ANALIZA POŠKODB

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	Analiza poškodb
Course title:	Failure Analyses
Članica nosilka/UL Member:	UL NTF

Študijski programi in stopnja	Študijska smer	Letnik	Semestri	Izbirnost
Metalurgija in materiali, druga stopnja, magistrski	Ni členitve (študijski program)	2. letnik	1. semester	izbirni

Univerzitetna koda predmeta/University course code:	0067975
Koda učne enote na članici/UL Member course code:	872

Predavanja /Lectures	Seminar /Seminar	Vaje /Tutorials	Klinične vaje /Clinical tutorials	Druge oblike študija /Other forms of study	Samostojno delo /Individual student work	ECTS
40	0	20	0	0	60	4

Nosilec predmeta/Lecturer:	Aleš Nagode, Borut Kosec

Izvajalci predavanj:	
Izvajalci seminarjev:	
Izvajalci vaj:	
Izvajalci kliničnih vaj:	
Izvajalci drugih oblik:	
Izvajalci praktičnega usposabljanja:	

Vrsta predmeta/Course type:	Izbirni / Elective

Jeziki/Languages:	Predavanja/Lectures:	Slovenščina
	Vaje/Tutorial:	Slovenščina

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	**Prerequisites:**
Pogoj za vključitev v delo oziroma za opravljanje študijskih obveznosti je vpis v 2. letnik študija. Izdelana in uspešno predstavljena projektna naloga je pogoj za pristop k pisnemu in ustnemu izpitu.	The condition to attend in the teaching course and to perform study obligations is an entry in the second year of study. Completed and successfully presented project work is required before taking the written and oral examination.

Vsebina:	**Content (Syllabus outline):**
Mehanizmi nastanka napak in poškodb. Najpogostejši mehanizmi nastanka poškodb; lom, krhki lom, obraba, utrujanje, temperaturno utrujanje, korozijsko	Mechanisms of failures and damages formation. The most frequent mechanisms of damages formation: fracture, brittle fracture, wear, fatigue, thermal fatigue,

utrujanje, napetostna korozija, …. Študij zaostalih napetosti. Identifikacija poškodb in napak. Analiza. Preiskovalne metode. Fizikalne metode: mehanske preiskave, metalografske preiskave, kemične analize, korozijski testi. Preiskave brez porušitve materiala: optične metode, metoda replik, preiskave s penetranti, radiografija, nevtronografija, magnetne preiskave, preiskave z ultrazvokom. Napake pri izdelavi in eksploataciji – primeri. Študija primerov poškodb in strojelomov. Modeliranje. Numerične simulacije. Standardi. Predpisi. Patenti. Izdelava ekspertiz, poročil in izvedeniških mnenj. Metodologija, zahteve in pravila izdelave mnenj za sodišča, zavarovalnice in druge naročnike. Predstavitve. Projektna naloga. Samostojna izdelava ekspertize ali izvedeniškega mnenja.	corrosion fatigue, stress corrosion, …. Study of residual stresses. Identification of failures and damages. Analyses. Examination methods. Physical methods: mechanical testing, metallographic examination methods, chemical analyses, corrosion tests. Non-destructive testing methods: optical examination methods, replicas methods, examinations by penetrants, radiography, neutronography, magnetic examination, ultrasonic examination. Failures at manufacturing and exploitation - examples. Study of cases of damages and machines breaking. Modeling. Numerical simulations. Standards. Rules. Patents. Working and preparation of exspertises, reports and expert elaborates. Methodology, requirements and rules of work and preparation of expert elaborates for courts, insurance companies and other clients. Presentations. Project work. Individual preparation of expertise or expert work.

Temeljna literatura in viri/Readings:

TIMMINS, F.P. Fracture Mechanics and Failure Control for Inspectors and Engineers. Materials Park Ohio: ASM International, 1994.
DAS, A.K. Metallurgy of Failure Analysis, New York: McGraw – Hill, 1996.
Handbook of Case Histories in Failure Analysis. Materials Park Ohio: ASM International, 1992.
Allianz Handbook of Loss Prevention. Berlin – München: Allianz Versicherungs AG, 1987.
Von AKEN, C.D., HOSFORD, F.W. Reporting Results – A Practical Guide for Engineers and Scientists. Cambridge: Cambridge University Press, 2008.
TOTTEN, G.E., HOWES, M.A.H., TATSUO, I. Handbook of Residual Stress and Deformation of Steel. Materials Park Ohio: ASM International, 2002.
Predpisi 10: Ljubljana: Zveza strojnih inženirjev in tehnikov, 2010.
MATTHEWS, C.A. Guide to Presenting Technical Information. London: Professional Engineering Publishing, 2000.
MONTGOMERY, C.D. Design and Analysis of Experiments. Haboken: John Wiley & Sons, 2009.
QUA H.-C., TAN C.-S., WONG K.-C. Applied Engineering Failure Analysis: Theory and Practice, CRC Press, Taylor & Francis Group, Boca Raton, 2015.
KOSEC B., NAGODE A., KOSEC G. Analiza napak in poškodb, Univerza v Ljubljani NTF, Ljubljana, 2017.

Cilji in kompetence:	**Objectives and competences:**
Namen predmeta Analiza poškodb je poglobiti poznavanje in uporabo metod identifikacije in analize napak in poškodb. Pokazati značilne pojave in oblike nastanka poškodb in napak na različnih materialih, izdelkih, konstrukcijah, delih orodij, strojev in naprav. Spoznati študente s standardi, predpisi in patenti. Naučiti sistematike analiz in raziskav ter izdelave ekspertiz in izvedeniških mnenj. Pridobljena teoretična znanja študent nadgradi z uporabo preiskovalnih metod, modelov in simulacij ter izdelavo mnenja o konkretnem kompleksnem problemu v okviru projektnega dela.	The purpose of the Failure analyses course is to increase the students' knowledge in application methods for identification and analyses of failure modes, errors and defects in manifold products, structures, parts of tools, machinery and equipment. Show the typical phenomena and forms of failure modes, damages and defects in various materials. To acquaint students with the standards, regulations and patents. Learn systematic analysis and research and to value expertise and expert opinions. Upgrade an acquired knowledge with the use of investigative methods, models and computer simulations within the scope of deliberations and complex project case study.

Predvideni študijski rezultati:	Intended learning outcomes:
Študent pridobi znanja o mehanizmih nastanka poškodb ter obvlada preiskovalne metode in orodja za njihovo objektivno inženirsko analizo in vrednotenje. V okviru praktičnega dela se spozna z značilnimi praktičnimi primeri havarij, poškodb in napak in z učiteljem ter kolegi analizira in podaja zaključke in rešitve. Študent nadgradi pridobljeno teoretično znanje z uporabo preiskovalnih metod, modelov in simulacij. Razumevanje vsebin in stopnjo obvladanih znanj dokaže z izdelavo mnenja o konkretnem inženirskem primeru.	Student acquire knowledge about the mechanisms of failure modes and mastered investigative methods and tools for their objective engineering analysis and evaluation. In practical work is familiar with typical examples of breakdown, failure and defects in various materials and products. Within the scope of deliberations with teachers and colleagues analyzes and presents conclusions and solutions for the case studies of practical failures. Student has to demonstrate his understanding of content and level of skills by making an expert opinion on the case study of engineering.

Metode poučevanja in učenja:	Learning and teaching methods:
Predavanja. Timsko in samostojno reševanje problemov. Računalniške simulacije in eksperimentalno delo. Raziskovalno delo in projektna naloga.	Lectures. Team and independent problem solving. Computer simulation and experimental work. Research work and project work.

Načini ocenjevanja:	Delež/Weight	Assessment:
ocena projektnega dela	45,00 %	the mark of project work
ocena pisnega dela izpita	25,00 %	the mark of written examination
ocena ustnega dela izpita	30,00 %	the mark of the oral examination

Reference nosilca/Lecturer's references:

KOSEC B., KOVAČIČ G., KOSEC L.. Fatigue cracking of an aircraft wheel. Engineering Failure Analysis, 9 (2002) 5, 603-609.

KOSEC G., **NAGODE A.,** BUDAK I., ANTIĆ A., **KOSEC B**.. Failure of the pinion from the drive of a cement mill. Engineering Failure Analysis, 8 (2011) 18, 450-454.

NAGODE A., KLANČNIK G., SCHWARCZOVA H., **KOSEC B.,** GOJIĆ M., KOSEC L. Analyses of defects on the surface of hot plates for an electric stove. Engineering failure analysis. 23 (2012) 23, 82-89.

KOVAČEVIĆ D., BUDAK I., ANTIĆ A**., NAGODE A., KOSEC B.** FEM modeling and analysis in prevention of the waterway dredgers crane serviceability failure. Engineering failure analysis. 28 (2013) 28, 328-339.

IVANIĆ I., KOŽUH S., KOSEL F., **KOSEC B.**, ANŽEL I., BIZJAK M., GOJIĆ M. The influence of heat treatment on fracture surface morphology of the CuAlNi shape memory alloy. *Engineering failure analysis*. 77 (2017), 85-92.

NAGODE A., JERINA K., JERMAN I., VELLA D., BIZJAK M., **KOSEC B.**, KARPE B., ZORC B. The effect of sol-gel boehmite coatings on the corrosion and decarburization of C45 steel. Journal of sol-gel science and technology. 86 (2018) 3, 568-579.

ZORC M., **NAGODE A., KOSEC B**., ZORC B. Determining the degree of admixing rate of the base material and the melting efficiency in single-bead surface welds using different methods, including new approaches. Materials. 12 (2019) 9, 1-15 (1479).

ZORC B., ZORC M., **KOSEC B., NAGODE A**. Effect of the shape of styrene-acrylonitrile water-filter housings on the destructive pressure, crack-initiation, propagation conditions and fracture toughness of styrene-acrylonitrile. Polymers. 12 (2020) 2, 1-22.

FIZIKALNA METALURGIJA 2

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	Fizikalna metalurgija 2
Course title:	Physical Metallurgy 2
Članica nosilka/UL Member:	UL NTF

Študijski programi in stopnja	Študijska smer	Letnik	Semestri	Izbirnost
Metalurgija in materiali, druga stopnja, magistrski	Ni členitve (študijski program)	1. letnik	1. semester	obvezen

Univerzitetna koda predmeta/University course code:	0067979
Koda učne enote na članici/UL Member course code:	854

Predavanja /Lectures	Seminar /Seminar	Vaje /Tutorials	Klinične vaje /Clinical tutorials	Druge oblike študija /Other forms of study	Samostojno delo /Individual student work	ECTS
45	10	25	0	10	90	6

Nosilec predmeta/Lecturer:	Boštjan Markoli, Iztok Naglič

Izvajalci predavanj:	
Izvajalci seminarjev:	
Izvajalci vaj:	
Izvajalci kliničnih vaj:	
Izvajalci drugih oblik:	
Izvajalci praktičnega usposabljanja:	

Vrsta predmeta/Course type:	Obvezni / Compulsory

Jeziki/Languages:	Predavanja/Lectures:	Slovenščina
	Vaje/Tutorial:	Slovenščina

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	Prerequisites:
Veljajo splošni pogoji za drugostopenjski študij. Pogoj za vključitev v delo oziroma za opravljanje študijskih obveznosti je vpis v I. letnik drugostopenjskega študija. Obvezna prisotnost pri laboratorijskih vajah. Prisotnost pri predavanjih in seminarskih vajah v skladu s pravili UL. Do frekvence so upravičeni vsi, ki glede prisotnosti izpolnjujejo predpise UL. K ustnemu izpitu lahko pristopijo tisti s pozitivno opravljenimi testi, seminarskimi obveznostmi ali s pozitivno oceno pisnega izpita in izpolnjenimi seminarskimi obveznostmi.	Subject to general conditions for the second cycle of studies. The condition for inclusion in the work or to undertake work commitments is an entry in the I. year study of Appeal. Attendance at the lab. Attendance at lectures and tutorials in accordance with the rules of University of Ljubljana (UL). The professor´s signature is awarded to all students who comply with regulations regarding the lecture and laboratory presence at UL. The oral examination may be given access to those with positive tests from, obligations or seminar with a positive assessment of the written exam and fulfilled the obligatory seminar.

