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Guide to Research

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Uvodna misel / Introductory Thought

Pričujoč raziskovalni vodnik podaja posodobljene informacije o zelo razvejani raziskovalni dejavnosti Fakultete za strojništvo Univerze v Mariboru, s katero pa ne tlakujemo le poti izobraževalni dejavnosti na fakulteti, temveč v največji možni meri izpolnjujemo tudi fakultetno poslanstvo, biti razpoznavna, raziskovalno in izobraževalno odlična tehniška fakulteta. Če želimo izobraževati inženirje, ki bodo soustvarjali našo skupno prihodnost, kar je nenazadnje tudi slogan fakultete, potem tega preprosto ne moremo početi brez raziskovanja, ustvarjanja novih znanj, ki jih prenašamo na naše študente. Le tako bodo namreč naši diplomanti kos izzivom sodobnega časa, ki se spreminjajo tako rekoč iz dneva v dan. Tega se zavedamo in zato na Fakulteti za strojništvo Univerze v Mariboru s povezovanjem kakovostnega znanstveno-raziskovalnega, strokovnega in izobraževalnega dela na področju inženirskih ved prispevamo k razvoju znanosti ter k tehnološkemu napredku gospodarstva in družbenega okolja. Pri tem so najvišje vrednote našega delovanja, ki smo jih zapisali tudi v fakultetni kodeks etike raziskovanja in objavljanja, naslednje:

- odličnost, avtonomija in odprtost raziskovalnega in izobraževalnega dela;
- poštenost, iskrenost, profesionalna etika in družbena odgovornost pri raziskovanju in izobraževanju;
- usmerjenost raziskovanja in izobraževanja v dobrobit človeštva in ustvarjanje vključujoče družbe.

Imamo odlične mednarodno priznane raziskovalce, ki z rezultati svojega dela fakulteto uvrščajo v sam vrh med članicami Univerze v Mariboru. V skladu s priporočili Evropske komisije si fakulteta prizadeva razvijati in vzdrževati spodbudno raziskovalno okolje in delovno kulturo, kjer so posamezniki in raziskovalne skupine spoštovani in deležni spodbud in podpore.

Z znanstvenoraziskovalno dejavnostjo se fakulteta aktivno vključuje v reševanje aktualnih družbenih problemov in skrbi za prenos in izmenjavo znanja v domačem in evropskem prostoru.

red. prof. dr. Simona Strnad
Prodekanja za raziskovalno dejavnost

red. prof. dr. Bojan Dolšak
Dekan

The present research guide provides up-to-date information about the highly diversified research activities of the Faculty of Mechanical Engineering, University of Maribor, which not only paves the way for teaching at the Faculty, but also fulfils the Faculty's mission to the greatest extent possible, to be an outstanding research and pedagogically excellent technical faculty. If we want to educate engineers who will help shape our common future, as is the motto of our Faculty, then we simply cannot do it without research, creating new knowledge that we pass on to our students. This is the only way our graduates will be able to cope with the challenges of modern times, which are changing almost daily. We are aware of this and that is why we at the Faculty of Mechanical Engineering, University of Maribor contribute to the scientific and technological advancement of economy and society by combining high quality scientific research with professional and educational work in the field of engineering sciences. In doing so, the highest values of our activities, which we have also written down in the ethical code for research and publication at the Faculty, are the following:

- *excellence, autonomy and openness of research and educational work;*
- *honesty, sincerity, professional ethics and social responsibility of the research and education;*
- *orientation of research and education towards welfare of humanity and creation of inclusive society.*

We have excellent internationally recognised researchers, whose work makes our faculty one of the top most successful faculties of the University of Maribor. In accordance with the European commission recommendations, we strive to develop and maintain a supportive research environment and work culture, where the researchers and research groups are respected, stimulated and supported.

Through its scientific and development research work, the faculty is actively involved in solving the current societal challenges, and takes care of the knowledge transfer in domestic and European space.

Prof. Dr. Simona Strnad
Vice Dean for Research

Prof. Dr. Bojan Dolšak
Dean

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Research and Innovation Centre for Design and Clothing Science

Kratka zgodovina / Brief History

Začetki dejavnosti Fakultete za strojništvo Univerze v Mariboru (FS Maribor) segajo v leto 1959, ko je 26.11. Ljudska skupščina RS sprejela Zakon o ustanovitvi Višje tehniške šole v Mariboru. Ustanovljeni so bili oddelki za strojništvo, tekstil in elektrotehniko. Oddelek za tekstilno tehnologijo je ostal integralni del fakultete vse do danes.

Leta 1973 se je Višja tehniška šola razvila v Visoko šolo, in njen najštevilnejši oddelek, to je Oddelek za strojništvo, je pričel z izvajanjem štiriletnega študijskega programa. Na strojništvu smo prvi pričeli s podiplomskim študijem in podelili prve magisterije in doktorate leta 1976.

Leta 1975 je Visoka tehniška šola postala članica novo ustanovljene Univerze v Mariboru in se po desetih letih razvila v Tehniško fakulteto, pri čemer je Oddelek za strojništvo postal eden od štirih oddelkov Tehniške fakultete s programi strojništva in tekstilnega inženirstva.

Do leta 1995 se je Tehniška fakulteta razširila do te mere, da se je preoblikovala v štiri fakultete (Fakulteta za strojništvo z oddelkom za tekstilstvo, Fakulteta za gradbeništvo, Fakulteta za računalništvo in informatiko ter Fakulteta za kemijo in kemijsko tehnologijo).

Danes na Fakulteti za strojništvo s povezovanjem kakovostnega znanstvenoraziskovalnega, strokovnega in izobraževalnega dela na področju inženirskih ved prispevamo k razvoju znanosti ter k tehnološkemu napredku gospodarstva in družbenega okolja. Pri tem so najvišje vrednote našega delovanja:

- odličnost, avtonomija in odprtost raziskovalnega in izobraževalnega dela;
- poštenost, iskrenost, profesionalna etika in družbena odgovornost pri raziskovanju in izobraževanju;
- usmerjenost raziskovanja in izobraževanja v dobrobit človeštva in ustvarjanje vključujoče družbe.

The beginnings of Faculty of Mechanical Engineering (FS Maribor) go back as far as 1959. In that very same year the Departments of Mechanical Engineering and Textile Technology at the College of Engineering and Technology opened their doors to students. The Textile Technology Department joined the Mechanical Engineering Department ten years later and has remained a constituent part ever since.

In 1973 the College of Engineering and Technology evolved into the Institution of Higher Education, and its strongest department, i.e. the Department of Mechanical Engineering, started to enrol students into four-year study courses. This department was also the first to introduce postgraduate study courses and began conferring M.Sc. and Ph.D. degrees in 1976.

In 1975 the Institution of Higher Education became a member of the newly founded University of Maribor and over ten years evolved into the Faculty of Technical Sciences. From this date onwards the Department of Mechanical Engineering became one of the four constituent departments of the Faculty of Technical Sciences, offering courses in Mechanical and Textile Engineering.

Until 1995 the Faculty of Technical Sciences grew so much that it was reorganised into four respective faculties (Mechanical and Textile Engineering, Civil Engineering, Chemical Engineering and Electrical Engineering).

Today our mission at the Faculty of Mechanical Engineering, University of Maribor is to contribute to the scientific and technological development of economy and society, through linking high quality scientific research work with professional and educational work in the fields of engineering sciences. The highest values of our activities are:

- *excellence, autonomy and openness of research and educational work;*
- *honesty, sincerity, professional ethics and social responsibility of the research and education;*
- *orientation of research and education towards welfare of humanity and creation of inclusive society.*

Organizacija / Organization

Na fakulteti deluje sedem kateder in dva inštituta (slika 1). Katedre so odgovorne za akademsko in izobraževalno dejavnost na svojih področjih delovanja:

- Katedra za proizvodno strojništvo,
- Katedra za energetsko, procesno in okoljsko inženirstvo,
- Katedra za konstruiranje in oblikovanje,
- Katedra za materiale in preoblikovanje,
- Katedra za tekstilne materiale in oblikovanje,
- Katedra za mehaniko,
- Katedra za temeljne in splošne predmete.

Raziskave in razvoj potekajo v okviru dveh inštitutov:

- Raziskovalni inštitut za strojništvo (29 laboratorijev in 2 centra),
- Inštitut za inženirske materiale in oblikovanje (7 laboratorijev in 3 centri).

Inštituta sestavlja več dobro opremljenih laboratorijev in raziskovalnih skupin. Vsako katedro ali inštitut vodi habilitirani učitelj, ki je odgovoren za delovanje in visok nivo akademske in strokovne usposobljenosti svojih članov.

The Faculty has seven Chairs and two Institutes (see Figure 1). The Chairs are responsible for academic and study related matters within their respective fields of expertise:

- *Chair of Production Engineering,*
- *Chair of Power, Process and Environmental Engineering,*
- *Chair of Structures and Design,*
- *Chair of Materials and Forming,*
- *Chair of Textile Materials and Design,*
- *Chair of Mechanics,*
- *Chair of Fundamental and General Subjects.*

The Research and Development (R&D) activities are carried out in two Institutes:

- *Mechanical Engineering Research Institute (29 laboratories and 2 centres),*
- *Institute of Engineering Materials and Design (7 laboratories and 3 centres).*

The Institutes are further divided into several well-equipped laboratories or research groups. Each Chair and Institute is chaired by professor, who is responsible for its operation and the required high level of academic and professional conduct of its members.

Dekan: red. prof. dr. Bojan Dolšak

Prodekan za izobraževalno dejavnost:	izr. prof. dr. Janez KRAMBERGER
Prodekanja za raziskovalno dejavnost:	red. prof. dr. Simona STRNAD
Prodekan za infrastrukturo in sodelovanje z okoljem:	red. prof. dr. Iztok PALČIČ
Prodekanja za kakovost:	red. prof. dr. Tatjana KREŽE
Prodekan za študentska vprašanja:	Jani HUMAR

- KATEDRA ZA ENERGETSKO, PROCESNO IN OKOLJSKO INŽENIRSTVO
- KATEDRA ZA INŽENIRSKE MATERIALE IN OBLIKOVANJE
- KATEDRA ZA KONSTRUIRANJE IN OBLIKOVANJE
- KATEDRA ZA MATERIALE IN PREOBLIKOVANJE
- KATEDRA ZA MEHANIKO
- KATEDRA ZA PROIZVODNO STROJNIŠTVO
- KATEDRA ZA TEMELJNE IN SPLOŠNE PREDMETE

- RAZISKOVALNI INŠTITUT ZA STROJNIŠTVO
- INŠTITUT ZA INŽENIRSKE MATERIALE IN OBLIKOVANJE

Slika 1: Organizacijska shema Fakultete za strojništvo.

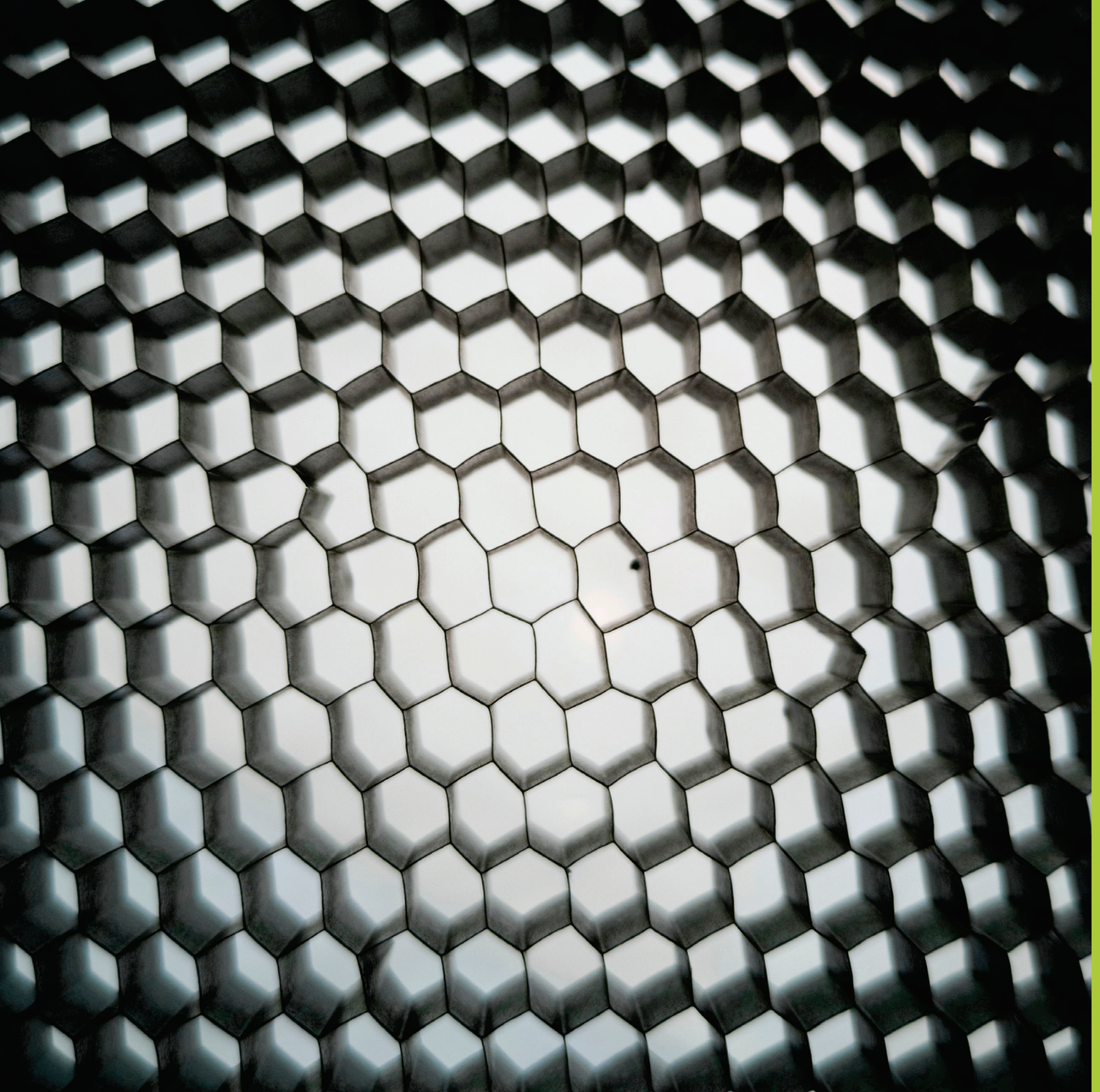
Dean: Prof. Dr. Bojan Dolšak

Vice-Dean for Studies:	Assoc. Prof. Dr. Janez KRAMBERGER
Vice-Dean for R&D:	Prof. Dr. Simona STRNAD
Vice-Dean for Infrastructure and Cooperation with Industry	Prof. Dr. Iztok PALČIČ
Vice-Dean for Quality:	Prof. Dr. Tatjana KREŽE
Vice-Dean for Students Issues:	Jani HUMAR

- CHAIR OF POWER, PROCESS AND ENVIRONMENTAL ENGINEERING
- CHAIR OF TEXTILE MATERIALS AND DESIGN
- CHAIR OF STRUCTURES AND DESIGN
- CHAIR OF MATERIALS AND FORMINGE
- CHAIR OF MECHANICS
- CHAIR OF PRODUCTION ENGINEERING
- CHAIR OF FUNDAMENTAL AND GENERAL SUBJECTS

- MECHANICAL ENGINEERING RESEARCH INSTITUTE
- INSTITUTE OF ENGINEERING MATERIALS AND DESIGN

Figure 1: Organisational chart of the Faculty of Mechanical Engineering.



