufacturing, information and communication technologies. New manufacturing paradigms (Holonic, biological , fractal and complex adaptive systems). Structural and operational complexity of manufacturing systems. Cybernetic structuring. System modeling. Digital factory. Distributed manufacturing systems. Manufacturing systems building blocks: autonomous work systems, elementary work systems. Computer integrated manufacturing systems. Principles of integration E-(lectronic) manufacturing, U-(biquitous) manufacturing. Interoperability. Workshop information system. Manufacturing execution (MES) and supervisory control and data acquisition (SCADA) systems. Data and knowledge bases. Grup technology. Automation, process design and optimization of manufacturing processes. Programming of work systems. Virtualization of processes and systems. Mechatronic manufacturing systems. Design of controllers for CNC, AC and CIM. Mini and microprocessors as control modules. On-line process identification and adaptive control. Modular design of systems. Reconfigurable manufacturing systems. Stability of dimensional and shape accuracy and surface roughness. Tool management systems. Clamping systems. Integration and automation of material flows and logistic functions in manufacturing. Automation of measuring processes. Testing systems. [1] Bedworth, D. D., Henderson, M. R., Wolfe, P. M.: Computer-integrated design and manufacturing.- McGraw-Hill, 1991 [2] Bjorke O., Manufacturing systems theory. Tapir Publishers, 1995 [3] Bollinger, J. G., Duffie, N. A.: Computer control of machines and processes.- Addison-Wesley Publishing Company, 1988 [4] Boothroyd, K., Dewhernst: Design for assembly [5] CIRP Manufacturing Systems Conferences proceedings (yearly) (different publishers), Current volumes. [6] CIRP annals. Elsevier. Current volumes. [7] Chryssolouris, G.: Manufacturing systems, Springer Verlag, 1992 [8] Daschenko A. (Ed.), Manufacturing technologies for machines of the future. Springer, 2003 [9] Foston, A. L., Smith, C. L., An, T.: Fundamentals of computer integrated manufacturing.- Prentice Hall, 1991 [10] Ham, I., Hitomi, K., Yoshica, T.: Group technology: applications to production.- Klunier-Nijhoff Publishing, 1985 [11] International Workshops on Emergent Synthesis IWES [12] Koren Y.: Computer control of manufacturing systems, 3rd edition, McGraw Hill, 1986 [13] Peklenik, J.: Manufacturing systems evolution: selected papers / Janez Peklenik; Ljubljana: Faculty of Mechanical Engineering, 1996
314	**QUALITY SYSTEMS** A System aspect to quality: Product and market. Motivation and customer behaviour. Definitions of quality. Attributes of quality. Quality as a value. Concepts of quality management. Quality model. Basic characteristics of the model, Quality control. A product value. Generic product specifications. Assessmet of functional values. A multi-attribute quality model of a product. Functional structuring of a quality in a manufacturing enterprise: A methodology of strategic quality deployment. A taxonomy of quality characteristics. Performance measures of manufacturing structures and their elements. Quality design on system level. Parameter and tolerance design. Quality and cost control. Quality assurance on production level: Methods for quality design and control. Techniques for process improvement. Computer-aided quality management system in an enterprise. [1] Cook, H.E.: Product Management - Value, quality, cost, price, Profit and organization, Kluwer Academic Publishers, 1997. [2] Phadke, M.S.: Quality engineering using robust design, Prentice-Hall International, 1989.