Vsebina:	Content (Syllabus outline):
Struktura kovinskih materialov in njene značilnosti v povezavi z lastnostmi ter možnosti njene karakterizacije s sodobnimi metodami na splošno(TEM, HRTEM, STEM, AFM, XPS, AES, DSC itd.) Struktura tretjega stanja-kvazikristalnega in obravnava dosežkov na področju kovinskih stekel. Dislokacije, dvojčenje in deformacija. Poprava in rekristalizacija. Trdne raztopine in substitucijska ter intersticijska difuzija. Strjevanje kovinskih talin. Nukleacija in rast. Fizikalno-metalurške osnove zgradbe binarnih in ternarnih zlitinskih sistemov. Fazna ravnotežja (reakcije in premene), ki nastopajo v teh sistemih. Fizikalno-metalurške zakonitosti in termodinamske značilnosti potekov reakcij evtektičnega, peritektičnega, monotektičnega, sintektičnega in metatektičnega tipa s praktičnimi primeri na tehničnih zlitinah. Obravnava premen poteka v zlitinskih sistemih v trdnem stanju (evtektoidna, peritektoidna, metatektoidna itd. premena) s primeri procesov razmešanja in urejevanja. Martenzitne premene. Precipitacija in utrjevanje. Scheilova metoda napovedovanja CCT diagramov na osnovi TTT diagramov. Predstavitev osnov napovedovanja konstitucije zlitinskih sistemov na osnovi fizikalno-kemijskih lastnosti kemijskih elementov. Modeliranje zgradbe zlitinskih sistemov in napovedovanje faznih ravnotežij s pomočjo programskih paketov.	The structure of metallic materials and its characteristics in relation to the properties and possibilities of its characterization using modern methods in general (TEM, HRTEM, STEM, AFM, XPS, AES, DSC, etc..) Structure of the third state of matter-quasicrystalline and evaluation of achievements in the field of metallic glasses. Dislocations, twinning and deformation. Recovery and recrystallization. Solid solution and substitutional and interstitial diffusion. Solidification of molten metal. Nucleation and growth. Physico-metallurgical basics of binary and ternary alloying systems. Phase equilibria (reactions and transformations) that occur in these systems. Physico-metallurgical fundamentals and thermodynamic characteristics of reactions features of eutectic, peritectic, monotectic, metatectic, sintectic type and practical examples of technical alloys. The treatment of transformations in the alloying systems in solid state (eutectoid, peritectoid, metatectoid etc. transformation), examples of decomposition and ordering processes. Martensite transformation. Precipitation and hardening. Scheilova forecasting method based on the CCT diagrams, TTT diagrams. Presentation of the basic constitution of alloying forecasting systems based on physico-chemical properties of chemical elements. Modeling building alloying systems and phase equilibria prediction using software packages.

Temeljna literatura in viri/Readings:

David A. Porter, Kenneth E. Easterling, Mohamed Y. Sherif, Phase Transformations In Metals And Alloys, 3rd Edition,
2010
Marinković, V., Fizikalna metalurgija II, (OMM,NTF,UL, Ljubljana,1999)
R. Abbaschian, L. Abbaschian, R.E. Reed-Hill, Physical Metallurgy Principles, Fourth Edition, SI, CENGAGE Learning, 2010
Markoli, B., Fizikalna metalurgija I: ternarni in kvaterni sistemi. 2. izd. Ljubljana: Naravoslovnotehniška fakulteta, Oddelek za materiale in metalurgijo, 2009. ISBN 978-961-6047-67-8

Cilji in kompetence:	Objectives and competences:
Cilj je študentu/ki dati potrebna teoretična znanja (podprta s praktičnimi primeri), ki mu/ji omogočajo razumevanje povezave med fizikalno-kemijskimi lastnostmi elementov in njihovimi interakcijami v zlitinskih sistemih. Študentje se usposobijo in pridobijo kompetence na področju fizikalne metalurgije, ki se posveča problematiki konstitucije zlitinskih sistemov in heterogenih ravnotežij pri strjevanju, procesov strjevanja, izločevalnega utrjanja, premen in fizikalno-metalurških procesov v trdnem in iz njih izhajajoče zgradbe kovinskih materialov.	The goal is to deliver the necessary theoretical knowledge (supported with practical examples) to to a student in order to enable him/her to understand the relationship between the physico-chemical properties of elements and their interactions in the alloying systems. Students learn and acquire skills in the field of physical metallurgy, which deals with the issue of the constitution alloying systems and heterogeneous equilibrium solidification, solidification processes, precipitation hardening, changes and physical-metallurgical processes in the solid and the resulting structure of metallic materials.

Predvideni študijski rezultati:	Intended learning outcomes:
Znanje in razumevanje: Deklarativno znanje: Spoznati in razumeti principe fizikalne metalurgije, ki vplivajo na lastnosti in obnašanje kovinskih materialov na višji ravni. Študentje naj bi dosegli raven znanja na področju fizikalne metalurgije (teoretično kot tudi praktično), ki jim daje kompetentnost pri razumevanju in vplivanju na koncept strukturo-lastnosti-uporaba.	Knowledge and understanding: Declarative knowledge: To learn and understand the principles of physical metallurgy governing the properties and behavior of metallic materials on a higher level. Students should achieve the level of knowledge in the field of physical metallurgy (both theoretical as well as practical) that will make them competent in understanding and influencing the concept structure-properties-purpose.

Metode poučevanja in učenja:	Learning and teaching methods:
Predavanja, konzultacije, seminarji, laboratorijske vaje, sodelovanje na aktualnih projektih.	Lectures, consultations, seminars, laboratory work, participation in current projects.

Načini ocenjevanja:	Delež/Weight	Assessment:
Test v semestru	30,00 %	Test in the semester
Ustni izpit	30,00 %	Oral exam
pisni izpit	30,00 %	examination
seminar	10,00 %	seminar

Reference nosilca/Lecturer's references:

SKOBIR, Danijela Anica, GODEC, Matjaž, JENKO, Monika, **MARKOLI, Boštjan.** Characterization of the carbides in the steel X20CrMoV12.1 used in thermal power plants. *Surf. interface anal.*, 2008, vol. 40, no. 3/4, str. 513-517.

MARKOLI, Boštjan, BONČINA, Tonica, ZUPANIČ, Franc. The solidification path of the complex metallic Al-Mn-Be alloy. *Croat. chem. acta*, Apr. 2010, vol. 83, no. 1, str. 49-54.

ZUPANIČ, Franc, **MARKOLI, Boštjan, NAGLIČ, Iztok**, BONČINA, Tonica. The experimental investigation of phase equilibria in the Al-rich corner within the ternary Al-Mn-Be system. *Journal of alloys and compounds*, ISSN 0925-8388. [Print ed.], 5. sep. 2013, vol. 570, str. 125-132, graf. prikazi, doi: 10.1016/j.jallcom.2013.03.048. [COBISS.SI-ID 16835862]

NAGLIČ, Iztok, SAMARDŽIJA, Zoran, DELIJIĆ, Kemal, KOBE, Spomenka, LESKOVAR, Blaž, **MARKOLI, Boštjan**. Synthesis of an Al-Mn-based alloy containing in situ-formed quasicrystals and evaluation of its mechanical and corrosion properties. JOM : The journal of minerals, metals and materials society. 2018, vol. 70, no. 11, str. 2698-2703. ISSN 1047-4838. DOI: 10.1007/s11837-018-2945-6. [COBISS.SI-ID 1731679]

NAGLIČ, Iztok, LESKOVAR, Blaž, SAMARDŽIJA, Zoran, **MARKOLI, Boštjan**. Influence of Ga on the formation of phases in cast Al-Mn-based alloys. Intermetallics, ISSN 0966-9795. [Print ed.], 2021, vol. 136, str. 1-6, doi: 10.1016/j.intermet.2021.107263. [COBISS.SI-ID 69218563]

FIZIKALNA METALURGIJA JEKEL

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	Fizikalna metalurgija jekel
Course title:	Physical Metallurgy of Steels
Članica nosilka/UL Member:	UL NTF

Študijski programi in stopnja	Študijska smer	Letnik	Semestri	Izbirnost
Metalurgija in materiali, druga stopnja, magistrski	Ni členitve (študijski program)	1. letnik	2. semester	obvezen

Univerzitetna koda predmeta/University course code:	0067980
Koda učne enote na članici/UL Member course code:	861

Predavanja /Lectures	Seminar /Seminar	Vaje /Tutorials	Klinične vaje /Clinical tutorials	Druge oblike študija /Other forms of study	Samostojno delo /Individual student work	ECTS
45	10	35	0	0	90	6

Nosilec predmeta/Lecturer:	Aleš Nagode

Izvajalci predavanj:	
Izvajalci seminarjev:	
Izvajalci vaj:	
Izvajalci kliničnih vaj:	
Izvajalci drugih oblik:	
Izvajalci praktičnega usposabljanja:	

Vrsta predmeta/Course type:	Obvezni / Compulsory

Jeziki/Languages:	Predavanja/Lectures:	Slovenščina
	Vaje/Tutorial:	Slovenščina

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	Prerequisites:
Opravljene vse vaje in seminar so pogoji za pristop k izpitu	The condition for taking an examination are successfully completed tutorials and seminars

Vsebina:	Content (Syllabus outline):
Fizikalna metalurgija jekla: 1 Jekla 1.1 Železo in intersticijske trdne raztopine: alotropija, polimorfizem, premene, ogljik in dušik v železu; 1.2 Utrjevanje železa in zlitin: deformacijsko utrjevanje, trdne raztopine, disperzijsko utrjevanje, kristalno zrno; 1.3 Ravnotežni diagram železo-ogljik, ogljikova jekla,	Physical metallurgy of steel: 1 Steels 1.1 Iron and interstitial solid solution allotropy, polymorphism, transformations, carbon and nitrogen in iron; 1.2 The strengthening of iron and alloys: work hardening, solid-solution, dispersion hardening, crystal grain

tvorba avstenita, transformacije avstenita v ferit, cementit, perlit; 1.4 Legirni elementi: porazdelitev v jeklih, vpliv na mikrostrukturo; transformacije avstenita v martenzit, v bainit, acikularni ferit, kinetika faznih transformacij (TTT, CCT); 1.5 Prekaljivost jekel, kalilne napetosti; 1.6 Popuščanje 1.7 Toplotne obdelave Spoznajo: toplotne obdelave jekel: normalizacijo, žarjenja, kaljenje, popuščanje, martempering, austempering, toplotne obdelave s podhladitvijo, toplotne obdelave visokotrdnih jekel; 1.8 Utrjevanje površin: kemotermične obdelave, lokalna kaljenja; 1.9 Meritve in kontrola temperature; pečne atmosfere, kontrola ogljika; varnost peči; 1.10 Toplotna obdelava železovih litin, toplotna obdelava orodnih jekel, toplotna obdelava nerjavnih jekel in temperaturno obstojnih zlitin; 1.11 Napake pri toplotni obdelavi; kontrolni postopki za toplotno obdelavo jekla in zlitin; 1.12 Jekla: ogljikova jekla, legirana jekla, maraging jekla, viskokotrdna malolegirana jekla, jekla z dualno mikrostrukturo, nerjavna jekla, orodna jekla, jekla iz prahov;	1.3 Iron-carbon equilibrium diagram, carbon steels, austenite formation, austenite to ferrite transformation, cementite, perlite 1.4 Alloying elements: distribution in steel, their influence on the microstructure; transformation of austenite in martensite (bainite, acikular ferrite), kinetics of phase transformations (TTT, CCT) 1.5 Hardenability of steels, quenching stresses; 1.6 Tempering, 1.7 Heat treatments Steel Heat treatment: normalisation, annealing, quenching, tempering, martempering, austempering, heat treatments with undercooling, heat treatments of high strength steels; 1.8 Surface hardening; chemo-thermal treatments, local meltings 1.9 Temperature measuring and controlling; the atmosphere in the furnace, carbon control, furnace safety 1.10 Heat treatment of cast iron, heat treatment of tool steels, heat treatment of stainless steels, heat treatment of temperature resistant alloys 1.11 Heat treatment defects: control processes of iron and alloys heat treatment 1.12 Steels: carbon steels, alloy steels, maraging steels, high-strength low-alloy steels, dual-phase steels, stainless steels, tool steels, steels made by powder metallurgy;

Temeljna literatura in viri/Readings:

1) H.K.D.H Bhadeshia; R.W.K. Honeycombe: Steels, Elsevier, Amsterdam, 2006;
2) R.E. Smallman; A.H.W. Ngan: Physical metallurgy and advanced materials, Elsevier, Amsterdam, 2007;
3) Metals Handbook, Vol. 1, Properties and selection: Iron Steels, High Performance Alloy, 1990, ASM;

Cilji in kompetence:	**Objectives and competences:**
Cilj predmeta je pokazati študentu uporabnost splošne teorije termodinamike in fizikalne metalurgije na posebnih primerih kovinskih materialov in dati podlage za načrtovanje in realizacijo tehnoloških postopkov.	The scope of the course is to demonstrate the applicability of general theory of thermodynamics and physical metallurgy to the students on special case of metal materials and to give them bases for planning and realisation of technological processes

Predvideni študijski rezultati:	**Intended learning outcomes:**
Znanje in razumevanje: To je eno temeljnih strokovnih predmetov inženirjev metalurgije in materialov, ki jim omogoča načrtovanje, sintezo in selekcijo materialov ter povezovalno in podporno področje drugim inženirskim področjem. Omogoča realizacijo vseh teoretičnih znanj s področja materialov in je osnova za izbiro materialov.	Knowledge and understanding: This is one of the fundamental courses for engineers of metallurgy and materials which enables to plan, to synthesise and to select the materials; however, it is also a supporting as well as a linking field to other engineering fields. It enables the realisation of all theoretical knowledge from the material science and is a base for material selection.