1 Raziskovalni inštitut za strojništvo

Mechanical Engineering Research Institute

Predstojnik inštituta: red. prof. dr. Jure Ravnik
Head of the Institute: *Prof. Dr. Jure Ravnik*
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PODROČJA RAZISKAV	***FIELDS OF RESEARCH***
Proizvodno strojništvo	*Production engineering*
Energetsko, procesno in okoljsko inženirstvo	*Power, process and environmental engineering*
Konstruiranje in oblikovanje	*Structures and design*
Materiali in tehnologije	*Material technology*
Mehanika	*Mechanics*

Proizvodno strojništvo

Production Engineering

LABORATORIJI / *LABORATORIES*	VODJA / *HEAD*
Laboratorij za prilagodljive obdelovalne sisteme *Laboratory for Flexible Manufacturing Systems*	Ivan Pahole
Laboratorij za tehnološke meritve *Laboratory for Production Measurement*	Bojan Ačko
Laboratorij za inteligentne obdelovalne sisteme *Laboratory for Intelligent Manufacturing Systems*	Mirko Ficko
Laboratorij za mehatroniko *Laboratory for Mechatronics*	Uroš Župerl
Laboratorij za odrezavanje *Laboratory for Machining Processes*	Simon Klančnik
Laboratorij za načrtovanje proizvodnih sistemov *Laboratory for Production and Operation Management*	Borut Buchmeister
Laboratorij za simulacije diskretnih sistemov *Laboratory for Discrete System Simulation*	Borut Buchmeister
Laboratorij za oljno hidravliko *Laboratory for Oil Hydraulics*	Darko Lovrec
Laboratorij za robotizacijo *Laboratory for Robotisation*	Karl Gotlih
Laboratorij za dodajalno izdelavo *Laboratory for Additive Manufacturing*	Igor Drstvenšek

1.1 Laboratorij za prilagodljive obdelovalne sisteme

Laboratory for Flexible Manufacturing Systems

Laboratorij se ukvarja s praktično uporabo obdelovalnih strojev in naprav v sodobni proizvodnji. Raziskave in razvojno delo je osredotočeno na: izdelavo orodij in naprav po lastnih načrtih, izdelavo prototipov, testiranje obstojnosti rezalnih orodij, testiranje obdelovalnosti materialov in pripravo novih tehnoloških rešitev. V laboratoriju tudi izdelujemo prototipe in nestandardne izdelke v manjših serijah, med drugim izvajamo tudi tečaje funkcionalnega in dodatnega izobraževanja na področju sodobnih obdelovalnih tehnologij.

This laboratory is concerned with practical use of machine tools and devices in modern industry. Research and development work is concentrated on the following activities: manufacturing of tools and devices according to own design documentation, manufacturing of product prototypes, endurance testing of cutting tools, testing of materials' machining ability and the development of new technological solutions. The laboratory also provides the following services for customers: manufacturing of product prototypes and non-standard products, small-scale services primarily on conventional machine tools, functional training and additional training in the field of manufacturing technologies, production control, programming of the manufacturing machines, etc.

Vodja laboratorija : izr. prof. dr. Ivan PAHOLE
Head of the Laboratory: Assoc. Prof. Dr. Ivo PAHOLE
Telefon / *Telephone:* +386 (0)2 220-7591
E-mail: ivan.pahole@um.si

1.2 Laboratorij za tehnološke meritve
Laboratory for Production Measurement

Laboratorij se ukvarja s temeljnimi in industrijskimi raziskavami, pedagoško dejavnostjo in strokovnim usposabljanjem na področjih dimenzionalnega meroslovja, industrijskih meritev in upravljanja kakovosti. Delo je usmerjeno predvsem v razvoj koordinatne, laserske in klasične merilne tehnike ter v umerjanje in meritve dimenzionalnih veličin. Laboratorij je akreditiran s strani SA (Slovenska akreditacija, podpisnica multilateralnega sporazuma EA MLA) za umerjanje dolžinskih etalonov in instrumentov ter vzdržuje in razvija nacionalni etalon za veličino dolžina. Svoje meroslovne zmogljivosti ima objavljene tudi v bazi nacionalnih meroslovnih inštitutov pri Mednarodnem uradu za uteži in mere (KCDB BIPM).

Laboratorij organizira strokovne seminarje, razvija in izdeluje merilne instrumente in metode, umerja dolžinske etalone in instrumente za merjenje dolžin ter izvaja kompleksne meritve geometrije na industrijskih izdelkih.

The activities of this laboratory are the following: basic and applied research, education, and training of experts in the fields of dimensional metrology, industrial measurements and quality management. The laboratory is focused in co-ordinate, laser, and conventional geometrical measurement techniques, as well as in calibration and measurements of dimensional quantities. This laboratory has obtained accreditation from the SA (Slovenian accreditation, signatory of multilateral agreement EA MLA) for calibration of length standards and instruments. The laboratory also develops and maintains the national standard of length. Its metrological capabilities are published in the database of national metrology institutes at the International Bureau for Weights and Measures (KCDB BIPM)

The laboratory organises professional seminars, develops and produces new measurement devices and methods, calibrates length measuring standards and instruments, and measures highly complex workpieces.

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1.3 Laboratorij za inteligente obdelovalne sisteme
Laboratory for Intelligent Manufacturing Systems

V Laboratoriju za inteligentne obdelovalne sisteme imamo na področju proizvodnih tehnologij in sistemov že več kot 25 letne izkušnje pri razvoju in uporabi sistemov, ki temeljijo na umetni inteligenci, še posebej strojnem učenju. Slednjega uporabljamo na različnih področjih, predvsem pri modeliranju in eno- ter večkriterijskih optimalizacijah proizvodnih postopkov in sistemov. Zbrano znanje in izkušnje se sedaj izvrstno vključuje v udejanjanje konceptov Industrije 4.0. Posebej bogate so naše izkušnje pri razvoju inteligentnih obdelovalnih sistemov, ki temeljijo na evolucijskih algoritmih (npr. genetskih algoritmih, genetskem programiranju), inteligenci rojev in umetnih nevronskih mrežah, vključno z globokim učenjem. Poglobljeno se ukvarjamo tudi z razvojem rešitev strojnega vida na področju obdelovalnih strojev in sistemov. Za analizo in optimalizacijo industrijskih sistemov ter vplivnih veličin obdelovalnih procesov snujemo in izvajamo poizkuse ter računalniške inženirske simulacije.

The Laboratory for Intelligent Machining Systems has over 25 years of experience in the field of manufacturing technologies and systems and in the development and application of systems based on artificial intelligence, in particular machine learning. The latter is used in various fields, especially in modeling and single- and multi-criteria optimizations of production processes and systems. The accumulated knowledge and experience are now very useful in the implementation of the concepts of Industry 4.0. We have extensive experience in the development of intelligent machining systems based on evolutionary algorithms (e.g. genetic algorithms, genetic programming), swarm intelligence and artificial neural networks, including deep learning. We have expertise in the development of machine vision solutions in the field of machine tools and systems. In order to analyze and optimize industrial systems and influence the parameters of processing processes, we prepare and perform experiments and computer-based engineering simulations.

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1.4 Laboratorij za mehatroniko
Laboratory for Mechatronics

Osnovna dejavnost laboratorija je načrtovanje krmilnih in regulacijskih postopkov vodenja tehničnih sistemov. V kompleksu načrtovanja sodijo dinamične analize obnašanja krmilnih in regulacijskih komponent različnih tehničnih izvedb: mehanskih, električnih, pnevmatskih, hidravličnih in hibridnih procesnih sistemov; snovanje krmilnih pogonov za programabilne krmilnike, optimiranje regulacijskih sistemov s pomočjo računalniških simulacijskih modelov in snovanje računalniških nadzornih sistemov za daljinsko vodenje in nadzor tehniških sistemov.

The basic activity of laboratory is designing of open and closed-loop control procedures of technical systems. The designing process includes dynamical analyses of behaviour of open and closed-loop control components of different technical varieties: mechanical, electrical, pneumatic, hydraulic and hybrid process systems; designing of control drives for programmable logic controllers, optimization of closed-loop control systems by computer simulations and designing of computer remote control systems for monitoring of technical systems.

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1.5 Laboratorij za odrezavanje
Laboratory for Machining Processes

Laboratorij izvaja raziskovalno in industrijsko razvojno delo, kakor tudi izobraževalne aktivnosti na dodiplomskem in podiplomskem študiju na področju obdelovalnih procesov. Glavne raziskovalne aktivnosti laboratorija so usmerjene v razvoj, modeliranje in optimizacijo obdelovalnih procesov, razvoj novih eksperimentalnih metod testiranja, uporabo izpopolnjenih rezalnih materialov, razvoj in izdelavo inteligentnih vpenjalnih priprav, izvedbo rezalnih orodij z ocenitvijo njihovih rezalnih sposobnosti ter adaptivno krmiljenje CNC obdelovalnih strojev. Pri analizi obdelovalnih postopkov uporabljamo klasične in nedeterministične metode. Velik poudarek dajemo uporabi metod umetne inteligence (globoko učenje, skupinska inteligenca, mehka logika itd.) pri reševanju kompleksnih problemov na področju obdelovalnih procesov. Poglobljeno se ukvarjamo tudi z razvojem rešitev strojnega vida, tako na področju obdelovalnih procesov, kot tudi na širšem področju uporabe v proizvodnih sistemih.

The laboratory performs research, industrial-development and graduate and postgraduate educational activities on field of machining processes. The laboratory focuses its research activities on the development, modelling and optimization of machining process, development of new experimental testing methods, cutting tools and use of advanced cutting materials, intelligent fixture design, cutting tool design with the evaluation of their cutting abilities and adaptive control of CNC machine tools. In the analysis of machining processes, we use classic and non-deterministic methods. We give great emphasis on the use of artificial intelligence methods (deep learning, swarm intelligence, fuzzy logic, etc.) for solving complex problems in a field of the machining processes. Our work is also deeply focused on the development of machine vision systems concerning machining processes, as well as broader use cases in production systems.

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1.6 Laboratorij za načrtovanje proizvodnih sistemov

Laboratory for Production And Operations Management

Dejavnost Laboratorija za načrtovanje proizvodnih sistemov se v glavnem deli na pedagoško in znanstveno raziskovalno delo, ki obsega temeljne in aplikativne raziskave. Osnovna področja delovanja laboratorija so razvoj izdelkov, načrtovanje in vodenje tehnoloških procesov, načrtovanje kapacitet in razmestitve delovnih mest, študij dela, upravljanje zalog, simulacije proizvodnih procesov in terminiranje, načrtovanje projektov in upravljanje kakovosti.

V laboratoriju izdelujemo programsko opremo za navedena področja, pa tudi prilagajamo v svetu uveljavljena orodja potrebam industrijskih uporabnikov.

The basic activities of the Laboratory for production and operations management can be divided into teaching and research, including scientific and applicable oriented research. The Laboratory is engaged in product development, technological process planning and control, capacity and layout planning, work study, inventory planning, production processes' simulation and scheduling, project planning and quality management.

The main products of the Laboratory are programming tools for the above mentioned fields of interest and adaptations of worldwide established programming tools for the needs of industrial users.

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1.7 Laboratorij za simulacije diskretnih sistemov

Laboratory for Discrete System Simulation

Aktivnosti Laboratorija za simulacije diskretnih sistemov obsegajo pedagoško delo (v okviru podiplomskega študija) ter teoretično in aplikativno naravnano raziskovalno delo (za ustanove, industrijo in svetovalna podjetja) na področju simulacije diskretnih dogodkov.

V proizvodnji uporabljamo rezultate simulacij pri določanju terminskih načrtov, obsega zalog, pretoka materiala, postopkov vzdrževanja; pri načrtovanju kapacitet, potreb po virih in procesov. V storitveni dejavnosti se simulacije obsežno koristijo za analiziranje čakalnih časov in terminiranje. Simulacije koristimo tudi v navezavi s tradicionalnimi statističnimi metodami in tehnikami menedžmenta.

The activities of the Discrete System Simulation Laboratory can be divided into teaching (within postgraduate courses) and theoretical and application-oriented research work (for institutions, industry and consultancy) in the area of discrete-event system simulation.

In manufacturing, simulation is used to determine production schedules, inventory levels, material flow, and maintenance procedures; to plan capacity, resource requirements, and processes. In services, simulation is widely used to analyse waiting times and scheduling operations. Simulation is also used in conjunction with traditional statistical and management science techniques.

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1.8 Laboratorij za oljno hidravliko
Laboratory for Oil Hydraulics

Glavna dejavnost laboratorija se nanaša na razvoj, avtomatizacijo in uporabo hidravličnih pogonov in sistemov, na matematično modeliranje in računalniško simulacijo dinamičnega obnašanja hidravličnih sistemov, na zajemanje in obdelavo podatkov, nadzor delovanja in vzdrževanje ter zagotavljanje zanesljivosti delovanja hidravličnih naprav, kot tudi na razvoj in testiranje različnih vrst hidravličnih tekočin.