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315	**SYSTEMS OF PRODUCTION PLANNING AND CONTROL** Strategies of production planning and control. Real flow time of operation and order as the basis for realistic production planning and control. Project production planning and control, MRPI and MRPII system planning and control of production, OPT - bottlenecks system, BORA - launching system of work orders in relation to the load, the system progressive numbers, Kanban system. Strategy: KAIZEN, lean production, Just in Time production. Overview of computer-based commercial systems for production planning and control. Three phase concept selection and introduction of computerized commercial system for production planning and control (preparation, selection and introduction of the system). [1] M. L Pinedo: **Planning and Scheduling in Manufacturing and Services**, Springer, 2007. [2] S. Shigeo: **Non-stock Production: The Shingo System of Continuos Improve**ment, Productivity Press, 2006. [3] H.P.Wiendahl**: Belastungsorientierte Fertigungssteuerung.-** München: C. Hanser, 1987 [4] J. Haizer, B. Render: **Operations Management**, 7th edition, Prentice Hall, Upper Saddle River**,** 2005. [5] J Fandel, G., Francois, P., Gubitz, K.M.: **PPS – und integrierte betriebliche Softwaresysteme:** Grundlagen, Methoden, Marktanalyse.- 2., völlig neu bearbeitete und erweiterte Aufl.- Berlin [etc.]: Springer, 1997
316	**CONCURRENT ENGINEERING** The lifetime cycle of the product, organizational structure, re-engineering of business processes and systems engineering. Definition of concurrent engineering and the transition from sequential to concurrent engineering. Concurrent engineering strategy: parallelism, standardization and integration. The process of concurrent product and process development: the composition of teams of concurrent product and process development in large and small company, determine the number of team members with the team roles test (Belbin's test). The transfer of information between the activities of the concurrent product and process development and design of loops of concurrent product and process development. Objectives and tools of concurrent engineering: the development of the functions of quality, design methodology, analysis of the value, usefulness and quality, design for manufacturing, assembly and disassembly, analysis of possible errors and their effects. Construction of combined computerized systems for a comprehensive evaluation of products, machinery and tools, and the search for optimal technological path. The integrated information system to support the implementation of concurrent engineering. The project approach in the concurrent product and process development. [1] Biren Prasad: **Concurrent Engineering Fundamentals**, Volume I, Prentice Hall PTR, 1996 [2] Biren Prasad: **Concurrent Engineering Fundamentals**, Volume II, Prentice Hall PTR, 1997. [3] Michel Fleischer, Jeffrey K. Liker: **Concurrent Engineering Effectiveness: Integrating Product Development Across Organisation,** Hanser Gardner Publishings, 1997. [4] W. Eversheim, W. Bochtler, L. Laufenberg: **Simultaneus Engineering**, Springer Verlag, 1995 [5] Starbek, Marko, Grum, Janez, Brezovar, Aleš, Kušar, Janez. T**echniques and analyses of sequential and concurrent product development processes**. V: LEONDES, Cornelius T. (ur.). *Intelligent knowledge-based systems : business and technology in the new millennium. Vol. 2, Information technology*. Kluwer Academic,

	2005, str. 123-176.
317	**INTELLIGENT HANDLING AND ASSEMBLY SYSTEMS** Handling and assembly (H&A) processes and systems (a review of technologies, tasks and basic concepts of (H&A) processes and systems, planning and evaluation of(H&A)systems). Assembly operations, sequence of assembly operations as a basis for defining the assembly process. Presentation of assemled part and assembly operations in the development and design and the creation of a database for computer-aided design of assemly systems. The design of products and simultaneous engineering. Automated handling and assembly systems: - Flexible automation of handling and assembly. - The modular design of the (H&A). Robotized handling and assembly systems: - Robots in handling and assembly. - Robotic assembly cells. - Robotic assembly line. - Flexible grippers in robotized (H&A) systems. Product design for automated and robotised handling and assembly and simultaneous development of products and (H&A)systems. Sensors and actuators in (H&A) systems: - Tactile and non-tactile sensors in the (H&A) system. - Machine vision in the (H&A) sitemi. - Intelligent sensors and actuators in the (H&A) system. The definition of intelligent handling and assembly systems: - Types of intelligent devices and systems. - Concepts of intelligent (H&A)systems. - The mastering of product variants in the process of assembly and handling. Intelligent handling and assembly (H&A) systems: - Hardware and software in the (H&A) system. - Artificial Intelligence in the (H&A) system. Planning of handling and assembly systems: - Computer-aided design of H&A systems with using the methods of simulation in the process of planning and analysis. - Modeling, simulation and optimization of H&A systems and equipment. - Resources and integration of storage and production. Low-cost intelligent hanling and assembly systems: - Handling and assembly systems in small and medium-sized enterprises. - The role of simple automation in a synchronous production systems. - Simple automation in handling and assembly. - Simple automation in the flow of semi-products, products and assembled parts and in the storage of finished products. - Pokayoke and use of simple sensors in the process of assembly and handling. Quality assurance and control in the process of handling and assembly. [1] Boothroyd, G.: Assembly Automation and Product Design, Second edition, CRC Press, 2005. [2] Herakovič, N., Noe, D.: Strežni in montažni procesi ter sistemi, Učno gradivo, FS, 2009 (v nastajanju). [3] Takeda, H.: LCIA – Low Cost Intelligent Automation – produktivitätsvorteile durch Einfachautomatisierung, Mi-Fachverlag, 2006. [4] Gemeinschaftsausschuss CIM: Rechnerintegrierte Konstruktion und Produktion, Band 8: Flexible Montage, VDI verlag, 1992. [5] Intelligent Assembly Systems, 1995, World Scientific, Edditors: M.H. Lee and J.J. Rowland. [6] S.Y. Nof, W.E. Wilhelm, H.-J. Warnecke, Industrial Assembly, Chapman & Hall, London, 1997. [7] P.K. Wright, D.A. Bourne, Manufacturing Intelligence, Addison-Wessley, 1988. [8] H.K. Rampersad, Integrated and Simultaneous Design for Robotic Assembly, John Wiley & Sons, Inc. New York, NY, USA, 1994.