Metode poučevanja in učenja:	**Learning and teaching methods:**
Predavanja, računske in laboratorijske vaje, numerične simulacije, seminar.	Lectures, calculating exercises and laboratory work, numerical simulations, seminar

Načini ocenjevanja:	Delež/Weight	Assessment:
ocena ustnega dela izpita	40,00 %	the oral examination
ocena pisnega dela izpita	40,00 %	the written examination
seminar	20,00 %	seminar

Reference nosilca/Lecturer's references:

NAGODE, Aleš, ULE, Boris, JENKO, Monika, KOSEC, Ladislav. A constitutive creep equation for 9Cr-1Mo-0.2V (P91-type) steel under constant load and constant stress. Steel research international, 2007, vol. 78, no. 8, str. 638-642.
ULE, Boris, NAGODE, Aleš. A model based creep equation for 9Cr-1Mo-0.2V (P91 type) steel. Mater. sci. technol., 2007, vol. 23, no. 11, str. 1367-1374.
NAGODE, Aleš, KOSEC, Ladislav, ULE, Boris. Uni-axial and multi-axial creep behavior of P91-type steel under constant load. Eng fail. anal.
NAGODE, Aleš, KOSEC, Ladislav, JENKO, Monika, ULE, Boris. An improved stress-dependent energy-barrier model for the creep of 9Cr-1Mo-0.2V steel under disc-bend loading. Kovové mater., 2010, vol. 48, no. 4, str. 233-239.

INDUSTRIJSKA EKOLOGIJA IN ENERGETIKA

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	Industrijska ekologija in energetika
Course title:	Industrial Ecology and Energetics
Članica nosilka/UL Member:	UL NTF

Študijski programi in stopnja	Študijska smer	Letnik	Semestri	Izbirnost
Metalurgija in materiali, druga stopnja, magistrski	Ni členitve (študijski program)	1. letnik	1. semester	obvezen

Univerzitetna koda predmeta/University course code:	0067981
Koda učne enote na članici/UL Member course code:	856

Predavanja /Lectures	Seminar /Seminar	Vaje /Tutorials	Klinične vaje /Clinical tutorials	Druge oblike študija /Other forms of study	Samostojno delo /Individual student work	ECTS
45	15	30	0	0	90	6

Nosilec predmeta/Lecturer:	Borut Kosec

Izvajalci predavanj:	
Izvajalci seminarjev:	
Izvajalci vaj:	
Izvajalci kliničnih vaj:	
Izvajalci drugih oblik:	
Izvajalci praktičnega usposabljanja:	

Vrsta predmeta/Course type:	Obvezni / Compulsory

Jeziki/Languages:	Predavanja/Lectures:	Slovenščina
	Vaje/Tutorial:	Slovenščina

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	Prerequisites:
Pogoj za vključitev v delo oziroma za opravljanje študijskih obveznosti je vpis v 1. letnik študija. Opravljeno in uspešno predstavljeno projektno delo je pogoj za pristop k pisnemu in ustnemu izpitu.	The condition to attend in the teaching course and to perform study obligations is an entry in the first year of study. Completed and successfully presented project work is required before taking the written and oral exam.

Vsebina:	Content (Syllabus outline):
Splošni pojmi. Okolje. Naravni viri. Varstvo okolja (varstvo tal, voda, zraka ter varstvo pred hrupom). Emisije / imisije. Vrste in količine emisij. Merjenje količine emisij. Ukrepi in možnosti za zmanjšanje emisij. Nadzor nad onesnaževanjem. Monitoring.	General definitions. Environment. Natural sources. Environmental protection (ground, water and air protection, and noise protection). Emissions / imissions. Emissions types and quantity. Emissions quantity measurements. Measures and

Temeljna načela ravnanja z odpadki. Obvladovanje odpadkov. Zbiranje, skladiščenje in odstranjevanje odpadkov. Ravnanje z odpadki. Postopki predelave in postopki odstranjevanja odpadkov. Celovito obvladovanje odpadkov. Dokumentacija za celovito obvladovanje odpadkov. Evidence o ravnanju z odpadki. Evidenca o embalaži in odpadni embalaži. Strokovna ocena odpadka. Načrt gospodarjenja z odpadki. Nadzorna merjenja in monitoring. Dovoljenja podjetja. Določitev odgovornosti in pooblastil. Vzpostavitev notranjega in zunanjega komuniciranja. Usposabljanje zaposlenih. Razvoj in investicije podjetja. Industrijski odpadki. Razdelitev. Koncept ravnanja z odpadki. Ločeno zbiranje odpadkov. Čistilne naprave za odpadne pline in vode. Ravnanje s trdnimi odpadki. Energetska in snovna izraba odpadkov. Recikliranje. Radioaktivni odpadki. Analiza ekološko kritičnih mest v proizvodnih procesih. Zbiranje podatkov, njihova analiza in prikaz. Modeliranje. Zakonski predpisi s področja varstva okolja. Sistemska ureditev na področju odpadkov v RS in EU. Nacionalni program varstva okolja. Zakon o varstvu okolja. Sistem ravnanja z okoljem ISO 14001. Standardi družine ISO 14000. Sistemi vodenja in certificiranje. Predstavitev standarda ISO 14001. Shema proizvodnega procesa izvedenega v skladu s standardom ISO 14001. PDAC cikel. Primer materialne in ekološko-energetske bilanca tehnološkega obrata izvedene v skladu s standardom ISO 14001. EMAS – shema okoljskega vodenja in presojanja. O energiji. Definicije. Enote energije. Energetska bilanca zemlje. Raba energije v svetu. Rast porabe primarne energije – analiza. Obnovljivi / neobnovljivi viri energije. Energija in okolje. Emisije in imisije. Ozonska luknja. Posledice ogrevanja ozračja. Pojav tople grede. Emisije CO2, SO2, NOx in emisije trdnih delcev. Ukrepi za zmanjšanje emisij. Trgovanje s kvotami za emisije toplogrednih plinov. Evropski register onesnaževalcev. Racionalna raba energije v metalurški in procesni industriji materialov. Energetski stroji in naprave. Osnovni pojmi. Uporaba različnih oblik energije. Razdelitev strojev in naprav. Delo, moč, izkoristek. Proizvodnja električne energije v Republiki Sloveniji. Hidroelektrarne. Termoelektrarne. Soproizvodnja električne in toplotne energije. Prednosti. Jedrske elektrarne. Načrtovanje in razvoj okolju prijaznih proizvodov, tehnologij in procesov. Metode in orodja. Življenjski krog proizvoda in recikliranje. Analiza: okoljsko, ekonomsko in tehnično vrednotenje.	possibilities for emissions reduction. Pollution control. Monitoring. Fundamental principles of the waste management. Waste control. Collection, stocking and removing. Waste handling. Methods of waste processing and methods of waste removing. Waste management. Documentation for waste management. Evidence of waste handling. Evidence of wrapping and waste wrapping. Expert waste evaluation. Waste management plan. Control measurements and monitoring. Enterprise licences. Determination of responsibility and authorization. Restoration of internal and external communication. Employees' qualification. Development and enterprise investments. Industrial waste. Classification. Concept of waste handling. Separate waste collection. Cleaning devices for waste gases and water. Handling with solid waste. Energetic and material waste utilization. Recycling. Radioactive waste. Analyses of ecological critical points in production processes. Data collection, analyses and presentation. Modeling. Obligatory regulations on the protection of the environment. Systematic regulation in the field of waste in RS and EU. National environment protection program. Environment protection law. Environmental protection management system ISO 14001. ISO 14000 family standards. Management systems and certification. Presentation of standard ISO 14001. Scheme of production process achieved according to the standard ISO 14001. PDAC cycle. Case of material and ecological-energetic balance in technological department achieved according to standard ISO 14001. EMAS – scheme of environmental management and audit. Energy. Definitions. Energy units. Energetics balance of the Earth. Energy use in the World. Growing of primary energy consumption – analyses. Renewable / fossil fuel energy sources. Energy and environment. Emissions and imissions. Ozonic hole. Effect of heating of atmosphere. Greenhouse effect. Emissions CO2, SO2, NOx and solid particles emissions. Measures for emissions reduction. Trade with the quotes of emissions of greenhouse gases. European pollutant emission registers. Rational use of energy in metallurgical and process industry of materials. Power plant technology. Basic concepts. Using various forms of energy. Breakdown of machinery and equipment. Work, power, efficiency. Electric power production in the Republic of Slovenia Hydroelectric power plants. Thermoelectric power plants. Cogeneration of electric and thermal energy. Advantages. Nuclear power plants.

Orodja in tehnike. Čiste tehnologije. Ekološko označevanje proizvodov, procesov in storitev. Študij praktičnih primerov. Projektno delo. Kompleksna analiza in optimiranje izbranega proizvoda, procesa ali tehnologije z vključitvijo vidikov in zahtev varstva okolja.	Designing environmentally-friendly products, technologies and processes. Methods and tools. Product life cycle and recycling. Analyses: environmental, economic and technical assessment. Tools and techniques. Clean technologies. Environmental labeling of products, processes and services. Case studies. Project work. Complex analyses and optimization of selected product, process or technology with inclusion of aspects and demands of environmental protection.

Temeljna literatura in viri/Readings:

BURKE, G., SINGH, B., THEODORE, L. Handbook of Environmental Management and Technology. New Yersey: John Wiley & Sons, 2005.
MASTERS, G.M. Introduction to Environmental Engineering and Science. New York: Prentice – Hall, 1997.
PRIBAKOVIĆ BORŠTNIK, A., ZORNIK, M., ŽAGAR, T. Odgovorno okoljsko delovanje – Sistemi ravnanja z okoljem. Ljubljana: SIQ, 2004.
LUND, H.F. The McGraw – Hill Recycling Handbook. New York: McGraw – Hill, 2001.
WHITELAW, W. ISO 14001 – Environmental System Handbook. London: Elsevier, 2004.
GREADEL, T.E., ALLENBY, B.R. Industrial Ecology. New Jersey: Pearson Education, 2003.
KUTZ, M. Environmentaly Conscious Mechanical Design. New Jersey: John Wiley & Sons, 2007.
ABELE, E., ANDERL, R., BIRKHOFER, H. Environmantally – Friendly Product Development – Methods and Tools. London: Springer Verlag, 2005.
KUTZ, M. Environmentaly Conscious Alternative Energy Production. New Jersey: John Wiley & Sons, 2007.
BUDAK, I., KOSEC, B., HODOLIČ, J., KARPE, B., STEVIĆ, M., VUKELIĆ, D. Environmental labelling of products. Novi Sad: Fakultet tehničkih nauka, 2009.

Cilji in kompetence:	**Objectives and competences:**
Industrijska ekologija in energetika predstavlja interdisciplinarno in sistematično preučevanje interakcij med industrijskimi in ekološkimi sistemi. Študent se pri predmetu Industrijska ekologija in energetika spozna z ekološko naravnanostjo posameznih tehnoloških procesov in postopkov, pravilnim ravnanjem z odpadki, njihovim vplivom na obremenitev okolja ter z zakonskimi predpisi s področja varstva okolja. Seznani se z temeljnimi viri energije, pretvorbami energij, energetskimi stroji in napravami ter povezavo med energijo in okoljem. Študent se navaja na timsko in projektno delo, uporabo strokovne literature in sodobnih virov informacij.	Industrial ecology and energetics presents interdisciplinary and systematical study of interactions between industrial and ecological systems. At the course Industrial ecology and energetics students recognizes ecological points of different technological processes and procedures, with the waste management, with the waste influence to the environment and obligatory regulations on the protection of the environment. They learn about fundamental energy sources, energy transformations, energetics engines and devices, and connection between energy and environment. Students will be accustomed to teamwork and project work, using professional literature and current sources of information.

Predvideni študijski rezultati:	**Intended learning outcomes:**
Pri predmetu Industrijska ekologija in energetika pridobi študent znanja o ekološki naravnanosti posameznih tehnoloških procesov in postopkov. Nauči se pravilnega ravnanja z odpadki, njihovim vplivom na obremenitev okolja ter se seznani z zakonskimi predpisi in standardi. Seznani se z temeljnimi viri energije, pretvorbami	In the Industrial ecology and energy teaching course the student acquires knowledge about the ecological orientation of individual technological processes and procedures. Learn the proper handling of waste, their impact on the environment and become acquainted with the legislative regulations and standards. They learn about of the fundamental sources of

energij, energetskimi stroji in napravami ter povezavo med energijo in okoljem. Spozna metode in tehnike načrtovanja in razvoja okolju prijaznih proizvodov, procesov in tehnologij.	energy, energy conversion, energy machinery and equipment and the relationship between energy and the environment. They learn methods and techniques of planning and development of environmentally friendly products, processes and technologies.

Metode poučevanja in učenja:	**Learning and teaching methods:**
Predavanja, računske vaje in simulacije, projektno delo.	Lectures. Exercises solving and simulations. Project work.

Načini ocenjevanja:	**Delež/Weight**	**Assessment:**
ocena projektnega dela	40,00 %	the mark of project work
ocena pisnega dela izpita	30,00 %	the mark of written examination
ocena ustnega dela izpita	30,00 %	the mark of the oral examination

Reference nosilca/Lecturer's references:

LOJEN, Gorazd, ANŽEL, Ivan, KNEISSL, Albert C., UNTERWEGER, E., KOSEC, Borut, BIZJAK, Milan. Microstructure of rapidly solidified Cu-Al-Ni shape memory alloy ribbons. J. mater. process. technol., May 2005, vol. 162/163, str. 220-229.

KOSEC, Borut, SOKOVIĆ, Mirko, KOSEC, Ladislav, BIZJAK, Milan, KAMPUŠ, Zlatko. Case of introduction of new ecologically safe material. J. Achiev. Mater. Manuf. Eng., 2006, letn. 17, št. 1/2, str. 85-88.