Uporabljamo in razvijamo klasične, sodobne in adaptivne regulacijske koncepte vodenja in nadzora, namenjene uporabi na elektrohidravličnih premočrtnih in rotacijskih pogonih s ciljem, povečati njihovo natančnost in dinamiko, npr. regulacija položaja ali sile hidravličnih valjev, regulacija tlaka ali pretoka hidravličnih črpalk, razvoj energetsko varčnih konceptov pogona. V laboratoriju tudi razvijamo namensko programsko opremo potrebno za načrtovanje, modeliranje in vodenje različnih hidravličnih sistemov, ter namenske testne naprave.

Pomemben del dejavnosti laboratorija predstavljajo šolanja za udeležence iz industrije, ki se pri svojem delu srečujejo s hidravličnimi in pnevmatičnimi sistemi. Laboratorij je član združenja Fluidna tehnika Slovenije in CETOP -evropskega komiteja za hidravliko in pnevmatiko.

The main objective of this laboratory is development, design and application of rotational and linear hydraulic drives, precise mathematical modelling and computer simulation of hydraulic systems' dynamic behaviour, data acquisition and analysis, monitoring and control of technical systems, reliability and maintainability assessment etc.

Conventional and modern close-loop control structures of linear hydraulic drives resulting in improved accuracy and dynamics (for example precise positioning and force control with hydraulic cylinder) as well as the flow and pressure control of hydraulic pumps, energy saving supply concepts (e.g. load sensing) are developed. The laboratory is also involved in the development of special software tools for the design, modelling and control of hydraulic systems.

An important part of the laboratory activities is devoted to the planning and organisation of different professional events. The Laboratory is member of Fluid Power Slovenia Association and CETOP – European Fluid Power Committee.

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1.9 Laboratorij za robotizacijo
Laboratory for Robotisation

Laboratorij za robotizacijo (LaRo) je opremljen z industrijskima robotoma ACMA XR 701, KUKA KR 15 in humanoidnim robotom SoftBank Robotics NAO. Industrijska robota sta postavljen v profesionalno izvedeno popolnoma opremljeno proizvodno celico. V celici so tudi vsi potrebni dodatni tehnološki in varnostni sistemi. Celico uporabljamo za poučevanje, raziskovanje, razvoj in inženirske aplikacije na področju industrijske robotike in avtomatizacije tehnoloških procesov. Humanoidni robot NAO je namenjen raziskavam sodelovanja človek stroj in promociji te servisne tehnologije.

V LaRo se ukvarjamo s temeljnim raziskovalnim delom na področju Soft robotics (DEA aktuatorji), implementacijo robotov v industrijsko okolje (študij delovnega prostora robota in lastnosti robota v posameznih delih prostora), s sodelovalnostjo robot – človek in možnostmi samoučljivosti pri robotih in integracijo teh elementov v sodobne industrijske sisteme.

The Laboratory for robotisation (LaRo) is equipped with robots ACMA XR 701, KUKA KR 15 and one humanoid robot SoftBank Robotics NAO. The industrial robots are located in a professional designed full equipped production cell. The cell is equipped with all required technological and safety systems. It is used for education, research and development of professional applications in the field of industrial robotics and automatisation of production processes. The humanoid robot NAO is dedicated for research on collaboration between humans and machines, and for promotion of this service technologies.

In LaRo the research is focused on developing new DEA actuators in the field of Soft robotics, the implementation of robots into industrial environment (research on properties of robot's work space), collaboration tasks between robots and humans and possibilities of self-learning abilities of robots and the integration of all these elements into modern industrial systems.

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1.10 Laboratorij za dodajalno izdelavo
Laboratory for Additive Manufacturing

Laboratorij je opremljen z napravo za selektivno lasersko sintranje, sistemom za vakuumsko litje polimerov in s sistemom za vakuumsko litje barvnih kovin po metodi iztaljenega jedra. Na tej opremi izvajajo raziskave in razvoj:

- dodajalnih tehnologij in 3D tiskanja,
- vzvratnega inženirstva,
- uvajanja dodajalnih tehnologij v medicino,
- oblikovanja plastičnih mas,
- novih izdelkov in prototipne proizvodnje.

Dodatno laboratorij ponuja naslednje storitve:

- tečaje za upravljalca stroja za lasersko sintranje,
- tečaje modeliranja v programskem okolju SolidWorks,
- svetovanje pri razvoju novih izdelkov,
- razvoj in izdelava prototipov in maloserijskih izdelkov,
- razvoj in izdelava medicinskih pripomočkov in modelov ter pomoč pri 3D, digitalnem načrtovanju operativnih posegov.

The laboratory is equiped by the selective laser sintering machine, the system for vacuum casting (Sillicona Rubber Molding) and the system for investment casting. These equipments are used for performing the following research and development activities:

- *additive Manufacturing and 3D printing,*
- *reverse Engineering,*
- *additive Manufacturing in Medicine,*
- *product development and prototyping.*

Additionally the laboratory performs the following services:

- *courses for SLS machine operator,*
- *courses of Modelling in SolidWorks,*
- *consulting for new product development,*
- *production of prototypes and low series production,*
- *development and manufacturing of medical devices and models and consulting during 3D surgical planning.*

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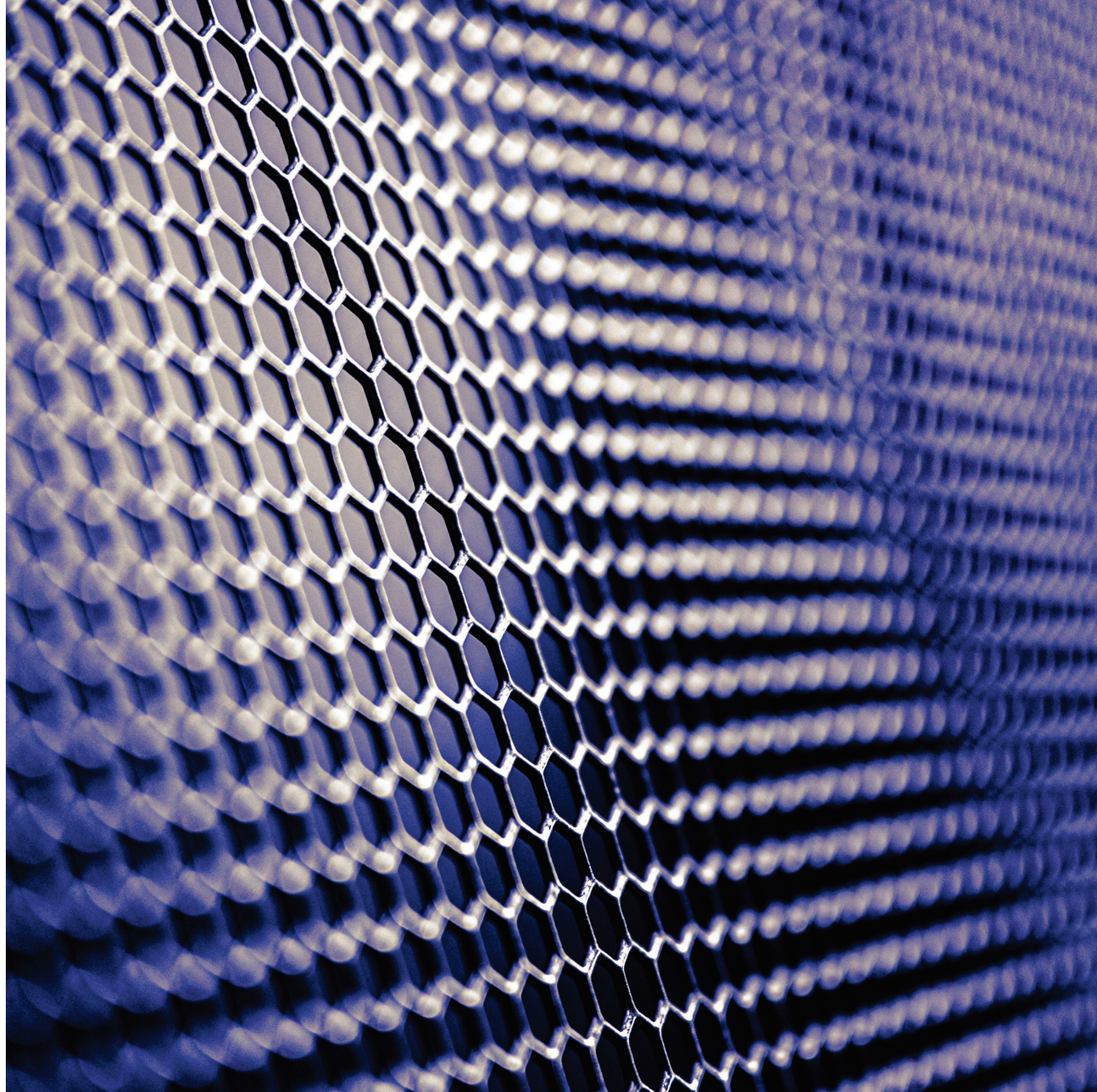

Energetsko, procesno in okoljsko inženirstvo

Power, Process and Environmental Engineering

LABORATORIJI / *LABORATORIES*	VODJA / *HEAD*
Laboratorij za toplotne stroje in tehniške meritve *Laboratory for Heat Engines and Engineering Measurements*	Aleš Hribernik
Laboratorij za motorje z notranjim zgorevanjem *Laboratory for Engine Research*	Aleš Hribernik
Laboratorij za termodinamiko, zgorevanje in okoljsko inženirstvo *Laboratory for Thermodinamics, Combustion and Environmental Engineering*	Niko Samec
Laboratorij za energetske sisteme in naprave *Laboratory for Power Systems and Devices*	Jure Marn
Laboratorij za računalniško dinamiko tekočin *Laboratory for Computational Fluid Dynamics*	Matjaž Hriberšek
Laboratorij za prenosne pojave v tekočinah in trdninah *Laboratory for Transport Phenomena in Solids and Liquids*	Jure Ravnik
Laboratorij za turbinske stroje *Laboratory for Turbomachinery*	Ignacijo Biluš

1.11 Laboratorij za toplotne stroje in tehniške meritve

Laboratory for Heat Engines and Engineering Measurements Laboratory

Osnovne aktivnosti laboratorija so razvoj in uporaba merilnih naprav za diagnostiko toplotnih strojev (pretoki, temperature, tlaki, hitrost, emisijske karakteristike), razvoj računalniško podprtih aplikacij za avtomatiziran zajem in obdelavo podatkov, z uporabo grafičnega programiranja v programskem okolju LabVIEW (National Instruments), razvoj in testiranje programske opreme za simulacijo termodinamičnih in tokovnih procesov v toplotnih strojih (motorji z notranjim zgorevanjem, plinske turbine in kompresorji) in njihove dinamike med obratovanjem v prehodnih režimih.

The main scopes of laboratory activities are: development and application of measuring devices for the diagnostics of heat engines (flow, temperature, pressure, speed, torque, power and gas emissions measurements); development of computer applications for automated data acquisition and processing, using LabVIEW graphical programming (Instrumentation software by National Instruments); development and testing of software for the simulation of thermodynamic and flow processes within heat engines (internal combustion engines, gas turbines and compressors) and their dynamic behavior during transient operation.

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1.12 Laboratorij za motorje z notranjim zgorevanjem

Laboratory for Engine Research

Glavne aktivnosti Laboratorija z motorje z notranjim zgorevanjem, se nanašajo na raziskave, razvoj in izobraževanje na področju motorjev z notranjim zgorevanjem, vključujoč pristope za zmanjšanje emisije in porabe goriva ter izboljšanje zmogljivosti motorjev. Pozornost je usmerjena v eksperimentalne in numerične raziskave alternativnih goriv in v optimizacijo karakteristik motorja, vbrizgavanja in curka goriva. Temeljne raziskave se nanašajo na numerično modeliranje dvofaznega toka v vbrizgalni šobi.

The main activities of this laboratory are related to the research, development and education in the field of internal combustion engines, including various approaches to reduce harmful emissions and specific fuel consumption, and to improve engine performance. Attention is mainly focused on the experimental and numerical investigation of alternative fuels as well as on the optimal design of engine, injection, and fuel spray characteristics. The fundamental research is related to the numerical modelling of two phase flow in the injection nozzle.

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1.13 Laboratorij za termodinamiko, zgorevanje in okoljsko inženirstvo

Laboratory for Thermodinamics, Combustion and Environmental Engineering

V tem laboratoriju se ukvarjamo z osnovami zgorevanja s poudarkom na kompleksnem modeliranju procesov zgorevanja z uporabo osnovnih enačb več-sestavinskega reaktivnega toka. Nadalje se ukvarjamo s posebnostmi zgorevanja v zgorevalnih komorah različnih kurilnih in sežigalnih naprav. Velik poudarek je na ugotavljanju okoljskih vidikov zgorevanja in sežiganja na osnovi testnih naprav. Ukvarjamo se tudi s tehnologijami predelave odpadkov, posebno z uvajanjem različnih tehnologij energijske izrabe odpadkov v prakso. Izvajamo tudi raziskave na področju termodinamičnih lastnosti alternativnih goriv in z izračunavanjem termodinamičnih stanj s pomočjo klasične in statistične termodinamike.

This Laboratory deals with combustion fundamentals. In particular, it involves the complex modelling of combustion processes using basic equations of multicomponent reactive flow. It further deals with combustion specifics in combustion chambers of different kind of combustion and incineration devices. The Laboratory features testing equipment and is geared towards the environmental aspects of combustion and incineration. It deals also with the waste treatment technologies implementing especially different waste to energy technologies in practice. We perform also research in the field of thermodynamic properties of alternative fuels and calculating thermodynamic states using classical and statistical thermodynamics.

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1.14 Laboratorij za energetske sisteme in naprave

Laboratory for Power Systems and Devices

Laboratorij se ukvarja predvsem z aplikacijami dvofaznega toka za različna področja uporabe v procesnem strojništvu. Bistvo dela je na področju naprav in instalacij procesnega strojništva, kot so primeroma, elektrarne. Oprema obsega sistem za zajemanje podatkov, dostop do laserskega doplerskega anemometra, anemometer z vročo žičko, kot tudi druga temperaturna, tlačna in tokovna tipala in merilniki. Laboratorij se je pričel ukvarjati z medicinskimi aplikacijami nenewtonskih tokov in analizami toka krvi skozi žile in srčne zaklopke.

The Laboratory is mainly involved with two-phase flow application in various engineering applications. The thrust of the work comes from process engineering facilities, such as complex power production facilities. The equipment includes a data acquisition system, access to a Laser Doppler Anemometer, hot wire anemometer as well as temperature, pressure, and flow sensors. The Laboratory has become involved with medical applications of non-Newtonian flow in analyses of blood flow through blood vessels and past heart valves.