318	**HEAT TREATMENT AND SURFACE TREATMENT OF MATERIALS** Basic physical, chemical and metallurgical concepts of heat treatments and thermo-chemical treatments of surface treatments. Diffusion, diffusion laws, diffusion mechanisms, activation energy, Kirkendall effect, influences on diffusivity. Solidification of metals, thermodynamics and kinetics of crystallization, forming of nucleus, critical nucleus size, nature of solidification. Standard processes of heat treatment, residual stresses, deformation of a sample during and after the heat treatment, atmosphere in a furnace, controlled protection atmosphere and active atmosphere, control of atmosphere in a furnace, theoretical basics of metal quenching, modeling of heat conditions during heating and quenching, model testing. New processes for heat treatment using different forms of energy: heat, electrics, laser beam and combined forms. Influencing parameters at individual processes. Surface treatment: plasma nitriding, plasma carbonitriding, ion implantation, chemical vapor deposition (CVD), physical vapor deposition (PVD), diamond coatings, Toyota procedure of diffusion coating deposition, surface modification using laser and electronic beam. Vacuum heat treatment, heat treatment in fluidized bed, vacuum furnaces, quenching media and procedures. Thermo-mechanical treatment of ferrous and non-ferrous alloys with and without polymorphic transformations, planning and optimization of thermo-mechanical treatment. Theory of plastic deformation of metals, theory of relaxation and relaxation at elevated temperatures. [1] Steel Heat Treatment Handbook, 2nd edition, Eds.: George E. Totten, M.A.H. Maurice; Marcel Dekker Inc, New York, 1997. [2] Chryssolouris, G.: Laser machining: theory and practice.- New York; Berlin: Springer-Verlag, 1991.- (Mechanical engineering series). [3] Steen, W.M.: Laser material processing.- London; Berlin: Springer-Verlag, 1991. [4] Advanced surface coatings: a handbook of surface engineering / ed. by D.S. Rickerby and A. Matthews.- Glasgow; London: Blackie & Son; New York: Chapman and Hall, 1991. [5] Selected journals: Materials science and engineering.- Heat treatment of metals.- Surface science.- Materials science forum surface engineering.- HTM: Härterei-Technische Mitteilungen.- Metal heat treating.
319	**WELDING, CUTTING AND SURFACING WITH HIGH ENERGY DENSITY** Physical, chemical and metallurgical phenomena of welding and cutting with a high energy density (electric arc, electron and laser beam, plasma arc). The theory of thermal cutting and welding with electric arc, plasma arc, the electron beam and the beam of light. Key-hole effect, Marangony effect. Metallurgical and technical phenomena in weld and cut. Technologies, machines and apparatus or systems for welding and cutting with plasma arc, the electron beam and laser beam. Basic materials and consumables, influential parameters in the welding processes. Combined welding processes (hybrid welding) and cutting with the high energy density. Status and trends of developments in welding and cutting processes with a high energy density. The theory of regeneration and processing of surface layers with surfacing and metallization. The suitability of consumable materials for a particular base material in the reconstruction of worn-out mechanical elements. The devices and systems. Status and trends of development. Physical, chemical and metallurgical processes basics of processing of protective surface layers using different surfacing and metallization processes. Electro-spark surfacing, laser beam surfacing, electron beam, plasma arc, and surfacing at room temperatures. Surface layers heat treatment. Opportunities and advantages of combining the various processes for surface renewal at the maintenance and construction of the new tools and wear loaded mechanical elements. [1] Boxman, R.L.: Handbook of vacuum, arc science and technology, Noyes Publication, Park Ridge, New Jersey, ZDA, 1995 [2] The Physics of welding /ed. by J.F. Lancaster.- 1st ed.- Oxford [et al.]: Pergamon Press, 1986. [3] Ninth Edition, Volumen 1, Welding Science and Technology; Welding Handbook AWS 550 N. W. Lejeeune road Miami FL 33126, 2006

	[4] Ninth Edition, Volumen 2, Welding Processes Part 1; Welding Handbook AWS 550 N. W. Lejeeune road Miami FL 33126, 2006 [5] N. N.: Ninth Edition, Volumen 3, Welding Processes Part 2; Welding Handbook AWS 550 N. W. Lejeeune road Miami FL 33126, 2008 [6] Mohler, R.: Practical Welding Technology, Industrial pressinc, 200 Madison Avenue, New York, 2006 [7] Steen, W.M.: Laser material welding.- 2nd ed.- London, 1998 [8] Marfels, W.: Der Lichtbogenschweißer: Leitfaden für Ausbildung und Praxis / Marfels, Orth.- 9.- überarbeitete und erweiterte Aufl.- Düsseldorf: DVS-Verlag, 1997 (Die schwiesstechnische Praxis; Band 2, [9] Schultz, H.: Elektronenstrahlschweißen.- 2., vollständig überarb. und erw. Aufl.- Düsseldorf: DVS-Verlag, 2000 (Fachbuchreihe Schweisstechnik; Bd. 93) [10] Welding of aluminium: 250 references from the METADEX database / prepared by the editors of Materials Information in cooperation with ASM International & the Institute of Materials.- London: Materials Information; Bethesda, MD: Cambridge Scientific Abstracts, [2005].- (Search-in-print report; ALU006) [11] Welding of dissimilar metals: 250 references from the METADEX database / prepared by the editors of Materials Information in cooperation with ASM International & the Institute of Welding.