KOSEC, Borut, SOKOVIĆ, Mirko, KOSEC, Ladislav, BIZJAK, Milan, PUŠAVEC, Franci, KAMPUŠ, Zlatko. Introduction of new ecologically safe material for fusible elements of low voltage fuses. Archives of materials science and engineering., 2007, vol. 28, issue 4, str. 211-216.

KOSEC, Borut, SENČIČ, Sandra, SOKOVIĆ, Mirko, KARPE, Blaž. Foundry waste management. International journal for quality research, 2008, vol. 2, no. 2, str. 129-133.

BUDAK, Igor, KOSEC, Borut, HODOLIČ, Janko, KARPE, Blaž, STEVIĆ, Miodrag, VUKELIĆ, Djordje. Environmental labelling of products. Novi Sad: Fakultet tehničkih nauka, 2009.

JUHART, Matjaž, PETER, Michael, KOCH, Klaus, LAMUT, Jakob. Picture analysis method of slag foaming behaviour. Steel res., 2001, jg. 72, no. 3, str. 81-85.

JUHART, Matjaž, KOCH, Klaus, LAMUT, Jakob. Foaming behaviour of secondary metallurgy slags. Berg-Huettenmaenn. Monatsh., 2001, jg. 146, hft. 11, str. 439-444.

KOLENKO, Tomaž, JAKLIČ, Anton, LAMUT, Jakob. Development of a mathematical model for continuous casting of steel slabs and billets. Math. comput. model. dyn. syst., 2007, vol. 13, no. 1, str. 45-61.

INDUSTRIJSKE IN PROCESNE PEČI

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	Industrijske in procesne peči
Course title:	Industrial and Process Furnaces
Članica nosilka/UL Member:	UL NTF

Študijski programi in stopnja	Študijska smer	Letnik	Semestri	Izbirnost
Metalurgija in materiali, druga stopnja, magistrski	Ni členitve (študijski program)	2. letnik	1. semester	izbirni

Univerzitetna koda predmeta/University course code:	0078003
Koda učne enote na članici/UL Member course code:	875

Predavanja /Lectures	Seminar /Seminar	Vaje /Tutorials	Klinične vaje /Clinical tutorials	Druge oblike študija /Other forms of study	Samostojno delo /Individual student work	ECTS
30	0	30	0	0	60	4

Nosilec predmeta/Lecturer:	Borut Kosec

Izvajalci predavanj:	
Izvajalci seminarjev:	
Izvajalci vaj:	
Izvajalci kliničnih vaj:	
Izvajalci drugih oblik:	
Izvajalci praktičnega usposabljanja:	

Vrsta predmeta/Course type:	Izbirni / Elective

Jeziki/Languages:	Predavanja/Lectures:	Slovenščina
	Vaje/Tutorial:	Slovenščina

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	**Prerequisites:**
Pogoj za vključitev v delo oziroma za opravljanje študijskih obveznosti je vpis v 2. letnik študija. Opravljeno in uspešno predstavljeno projektno delo je pogoj za pristop k pisnemu in ustnemu izpitu.	The condition to attend in the teaching course and to perform study obligations is an entry in the second year of study. Completed and successfully presented project work is required before taking the written and oral exam.

Vsebina:	**Content (Syllabus outline):**
Uvod. Razdelitev industrijskih in procesnih peči. Po vrsti, namenu, načinu kurjenja, atmosferi, … Temeljni procesi dela industrijskih in procesnih peči. Gorenje, aerodinamika, prenos toplote.	Introduction. Classification of industrial and process furnaces. By type, purpose, heating system, atmosphere, … Fundamental processes of working of industrial and

Mehanizmi prenosa toplote v industrijskih in procesnih pečeh. Parametri, ki vplivajo na prenos toplote v peči. Prenos toplote na vložek v peči. Delovne temperature industrijskih in procesnih peči. Temperaturna območja delovanja. Temperaturne tolerance. Zgorevanje in atmosfera v peči. Goriva in njihove lastnosti. Zgorevalne toplote in kurilnosti. Vžigne meje. Koraki pri gorenju. Gorilniki. Naloge gorilnika. Razdelitev gorilnikov. Dimenzioniranje. Varovalne atmosfere. Delovne atmosfere. Atmosfere inertnih plinov. Določitev sestave in priprava varovalnih atmosfer. Toplotne obdelave. Modeliranje procesov toplotnih obdelav. Dimniki. Statični vlek dimnika. Višina in presek ustja dimnika. Dimenzioniranje. Cevovodi. Elementi cevovodov. Upori in izgube v cevovodih. Dimenzioniranje. Elektrouporovno ogrevanje. Induktivno ogrevanje. Principi. Prednosti in slabosti. Ognjevzdržna gradiva in obzidava industrijskih peči. Razdelitev. Lastnosti. Kriteriji selekcije in izbire ognjevzdržnih gradiv. Obzidava peči. Osnove dimenzioniranja, projektiranja in izdelave industrijskih in procesnih peči. Vodenje in nadzor procesov v industrijskih in procesnih pečeh. Oprema za optimalno vodenje in nadzor procesov. Poraba energije in toplotne izgube pri različnih tipih industrijskih in procesnih peči. Toplotni izkoristek peči. Sankeyev diagram. Efektivnost peči. Toplotne izgube skozi stene, strop in dno peči ter toplotne izgube med odprtjem peči. Stroški ogrevanja. Sestava stroškov ogrevanja. Ukrepi za zmanjševanje. Toplotna in masna bilanca peči. Energetsko /ekološka bilanca peči. Vrednotenje. Postopki in pristopi. Možnosti in načini izkoriščanja odpadne toplota. Prenosniki in izmenjevalci toplote. Dimenzioniranje. Študij in analiza praktičnih problemov. Izdelava in predstavitev projektnega dela.	process furnaces. Combustion, aerodynamics, heat transfer. Heat transfer mechanisms in industrial and process furnaces. Parameters with the influence on heat transfer in furnace. Heat transfer to the charge. Operating temperatures of industrial and process furnaces. Operation temperature range. Temperature tolerances. Combustion and furnace atmosphere. Fuels and their properties. Higher and lower calorific value. Limits of inflammability. Combustion steps. Burners. Burner tasks. Classification. Dimensioning. Protection atmospheres. Working atmospheres. Atmospheres of inert gases. Determination of composition and preparation of protective atmospheres. Heat treatment. Modeling of the heat treatment processes. Chimneys. Static pressure. Height and cross-section of chimney nose. Engineering. Pipelines. Elements of pipelines. Frictional losses in pipes. Dimensioning. Electro resisting heating. Inductive heating. Principles. Advantages and disadvantages. Refractories and lining of industrial furnaces. Classification. Properties. Criterion refractories selection. Lining of furnaces. Fundamentals of designing, projecting and manufacturing of industrial and process furnaces. Management and process control of industrial and process furnaces. Equipment for optimal management and process control. Energy consumption and heat losses at different types of industrial and process furnaces. Heat efficiency of furnace. Sankey diagram. Furnace efficiency. Heat losses through walls, roof and bottom of the furnace, and heat losses at the opening of the furnace. Heating costs. Composition of the heating costs. Measures to reduce costs of heating. Heat and mass balance of the furnace. Energetics /ecological balance of the furnace. Assessment. Procedures and accessions. Possibilities and ways of waste heat utilization. Heat exchangers. Dimensioning. Study and analyses of practical cases. Preparation and presentation of project work.

Temeljna literatura in viri/Readings:

HEILIGENSTEADT, W. Waermetechnische Rechnungen fuer Industrieoefen. Duesseldorf: Stahleisen Verlag, 1969.
POPOVIĆ, Z., RAIĆ, K. Peći i projektovanje u metalurgiji. Beograd: Naučna knjiga 1988.
TRINKS, W., MAWHINNEY, M.H., SHANNON, R.A., REED, R.J., GARVEY, J.R. Industrial Furnaces. New Jersey: John Wiley Sons, 2004.
WARD, J., COLLIN, R. Short Course on Industrial Furnace Technology, Vol.1, Vol. 2. Rio Tinto: CENERTEC, 2002.
DESHMUKH, Y.V. Industrial Heating – Principles, Techniques, Materials, Applications and Design. London:

Taylor Francis, 2005.
MULLINGER, P., JENKINS, B. Industrial and Process Furnaces – Principles, Design and Operation. Amsterdam: Butterworth – Heinemann, 2008.

Cilji in kompetence:	**Objectives and competences:**
V okviru predmeta Industrijske in procesne peči se študent spozna s pomenom industrijskih procesnih peči za posamezne tehnološke postopke in procese. Seznani se z elementi peči, dimenzioniranjem in kriteriji izbire peči ter spozna njihov ustroj. Obvlada in razume pomen in delovanje spremljajočih naprav in opreme za optimalno vodenje. Študent se navaja na samostojno, timsko in projektno delo, uporabo strokovne literature in sodobnih virov informacij.	In the teaching course Industrial and process furnaces student recognizes the importance of industrial process furnaces for individual technological procedures and processes, elements of the furnace, dimensioning and selection criteria and understand the furnace structure. Student acquires knowledge about importance and operation of supporting facilities and equipment for optimal control. Students are accustomed to self, team and project work, using professional literature and current sources of information.

Predvideni študijski rezultati:	**Intended learning outcomes:**
V okviru predmeta Industrijske in procesne peči študent spozna pomen peči za posamezne tehnološke postopke pri izdelavi, predelavi in toplotni obdelavi. Spozna mehanizme prenosa toplote, zgorevanje in aerodinamiko peči. Pozna elemente peči. Razume principe delovanja peči in obvlada vodenje in nadzor procesov. Osvoji inženirske principe in postopke dimenzioniranja, projektiranja in izdelave industrijskih peči. Spozna pomen spremljajočih naprav in opreme za optimalno vodenje in nadzor tehnoloških procesov.	Students learn the importance of the furnaces in in the manufacturing processing and heat treatment. They learn the mechanisms of heat transfer, combustion and aerodynamics of the furnace. Acquire knowledge of the furnace elements and understand the principles of operation, command and control of the processes in the furnace. Acquire engineering principles and procedures for dimensioning, design and manufacture of industrial furnaces. They learn the importance of supporting facilities and equipment for optimal operation and control of technological processes.

Metode poučevanja in učenja:	**Learning and teaching methods:**
Predavanja, računske vaje in simulacije, delo v neposrednem industrijskem okolju in projektno delo.	Lectures. Exercises solving and simulations. Experimental work in industrial environment. Project work.

Načini ocenjevanja:	**Delež/Weight**	**Assessment:**
ocena projektnega dela	40,00 %	the mark of project work
ocena pisnega dela izpita	30,00 %	the mark of written examination
ocena ustnega dela izpita	30,00 %	the mark of the oral examination

Reference nosilca/Lecturer's references:

KOSEC, Borut, KOSEC, Gorazd. Temperature field analysis on active working surface of the die-casting die. Metall, 2003, vol. 57, no. 3, pp. 134-136.
GOJIĆ, Mirko, LAZIĆ, Ladislav, KOSEC, Borut, BIZJAK, Milan. Application of mathematical modelling to hardenability testing of low-alloyed Mn-Mo steel. Journal of Mechanical Engineering, 2005, vol. 47, no. 3-4, pp. 101-108.
KOSEC, Borut, BREZIGAR, Matjaž, KOSEC, Gorazd, BERNETIČ, Jure, BIZJAK, Milan. Heat treatment of cold formed steel forgings for the automotive industry. J. Achiev. Mater. Manuf. Eng., June 2007, vol. 22,

issue 2, pp. 87-90.
JAKLIČ, Anton, GLOGOVAC, Branislav, KOLENKO, Tomaž, ZUPANČIČ, Borut, TEŽAK, Bojan. A simulation of heat transfer during billet transport. Appl. therm. eng., 2002, no. 22, 873-883.
JAKLIČ, Anton, VODE, Franci, KOLENKO, Tomaž. Online simulation model of the slab-reheating process in a pusher type furnace. Appl. therm. eng., 2007, vol. 27, no. 5-6, pp. 1105-1114.
KOLENKO, Tomaž, JAKLIČ, Anton, LAMUT, Jakob. Development of a mathematical model for continuous casting of steel slabs and billets. Math. comput. model. dyn. syst., 2007, vol. 13, no. 1, pp. 45-61.
KARPE, Blaž, KOSEC, Borut, KOLENKO, Tomaž, BIZJAK, Milan. Heat transfer analyses of continuous casting by free jet meltspinning device. Metallurgy, 2011, vol. 50, no. 1, pp. 13-16.