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1.15 Laboratorij za računalniško dinamiko tekočin

Laboratory for Computational Fluid Dynamics

V laboratoriju se ukvarjamo z uporabo in razvojem lastnega računalniškega programa BEMFLOW, komercialnih računalniških programov ANSYS-CFX in AVL-FIRE ter odprtokodnega programa OpenFOAM. Razvijamo programske vstavke za CFD orodja za posamezne pojave, ki niso del CFD paketov (sublimacija, sušenje, filtracija, LED toplotni izvori, …). Veliko truda posvečamo pedagoškemu delu z dodiplomskimi in podiplomskimi študenti ter prenosu CFD znanja v industrijsko prakso. Laboratorij je dobro opremljen in upravlja tudi hitro računalniško gručo, delujočo pod Linux operacijskim sistemom.

The main task of the Laboratory is to facilitate the use and improvement of CFD computer codes such as proprietary BEMFLOW, commercial flow packages such as ANSYS-CFX and AVL-FIRE as well as open-cource code OpenFOAM. Special puprose program subroutines are developed for simulation of processes, not covered by the CFD codes (sublimation, drying, filtration, LED heat source...). The Laboratory devotes much of its capacities toward education of undergraduate and graduate students as well as knowledge transfer for the use of CFD in industrial environment. The Laboratory is well equipped including managing a small Linux based cluster.

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1.16 Laboratorij za prenosne pojave v trdninah in tekočinah

Laboratory for Transport Phenomena in Solids and Liquids

V laboratoriju se ukvarjamo z razvojem in uporabo numeričnih metod, kot so metoda robnih in končnih elementov ter metoda kontrolnih volumnov. Te metode predstavljajo osnovo za numerično modeliranje in simulacijo prenosa gibalne količine, toplote in snovi v laminarnem in turbulentnem režimu tečenja na področju večfaznih in večsestavinskih tokov. Praktična uporaba omenjenih metod poteka skozi reševanje zahtevnih tokovnih problemov in problemov prenosa toplote v procesni industriji, okoljevarstvu in energetiki, in sicer s pomočjo lastne računalniške kode ter uveljavljene komercialne kode ANSYS-CFX. Poseben del tega laboratorija predstavlja oddelek za neinvazivne laserske meritve. Metodo merjenja hitrosti s tehniko zasledovanja osemenjevalnih delcev (PIV) uporabljamo za analizo enofaznih tokov v procesni industriji, kot tudi za preučevanje dvofaznih tokov s posebnim poudarkom na mehurčastem toku in bazenskem vrenju. Laserska Doplerjeva anemometrija (LDA) je prav tako ena izmed eksperimentalnih metod, ki jo uporabljamo za točkovno analizo tokovnih razmer v energetskih sistemih in različnih vrstah procesnih naprav.

The Laboratory deals with the development and application of numerical methods, like boundary and finite elements and control volumes, for the numerical modelling and simulation of momentum, heat and mass transfer in laminar and turbulent flow of multi-phase and multi-component flows. Practical implementation is found in solving complex heat and flow problems in the process, environmental and power industry by the use of their own-developed code as well as complementary professional codes ANSYS-CFX. A special part of this laboratory is section for non-invasive flow measurement. Particle Image Velocimetry (PIV) is used for single flow analysis in process industry applications as well as for two phase flow investigations that include bubbly flow regime and nucleate pool boiling. Laser Doppler Anemometry (LDA) is also employed for single point flow analysis in power generation systems and in different kind of process engineering equipment.

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1.17 Laboratorij za turbinske stroje

Laboratory for Turbomachinery

Dejavnost laboratorija poteka na področju raziskav turbo-strojev, ki zajema določanje obratovalnih karakteristik, vibracij, hrupa in tokovnih lastnosti. Zadnja dela so fokusirana na kavitacijo in alternativne zračne energetske sisteme, predvsem na različne kavitacijske režime in testiranja različnih geometrij vetrnih turbin. Testirani so tudi novi porozni materiali, ki bi lahko bili primerni za uporabo na področju hidravličnih strojev in na drugih hidravličnih sistemih. Razvijamo tudi nove merilne metode, postopke in naprave, kot tudi kompletne sistemske rešitve za izvajanje meritev na energetskem področju. Laboratorij je opremljen za eksperimentalne raziskave na turbinah, črpalkah, ventilatorjih in turbo-kompresorjih, pri katerih lahko snemamo obratovalne karakteristike do nominalnih moči 10 kW. Izvajamo tudi numerične simulacije tako energetskih procesov, kot tudi tokovnih razmer znotraj turbostrojev in drugih hidravličnih sistemov, s CFD analizo.

The activity of the laboratory comprises the experimental research of the turbo-machines, including determination of operating characteristics, vibrations, noise and fluid flow properties. The latest research is focused on cavitation and alternative aero energy systems, such as different cavitation types and various wind turbines geometry testing. Tested are new porous materials that are suitable for using at the hydraulic machinery and in others hydraulic systems. New measurement methods, procedures and devices are developed, as well as a complete engineering service. The laboratory is qualified for the experimental research and measurement of pumps, blowers, turbo-compressors operating characteristic determination up to the nominal power of 10 kW, turbo-machine model research, etc. We are able to perform the numerical analyses of process as well as fluid flow modelling inside turbomachines and other hydraulic systems, using CFD.

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Konstruiranje in oblikovanje

Structures and Design

LABORATORIJI / *LABORATORIES*	VODJA / *HEAD*
Laboratorij za strojne elemente in konstrukcije *Laboratory for Machine Elements and Structures*	Nenad Gubeljak
Laboratorij za inteligentne CAD sisteme *Laboratory for Intelligent CAD systems*	Bojan Dolšak
Laboratorij za vrednotenje konstrukcij *Laboratory for Structures Evaluation*	Srečko Glodež
Laboratorij za zahtevne inženirske simulacije in eksperimentiranje *Laboratory for Advanced Computational Engineering and Experimenting*	Zoran Ren
Laboratorij za varjenje *Laboratory for Welding*	Tomaž Vuherer
Laboratorij za transportne naprave, sisteme in logistiko *Laboratory for Materials Handling Systems and Logistics*	Tone Lerher
Laboratorij za inženirsko oblikovanje *Laboratory for Product Design*	Sonja Šterman

1.18 Laboratorij za strojne elemente in konstrukcije

Laboratory for Machine Elements and Structures

Laboratorij izvaja raziskovalno in industrijsko razvojno delo, kakor tudi izobraževalne aktivnosti na dodiplomskem in podiplomskem študiju v obliki meritev in karakterizacije obnašanja konstrukcijskih komponent in materialov. Raziskovalne aktivnosti so osredotočene na področje eksperimentalne mehanike loma in utrujanje materialov z namenom določiti lomne parametre jekel, zvarnih spojev, kompozitov in elastomerov. Industrijsko-razvojne aktivnosti slonijo na določevanju mehanskih karakteristik konstrukcijskih sklopov in elementov. Laboratorij je opremljen s preizkuševalnimi stroji, integralnim stereo-optičnim merilnim sistemom za meritev deformacij, sistemom za simulacijo, vrednotenje in oblikovanje krivulj mejnih obremenitev, kot tudi s sistemom za dimenzioniranje, trdnostne analize in analize celovitosti konstrukcij. Pri raziskovalnih aktivnosti kombiniramo numerične simulacije in eksperimentalno potrditev rešitev za praktične inženirske probleme. Laboratorij razvija in patentira strojne elemente in sklope, ki so namenjeni zmanjšanju tveganja za nastanek utrujenostnih razpok in loma v obratovalni življenjski dobi. Laboratorij organizira industrijske seminarje na področju celovitosti konstrukcij in ocene preostale življenjske dobe skupaj z univerzami in inštituti v tujini. Danes je osebje laboratorija vključeno v različne industrijsko razvojne in izobraževalne Evropske projekte. Laboratorij se bo potrudil poiskati najboljšo rešitev in tehnično podporo za vaše aplikacije.

The laboratory performs research, industrial-development and also graduate and postgraduate educational activities. Research activities are focused on fracture mechanics and fatigue testing, based on evaluating the fracture parameters of steels, welded joints, composites and elastomers. The industrial-development activities are based on determining the mechanical characteristics of structures components and parts. The laboratory is equipped with testing machines, full-field strain measurement system, systems for simulation verification and forming limit curve, as well with system for component dimensioning, strength assessment and structure integrity analysis. Research activity combines numerical simulation and experimental verification of solutions for practical engineering problems. The laboratory developed and patented machine parts for reducing the risk of fatigue and fracture in service life time. The laboratory organizes industrial workshop on structure integrity and residual life time together with foreign universities and institutes. Today, the laboratory staff is involved in different European projects, however the laboratory will try to provide the best solutions and technical support for your application.

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1.19 Laboratorij za inteligentne CAD sisteme
Laboratory for Intelligent CAD Systems

Raziskovalno delo laboratorija je usmerjeno v premostitev vrzeli med tradicionalnim računalniško podprtim konstruiranjem na eni in metodami umetne inteligence na drugi strani. V okviru tega interdisciplinarnega raziskovalnega področja, ki ga poznamo pod imenom inženiring znanja, je osrednji raziskovalni cilj laboratorija razvoj inteligentnih računalniških modulov za podporo procesa konstruiranja in njihova integracija z obstoječimi CAD sistemi. Pri tem dejavnost laboratorija ni usmerjena v razvoj metod umetne inteligence, temveč na njihovo uporabo pri računalniško podprtem konstruiranju. Poleg temeljnih raziskav in z računalniško podprtim razvojem izdelkov povezanega pedagoškega dela, pomembnejše aktivnosti laboratorija vključujejo aplikativno raziskovalno delo, svetovanje in izobraževanje za zunanje naročnike predvsem na področju ciljno vodenega razvoja izdelkov s poudarjeno ergonomsko vrednostjo.

The aim of research work of the laboratory is to bridge the gap between traditional computer-aided engineering design process on one side and the methods of artificial intelligence on the other side. Within this interdisciplinary research area, known as knowledge-based engineering, the main research objective of the laboratory is development of the intelligent computer modules for supporting specific design issues and their integration with the existing CAD systems. The mission of the laboratory does not anticipate development work on methods of artificial intelligence, but rather the application of these methods in the field of computer-aided design. In addition to the basic research and computer-aided product development related education process, the other important activities of the laboratory include application related research work, expert counselling and practically oriented education for customers from industry, mainly in field of goal-oriented product development with emphasize on the ergonomic value.

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1.20 Laboratorij za vrednotenje konstrukcij
Laboratory for Structures Evaluation

Laboratorij sodeluje pri bistvenih raziskavah in razvoju različnih elementov prenosa in na področju splošnega strojništva. Bistvo raziskovalnega dela je razvoj računalniških inženirskih rešitev, mehanike loma, analiza vibracij, vzdrževanje, metode verjetnosti in optimiranje postopkov konstruiranja z uporabo modernih računalniških metod in mehanike loma v procesu konstruiranja za določanje pričakovane življenjske dobe zobnikov preden so izdelani. Raziskovalno delo temelji na uporabi modernih računalniških tehnologij, vključujoč pri tem spoznanja iz področja CAD in CAE. V laboratoriju potekajo raziskave pri razvoju modernih zobniških gonil, ki se vedno bolj uporabljajo v moderni strojegradnji in ostalih strojnih elementov in sklopov. Raziskovalno delo na področju vseh vrst zobniških dvojic temelji na uporabi ISO standardov. Raziskovalna skupina se v okviru laboratorija prvenstveno ukvarja s parcialnimi inženirskimi problemi, ki zahtevajo aplikacijo ali razvoj novih tehniških rešitev.

The Laboratory contributes a substantial research effort in the development of various transmission elements and general mechanical engineering. Their research work focuses mainly on the development of procedures for computational engineering mechanics, fracture mechanics, vibration analysis, maintenance, probability methods and those design optimisation procedures which are based on the finite element method. The research group is in a leading position for using modern computational methods and fracture mechanics in the design process for determining the expected service life of gears before they are produced. The research work is mainly performed by taking full advantage of modern computer technology, including building and connecting various basic elements of CAD and CAE. The particular areas of research include the development of modern gear assemblies, which are increasingly being used in modern machines, as well as in other mechanical elements and assemblies. This research resulted in the production of a dedicated computer software system for the design of spur, helical, bevel and worm gears made with respect to currently valid ISO standards. The research group is concerned mainly with particular engineering problems that require the application or development of novel solution techniques.

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1.21 Laboratorij za zahtevne inženirske simulacije in eksperimentiranje

Laboratory for Advanced Computational Engineering and Experimenting

Glavne raziskovalne aktivnosti laboratorija so usmerjene v razvoj, modeliranje in karakterizacijo geometrijskih in mehanskih lastnosti nehomogenih, celičnih in kompozitnih metamaterialov. Ob tem razvija tudi nove metode in optimizacijske algoritme za zahtevne računalniške simulacije inženirskih problemov s poudarkom na naslednjih specifičnih področjih: linearna in nelinearna mehanika trdnih teles, mehanika hitrih prehodnih pojavov, mehanika sistemov deformabilnih teles, kontaktna mehanika in vezani problemi. Temeljne raziskave večinoma potekajo v okviru nacionalnih in mednarodnih raziskovalnih projektov. Aplikativne raziskave so usmerjene na razvoj robustnih numeričnih orodij in postopkov za uporabo v raznih industrijskih aplikacijah, kot so: natančne analize napetostno-deformacijskega stanja mehanskih komponent, analize trka in udarne simulacije, porušitvene analize konstrukcij in konstrukcijskih spojev, optimizacija komponent in sklopov, vodenje mehanizmov itd. Sodelavci laboratorija nudijo tudi tehnično in svetovalno pomoč na širšem področju učinkovite uporabe komercialnih računalniških sistemov za modeliranje in simulacije inženirskih problemov.

The laboratory focuses its research activities on the development, modelling and characterisation of geometrical and mechanical properties of non-homogeneous, cellular and composite metamaterials. It is also involved in development of new methods and optimisation algorithms for advanced computational simulations of engineering problems, primarily in the following specific areas: linear and non-linear solid mechanics, transient dynamics and strain-rate dependent problems, multi-body-system dynamics of deformable bodies, contact mechanics and multiphysics problems. The basic research is primarily done within the framework of national and international research projects. Applied research is focused on development of robust computational tools and procedures for use in specific industrial applications, such as: accurate stress-strain analysis of mechanical components, crash and impact simulations, limit-load analysis of structures and structural joints, collapse of structures, element and structural design optimization, control of mechanisms etc. The laboratory staff also provides technical support and consultancy in the broad area covering the effective use of advanced modelling and computational engineering simulation tools.