019	**APPLIED STATISTICS FOR ENGINEERS** Introduction to engineering statistics: importance and role of statistical analysis in engineering, important statistics, probability distributions of statistics; point estimators; methods of determining estimators; confidence intervals; statistical hypothesis, tests and inference; inference errors; goodness of fit tests, independence and homogeneity test; analysis of variance. Alternative statistical methods: nonparametric statistics, bootstrap statistical methods, methods of robust statistics. Function estimatiors and empirical modeling: parametric regression, simple and multiple linear regression, nonlinear regression, nonparametric regression. Stohastic processes: stationarity and ergodicity, moments and processes characteristics, autocorrelation function, spectral density, non-linear and advanced methods of analysis and characterization of stochastic processes, ARMA and ARIMA processes, empirical modeling and forecasting of processes. [1] I. Grabec, J. Gradišek: Naključni pojavi; Fakulteta za strojništvo, 2000; [2] E. Govekar. Naključni pojavi: elektronski zapiski in interaktivni učbenik. Ljubljana: Fakulteta za strojništvo, 2005. http://lab.fs.uni-lj.si/lasin/www/teaching/np/predavanja.htm [3] L. Wasserman; All of Statistics, A concise Course in Statistical Inference, Springer, 2004 [3] D. C. Montgomery in G. C. Runger: Applied Statistics and Probability for Engineers, John Wiley & Sons, Inc., New York, 1994. [4] P.J.Huber, E. M. Ronchetti; Robust Statistics, Second Edition, John Wiley, 2009 [5] A.C. Davison, D.V.Hinkley: Bootsrap Methods and their Applications. Cambridge University Press 2009. [4] P. J. Brockwell: Introduction to Time Series and Forecasting, Second Edition, Springer, 2002 [5] T. Masters; Advanced algorithms for neural networks, John Willey & Sons (1991)
116	**PRODUCT DATA MANAGEMENT SYSTEM** An overview of building blocks and a structure of product data management systems (PDM/PLM), the role in a manufacturing company and virtual project team. Production information system. Product or service as a carrier of the process. Methods to analyse information flows: function diagrams IDEF0, ARIS model, organisation structure model, document flow, department – time diagram, model of communication, simulation of processes, Petri nets. Modelling of an enterprise, product data and processes with E/R diagrams, EXPRESS language, object models. Data models for engineering: STEP standard for exchange of product data from conceptual design to manufacturing and maintenance. Product data model or service through the whole life-cycle. Product and process data

	identification and generation in the manufacturing process. Functionality of production information systems (ERP). Functionality of product data management systems (PDM/PLM). Overview of the modules in the PDM/PLM systems: documents management, natural classification, development phases of building blocks and documents, information and documents flow, bill of materials: variant, structural, modular, integration with CAD/CAM tools, integration with project management. Data security background: backups, access control, security in the Internet, user identification. Long-term data archiving, legislation requests, standards (EDI, SGML). PDM/PLM systems as knowledge database and as backbone for virtual product development teams. Reference examples for different type of production: mass, serial or individual. Reference models for key processes: engineering change management, technical documentation management, system documentation. Procedure of applying of product data management systems to manufacturing enterprise or to support virtual product development teams. [1] Rude S.: Wissenbasiertes Konstruieren, Shaker Verlag, Aachen, 1998 [2] Prasad B.: Concurrent Engineering Fundamentals, Vol. I Integrated product and process, Prentice Hall 1996 [3] Stefan Brandner, Markus Kelch, Helmut Stengele, Martin Eigner, Alexander Suhm, Gunther Reinhart,: EDM Engineering Data Management, Seminarberichte, IWB, 1996 [4] August- Wilhelm Scheer: ARIS - Architecture and Reference Models for Business Process Management, Springer 2000 [5] Stark, J.: Engineering information management systems: beyond CAD/CAM to concurrent engineering support.- New York: Van Nostrand Reinhold, 1992.- (Automation in manufacturing series)