IZBIRNI PREDMET 1

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	Izbirni predmet 1
Course title:	Optional course 1
Članica nosilka/UL Member:	UL NTF

Študijski programi in stopnja	Študijska smer	Letnik	Semestri	Izbirnost
Metalurgija in materiali, druga stopnja, magistrski	Ni členitve (študijski program)	2. letnik	1. semester	izbirni

Univerzitetna koda predmeta/University course code:	0111858
Koda učne enote na članici/UL Member course code:	890

Predavanja /Lectures	Seminar /Seminar	Vaje /Tutorials	Klinične vaje /Clinical tutorials	Druge oblike študija /Other forms of study	Samostojno delo /Individual student work	ECTS
30	0	30	0	0	60	4

Nosilec predmeta/Lecturer:	

Izvajalci predavanj:	
Izvajalci seminarjev:	
Izvajalci vaj:	
Izvajalci kliničnih vaj:	
Izvajalci drugih oblik:	
Izvajalci praktičnega usposabljanja:	

Vrsta predmeta/Course type:	

Jeziki/Languages:	Predavanja/Lectures:	
	Vaje/Tutorial:	

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	**Prerequisites:**

Vsebina:	**Content (Syllabus outline):**

Temeljna literatura in viri/Readings:

Cilji in kompetence:	**Objectives and competences:**

Predvideni študijski rezultati:	Intended learning outcomes:

Metode poučevanja in učenja:	Learning and teaching methods:

Načini ocenjevanja:	Delež/Weight	Assessment:

Reference nosilca/Lecturer's references:

IZBIRNI PREDMET 2

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	Izbirni predmet 2
Course title:	Optional course 2
Članica nosilka/UL Member:	UL NTF

Študijski programi in stopnja	Študijska smer	Letnik	Semestri	Izbirnost
Metalurgija in materiali, druga stopnja, magistrski	Ni členitve (študijski program)	2. letnik	1. semester	izbirni

Univerzitetna koda predmeta/University course code:	0111859
Koda učne enote na članici/UL Member course code:	891

Predavanja /Lectures	Seminar /Seminar	Vaje /Tutorials	Klinične vaje /Clinical tutorials	Druge oblike študija /Other forms of study	Samostojno delo /Individual student work	ECTS
30	15	15	0	0	60	4

Nosilec predmeta/Lecturer:	

Izvajalci predavanj:	
Izvajalci seminarjev:	
Izvajalci vaj:	
Izvajalci kliničnih vaj:	
Izvajalci drugih oblik:	
Izvajalci praktičnega usposabljanja:	

Vrsta predmeta/Course type:	

Jeziki/Languages:	Predavanja/Lectures:	
	Vaje/Tutorial:	

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	**Prerequisites:**

Vsebina:	**Content (Syllabus outline):**

Temeljna literatura in viri/Readings:

Cilji in kompetence:	**Objectives and competences:**

Predvideni študijski rezultati:	Intended learning outcomes:

Metode poučevanja in učenja:	Learning and teaching methods:

Načini ocenjevanja:	Delež/Weight	Assessment:

Reference nosilca/Lecturer's references:

IZBIRNI PREDMET 3

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	Izbirni predmet 3
Course title:	Optional course 3
Članica nosilka/UL Member:	UL NTF

Študijski programi in stopnja	Študijska smer	Letnik	Semestri	Izbirnost
Metalurgija in materiali, druga stopnja, magistrski	Ni členitve (študijski program)	2. letnik	1. semester	izbirni

Univerzitetna koda predmeta/University course code:	0111860
Koda učne enote na članici/UL Member course code:	892

Predavanja /Lectures	Seminar /Seminar	Vaje /Tutorials	Klinične vaje /Clinical tutorials	Druge oblike študija /Other forms of study	Samostojno delo /Individual student work	ECTS
30	10	20	0	0	60	4

Nosilec predmeta/Lecturer:	

Izvajalci predavanj:	
Izvajalci seminarjev:	
Izvajalci vaj:	
Izvajalci kliničnih vaj:	
Izvajalci drugih oblik:	
Izvajalci praktičnega usposabljanja:	

Vrsta predmeta/Course type:	

Jeziki/Languages:	Predavanja/Lectures:	
	Vaje/Tutorial:	

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	**Prerequisites:**

Vsebina:	**Content (Syllabus outline):**

Temeljna literatura in viri/Readings:

Cilji in kompetence:	**Objectives and competences:**

Predvideni študijski rezultati:	Intended learning outcomes:

Metode poučevanja in učenja:	Learning and teaching methods:

Načini ocenjevanja:	Delež/Weight	Assessment:

Reference nosilca/Lecturer's references:

IZBRANA POGLAVJA IZ VIŠJE MATEMATIKE

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	Izbrana poglavja iz višje matematike
Course title:	Selected Topics in Higher Mathematics
Članica nosilka/UL Member:	UL NTF

Študijski programi in stopnja	Študijska smer	Letnik	Semestri	Izbirnost
Metalurgija in materiali, druga stopnja, magistrski	Ni členitve (študijski program)	2. letnik	1. semester	izbirni

Univerzitetna koda predmeta/University course code:	0078004
Koda učne enote na članici/UL Member course code:	868

Predavanja /Lectures	Seminar /Seminar	Vaje /Tutorials	Klinične vaje /Clinical tutorials	Druge oblike študija /Other forms of study	Samostojno delo /Individual student work	ECTS
30	0	30	0	0	60	4

Nosilec predmeta/Lecturer:	Janko Bračič

Izvajalci predavanj:	
Izvajalci seminarjev:	
Izvajalci vaj:	
Izvajalci kliničnih vaj:	
Izvajalci drugih oblik:	
Izvajalci praktičnega usposabljanja:	

Vrsta predmeta/Course type:	Izbirni / Elective

Jeziki/Languages:	Predavanja/Lectures:	Slovenščina
	Vaje/Tutorial:	Slovenščina

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	Prerequisites:
Pogoj za vključitev v delo oziroma za opravljanje študijskih obveznosti je vpis v 1. letnik študija.	The condition for attending the programme is enrolment in 1st year of study.

Vsebina:	Content (Syllabus outline):
1. VEKTORSKA IN TENZORSKA ANALIZA 2. METODA KONČNIH ELEMENTOV 3. PARCIALNE DIFERENCIALNE ENAČBE	1. Vector and tensor analysis 2. Finite element method 3. Partial diferential equations

Temeljna literatura in viri/Readings:

1. Križanič: Parcialne diferencialne enačbe, DMFA-založništvo, Ljubljana, 2004.
2. Vidav: Višja Matematika II, DZS, Ljubljana, 1981.

3. Kuščer, Kodre: Matematika v fiziki in tehniki, DMFA-založništvo, Ljubljana, 2006.

Spletna stran/webpage
http://mathworld.wolfram.com/

Cilji in kompetence:	**Objectives and competences:**
Cilji: Študent spozna osnovne pojme iz analize funkcij več spremenljivk in parcialnih diferencialnih enačb. Na vajah se utrdijo spretnosti v odvajanju in integriranju funkcij dveh ali treh spremenljivk ter v reševanju parcialnih diferencialnih enačb, s poudarkom na uporabi v stroki. Predmetno specifične kompetence: • Razumevanje vektorskega in tenzorskega računa • Poznavanje metode končnih elementov • Razumevanje diferencialnega in integralskega računa funkcij več spremenljivk in poznavanje njihove uporabe v naravoslovju.	Objectives: A student gets familiar with analysis of functions of several variables and partial differential equations. With exercises he gets skills in differentiation, integration, and solving partial differential equations with special emphasis in applications. Competencies: • Understanding of vector and tensor calculus • Understanding of finite element method • Understanding of calculus for function of several variables and knowledge how to use this in applications.

Predvideni študijski rezultati:	**Intended learning outcomes:**
Znanje in razumevanje: Poznavanje diferencialnega in integralnega računa za funkcije več spremenljivk in metod reševanja parcialnih diferncialnih enačb. Obvladanje metode končnih elementov. Poznavanje vektorskega in tenzorskega računa.	Knowledge and understanding: Basic knowledge about calculus and differential equations, also for functions for several variables. Knowledge about finite element method and about vector and tensor analysis.

Metode poučevanja in učenja:	**Learning and teaching methods:**
Predavanja, vaje in individualno delo.	Lectures, tutorial, individual work.

Načini ocenjevanja:	**Delež/Weight**	**Assessment:**
Izpit je samo v pisni obliki: reševanje naloge. Izpit je mogoče opraviti tudi tako, da se piše dva kolokvija v povprečju vsaj 50%.	100,00 %	There is only a writing exam: solving exercises. It is possible to pass the exam with two partial exams if they are done by 50% in average.

Reference nosilca/Lecturer's references:

Znanstvena dela
1. BRAČIČ, Janko. Algebraic reflexivity for semigroups of operators, ELA, 18 (2009), 745-760.
2. BRAČIČ, Janko, MÜLLER, Vladimir, ZAJAC, Michal. Reflexivity and hyperreflexivity of the space of locally intertwining operators, J. Operator Theory, 63:1 (2010), 101-114.
3. BESSONOV, Roman B., BRAČIČ, Janko, ZAJAC, Michal. Non-hyperreflexive reflexive spaces of operators, Studia Mathematica, 202 (1) 2011, 65-80.

Univerzitetni učbenik z recenzijo
BRAČIČ, Janko. Matematika za visokošolske strokovne programe, Oddelek za materiale in metalurgijo NTF UL, 2009, 142 str. ISBN 978-961-6047-65-4.

JEKLARSTVO 2

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	Jeklarstvo 2
Course title:	Steelmaking 2
Članica nosilka/UL Member:	UL NTF

Študijski programi in stopnja	Študijska smer	Letnik	Semestri	Izbirnost
Metalurgija in materiali, druga stopnja, magistrski	Ni členitve (študijski program)	1. letnik	2. semester	obvezen

Univerzitetna koda predmeta/University course code:	0067982
Koda učne enote na članici/UL Member course code:	858

Predavanja /Lectures	Seminar /Seminar	Vaje /Tutorials	Klinične vaje /Clinical tutorials	Druge oblike študija /Other forms of study	Samostojno delo /Individual student work	ECTS
30	20	25	0	15	90	6

Nosilec predmeta/Lecturer:	Matjaž Knap

Izvajalci predavanj:	
Izvajalci seminarjev:	
Izvajalci vaj:	
Izvajalci kliničnih vaj:	
Izvajalci drugih oblik:	
Izvajalci praktičnega usposabljanja:	

Vrsta predmeta/Course type:	Obvezni / Compulsory

Jeziki/Languages:	Predavanja/Lectures:	Slovenščina
	Vaje/Tutorial:	Slovenščina

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	Prerequisites:
Opravljanje študijskih obveznosti je opredeljeno v pravilniku o preverjanju in ocenjevanju študentov na UL NTF. Za pozitivno in uspešno opravljanje študijskih obveznosti ter vključevanje v študijsko delo se priporoča redno obiskovanje predavanj, reševanje dodatnih domačih bolj zahtevnih nalog in ustrezna predpriprava pred izvajanjem laboratorijskih vaj ter izkazana aktivnost in vsaj 80 % prisotnost na vajah.	Liabilities are defined in the regulations on examination and evaluation of students at ULNTF. For a positive and successful attendance of their duties students are encourage to regular attendance of lectures, additional domestic more complex work more and appropriate preparing to laboratory work. At least 80% attendance at tutorials is needed.

Vsebina:	Content (Syllabus outline):
Pogoji za proizvodnjo jekla: Surovine, legirni elementi, energija, okolje, znanje, proizvodi, trg.	Requirements for the production of steel: Raw materials, alloying elements, energy, environment,