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1.22 Laboratorij za varjenje

Laboratory for Welding

Laboratorij je vključen v različne raziskovalne in razvojne aktivnosti na projektih, ki so temeljne ali uporabne narave. Ti so usmerjeni v razvoj in izboljšanje materialov za varjenje in termično rezanje, tehnologije varjenja in rezanja ter kakovosti varjenih proizvodov.

- Raziskave so kombinacija mehanskih, metalografskih, fraktografskih in nekaterih drugih testiranj, katerih rezultati se lahko vključijo kot vhodni podatki pri numeričnih simulacijah obnašanja varjenih konstrukcij pri različnih vrstah obremenitev.
- Pri napovedovanju obnašanja realnih zvarov upoštevamo lastnosti specifičnih delov zvarov kot so enovarkovno in večvarkovno področje kot tudi TVP (grobozrnato, finozrnato, interkritično segreto, itd.).
- Vršimo preizkuse varjenih spojev glede možnega loma, utrujenosti materiala in porušitve zaradi prevelike plastične deformacije na reprezentativnih majhnih vzorcih in na varjenih konstrukcijah ali strojih v naravni velikosti.
- Toplotni cikel varjenja, ki je glavni vzrok za mikrostrukturne spremembe med varjenjem v osnovnem materialu. Izvajamo eksperimentalne študije na simulatorju varjenja. Testiranje mehanskih in lomnih lastnosti na vzorcih materiala s simulirano mikrostrukturo zvarov.

The laboratory is engaged in different research and development activities and participates in the basic and applicable research projects. They are oriented towards the development and improvement of materials for welding and thermal cutting, welding and cutting technology and quality of welding products.

- *Ivestigations are combination of mechanical, metallographic, fractographic and some other testing which results can be integrated as input data into the numerical simulations of welded structures behaviour under different types of loading.*
- *For the prediction of real welds behaviour properties of specific parts of welds are taken into account, for instance different areas of single or multi pass HAZ (coarse grain, fine grain, inter-critically heated, etc).*
- *The weld thermal cycle which is the primary reason for microstructure changes during welding. Classical mechanical and micromechanical testing as well as fracture-mechanics and fatigue testing are used to determine properties of material with microstructure of simulated weld regions.*

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1.23 Laboratorij za transportne naprave, sisteme in logistiko

Laboratory for Materials Handling, Systems and Logistics

Raziskovalno delo Laboratorija za transportne naprave sisteme in logistiko (LTN) je usmerjeno na področje razvoja, modeliranja in optimizacije dvižnih in transportnih sistemov skupaj s skladiščnimi in komisionirnimi sistemi v intralogistiki. V laboratoriju sledimo inženirskemu pristopu načrtovanja z uporabo sodobnih inženirskih metod, analitičnih in numeričnih modelov, kjer so upoštevani vsi odgovarjajoči standardi in predpisi. Težišče temeljnega raziskovalnega dela laboratorija predstavlja razvoj sodobnih analitičnih in numeričnih modelov za analize in optimiranje naprav in sistemov za transport ter skladiščenje v intralogistiki. Industrijske raziskave laboratorija so usmerjene v načrtovanje dvižnih in transportnih naprav, načrtovanje in optimiranje skladiščnih in komisionirnih sistemov, analize toka materiala intralogističnih sistemov in v zadnjem času načrtovanje sistemov avtomatizacije transportno-skladiščnih procesov. V okviru laboratorija nudimo izdelavo strokovnih mnenj pri razvoju transportno-skladiščnih sistemov.

The research work of the Laboratory for Materials Handling Systems and Logistics (LTN) is focused on the development, modelling and optimization of lifting and material handling systems, along with warehouse and order-picking systems in intralogistics. In the laboratory, we follow the engineering design approach by using modern engineering methods, analytical and numerical models, where all relevant standards and regulations are taken into account. The focus of the basic research work of the laboratory is development of modern analytical and numerical models for the analysis and optimization of devices and systems for material handling and warehousing in intralogistics. The industrial research of the laboratory is focused on the design of lifting and material handling equipment, design and optimization of warehousing and order-picking systems, analysis of the material flow in intralogistic and, most recently, the development of automation systems for material handling and warehouse processes. Within the laboratory, we offer expert opinions on the development of material handling and warehouse systems.

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1.24 Laboratorij za inženirsko oblikovanje

Laboratory for Product Design

V Laboratoriju za inženirsko oblikovanje pokrivamo več področij industrijskega oblikovanja, od konstruktivnega do evolutivnega s 3D skenerjem, aplikacijami s 3D tiskom in drugimi sorodnimi tehnologijami hitre izdelave. Na področju industrijskega oblikovanja sodeluje naš laboratorij z različnimi podjetji, za katere oblikujemo in modeliramo različne predmete, opravimo 3D skeniranje, vzvratni inženiring in hitre izdelave prototipov za različne namene, kot so ohišja elektronskih naprav, plastična embalaža, plastenke, projektiranje kalupov in orodij za plastenke, oblikovanje karoserij za avtomobile in avtomobilske dele, kolesa, kuhinjske in sanitarne armature, arhitekturne prototipe itd.

V Laboratoriju razpolagamo z opremo za zelo natančno 3D skeniranje objektov, Atos II 400. Za velike objekte in konstrukcije pa Tritop – fotogrametrično kamero. Za pripravo, rekonstrukcijo in obdelavo podatkov uporabljamo Rhinoceros 3D, ter GOM Inspect, orodje za inspekcijske primerjalne analize poligonskih in CAD modelov.

The laboratory has developed a number of different fields of industrial design, under constructive and evolutionary principles, with a 3D scanner and 3D applications with a 3D printer, and other RP technologies. In the field of industrial design the laboratory collaborates with various companies which results in a multitude of applications such as: product design, 3D scanning, reverse engineering, rapid prototyping for different purposes, including housing for electronic devices, plastic bottles and flasks with mould construction, design for car bodies, bikes, kitchen and bathroom taps, architectural prototypes, etc.

The laboratory has high accuracy equipment for 3D scanning, Atos II 400 and Tritop - photogrammetric camera for large objects and constructions. For preparation, 3D reconstruction and data editing, we use Rhinoceros 3D, and GOM Inspect for polygonal and CAD comparisons, inspections and analysis.

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Tehnologija materialov

Material Science

LABORATORIJI / *LABORATORIES*

Laboratorij za materiale
Laboratory for Materials

Laboratorij za preoblikovanje materialov
Laboratory for Materials Forming

VODJA / *HEAD*

Franc Zupanič

Ivan Anžel

1.25 Laboratorij za materiale

Laboratory for Materials

Laboratoriju za materiale se ukvarjamo z znanstveno-raziskovalno in razvojno dejavnostjo, nova spoznanja in odkritja pa uvajamo v pedagoški proces. Glavno področje raziskav je razvoj kovin in zlitin ter metode materialografije. Izvajamo raziskave na temah: kontinuirno litje zlitin, vakuumska metalurgija, študij faznih premen in reakcij v trdnem stanju, razvoj novih metod za metalografsko preiskavo, proučevanje nikljevih superzlitin, kvazikristalnih aluminijevih zlitin, bakrovih zlitin za steklarsko industrijo, jekel, dentalnih zlitin, toplotna obdelava zlitin, ugotavljanje mehanskih lastnosti in karakterizacija tankih plasti in prevlek. Smo specialisti za elektronsko vrstično mikroskopijo (HRSEM); mikroskopijo s fokusiranim ionskim snopom (FIB/SEM), ki omogoča tudi površinsko obdelavo vzorcev; in okoljsko vrstično mikroskopijo (SEM ESEM), ki omogoča mikroskopiranje neprevodnih, bioloških in medicinskih vzorcev v nizkem vakuumu. Naša najnovejša dosežka sta »Razvoj nove visokotrdnostne in toplotno obstojne aluminijeve zlitine z dvojnimi izločki, ki imajo kristalno in kvazikristalno zgradbo« ter »Razvoj nove dentalne nikljeve superzlitine, izdelane s kontinuirnim litjem.

Med najpomembnejšo raziskovalno opremo v laboratoriju spadajo: vakuumska indukcijska talilna peč, naprava za vertikalno kontinuirno litje, naprave za mehansko preskušanje materialov, svetlobni mikroskopi in elektronski vrstični mikroskopi s programsko opremo za kvalitativno in kvantitativno metalografsko analizo ter peči za toplotno obdelavo.

The Laboratory for Materials is engaged in research and development activities, and we introduce new findings and discovery to teaching. The main topic is development of metallic alloys and materialographic methods. Our research topics encompass continuous casting of alloys, vacuum metallurgy, study of phase transformations and reactions in the solid state, development of metallographic techniques, study of Ni-based superalloys, quasicrystalline aluminium alloys, copper alloys for the glass industry, steels and dental alloys, heat treatment, measuring of mechanical properties and characterisation of films and coating. We are specialists for the scanning electron microscopy (HRSEM); microscopy with a focussed ion beam (FIB/SEM), which also allows surface modifications of samples; and environmental scanning microscopy, enabling microscopy of un-conductive, biological and medical samples in low vacuum. Our latest achievements are "The development of a novel high-strength and heat resistant aluminium alloy with dual precipitates (crystalline and quasicrystalline), and "The development of a new dental Ni-based superalloy, manufacture by continuous casting.

The most important equipment in the laboratory: vacuum induction melting furnace, small-sections vertical continuous caster, equipment for mechanical testing, light and scanning electron microscopes with software for qualitative and quantitative metallographic analysis and heat treatment furnaces.

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1.26 Laboratorij za preoblikovanje materialov
Laboratory for Materials Forming

V laboratoriju za preoblikovanje materialov potekajo aktivnosti na področju znanstveno raziskovalnega dela in na področju pedagoškega procesa. Med najpomembnejše raziskovalne aktivnosti sodijo študije vpliva deformacijskih procesov na razvoj mikrostrukture in s tem povezano spreminjanje lastnosti deformiranih materialov, razvoj novih algoritmov za inženirsko analizo in dopolnjevanje baze podatkov za CAD/CAM preoblikovalna orodja in preoblikovalne tehnologije (globoko vlečenje, striženje, kovanje, ekstrudiranje, valjanje in druge). V okviru pedagoškega procesa se študentje v laboratoriju za preoblikovanje materialov seznanijo z eksperimenti, ki omogočajo lažje razumevanje osnov teorije plastičnosti, z nekaterimi tehnološkimi postopki preoblikovanja kovinskih in polimernih materialov, ter s tehnologijami stiskanja in sintranja keramičnih in kompozitnih materialov. Laboratorij je opremljen z več prešami, pnevmatskim kladivom, elektrouporovnimi pečmi za segrevanje obdelovancev in številna eksperimentalna orodja s pripadajočo merilno opremo za določitev krivulj tečenja in upogibne togosti različnih materialov.

The activities of the Metal Forming Laboratory can be divided into research work and the teaching process. The main research activities consist of studying the influence of deformation processes on a microstructure's evolution and with this connected changes of the properties of deforming materials, development of new algorithms for engineering analysis and the improvement of data bases for CAD/CAM metal forming tools and metal forming technologies (deep drawing, shearing, forging, extrusion, rolling etc.). In the field of teaching activities the students are introduced into the experiments that enable better understanding the basic theories of plasticity, metal and polymer forming technologies and technologies of pressing and sintering of ceramic and composite materials. The laboratory is equipped with several presses, pneumatic hammer, electrical furnace for heating the work pieces and several experimental tools with appropriate measurement equipment for the determination of flow curves and tools for the bending stiffness determination of different materials.

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Mehanika / Mechanics

LABORATORIJI / *LABORATORIES*

Laboratorij za aplikativno mehaniko
Laboratory for Applied Mechanics

VODJA / *HEAD*

Marko Kegl

1.27 Laboratorij za aplikativno mehaniko
Laboratory for Applied Mechanics

Dejavnost laboratorija se nanaša na razvoj modelov mehanskih sistemov zasnovanih na odzivnih enačbah in mehanskih pogojih, postavljenih s strani inženirja. Raziskovalno delo je osredotočeno na razvoj numeričnih metod in metod matematičnega programiranja za sintezo mehanskih modelov z avtomatičnim določanjem optimalnih vrednosti še neznanih parametrov v procesu CAE/FEA. Pomembne dejavnosti so orientirane tudi v razvoj numeričnih metod za analizo dinamičnih sistemov. Glavno delo laboratorija je bilo osredotočeno na naslednje teme:

- konstrukcije (konvencionalna optimizacija, optimizacija oblike, optimizacija topologije, parametrizacija oblike mrež končnih elementov, obravnavanje stabilnosti med optimizacijo,
- nelinearna nihanja dinamičnih sistemov z mnogo prostostnimi stopnjami (rotirajoči sistemi, sistemi s spremenljivo strukturo, krmilni sistemi, deterministična in naključna vsiljena nihanja sistemov),
- dinamika nihajočih sistemov (vzmetenje vozila, mehanizem odmikalo-slednik, roboti).

The activity in the laboratory concerns the development of mechanical system models based on response equations and mechanical constraints set up by the design engineer. The research work is focused on the development of numerical methods and mathematical programming methods for the synthesis of mechanical models with automatic determination of optimal values for some undetermined parameters in the procedure of CAE/FEA. The activities are also oriented towards the development of numerical methods for the analysis of dynamical systems. The laboratory's main research effort was focused on the following topics:

- *structures (conventional optimization, shape optimization, topology optimization, shape parametrization of finite element meshes, stability considerations during optimization),*
- *nonlinear vibrations of dynamical systems with many degrees of freedom (rotating systems, systems with variable structures, valve gear systems, deterministic and random forced vibrational systems,*
- *dynamics of multibody systems (vehicle suspension, cam-follower mechanism, robots).*

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Univerzitetni center za elektronsko mikroskopijo

University Centre for Electron Microscopy

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University of Maribor, Faculty of Mechanical Engineering Raziskovalni vodnik / *Guide to research*

Univerzitetni center za elektronsko mikroskopijo je prvi infrastrukturni raziskovalni center na Univerzi v Mariboru. Ustanovljen je bil avgusta 2005 z namenom, da bi poglobili sodelovanje med raziskovalci Univerze v Mariboru na področju elektronske mikroskopije ter da bi omogočili dostop do vrhunske opreme tudi industrijskim partnerjem. Center je opremljen z vrstičnim elektronskim mikroskopom JEOL 840A z analizatorjem EDS (za mikrokemično analizo), visokoločljivostnim elektronskim mikroskopom SIRION 400 NC z analizatorjem EDS ter z okoljskim vrstičnim elektronskim mikroskopom QUANTA 200 3D. Slednji mikroskop ima dva snopa: elektronski snop (SEM) in fokusirani ionski snop (FIB). Poleg tega ima še plinski sistem za nanašanje platine (GIS). S to opremo lahko opazujemo vse vrste tehničnih materialov, kakor tudi biološke in medicinske vzorce. Na opremi v centru se lahko izvede tudi kemična analiza v mikrometrskem in nanometrskem področju, mikroobdelava materialov, nanašanje tankih plasti Pt ter opazovanje dinamičnih procesov.