Jeklarske tehnologije: Izdelava jekla iz grodlja in izdelava jekla iz starega železa. Sodobne tehnologije izdelave jekla. Sestava vložka in pretaljevanje. Procesna tehnika jeklarskih procesov: Taljenje kovinskih in nekovinskih materialov. Reakcije v trdnem in tekočem. Ravnotežje železo-kisik, železo-kisik-silicij, železo-kisik-mangan, železo-kisik-fosfor, železo-kisik-žveplo, železo-kisik-krom, železo-kisik-titan, železo-kisik-volfram, ogljik-krom. Termodinamične in kinetične osnove . Sistematika osnovnih surovin: Grodelj, staro železo, metalizirani peleti, ferozlitine. Surovinski in energetski potenciali v jeklarski industriji: Pridobivanje in priprava surovin in predzlitin za pridobivanje jekla. Redukcija železovih oksidov in taljenje starega železa. Klasifikacija starega železa. Trdna, tekoča in plinasta goriva ter električna energija. Legirni elementi in ferozlitine: Sistematizacija legirnih elementov glede na njihovo namembnost. Surovine in postopki izdelave legirnih elementov in ferozlitin. Kemična in mineraloška sestava ferozlitin in legirnih elementov. Dezoksidanti in legirni elementi: sestava, načini legiranja in dezoksidacija. Žlindre – oksidacijske in rafinacijske: Nastajanje žlindre. Vpliv MgO, MnO, Al2O3 na sistem CaO-SiO2-FeO. Sintetične žlindre, raztapljanje apna, obraba ognjevzdržnega materiala. Žlindre pri izdelavi raznih vrst jekel v obločnih pečeh, žlindre in oksidacija elementov, redukcija žlinder. Večkomponentni sistemi: CaO-SiO2, CaO-Al2O3, Al2O3- SiO2, MgO-SiO2, CaO-MgO-SiO2- Al2O3, CaO-FeO-SiO2, CaO-CaF2, CaO-Al2O3-CaF2, SiO2-Na2O, SiO2-Al2O3-K2O (Na2O) Metalurški procesi na faznih mejah: Reakcija med žlindro in talino, žlindro in steno peči. Procesi na fazni meji med legiranjem, dezoksidacijo, oksidacijo elementov, med razžveplanjem. Tvorba nekovinskih vključkov: Reakcija med kisikom v talinah in dezoksidanti, produkt dezoksidacije. Nastajanje vključkov, rast in velikost, sestava med izdelavo jekla in med vlivanjem. Izločanje vključkov. Nekovinski vključki v sistemu FeO-MnO-SiO2, CaO-Al2O3, Al2O3, oksisulfidi, MnS, CaS, FeO·Cr2O3, MgO. Velikost in razdelitev vključkov v jeklu glede na njihove lastnosti. Procesni in termični pogoji izdelave jekla v elektro-obločni peči: Konstrukcija. Priprava peči, vložek in zakladanje, taljenje, oksidacija, redukcija, razžveplanje, dezoksidacija, legiranje. Obzidava peči in obraba ognjevzdržnega gradiva, reakcije med žlindro, talino in obzidavo. Kakovost izdelanega jekla, merjenje kisika in izračun dezoksidantov. Tehnologija taljenja s starim železom in grodljem. Staro železo in ogljik, metalizirani peleti, briketi. Električna oprema, regulacija, elektrode. Sestava žlindre pri izdelavi jekla. Procesi in tehnologija izdelave jekla v konvertorju: Konstrukcija peči, vložek in zakladanje. Procesi	knowledge, products, market. Steelmaking technologies: Production of pig iron and steel making steel from scrap iron. Modern steelmaking technologies. The charge composition and remelting. Process engineering in steelmaking: Melting of metallic and non-metallic materials. Reactions in the solid and liquid. Balance iron-oxygen, iron-oxygen-silicon, iron-oxygen-manganese, iron-oxygen-phosphorous, iron- oxygen-sulphur, iron-oxygen-chromium, iron-oxygen-titanium, iron -oxygen-tungsten, carbon- chromium. Basic of thermodynamic and kinetic. The systematology of basic raw materials: Pig iron, scrap metal, metallized pellets, ferroalloys. Raw materials and energy potentials of the steel industry: Acquisition and preparation of raw materials and master alloys for steelmaking. Reduction of iron oxides and the melting of scrap. Classification of scrap iron. Solid, liquid and gaseous fuels and electricity. Alloying elements and ferroalloys: The systematisation of alloying elements according to their purpose. Raw materials and processes for production of alloying elements and ferroalloys. Chemical and mineralogical composition of ferroalloys and alloying elements. Deoxidizer and alloying elements: composition, alloying method and deoxidation. Slag - oxidizing and refining: Formation of slag. Influence of MgO, MnO, Al2O3 in the system CaO-SiO2-FeO. Synthetic slag, the dissolution of lime, refractory material wears. Slag in the production of various types of steel in arc furnaces, slag and oxidation of elements, reduction of slags. Multicomponent systems: CaO-SiO2, CaO-Al2O3, Al2O3- SiO2, MgO-SiO2, CaO-MgO-SiO2- Al2O3, CaO-FeO-SiO2, CaO-CaF2, CaO-Al2O3-CaF2, SiO2-Na2O, SiO2-Al2O3-K2O (Na2O) Metallurgical processes at interfaces: The reaction between slag and melt, slag and furnace wall. Processes at the interface during alloying, deoxidation, oxidation of the elements and desulphurization. Formation of non-metallic inclusions: The reaction between oxygen in melts and deoxidizer, the product of deoxidation. The formation of inclusions, their growth and size, their composition during steelmaking and during the casting process. Precipitation of inclusions. Non-metallic inclusions in the system FeO-MnO-SiO2, CaO-Al2O3, Al2O3, oxysulphide, MnS, CaS, FeO·Cr2O3, MgO. The size and distribution of inclusions in steel with regard on their properties. Process and thermal conditions of steelmaking in the electric arc furnace: Furnace design, preparation, charge and charging, melting, oxidation, reduction, desulphurization, deoxidation, alloying. Furnace

razogljičenja in razfosforjevanja. Obvladovanje temperature. Obzidava peči in obraba ognjevzdržnega gradiva. Grodelj in staro železo. Oprema in regulacija. Sestava žlindre pri izdelavi jekla. Rafinacija izven talilnega agregata: Postopki izdelave jekla v loncu. Vakuum v metalurgiji. Argon za mešanje talin. Tehnika izdelave jekla v kombinaciji obločna peč – izvenpečna obdelava talin. Reakcije med talino in žlindro v odvisnosti od sestave taline, metalurške možnosti postopkov, primeri izdelave raznih vrst jekel. Čistost jekla, ogrevanje taline, termodinamične, kinetične in procesno-metalurške ter tehnološke zakonitosti. Priprava taline za nadaljnjo obdelavo in izdelavo želene vrste jekla v loncu. Redukcija žlinder. Rafinacijski konvertor (MRP). Žilavenje s kisikom in mešanico inertni plin - kisik. Energija mešanja, metalurgija procesa, kinetika reakcij. Izdelava čistega jekla. Elektropretaljevanje pod žlindro. Vpliv in lastnosti pomožnih materialov na izdelavo jekla: Pomožna sredstva; Žlindrotvorni dodatki. Ognjevzdržni materiali, izolacije, eksotermna sredstva. Vlivanje in strjevanje jekla v jeklarnah: Pomožna sredstva pri vlivanju jekla: ulivni sistemi, livne ponovce (lonci), vmesne ponovce, izlivki in izlivne šobe, drsna zapirala. Reakcije med ognjevzdržnim materialom in talino pri vlivnih sistemih, zaščita curka taline. Hitrost in tehnika vlivanja, kristalizacija v ingotu in brami. Izceje. Livni prahovi in izolacijska sredstva Fizikalne lastnosti jeklenih talin in tekočih žlinder: Načini merjenja površinske napetosti in njen vpliv na procese. Merjenje viskoznosti talin pri visokih temperaturah. Načini določevanje toplotne prevodnosti talin pri visokih temperaturah. Pridobivanje kovin iz sekundranih proizvodov: Žlindra in prah kot sekundarna surovina. Načini pasivizacije potencialno škodljivih elementov. Inovativne rešitve za pridobivanje granul jekla iz jeklarskih žlinder. Pirometalurški način reafinacije kroma iz žlinder. Sonaravna proizvodnja jekla: Zaščita okolja. Ekonomski kazalci proizvodnje. Surovinsko in energetsko optimiranje izdelave jekla. Izdelava raznih vrst jekla, izračun vložka in dodatkov z vidika sonaravne proizvodnje jekla. Informatika v jeklarstvu: Sistemi za meritve, regulacijo in avtomatizacijo v proizvodnji jekla. Analiza meritev z osnovnimi statističnimi metodami, z linearno in multiplo regresijo ter z uporabo umetne inteligence (npr. nevronske mreže). Uporaba umetne inteligence pri on-line vodenju procesov. Pred začetkom predavanj in vaj bo študentom razdeljeno študijsko gradivo.	linings and wear of refractory material, the reaction between the melt, slag and linings. The quality of the steel, oxygen measurements and calculating the deoxidizer. Technology of melting using scrap and pig iron. Scrap iron and carbon, metallized pellets, briquettes. Electrical equipment, control, electrodes. Composition of slag in steelmaking. Processes and technology of making steel in the converter: Furnace design, preparation, charge and charging. Processes of decarburization and dephosphorization. Temperature control. Furnace linings and wear of refractory materials. Pig iron and scrap iron. Equipment and control. Composition of slag in steelmaking. Refining outside the melting aggregates: Methods of steelmaking in the ladle. Vacuum in metallurgical practice. Argon for melt stirring. Steelmaking technique in combination arc furnace - melt processing outside the furnace. Reaction between the melt and slag as a function of melt composition, possibility metallurgical processes, examples of production of various types of steel. Steel cleanliness, melt heating, thermodynamic, kinetic, technological and process-metallurgical rules. Preparation of melt for further processing and producing of particular steel type in the pot. Reduction of slags. Refining converter (MRP). Oxygen refining and refining with inert gas - oxygen mixture. Mixing energy, metallurgy process, the kinetics of reactions. Pure steel production. Electric slag remelting. Effects and properties of extra materials to produce steel: Auxiliary materials; Slag making additions. Refractory materials, insulation, exothermic materials. Casting and solidification of steel in steel plants: Auxiliary products in steel casting: casting system, casting ladles, tundish, the outflows and nozzles, sliding closures. Reactions between refractory material and melt in casting system, protection of melt jet. Speed and technique of casting, solidification in ingot and slab. Segregations. Casting powders and insulation materials. Physical properties of molten steel and liquid slags: Methods of surface tension measurement and its impact on the processes. Viscosity measurement of melts at high temperatures. Methods for determination of thermal conductivity of melts at high temperatures. Extraction of metals from secondary products: Slag and dust as a secondary raw material. Methods for passivation of potentially harmful elements. Innovative solutions for getting steel granules from the steel slags. Pyro metallurgical methods for chromium refining from slags. Sustainable production of steel: The environmental protection. Economic indicators of production. Optimization of steel making regarding raw materials and energy. Production of various steel grades, the calculation of the charge and alloys in terms of

	sustainable production of steel. Informatics in the steel industry: Systems for measurement, control and automation in steel industry. Analysis of measurements with usage of basic statistical methods, with linear and multiple regression analysis and the use of artificial intelligence (eg neural networks). Using artificial intelligence for on-line process control. Prior to the beginning of lectures and tutorials literature will be distributed.

Temeljna literatura in viri/Readings:

Ghosh A., Chatterjee A.: Ironmaking and Steelmaking Theory and Practice, PHI, 2008

F. Oeters: Steelmaking Metallurgie ali Metallurgie der Stahlherstellung, Springer-Verlag Berlin, Heidelberg und Verlag Stahleisen, 1989

B. Deo, R. Boom: Fundamentals of Steelmaking Metallurgy, Prentice Hall International, UK, 1993

M. Jellinghaus: Stahlerzeugung im Lichtbogenofen, Verlag Stahleisen, Düsseldorf, 1994

U. K. Mudali, B. Raj: High Nitrogen Steels and Stainless Steels, Alpha Science International Ltd., UK, 2004

Cilji in kompetence:	**Objectives and competences:**
Jeklo, kot na nek način masovni material, z izrednimi mehanskimi in drugimi uporabnimi lastnostmi, uporabnikom omogoča široko področje uporabe. Osnovni cilj tega predmeta je študentom najprej prikazati pomen jekla kot nenadomestljivega materiala v razvoju družbe, povezane z vsemi okoljskimi problemi. Pri predmetu se bodo študenti naučili postopke izdelave jekla in ferozlitin. Predmet daje znanje o kemični sestavi in lastnostih jekla ter njihovo uporabnost. Študenti bodo dobili vpogled v pomen surovin kot so grodelj, staro železo in metalizirani peleti ter pomožna sredstva, ki jih rabimo za izdelavo kakovostnih vrst jekla. Teoretične osnove dobljene pri osnovnih predmetih, o posameznih delnih procesih, bodo povezali v tehnološki proces, s ciljem izdelati jeklo. Dobili bodo pravilen odnos do materiala in surovin, ter varčevanje z energijo in zaščito okolja. Učili se bodo izdelati razne vrste jekel in zlitin, od nelegiranih do visoko legiranih in jih vliti po različnih postopkih ali pa kontinuirano in blizu končnih dimenzij. Študenti bodo dobili znanje o vodenju procesov in načrtovanju proizvodnje. Nadaljnji cilj je, da študenti pri tem predmetu nadgradijo znanje, ki so ga dobili pri predmetu Pirometalurgija železa in zlitin. Pridobljeno znanje in veščine bodo študentom omogočili, da bodo razumeli procese pri izdelavi jekla, da bodo sposobni inovativnega mišljenja in bo služilo kot osnova za nadaljnje, poglobljeno izobraževanje.	Steel as a mass material with extraordinary mechanical and other valuable properties allows a wide range of use. The primary objective of this course is first to demonstrate the importance of steel as a unique material in the development of mankind in relation to all environmental problems. In this course, students will learn the processes of steel and ferroalloy production. Course provides knowledge about the chemical composition and properties of steel and their applicability. They will gain insight into the importance of raw materials such as pig iron, scrap metal and metallized pellets and additives, which are needed in production of high-quality steel grades. Theoretical knowledge gained from the basic subjects and from the individual partial processes, will be linked together to the steelmaking technological process. They will get the correct attitude to materials, raw materials, energy saving and environmental protection. They will learn how to make various types of steels and alloys, from non-alloyed to high-alloyed. Various casting processes, continuous and close to final dimensions will be presented. Students will gain knowledge on processes and production planning. Another objective is that students expend knowledge obtained from course Pyrometallurgy of iron and alloys. The knowledge will enable students to understand the processes in steelmaking industry and that they will be capable of innovative thinking what will serve as a basis for further, profounder study.

Študenti bodo sposobni presojati procese tudi s stališča energetske učinkovitosti in s tem z zornega kota varstva okolja.	Students will be able to evaluate the processes in terms of energy efficiency and the viewpoint of environmental protection.