The University centre for electron microscopy is the first infrastructural research unit at the University of Maribor. It was founded in august 2005 with the aim to deepen the cooperation in the field of electron microscopy between the researchers at the University of Maribor and to enable the access to the microscopy equipment to industrial partners. The centre is equipped with a scanning electron microscope JEOL 840 A with EDS analyser, an environmental scanning electron microscope QUANTA 200 3D with FIB (dual beam SEM, with both an electron beam and a focussed ion beam and a system for deposition of platinum) and a high resolution scanning electron microscope SIRION 400 NC with EDS analyser for microchemical analysis INCA 350. Research activities in the centre comprise the observations of all kinds of engineering materials, as well as biological and medical samples, chemical analysis of nano- and micro-sized regions, micromachining, deposition of Pt and observation of dynamical processes.

Center za senzorsko tehniko

Centre of Sensor Technology

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Center za senzorsko tehniko (CST) je bil ustanovljen na Univerzi v Mariboru, Fakulteti za strojništvo, v letu 2001. Ustanovljen je bil z namenom, da se aktivno vključimo v reševanje problematike varstva okolja, s pomočjo izvajanja različnih monitoringov, pilotnih poskusov čiščenja voda in razvijanja novih metod (senzorjev) za spremljanje ekoloških in procesnih parametrov. Razpolagamo z opremo za izvajanje pilotnih poskusov sanacije različnih tipov odpadnih voda po raznovrstnih tehnoloških metodah (kemijske oksidacije, membranske tehnologije, biološko čiščenje), izvajamo ustrezno analitiko za nadzor učinkovitosti izvedenih poskusov ter svetujemo na področju čiščenja in analitike voda. Poleg tega se v Centru za senzorsko tehniko (CST) ukvarjamo z razvojem novih on-line, in-situ senzorjev in senzorskih sistemov za merjenje ekoloških in procesnih parametrov v okviru gradbene, strojne, živilske, farmacevtske, kemijske, papirne, tekstilne industrije. Posebno raziskovalno sfero predstavlja razvoj senzorjev na področju osebne zaščite, tako na delovnem mestu kot tudi v okolju, ki predstavlja potencialno nevarnost za naše zdravje. Novo področje CST je razvoj atraktivnih biosenzorjev, razvoj novih mikrosenzorjev in nano-senzorjev. Nano aplikacije razvijamo tako na področju senzorjev, kot tudi na področju izboljšanja funkcionalnih lastnosti materialov (z nano-nanosi, nano-filmi). Na ta način stopamo v korak z EU smernicami razvoja in raziskav. Center za senzorsko tehniko se ukvarja tudi z organizacijo in izvedbo seminarjev, tečajev, ki so namenjeni informiranju in neposrednemu prenosu znanstvenih dosežkov v slovensko industrijo.

Centre of Sensor Technology (CST) was established at the University of Maribor, Faculty of Mechanical Engineering in 2001. The purpose of its foundation was to actively participate in solving environmental protection problems, by implementing different monitoring, pilot plant cleaning water trials and by developing new methods (sensors) for ecological and process parameters monitoring. We provide equipment for pilot plant trials for executing various types of wastewater sanitation after diverse engineering procedures (chemical oxidations, membrane technologies and biological treatment). We perform adequate analysis for the performed experiments' efficiency controls, and we propose water treatment recommendations and analysis. Furthermore, in the CST we develop new on-line, in-situ sensors and sensor systems for ecological and process parameters' determination within the framework of building, mechanical, food, pharmaceutical, chemical, paper, and textile industries. A special research area represents the sensors development for personal protection in a particular place, as well as in an environment that is potentially hazardous for human health. Recently, we have focused on the development of new attractive microsensors and nanosensors. We use nanotechnology for applications in the field of sensors, and also in the field of functional characteristic materials' improvement (nano-layers, nano-films). In this way, we keep up with EU research and development directives. The Centre of Sensors Technology organizes seminars and courses for the direct transfer of scientific achievements in Slovenian industry.

Katedra za temeljne in splošne predmete

Chair of Fundamental and General Subjects

LABORATORIJI / *LABORATORIES*

Laboratorij za matematiko
Laboratory for Mathematics

Laboratorij za fiziko
Laboratory for Physics

VODJA / *HEAD*

Irena Kosi-Ulbl

Jana Padežnik Gomilšek

1.28 Laboratorij za matematiko

Laboratory for Mathematics

Osnovna naloga Laboratorija za matematiko je poučevanje matematičnih predmetov na Fakulteti za strojništvo in na drugih fakultetah Univerze v Mariboru. Sodelavci laboratorija kot raziskovalci občasno sodelujemo v raziskovalnih in razvojnih projektih drugih laboratorijev, pretežno pa pri raziskovalnih projektih na drugih institucijah. Večina raziskav je s področja teorije grafov, pri čemer so v ospredju produkti grafov in grafi, vloženi na ploskve. S produkti grafov pogosto modeliramo omrežja. Grafovske invariante, kot sta povezanost po vozliščih in povezanost po povezavah, dajejo informacije o zanesljivosti teh omrežij. Del raziskovalnega dela v okviru teorije grafov je namenjen barvanjem direktnih produktov grafov, kjer je osrednji odprt problem Hedetniemijeva domneva in njene variacije.

Drugi del raziskovalnega dela sodi na področje teorije nekomutativnih kolobarjev. Proučujemo identitete z aditivnimi preslikavami, za katere se izkaže, da so odvajanja ali jordanska *-odvajanja pri določenih pogojih za kolobarje. Raziskujemo karakterizacije centralizatorjev med vsemi aditivnimi preslikavami na polprakolobarjih s primernimi omejitvami glede reda elementov. Ukvarjamo se tudi z reševanjem funkcionalnih enačb na operatorskih algebrah, kjer operatorji delujejo na Banachovih ali Hilbertovih prostorih.

The primary objective of the Laboratory is teaching mathematical subjects at the Faculty of Mechanical Engineering and other faculties of the University of Maribor. The laboratory also cooperates in the development-research projects of other laboratories as well as in projects carried out at other institutions. The main part of our research work is focused on graph theory where the major areas of research are graph products and graphs on surphaces. Products of graphs are used to model different types of networks, and we study graph products to determine properties of these networks, such as its reliability and redundance. The research is also partly done on colorings of direct products of graphs, where the main open problem is the Hedetniemi's conjecture and its variations.

*The other part of the research work is taking place in the area of noncommutative rings. We study identities, satisfied by additive mappings of the ring into itself, for which it turns out to be derivations or Jordan *-derivations under some restrictions for the ring. We also consider characterizations of additive mappings which are centralizers among all additive mappings on semiprime rings with suitable torsion restrictions. A part of our research work belongs to solving functional equations on operator algebras, where operators act on Banach or Hilbert spaces.*

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1.29 Laboratorij za fiziko
Laboratory for Physics

Osnovna naloga Laboratorija za fiziko je poučevanje fizike na Fakulteti za strojništvo. Sodelavci laboratorija so aktivni tudi kot raziskovalci in sodelujejo z raziskovalnimi ustanovami v Sloveniji in tujini na področjih atomske fizike, biofizike in fizike mehke snovi. Na področju atomske fizike z metodami rentgenske absorpcije in fluorescence preučujejo večelektronske fotovzbuditve v atomu in analizirajo bližnjo okolico atoma (tehniki EXAFS in XANES). Večina raziskovalnega dela je opravljena na sinhrotronih v Hamburgu, Grenoblu in Trstu. Temu sledi analiza in interpretacija rezultatov v sodelovanju s številnimi raziskovalnimi organizacijami. Raziskovanje v biofiziki se osredotoča na biološko pomembne molekule, posebej gvanozin in DNK. Samourejanje teh molekul v raztopinah se preučuje s sipanjem svetlobe in spektroskopijo jedrske magnetne resonance na P31, njihova organizacija na trdnih površinah pa z mikroskopom na atomsko silo. V fiziki mehke snovi preučujejo osnove in uporabo površinske urejenosti kompleksnih polimernih sistemov z mikroskopom na atomsko silo. Eksperimentalno delo na področju fizike mehke snovi in biofizike poteka v sodelovanju z Institutom Jožef Stefan v Ljubljani.

Primary objective of the Laboratory is teaching physics at the Faculty of Mechanical Engineering. The members of the Laboratory are also active as researchers and collaborate with research institutions in Slovenia and abroad. Their main fields of interest are: atomic physics, biophysics and soft matter physics. In the field of atomic physics, x-ray absorption and fluorescence techniques are used to study multiple photoexcitations in the atom and to analyze local structure of materials (techniques EXAFS and XANES). Most of the experimental research work is done on synchrotrons in Hamburg, Grenoble and Trieste and is followed by analysis and interpretation of the results in cooperation with numerous research institutions. The research in biophysics focuses on biologically important molecules, especially guanosine and DNA. Self-assembly of these molecules in solutions is studied by Light Scattering and 31P NMR spectroscopy, their organisation at solid surfaces is investigated by Atomic Force Microscopy. In soft matter physics, the fundamentals and applications of surface organisation of complex polymer systems are studied by Atomic Force Microscopy. Experimental work in both, biophysics and soft matter physics, is conducted in collaboration with J. Stefan Institute, Ljubljana.

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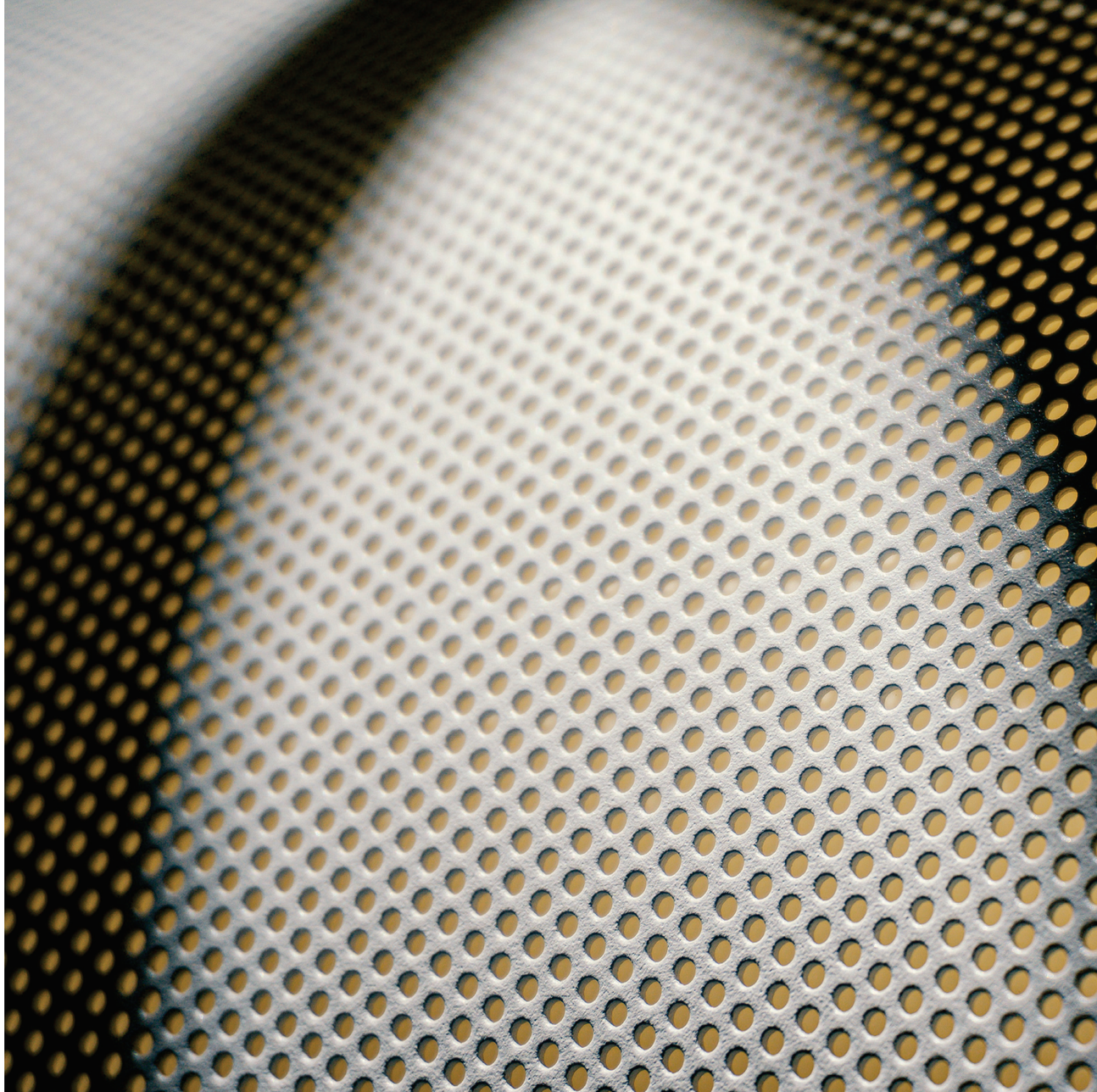

2 Inštitut za inženirske materiale in oblikovanje

Institute of Engineering Materials and Design

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LABORATORIJI / *LABORATORIES*	**VODJA / *HEAD***
Laboratorij za obdelavo in preizkušanje polimernih materialov *Laboratory for Characterization and Processing of Polymers*	Olivera Šauperl
Laboratorij za barvanje, barvno metriko in ekologijo plemenitenja *Laboratory for Dyeing, Colorimetry and Finishing Ecology*	Darinka Fakin
Laboratorij za tiskanje tekstilij in nego oblačil *Laboratory for Textile Printing and Textile Care*	Branko Neral
Laboratorij za kemijo in okoljevarstvo *Laboratory for Chemistry and Environmental Protection*	Aleksandra Lobnik
Laboratorij za tekstilne tehnologije in računalništvo v tekstilstvu *Laboratory for Textile Technologies and Computer-based Textile Applications*	Zoran Stjepanovič

LABORATORIJI / *LABORATORIES*	**VODJA / *HEAD***
Laboratorij za projektiranje in konstrukcijo tekstilij *Laboratory for Fabric Planning and Construction*	Polona Dobnik Dubrovski
Laboratorij za oblačilno inženirstvo, fiziologijo in konstrukcijo oblačil *Laboratory for Clothing Engineering, Physiology and Garment Construction*	Jelka Geršak

CENTRI / *CENTRES*	**VODJA / *HEAD***
Center za nego tekstilij in oblačil *Centre for Textile Care*	Branko Neral
Center za barvanje in barve *Centre for Dyeing and Colour*	Darinka Fakin
Raziskovalno inovacijski center za design in oblačilno inženirstvo *Research and Innovation Centre for Design and Clothing Science*	Jelka Geršak

Aktivnosti inštituta (IIMO) zajemajo temeljne in aplikativne raziskave ter izobraževanje na področju inženirskih polimernih materialov in kompozitov, kakor tudi s področja oblikovanja tekstilij in oblačil ter razvoja pametnih materialov in oblačil. Poleg tega inštitut aktivno sodeluje z gospodarskimi organizacijami tako na področju raziskav in razvoja, kakor tudi s ponudbo storitev preskušanja tekstilij in drugih polimernih materialov, svetovanja, itd. Raziskovalna dejavnost IIMO obsega raziskave z različnih področij tekstilstva in oblikovanja s poudarkom na raziskovalnih aktivnostih novo razvijajočih se znanosti in tehnologij, npr. nanomaterialov in nanotehnologij, biološko aktivnih materialov in funkcionalnih površin, itd. V okviru IIMO je aktivnih preko 50 raziskovalk in raziskovalcev, organiziranih v sedem laboratorijev in tri centre, in ki so aktivno vključeni v številne raziskovalne programe in projekte, namenjene raziskavam naprednih polimernih materialov, njihovi predelavi in oblikovanju. Inštitut pomembno prispeva k razvoju in napredku omenjenih področij predvsem z aktivno udeležbo odličnih raziskovalcev v mednarodnih raziskovalnih programih in projektih, kot so Horizon2020, EraNet, Erasmus+, itd.

The Institute performs basic and applied research, as well as teaching activities in the area of engineering polymer materials and composites as well as in the field of textiles and clothing design and development of intelligent materials and garments. Furthermore, institute very actively cooperates with companies through the research and development as well as through the support and services in testing and characterisation of textile and polymer materials.
While the Institute conducts some research in traditional textile science, its main research activities are focused on a wide variety of newly developing sciences and technologies, like nanomaterials and nanotechnologies, biologically active materials and functional surfaces. At the institute there is over 50 active researchers organised in seven laboratories and three research centres. Institute of Engineering Materials and Design actively participates in numerous international programmes and projects devoted to advanced polymer materials processing and design. In this way institute significantly contributes to development and progress of this important area first of all through the cooperation of the researchers in numerous international programmes and projects, like HORIZON2020, EraNet, Erasmus+, etc.

2.1 Laboratorij za obdelavo in preskušanje polimernih materialov

Laboratory for Characterization and Processing of Polymers

V laboratoriju potekajo raziskave polimerov s poudarkom na vlaknotvornih polimerih. Raziskovalne teme zajemajo proučevanje strukture naravnih in sintetičnih vlaknotvornih polimerov in njihovo modifikacijo, vpliva različnih procesnih parametrov na strukturne spremembe in s tem na tehnološke in uporabne lastnosti vlaken. Raziskovalno delo je usmerjeno predvsem v študijo površinskih interakcij vlaknotvornih polimerov (mejna površina tekoče/trdno, interakcije funkcionalnih skupin s procesnimi kemikalijami v vodnih raztopinah., itd). V laboratoriju je prav tako možno določanje optične dvolomnosti, gostote vlaken, molskih mas, polimerizacijske stopnje, navzemanja in zadrževanja vode, mehanskih lastnosti ter ATR-FTIR, SEM in slikovno analiziranje. Dejavnost laboratorija je prav tako usmerjena v površinsko modifikacijo vlaken (termična, kemijska, ultra-zvočna, sol-gel obdelave) in njihovo vrednotenje (površinska morfologija, površinski naboj, zeta potencial, delež in vrsta disocirajočih in dostopnih skupin, konstanta disociacije (pK vrednosti) v topilih različne polarnosti, stični kot, površinska prosta energija), in na področje nanotehnologij ter biotehnologij (medicinski in visoko funkcionalni materiali (samočistilnost, negorljivost, ionska izmenjava, itd). Razen omenjenega, obsega dejavnost laboratorija še konvencionalne analize tekstilnih materialov.

The team performs study of natural and synthetic fibre-forming polymers structure, their modification, influence of different processing parameters on structural changes, etc. The research work comprises study of fibre-forming polymers surface interaction (liquid/solid interface, interactions of functional groups with chemicals in aqueous solutions, etc.). In the laboratory it is also possible to determine optical birefringence, fibre density, molar mass and polymerization rate, water uptake and water retention, mechanical properties, together with the ATR-FTIR, SEM, and image analysis. The activity of the laboratory is also focused on the surface modification of fibres (thermal, chemical, ultra-sound, sol-gel treatments) and their evaluation (surface morphology, surface charge, zeta potential, proportion and type of dissociating and accessible groups, dissociation constant (pK values) in solvents of different polarity, contact angle, surface free energy) and is oriented also towards the field of nanotechnology/biotechnology (medical and highly functional materials (self-cleaning, fire-retardancy, ion exchange, etc.). Together with this, the team performs also conventional analyses of textile materials.

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2.2 Laboratorij za barvanje, barvno metriko in ekologijo plemenitenja

Laboratory for Dyeing, Colorimetry and Finishing Ecology

Laboratorij se ukvarja s temeljnimi in aplikativnimi raziskavami, izvaja izobraževalne programe in nudi servis na področju barvanja materialov, vrednotenja barv in optičnih lastnosti materialov v UV/Vis/NIR področju valovnih dolžin 200 - 2500 nm. ter odstranjevanja onesnaževal iz odpadnih vod in določanja parametrov onesnaženja odpadnih vod.

Pomemben del raziskav predstavlja priprava in uporaba novih kromnih barvil in funkcionalnih pigmentov ter razvoj inovativnih postopkov za nanos/vgradnjo več-kromnih oz. več-funkcionalnih sistemov (enkapsuliranje, ink-jet tiskanje, sol-gel, elektropredenje, itd.) za različne namene: za zaščito, kamuflažo, senzoriko, modo/dizajn, itd.

Druge raziskovalne aktivnosti so namenjene modifikaciji bio-polimernih materialov s fluorescentnimi barvili (tj. fluorescentno označevanje), kot so beljakovine in celulozni nanodelci, z uporabo ˝zelene˝ kemije. Njihovo aplikacijsko okno seže od sledenja mikrostrukturnih parametrov (velikost in porazdelitev por in njihovih sten) v 2D in 3D kompleksnih sistemih z orodjem Konfokalne Mikroskopije, do njihove lokalizacije v človeških osteoblastih. Izkoristek označevanja z barvili ter njihov vpliv na konformacijo in velikost celuloznih nanofibrilov lahko sledimo z razpoložljivimi analitskimi tehnikami kot so HPLC in CE ter jih mikroskopsko dopolnjujemo.

This laboratory performs basic and applied research, teaching activities and offers services in the fields of materials dyeing, colour and optical properties evaluation of materials in UV/Vis/NIR region of wavelengths from 200 up to 2500 nm., removal of pollutants from wastewaters and determination of wastewater pollution parameters.

The expanded research interest is the preparation and usage of new chromic dyes and functional pigments, and development of innovative processes for application/incorporation of multi-chromic and multi-functional systems (encapsulation, ink-jet printing, sol-gel, electrospinning, etc.) for diverse purposes: for protection, camouflage, senzoric, fashion/design, etc.

Other branch research activities is devoted to fluorescent dye-modification (i.e. labelling) of bio-polymeric materials such as proteins and cellulosic nanoparticles, utilizing "green", solvent-free chemistry. Their application window ranges for tracking of microstructure parameters (size and distribution of voids and walls thickness) within 2D and 3D complex systems by Confocal Microscopy tool, up to localization of same when internalized by human –derived osteoblast cells. Yield of dye labelling as well as its effect on cellulose nanofibrils conformation and size are tracked by available HPLC and CE analytical techniques and complementary confirmed microscopically.

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2.3 Laboratorij za tiskanje tekstilij in nego oblačil

Laboratory for Textile Printing and Textile Care

Pedagoške in raziskovalne aktivnosti laboratorija so usmerjene na naslednja področja: *Tehnologija tiskanja (ploski filmski tisk; rotacijski tisk; toplotni tisk; kosmičasti tisk; digitalni tisk: ekološka sprejemljivost tehnologij tiskanja, oblikovanje vzorcev za digitalni tisk tekstilij), *Reologija (gostila; tiskarske gošče, tiskarske barvne gošče), *Tekstilna pomožna sredstva (ekološka sprejemljivost tekstilnih pomožnih sredstev, plemenitilnih in pralnih sredstev), *Nega tekstilij in oblačil (razvoj na področju nege tekstilij; tekstilna vlakna: uporabnost, preizkušanje in identifikacija za pripravo priporočil za nego, pomen simbolov nege tekstilij in oblačil), *Pralna sredstva; pranje tekstilij, *Tehnološke vode pralnic in kemičnih čistilnic (zakonodaja, postopki čiščenja tehnoloških vod pralnic in kemičnih čistilnic, uporaba naprednih tehnologij čiščenja; kemično čiščenje: alternativna topila in alternativni postopki kemičnega čiščenja; zakonodaja, ekologija, parametri kakovosti in standardizacija na področju nege tekstilij in oblačil; odstranjevanje madežev; higiena tekstilij, vrste mikroorganizmov v pralnicah, izvor mikroorganizmov, postopki dezinfekcije; postopki zagotavljanja higiene; zagotavljanje higiene pranja v pralnicah po RAL-GZ 992), *Strokovno izobraževanje in usposabljanje (ekološko sprejemljivi postopki tiskanje tekstilij; ekološko sprejemljivi postopki pranja in kemičnega čiščenja; računalniške tehnologije in metode priprave tiskanja tekstilij; digitalni tisk tekstilij).

*The activities of laboratory can be divided into research work and teaching activities in the following areas: *Printing technology (flat screen-printing; rotary printing; thermo printing; flock printing; digital printing; ecological acceptance of printing technologies, designing for digital textile printing), *Rheology (thickeners; printing pastes), *Textile auxiliary agents (ecological acceptance of textile auxiliary agents in chemical finishing and washing), *Textile care (important developments in the field of textile care; textile fibres: applicability, testing and identification for the preparation of textile care labels, meaning of symbols for textile care), *Washing agents; textile washing; *Laundry wastewaters (procedures for cleaning laundry wastewaters, legislation, use of progressive technologies; dry cleaning: alternative solvents and alternative dry cleaning procedures; legislation, ecology, quality parameters and standardization in the field of textile and garment care; stain removal; textile hygiene, types of micro-organisms found in laundries, origin of micro-organisms, disinfection procedures, hygiene assurance procedures; quality assurance for washing and textile hygiene RAL-GZ 992), *Professional qualification (ecologically acceptable textile printing procedures; ecologically acceptable washing and dry-cleaning procedures; computer technologies and methods of preparation for textile printing; digital textile printing).*

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2.4 Laboratorij za kemijo in okoljevarstvo

Laboratory for Chemistry and Environmental Protection

Raziskovalna dejavnost Laboratorija za kemijo in okoljevarstvo obsega:

- sintezo in modifikacijo barvil, polifukcionalnih reagentov in farmakološko aktivnih organskih spojin,
- iskanje učinkovite metode za odstranitev nečistoč iz odpadnih vod,
- obdelavo odpadnih vod z naprednimi oksidacijskimi postopki (AOP) (H_2O_2/UV, H_2O_2/O_3, H_2O_2/Fenton, H_2O_2/ultrazvok, termo/H_2O_2),
- primerjalne študije različnih naprednih oksidacijskih postopkov (AOP) za čiščenje modelnih in realnih odpadnih vod,
- aplikacijo ultrazvoka za čiščenje odpadnih vod,
- spremljanje prisotnosti toksičnih organskih spojin v barvilih, odpadnih vodah in v odpadnih vodah po obdelavi z AOP postopki,
- analizne metode v tekstilnih raziskavah (kromatografija: TLC, HPLC, MPLC, GC, SEC; spektroskopija: UV/VIS, FTIR, ATR-FTIR, RAMAN),
- uporabo ultrazvoka pri spreminjanju lastnosti tekstilnih površin,
- optimiranje postopkov čiščenja odpadnih vod,
- študij problematike formaldehida,
- sinteze različnih mikro/nano kapsul (kontrolirano sproščanje aktivnih snovi),
- obdelavo tekstilnih materialov z mikro/nano kapsulami in supramolekularnimi kompleksi,
- študij biorazgradljivosti različnih materialov ter
- kemijsko recikliranje različnih polimernih materialov in izolacija sekundarnih surovin.