Predvideni študijski rezultati:	**Intended learning outcomes:**
Znanje in razumevanje: Študenti bodo nadgradili znanje, ki so ga dobili pri predmetu Pirometalurgija železa in zlitin. Razumeli bodo termodinamične in metalurške zakonitosti reakcij, ki nastopajo v postopku izdelave jekla. Študenti bodo dobili osnove, ki so potrebne za izdelavo kvalitetnih vrst jekla. Spoznali bodo osnovne agregate v katerih se izdeluje jeklo, dobili pregled nad postopki, ki se uporabljajo v jeklarski industriji. Znanje, ki ga bo pridobil pri tem predmetu je osnova za poglobljen študij posameznih faz v procesu izdelave jekla, kot so npr. izdelava jekla v elektroobločni peči, redukcijski in rafinacijski postopki, vakuumska metalurgija itd. Prav tako bodo razumeli osnovne termodinamične in metalurške reakcije, ki nastopajo v postopku izdelave jekla.	Knowledge and understanding: Students will build upon the knowledge that they obtained from course Pyrometallurgy of iron and alloys. They will understand thermodynamic laws and metallurgical reactions that occur in the process of steelmaking. Students will get the basics that are necessary for production of quality steel grades. They will get basic knowledge of steelmaking aggregates and an overview of the procedures used in the steel industry. Acquired knowledge is the basis for detailed studies of individual phases in steelmaking process, for example production of steel in electric arc furnaces, reduction and refining processes, vacuum metallurgy, etc. They will also understand the basic thermodynamic and metallurgical reactions that occur during the steelmaking process.

Metode poučevanja in učenja:	**Learning and teaching methods:**
Predavanja, seminarji, seminarske in laboratorijske vaje, terenske vaje, samostojno delo	Lectures, seminars, tutorial and laboratory work, fieldwork, individual work

Načini ocenjevanja:	**Delež/Weight**	**Assessment:**
ustni izpit	60,00 %	oral exam
pisni izpit	20,00 %	examination
seminarska naloga in poročilo laboratorijskih vaj	20,00 %	seminar work and the report of the laboratory work

Reference nosilca/Lecturer's references:

ROZMAN, Alojz, LAMUT, Jakob, DEBELAK, Martin, KNAP, Matjaž. Stabilization of ladle refining slags with borax. V:Slag products - Providing sustainable solutions for the built environment : 5th European Slag Conference : proceedings : 19th - 21st September 2007, Luxembourg, (EUROSLAG publication, no. 4). Duisburg: Euroslag, 2008, str. 137-145. [COBISS.SI-ID 972895]

KOMPOZITI

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	Kompoziti
Course title:	Composites
Članica nosilka/UL Member:	UL NTF

Študijski programi in stopnja	Študijska smer	Letnik	Semestri	Izbirnost
Metalurgija in materiali, druga stopnja, magistrski	Ni členitve (študijski program)	2. letnik	1. semester	obvezen

Univerzitetna koda predmeta/University course code:	0067990
Koda učne enote na članici/UL Member course code:	866

Predavanja /Lectures	Seminar /Seminar	Vaje /Tutorials	Klinične vaje /Clinical tutorials	Druge oblike študija /Other forms of study	Samostojno delo /Individual student work	ECTS
45	0	45	0	0	90	6

Nosilec predmeta/Lecturer:	Aleš Nagode

Izvajalci predavanj:	
Izvajalci seminarjev:	
Izvajalci vaj:	
Izvajalci kliničnih vaj:	
Izvajalci drugih oblik:	
Izvajalci praktičnega usposabljanja:	

Vrsta predmeta/Course type:	Obvezni / Compulsory

Jeziki/Languages:	Predavanja/Lectures:	Slovenščina
	Vaje/Tutorial:	Slovenščina

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	Prerequisites:
Pogoj za vključitev v delo oziroma za opravljanje študijskih obveznosti je vpis v 2. letnik študija. Opravljeno in uspešno predstavljeno projektno delo je pogoj za pristop k pisnemu in ustnemu izpitu.	The condition to attend in the teaching course and to perform study obligations is an entry in the second year of study. Completed and successfully presented project work is required before taking the written and oral exam.

Vsebina:	Content (Syllabus outline):
Karakteristike kompozitov. Sestavine kompozitov. Matice: kovinske, keramične, polimerne, ogljikove. Lastnosti matice.	Composites characteristics. Constituents of composites. Matrix materials: metal, ceramics, polymer, carbon. Matrix properties.

Materiali za elemente utrjevanja. Lastnosti. Kovine, keramike, polimeri, ogljikova vlakna. Vlakna. Lastnosti vlaken. Sinteza vlaken. Viskersi. Sinteza viskersov. Mejne površine v kompozitih. Pogoji kompatibilnosti sestavin kompozitov. Mehanika kompozitov. Analiza in načrtovanje. Minimalni in kritični volumski deleži vlaken. Prenos obremenitve z matice na vlakna. Kritična dolžina vlaken. Porušitev kompozitov. Puljenje vlaken. Mehanizmi povečevanja žilavosti kompozitov. Utrujenost kompozitov. Računalniško podprto načrtovanje. Mehanika loma kompozitov s kovinsko in keramično matico. Druge aditivne lastnosti kompozitov. Izdelava kompozitov. Obdelovalni postopki za kompozite. Spajanje kompozitov. Preizkušanje kompozitov. Preiskave poškodb. Problemi recikliranja. Primeri uporabe kompozitov.	Reinforced materials. Properties. Metals, ceramics, polymers, carbon fibers. Fibers properties. Fibers synthesis. Whiskers. Whiskers synthesis and properties. Interfaces in composites. Compatibility of composite materials. Mechanics of composites. Analysis and design of composites. Minimal and critical volume part of fibers. Mechanics of load transfer from matrix to fibers. Fiber critical length. Composite fracture. De-bonding. Fibers pullout. Toughness arising. Fatigue of composites. Computer added design. Fracture mechanics of metal and ceramics matrix composites. Heat properties of composites. Superconducting composites, Composite density. Fabrication of composites. Machining procedures. Composite joining. Composite testing. Nondestructive testing. Failure analysis. Recycling of composite materials. Application and experience.

Temeljna literatura in viri/Readings:

CHAWLA, K.K. Composite Materials: Science and Engineering. Berlin: Springer Verlag, 1987.
CHAWLA, K.K. Fibrous Materials. Cambridge: Cambridge University Press, 1998.
MATTHEWS, F.L. in RAWLINGS, R.D. Composite Materials: Engineering and Science. London: Chapman and Hall, 1994.
HULL, D., CLYNE, T.W. An Introduction to Composite Materials. Cambridge: Cambridge University Press, 1996
ASHBY, M., SHERCLIFF, H., CEBON, D. Materials – Engineering, Science, Processing and Design. Amsterdam: Elsevier, 2007.

Cilji in kompetence:	**Objectives and competences:**
Vsebina predmeta Kompoziti obsega metodiko načrtovanja, sinteze in karakterizacije kompozitov. Obsega selekcijo, sintezo in lastnosti sestavin kompozitov in načrtovanje in napoved mehanskih lastnosti, posebej trdnosti in žilavosti, oblikovanje, spajanje in inženirske aplikacije. Študent se vpelje v svet materialov, ki so po svojem konceptu, zgradbi, sintezi in lastnostih bistveno različni od klasičnih. Študent se navaja na timsko in projektno delo, uporabo strokovne literature in sodobnih virov informacij.	The teaching course Composites scales methodology design, synthesis and characterization of composites. It includes selection, synthesis and properties of composites and its components, design and prediction of mechanical properties (particularly strength and toughness), forming, bonding and engineering applications. The student is introduced to the world of materials which are in their concept, structure, synthesis and properties substantially different from the classical materials. Students will be accustomed to teamwork and project work, using professional literature and current sources of information.

Predvideni študijski rezultati:	Intended learning outcomes:
Osnova za razumevanje vsebin in napredek pri tem predmetu zahteva znanje osnovnih strokovnih predmetov, mehanike, osnove inženirstva in širše poznavanje področja materialov. Napredovanje omogoča prepletajoče se znanje več predmetov predhodnih semestrov, predmet zahteva od študenta interdisciplinarno znanje in organiziranost. Je neke vrste diplomski predmet pred diplomo. Predmet zahteva od študenta interdisciplinarno znanje in organiziranost in predstavlja neke vrste diplomski izpit pred diplomo, ki vključuje znanje več predmetov iz predhodnih semestrov.	The basis for understanding the content of this subject requires knowledge of basic technical courses, mechanics, and fundamentals of engineering and general knowledge of the materials science. The course requires from the student interdisciplinary knowledge and organization and is a kind of graduation exam before graduation, which involves knowledge of several subjects from previous semesters.

Metode poučevanja in učenja:	Learning and teaching methods:
Predavanja, računske in laboratorijske vaje, numerične simulacije, projektno delo.	Lectures. Exercises solving. Laboratory. Numerical simulations. Project work.

Načini ocenjevanja:	Delež/Weight	Assessment:
ocena projektnega dela	40,00 %	the mark of project work
ocena pisnega dela izpita	30,00 %	the mark of written examination
ocena ustnega dela izpita	30,00 %	the mark of the oral examination

Reference nosilca/Lecturer's references:

NAGODE, Aleš, RESNIK, Andrej, VERTNIK, Robert, BIZJAK, Milan, KOSEC, Borut, GOJIĆ, Mirko, KOSEC, Gorazd, ŠARLER, Božidar, ZORC, Borut. The development of a banded microstructure in S355J2 steel bar. Kovové materiály, ISSN 0023-432X, 2017, vol. 55, no. 1, str. 51-56. [COBISS.SI-ID 1666655], [JCR, SNIP, WoS do 2. 4. 2017: št. citatov (TC): 0, čistih citatov (CI): 0, Scopus do 10. 3. 2017: št. citatov (TC): 0, čistih citatov (CI): 0]

GODEC, Matjaž, ŠETINA, Barbara, MANDRINO, Djordje, NAGODE, Aleš, LESKOVŠEK, Vojteh, ŠKAPIN, Srečo D., JENKO, Monika. Characterization of the carbides and the martensite phase in powder-metallurgy high-speed steel. Materials characterization, ISSN 1044-5803. [Print ed.], April 2010, vol. 61, no. 4, str. 452-458

ZORC, Borut, NAGODE, Aleš. Determination of the crack-initiation and propagation conditions in a styrene-acrylonitrile water-filter housing with external ribs based on destructive pressure tests. Engineering failure analysis, ISSN 1350-6307. [Print ed.], Sept. 2017, vol. 79, str. 491-503. http://www.sciencedirect.com/science/article/pii/S1350630716305362, doi: 10.1016/j.engfailanal.2017.05.010. [COBISS.SI-ID 1678175], [JCR, SNIP, Scopus do 28. 5. 2017: št. citatov (TC): 0, čistih citatov (CI): 0]

NAGODE, Aleš, RESNIK, Andrej, BIZJAK, Milan, KOSEC, Gorazd, KARPE, Blaž, BUDAK, Igor, KOSEC, Borut, ZORC, Borut. Development of banded microstructure in 34CrNiMo6 steel. Metalurgija, ISSN 0543-5846, 2016, vol. 55, no. 3, str. 329-332. [COBISS.SI-ID 1602911], [SNIP, WoS do 16. 4. 2016: št. citatov (TC): 0, čistih citatov (CI): 0, Scopus do 25. 3. 2016: št. citatov (TC): 0, čistih citatov (CI): 0]

KOROZIJA

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	Korozija
Course title:	Corrosion
Članica nosilka/UL Member:	UL NTF

Študijski programi in stopnja	Študijska smer	Letnik	Semestri	Izbirnost
Metalurgija in materiali, druga stopnja, magistrski	Ni členitve (študijski program)	2. letnik	1. semester	izbirni

Univerzitetna koda predmeta/University course code:	0078005
Koda učne enote na članici/UL Member course code:	870

Predavanja /Lectures	Seminar /Seminar	Vaje /Tutorials	Klinične vaje /Clinical tutorials	Druge oblike študija /Other forms of study	Samostojno delo /Individual student work	ECTS
30	15	15	0	0	60	4

Nosilec predmeta/Lecturer:	Jožef Medved, Milan Bizjak

Izvajalci predavanj:	
Izvajalci seminarjev:	
Izvajalci vaj:	
Izvajalci kliničnih vaj:	
Izvajalci drugih oblik:	
Izvajalci praktičnega usposabljanja:	

Vrsta predmeta/Course type:	Izbirni / Elective

Jeziki/Languages:	Predavanja/Lectures:	Slovenščina
	Vaje/Tutorial:	Slovenščina

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	**Prerequisites:**
Pogoj za vključitev v delo oziroma za opravljanje študijskih obveznosti je vpis v 3. letnik študija. Študijske obveznosti lahko opravljajo tudi ponavljalci.	The condition for including in the programme is enrolment in 3rd year of study. The study programme can be also attended by the student who has failed and must repeat the year's work.