Research activities of the Laboratory are:

- *synthesis and modification of dyes, polyfunctional reagents and pharmacologically active organic compounds,*
- *searching for an efficient method for pollutants removal from waste waters,*
- *treatment of wastewater with advanced oxidation processes (AOP) (H_2O_2/UV, H_2O_2/O_3, H_2O_2/Fenton, H_2O_2/ultrasound, thermal/H_2O_2),*
- *comparative studies of various advanced oxidation treatment for model wastewater solutions and real waste water,*
- *ultrasound application for wastewater treatment,*
- *detection of toxic organic compounds in dyes, wastewater and wastewater after treated with AOP,*
- *analytical methods in textile research (chromatographic: TLC, HPLC, MPLC, GC; spectroscopic: UV/VIS, FTIR, ATR-FTIR, NMR and other chemical analysis),*
- *ultrasound assisted modification of textile surfaces,*
- *optimization of waste water treatment systems,*
- *study formaldehyde issues,*
- *synthesis of various micro/nano-capsules (controlled release of active compounds).*
- *application of micro/nano-capsules and supramolecular compounds onto textile surfaces,*
- *study the biodegradability of various materials.*

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2.5 Laboratorij za tekstilne tehnologije in računalništvo v tekstilstvu

Laboratory for Textile Technologies and Computer-Based Textile Applications

Laboratorij za tekstilne tehnologije in računalništvo v tekstilstvu se vključuje v raziskovalno delo Inštituta za inženirske materiale in oblikovanje in pedagoško delo Katedre za tekstilne materiale in oblikovanje. Področje tekstilnih tehnologij predstavlja nadaljevanje tradicije raziskovanja in razvoja na področjih tekstilno mehanskih tehnologij in procesov, predvsem procesov izdelave predivnih prej in pletiv. Raziskovalne aktivnosti na področju predenja so usmerjene v kakovostno in cenovno optimiranje mešanice prediv in napovedovanje rezultirajočih mehanskofizikalnih in vizualnih lastnosti predivnih prej ob upoštevanju robnih pogojev predilnega procesa. Raziskave na področju računalništva v tekstilstvu so usmerjene predvsem na področje vizualizacije linijskih in ploskih tekstilij, oblačil in drugih tekstilnih form. Razvojno delo laboratorija podpira inoviranje tekstilno mehanskih procesov predenja in pletenja z uvajanjem ustreznih računalniško podprtih informacijskih sistemov. Najpomembnejši izvedeni mednarodni raziskovalni projekti, v katere se vključuje laboratorij, sodijo v raziskovalne programe Erasmus+, LdV in INCO-Copernicus; pomembni pa so tudi izvedeni mednarodni bilateralni projekti. Aktualni projekt je E+ Skills4Smartex - Pametne tekstilije za izobraževanje po načelu »STEM«.

Textile technologies and computer-based textile applications laboratory is integrated into research activities of the Institute for Engineering Materials and Design and educational activities of the Chair for Textile Materials and Design. Area of textile technologies represents the continuation of tradition related to research and development in the field of mechanical textile technologies and processes, above all production of spun yarns and knitted fabrics. Research activities in the area of spinning are focused towards quality- and economy-related optimisation of fibre blends, as well as prediction of mechanical and visual properties of spun yarns. Research activities, related to the area of computer-based applications, are mainly directed towards visualisation of yarns, fabrics, garments and other types of textile forms. With its professional activities the laboratory supports innovation of spinning and knitting processes by introducing suitable computer-based systems. The most important international research projects involving the laboratory belong to Erasmus+, LdV and INCO-Copernicus research programs. The current project is E+ Skills4Smartex - Smart textiles for STEM training.

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2.6 Laboratorij za projektiranje in konstrukcijo tekstilij

Laboratory for Fabric Planning and Construction

Laboratorij za projketiranje in konstrukcijo tekstilij se ukvarja s pedagoškim in raziskovalnim delom na področju projektiranja in konstruiranja linijskih in ploskih tekstilij za oblačila, notranjo opremo in v tehnične namene. Pomembnejša tematska področja raziskav v okviru laboratorija so:

- študij poroznosti tekstilnih in netekstilnih materialov,
- razvoj tekstilij za zaščito pred vremenskimi vplivi in ultravijoličnim sevanjem,
- razvoj tekstilij za skladiščenje sončne energije,
- modeliranje funkcionalnih lastnosti tekstilij,
- načrtovanje mehanskih lastnosti tehničnih tekstilij,
- posodabljanje procesa vzorčenja in konstruiranja tkanin.

Za analiziranje parametrov poroznosti in mehanskih lastnosti tekstilnih materialov koristimo v laboratoriju sodobno, računalniško podprto opremo – živosrebrni porozimeter Pascal, optični sistem za slikovno analizo tekstilnih materialov Lucia ter Tinius Olsen elektromehanski sistem za testiranje mehanskih lastnosti linijskih in ploskih tekstilij. V laboratoriju je instaliranih več delovnih postaj oz. sodobnih CAD sistemov Arahne za simulacijo listnih in žakarskih tkanin ter njihovo vizualizacijo v končnem izdelku.

The laboratory performs teaching activities and research work focused on the specific research field, e.g. Yarn/Fabrics engineering and Construction planning for garments, interior, and technical purposes. The most important research topics are:

- *study of porosity in textile and non-textile materials,*
- *development of fabrics for protection against weather conditions and solar UV radiation,*
- *development of solar textiles,*
- *modelling of fabric performance properties,*
- *engineering of technical textiles mechanical properties,*
- *modernisation of woven fabric patterning and construction.*

The Laboratory is equipped with modern computer aided measuring equipment, e.g. mercury porosimeter Pascal, optical system for textile material image analyses Lucia and Tinius Olsen electromechanical testing machine, which are used for analysing porosity parameters and mechanical properties of textiles. Modern CAD systems for dobby and jacquard woven fabric simulation and their visualisation in the final products are also installed in the laboratory.

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2.7 Laboratorij za oblačilno inženirstvo ter fiziologijo in konstrukcijo oblačil

Laboratory for Clothing Engineering, Physiology and Garment Construction

Osnovni dejavnosti laboratorija sta pedagoška in raziskovalna dejavnost. Raziskave so pomemben in vidni del aktivnosti. S tematskega vidika zaokrožujejo kompleksno področje med seboj povezanih tematik, kot so:

- mehanika ploskih tekstilij, ki obsega raziskave elastičnih deformacij, viskoelastično obnašanje tekstilnih struktur in kompleksne deformacije,
- inženirsko projektiranje, usmerjeno na področje razvoja in projektiranja funkcionalnih in inteligentnih oblačil,
- ergonomija toplotnega okolja, ki združuje kompleksno proučevanje oblačilnega sistema, kakovostnih zahtev tekstilnih materialov in udobja pri nošenju.

Laboratorij je opremljen s sodobno opremo za objektivno vrednotenje mehanskih in fizikalnih lastnosti ploskih tekstilij (KES-FB AUTO in FAST merilni sistem), parametrov drapiranja (Cusick drape tester), toplotnih lastnosti (KES-F7 Thermo Labo) in CAD sistemom za konstrukcijo oblačil (OptiTex). Pomemben del raziskovalne infrastrukture predstavlja računalniško krmiljena klima komora za raziskave toplotnega udobja pri nošenju oblačil z ustrezno opremo za merjenje toplotno fizioloških parametrov – bio signalov testnih oseb (MSR12, pomični ergotrak, IR kamera FLIR P65, PicoPress).

The core activities of the laboratory are educational and research activities. Research is an important and visible part of the activities. From a thematic perspective connects the complex field of interrelated topics, such as:

- *the mechanics of textiles (research into elastic deformations, viscoelastic behaviour, and complex deformations of textile structures),*
- *engineering design focused on the development and design of functional and intelligent clothing,*
- *ergonomics of the thermal environment that is focuses on human thermal physiology, based on studying complex aspects of clothing system, textile materials performance, and wearing comfort.*

The Laboratory is equipped with modern devices and measuring equipment for objective evaluation of the mechanical and physical properties of textile materials (KES-FB AUTO and FAST System), draping parameters (Cusick drape tester), thermal properties (KES-F7 Thermo Labo) and garment construction CAD systems OptiTex. Furthermore, the laboratory is equipped with a computer-controlled climatic chamber for investigation of wearing comfort (MSR12, treadmill, IR camera FLIR P65, PicoPress).

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Center za nego tekstilij in oblačil

Centre for Textile Care

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Center za nego tekstilij in oblačil je institucija, ki se sistematično in poglobljeno ukvarja z nego tekstilij in oblačil. Ustanovljen je bil v sodelovanju s Čistilnico in pralnico Labod, d.o.o. Ljubljana, s strani Fakultete za strojništvo Univerze v Mariboru pa so vodjo in Center potrdili dne 01.01.1999.

S Centrom za nego tekstilij in oblačil Univerze v Mariboru sodelujejo tudi laboratoriji, kjer se izvajajo temeljne in aplikativne raziskave, ki se prenašajo v tekstilno industrijo, kemične čistilnice, pralnice, k proizvajalcem čistilnih in pralnih sredstev ter proizvajalcem čistilnih in pralnih strojev, itd.

Center objavlja aktualne informacije na področju nege tekstilij in oblačil v reviji Tekstilec.

Dejavnosti Centra:

- zbiranje informacij o novostih na področju nege tekstilij in oblačil,
- svetovanje na področju nege tekstilij in oblačil,
- reklamacije s področja nege tekstilij in oblačil,
- informiranje in uvajanje standardov,
- izobraževanje,
- prenos znanja k uporabnikom.

The Textile Care Centre is an institution where systematic in-depth research is carried out based on textile care. It was established in collaboration with the Labod d.o.o. dry cleaner and laundry, Ljubljana. The leader from the Faculty of Mechanical Engineering was confirmed on the 1st of Jan 1999.

The Centre also co-operates with laboratories where fundamental and applicative research is carried out in collaboration with the textile industry, dry cleaners, laundries and the producers of cleaning and washing agents, and machines, etc.

In collaboration with Slovenian laundries, the Centre has conducted a detailed control examination of the current conditions for wastewater, in regard to statutory regulations.

The Centre publishes actual information about textile care in Slovene journal for textile and clothing technology "Tekstilec".

Main goals of the Centre are:

- *to collect new information about textile care,*
- *to advise about textile care,*
- *to work on reclamations,*
- *to inform and introduce standards,*
- *to educate and*
- *to transfer the knowledge to the users.*

Center za barvanje in barve

Centre for Dyeing and Colour

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Center za barvanje in barve izvaja vrsto aktivnosti, ki so povezane z barvanjem, barvnim zaznavanjem in merjenjem barve. Področje delovanja vključuje različna področja kot je tekstil, papirna industrija arhitektura, umetnost, psihologija, prehrambena industrija, medicina in ostala področja povezana z barvo.

V okviru svoje dejavnosti center izvaja naslednje aktivnosti:

- meritve refleksijskih vrednosti obarvanih vzorcev z različnimi merilnimi inštrumenti kot so UV/VIS spektrofotometer Varian Carry 50, ima pa tudi sodoben UV/VIS/NIR spektrofotometer Lambada 900, z nastavkom PELA 1020,
- meritve transmisijskih vrednosti prozornih in prosojnih vzorcev v trdnem ali tekočem stanju,
- določanje barvnometričnih vrednosti (X,Y,Z, x, y, L*, a*, b*, C*, h),
- določanje barvnih razlik (CIELAB, CIELUV, CMC(l:c), CIE94, CIEDE2000, …),
- določanje beline (CIE, Ganz, Harrison, Stephensen, Berger, Stensby, Hunter),
- računalniško receptiranje,
- meritve v UV-VIS-NIR področju (250-2500nm),
- določanje zaščitnega faktorja vzorca (UPF - Ultraviolet Protective Factor),
- izobraževanje in svetovanje, študije, mnenja.

Center ima tudi različne sistemizirane barvne karte, barvne sisteme in barvne kataloge.

The dyeing and colours centre working domain encompasses all activities connected with dyeing, colour sense and measurement. It incorporates various branches such as textiles, papermaking, pigments, architecture, civil engineering, art, psychology, the food-processing industry, medicine and others.

Main activities of the Centre are:

- *reflexion values measurement of coloured samples using different measuring equipment, UV/VIS/NIR Spectrophotometer Lambda 900 (PELA 1020), Datacolor,*
- *transmittance value measurement of transparent and translucent samples in solid and liquid condition,*
- *determination of colour values (X,Y,Z, x, y, L*, a*, b*, C*, h),*
- *determination of colour differences (CIELAB, CIELUV, CMC(l:c), CIE94, CIEDE2000, …),*
- *determination of whiteness (CIE, Ganz, Harrison, Stephensen, Berger, Stensby, Hunter),*
- *computer match prediction,*
- *reflexion values measurement in UV, VIS and near IR range (250-2500nm),*
- *determination of Ultraviolet Protective Factor (UPF),*
- *education and consultation, expertise.*

The Centre possesses an extensive collection of various colour systems, colour cards and catalogues.

Raziskovalno-inovacijski center za design in oblačilno inženirstvo

Research and Innovation Centre for Design and Clothing Science

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Raziskovalno-inovacijski center za design in oblačilno inženirstvo (RICDOI) je bil oblikovan na Fakulteti za strojništvo Univerze v Mariboru v skladu s potrebami izvajanja, učinkovitega razvijanja, organiziranja in spodbujanja izobraževalnega in znanstveno-raziskovalnega dela na področju oblikovanja, oblačilne znanosti in inovativnega razvoja tekstilnih izdelkov.

V okviru RICDOI delujeta Laboratorij za oblačilno inženirstvo, fiziologijo in konstrukcijo oblačil in Modni atelje.

Raziskovalna dejavnost se odvija v okviru raziskovalnega programa Oblačilna znanost, udobje in tekstilni materiali ter v okviru domačih in mednarodnih znanstveno-raziskovalnih projektov.

Raziskovalni program vključuje proučevanje fenomenov obnašanja tekstilnih struktur pri malih obremenitvah, razvoj pametnih, inteligentnih in/ali funkcionalnih oblačil in ergonomijo toplotnega okolja s poudarkom na študiju celovitega zagotavljanja udobja pri nošenju oblačil.

Viden del raziskovalnih aktivnosti je usmerjen na ožje področje oblačilnega inženirstva, eksperimentalno oblikovanje in razvoj, inovativne tehnologije na področju razvoja pametnih in inteligentnih oblačil in/ali drugih izdelkov za tehnično aplikacijo, osebno zaščitno opremo, fiziologijo oblačil in udobje pri nošenju.

The Research and Innovation Centre for Design and Clothing Science (RICDCS) at the Faculty of Mechanical Engineering, University of Maribor, was designed according to the need for implementing effective development, organising and promoting educational and scientific-research work in the fields of design, clothing science, and innovative designing of textile products.

Laboratory of Clothing Engineering, Physiology and Construction of Garments and Fashion studio are active within RICDCS.

The research activity is carried out within the research program Clothing Science, Comfort and Textile Materials, as well as domestic and international scientific research projects.

The research program involves the study of phenomena related to the behaviour of textile structures at lower loads, development of smart and intelligent garments and ergonomics of thermal environment with an emphasis on wearing comfort.

The visible part of research activity focuses on areas of clothing engineering, experimental design and development, innovative technologies by development of smart and intelligent clothing and wearing comfort.