Vsebina:	**Content (Syllabus outline):**
Uvod. Elektrokemjska korozija kovin: termodinamika in kinetika elektrokemijskih reakcij, osnovna korozijska celica, polarizacija, pasivacija kovin. Vrste korozije: lokalna, špranjska, jamičasta, metalurško vplivana, interkristalna korozija,	Introduction Electrochemical corrosion of the metals: Thermodynamics and kinetics electrochemical reactions, basic corrosion cell, polarisation, metal passivation Types of corrosion: local corrosion, crevice

selektivno raztapljanje, mehansko podprta degradacija, erozivna, udarno delovanje korodiranega medija, torna kavitacija, korozijsko utrujanje, napetostna korozija, vodikova krhkost. Korozijske lastnosti nekaterih kovinskih materialov: atmosferska korozija ogljikovih jekel, nerjavna jekla, železove litine, aluminij in njegove zlitine, baker in njegove zlitine, titan, nikelj in zlitine. Korozija pri visokih temperaturah: reakcije s plini in s staljenimi kovinami in solmi, kovinski oksidi, rast oksidnega filma, oksidacija zlitin. Principi in metodika zaščite proti koroziji. Katodna in anodna zaščita. Praktični problemi in računski primeri.	corrosion, pit corrosion, metallurgical influenced corrosion, intergranular corrosion, selective dissolution, mechanical supported degradation, erosion corrosion, corrosive medium, cavitation corrosion, corrosion fatigue, stress corrosion, hydrogen embrittlement Corrosion properties of some metallic materials: atmosphere corrosion of carbon steels, stainless steel, iron casts, Al and Al-alloys, Cu and Cu-alloys, Ti, Ni and Ni-alloys. Corrosion at high temperatures: reaction with gases and melted metals and salts, metal oxides, the growth of the oxide film, oxidation of alloys. Principles and methods of preventing from corrosion. Cathodic and anodic preventing. Practical problems and calculation examples

Temeljna literatura in viri/Readings:

SMITH, W.F. Foundations of Materials Science and Engineering. Singapure: McGraw - Hill, 1993.
VEHOVAR, L. Korozija kovin. Ljubljana: IMT, 1991.
FONTANA, M.G. Corrossion Engineering. New York: McGraw - Hill, 1987.

Cilji in kompetence:	**Objectives and competences:**
Osnovni namen predmeta je seznaniti študente z vzroki, mehanizmi in načini propada materialov in naprav zaradi vpliva okolja in v kombinaciji z njim tudi drugih vplivov. Študentje spoznajo načine borbe s korozijo, ki povzroča enormne gospodarske škode in ogroža varnost ljudi in integriteto produktov človeških rok.	The main purpose of the course is to introduce the causes, the mechanisms as well as the ways of degradation of the materials and devices due to the influence of the environment as well as in combination with the other influences. The students get to know how to prevent from corrosion which causes enormous economic loss and threats people safety and integrity of products of human hands.

Predvideni študijski rezultati:	**Intended learning outcomes:**
Znanje in razumevanje: Za spremljanje predmeta je potrebno znanje termodinamike materialov, materialografije in fizikalne metalurgije. Namen predmeta je spoznati študente s korozijo in načini zaščite in preprečevanja. Cilj predmeta je tudi spodbuditi študente k samostojnemu delu na tem zahtevnem področju.	Knowledge and understanding: For attending a course knowledge of the thermodynamics of materials, materialography and physical metallurgy is necessary. The main purpose of the course is to introduce the students with the corrosion and the ways of preventing from it as well as encourage the students to work independently on this demanding field.

Metode poučevanja in učenja:	**Learning and teaching methods:**
Predavanja, računske in laboratorijske vaje, seminar.	Lectures, calculating tasks, laboratory work

Načini ocenjevanja:	**Delež/Weight**	**Assessment:**
ustni izpit	50,00 %	oral exam
pisni izpit	40,00 %	written exam
lab. delo in seminar	10,00 %	lab work and seminar

Reference nosilca/Lecturer's references:

GOJIĆ, Mirko, LAZIĆ, Ladislav, KOSEC, Borut, BIZJAK, Milan. Application of mathematical modelling to hardenability testing of low-alloyed Mn-Mo steel. Strojarstvo, 2005, god. 47, br. 3-4, str. 101-108.

ROTH, Jože, KOSEC, Ladislav, ŠKRABA, Polona, BIZJAK, Milan, MEDVED, Jože, DOBNIKAR, Meta, ANŽEL, Ivan. Internal oxidation of a Ag-1.3at.%Se alloy. Part I. Composition and Appearance of Oxidation Produces. Oxid. met., October 2004, vol. 62, no. 3/4, 273-291 str.

ŠKRABA, Polona, KOSEC, Ladislav, BIZJAK, Milan, RUDOLF, Rebeka, ROMČEVIĆ, Nebojša, KOSEC, Gorazd, KOSEC, Borut, LAZAREVIĆ, Zorica, ROTH, Jože, ANŽEL, Ivan. Internal oxidation of Ag-VC composites. Corros. sci.. [Print ed.], Available online 16 September 2010., doi: 10.1016/j.corsci.2010.09.003.

MEDVED, Jože, MRVAR, Primož, VONČINA, Maja. Oxidation resistance of AM60, AM50, AE42 and AZ91 magnesium alloys. V: CZERWINSKI, Frank (ur.). Magnesium alloys : corrosion and surface treatments. Rijeka: InTech. cop. 2011, str. 15-28, ilustr. [COBISS.SI-ID 1105759]

VONČINA, Maja, TISU, Robert, MEDVED, Jože. Oxidation stability of various Ti-alloys. Journal of thermal analysis and calorimetry, ISSN 1588-2926. [Online ed.], 2017, vol. 129, iss. 1, str. 117-122, doi: 10.1007/s10973-017-6154-2. [COBISS.SI-ID 1666399]

MEDVED, Jože, MRVAR, Primož, VONČINA, Maja. Oxidation resistance of cast magnesium alloys. Oxidation of metals, ISSN 0030-770X, 2009, vol. 71, no. 5/6, str. 257-270. http://www.springerlink.com/openurl.asp?genre=article&id=doi:10.1007/s11085-009-9141-6. [COBISS.SI-ID 909151]

LIVARSKE TEHNIKE

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	Livarske tehnike
Course title:	Casting Techniques
Članica nosilka/UL Member:	UL NTF

Študijski programi in stopnja	Študijska smer	Letnik	Semestri	Izbirnost
Metalurgija in materiali, druga stopnja, magistrski	Ni členitve (študijski program)	2. letnik	1. semester	izbirni

Univerzitetna koda predmeta/University course code:	0078006
Koda učne enote na članici/UL Member course code:	878

Predavanja /Lectures	Seminar /Seminar	Vaje /Tutorials	Klinične vaje /Clinical tutorials	Druge oblike študija /Other forms of study	Samostojno delo /Individual student work	ECTS
30	5	20	0	5	60	4

Nosilec predmeta/Lecturer:	Primož Mrvar

Izvajalci predavanj:	
Izvajalci seminarjev:	
Izvajalci vaj:	
Izvajalci kliničnih vaj:	
Izvajalci drugih oblik:	
Izvajalci praktičnega usposabljanja:	

Vrsta predmeta/Course type:	Izbirni / Elective

Jeziki/Languages:	Predavanja/Lectures:	Slovenščina
	Vaje/Tutorial:	Slovenščina

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	Prerequisites:
Vpis v letnik	Entry in the academic year

Vsebina:	Content (Syllabus outline):
Oblikovanje notranjih in zunanjih površin ulitka: TEHNIKE IZDELAVE ENKRATNIH FORM: Tehnike formanja z bentonitnimi peščenimi mešanicami: modeli in jedrniki, izdelava modelov, materiali za modele, vrste modelov Materiali za izdelavo form, veziva in dodatki, bentonitna peščena mešanica, izdelava forme, lastnosti in priprava mešanic, obremenitve pri litju, reakcije med formo in talino, krožni proces v livarnah, recikliranje in odpadni materiali Izdelava jeder: materiali za izdelavo jeder, vrste veziv,	Designing inner and outer surfaces of castings MOLD DESIGNING TECHNIQUE Molding technique with bentonite sand mixtures: models and cores, making of models, model materials, types of models Materials for mold making, binders and additions, bentonite sand mixture, mold making, properties and mixture preparation, pouring loads, reactions between mold and melt, sand circulation in foundry, recycling and waste material.

postopki, veziva na osnovi umetnih smol, stroji za izdelavo jeder Naprave za visoko produktivno izdelavo form in jeder Tehnike izdelave posamičnih form za velike ulitke: Materiali za izdelavo form, veziva na osnovi umetnih smol, dodatki formarskim mešanicam, premazi, postopki izdelave form TEHNIKE LITJA V TRAJNE FORME: Izdelava trajne forme, značilnosti procesov, postopki in materiali za tlačno, nizkotlačno, kokilno, centrifugalno, kontinuirno, plastno litje, litje v testastem stanju Stroji za tlačno litje,elementi ulivnega sistema, orodja in materiali, računalniško podprto vodenje procesov, squeezing Livne zlitine: Tehnologija livnih zlitin iz skupine železovih litin: Siva litina z lamelnim, vermikularnim, kroglastim grafitom in s feritno, perlitno, bainitno ter avstenitno osnovo, temprana litina, bela litina, litine s trdo oblo, osnovni elementi, elementi v sledovih, legirni elementi, jeklene litine Tehnike taljenja železovih litin: priprava vložka in zakladanje, obdelava taline, reakcije v talini, prehod plinov, kisle žlindre Tehnike za kontrolo stanja talin: plini, kali, cepljenje, ohlajevalna krivulja, kisikov potencial, pospeševanje stabilnega strjevanja, evtektoidna premena, standardi s tega področja Tehnologija neželeznih livnih zlitin: aluminijeve in magnezijeve livne zlitine, bakrove, cinkove, svinčeve zlitine, titanove zlitine, livne lastnosti, fazni diagrami, makro in mikro struktura, uporabne lastnosti materialov Tehnike taljenja neželeznih livnih zlitin: Sestava vložka, oksidacija in redukcija, talila, razplinjevanje, nagibno litje Livarske peči kot integralni del livarske tehnike: Indukcijske mrežno in srednje frekvenčne, električne peči, peči za vzdrževanje temperature, livne peči, bobnaste peči, kupolka, konstrukcijske značilnosti, obloge, sestava žlinder, procesi pri taljenju, poraba energije Peči za taljenje neželeznih zlitin v livarni: uporovne peči, plamenske peči, taljenje v zaščitni atmosferi Napake na ulitkih, livarna kot zaključen proizvodni proces, varovanje okolja v livarni	Core making: materials for core making, type of binders, procedures, synthetic resin binders, core making machines. High productivity mold and core making machines. Moulding technique for making big unique castings: mold materials, synthetic resin binders, additives for molding mixtures, coatings, procedures for mold making. PERMANENT MOLD DESIGENIN: Making of permanent mold, process features, materials and procedures for high pressure, low pressure, die, centrifugal, continuous, layer and semisolid casting. High pressure die casting machines, gating systems, tools and materials, computer added process control, squeezing Casting alloys: Ferrous casting alloys technology: Gray iron with lamellar, vermicular and spheroidal graphite with perlite, bainite and austenite matrix, malleabke cast iron, white iron, cast alloys with hard shell, basic elements, oligo elements, alloy elements, steel iron Cast iron melting technique: charge preparation and charging, reactions in melt, degasation methods, acid slag Melt condition control technique: gases, nucleate, inoculation, cooling curve, oxygen potential, stabile solidification acceleration, eutectoid transformation, standards Nonferrous alloy techniques: aluminum and magnesium casting alloys, cooper, zinc, lead alloys, titanium alloys, phase diagrams, macro and microstructure, useful material properties. Nonferrous alloys melting technique: charge composition, oxidation and reduction, flux, gassing, tilt casting Casting furnace as part of foundry technique: induction grid frequency and middle frequency furnace, electrical furnace, furnace for temperature maintenance, casting furnace, cupola, construction feature, coverings, slag composition, melting processes, energy consumption. Melting furnace for nonferrous melting in foundry: resistance furnaces, flame furnaces, melting in protected atmosphere. Casting defects, foundry as complete production process, environment protection in foundry.

Temeljna literatura in viri/Readings:

TRBIŽAN, M.: Livarstvo, skripta, Ljubljana 2003.
MRVAR, P.: Livarski praktikum, skripta, Ljubljana 2006.
CAMBELL, J.: Castings, OBE, Feng, Butterworth Heinemann Ltd, 1991.
SAHM, P.R.: Giessereikunde, Aachen 2003

Cilji in kompetence:	Objectives and competences:
Osnovni smotri predmeta so naučiti študente livarskih tehnik, ki zajema oblikovanje zunanjih in notranjih površin, tehnologijo litja in ohlajanja v formi, tehnike iztresovanja enkratnih form in izmetovanja ulitkov iz trajnih form ter poznavanje in razumevanje lastnosti osnovnih livnih materialov, kot tudi materialov forme. Poseben poudarek predmeta je na strojih, ki so neobhodno potrebni za izdelavo peščene mešanice, transport in regeneracijo le te, tehnike formanja in izdelave jeder, sklaplanja forme in avtomatiziranega in/ali enkratnega litja, sistemov za hlajenje form in izstresanje le teh, ter odstranjevanje elementov ulivnega in napajalnega sistema, peskanja, brušenja in mehanske obdelave. Tehnike s stroji so tudi predmet obravnave v sekvenci izdelave in obdelave litine. Vse razlage so združene z seminarskim delom, simulacijami ter projektnim delom načrtovanja, izdelave in karakterizacije materiala na relaciji livarska tehnika-material izdelka-material forme - livarska tehnologija.	Main competences for students are to learn basics of foundry that concerns shaping of inner and outer surfaces of casting, casting technology, solidification in mold, wreaking from unique sand mold, casting ejection from permanent molds, knowing and understanding the basic properties of casting and mold materials. Special aim is on machines that are necessary for sand mixture making, sand transport and sand regeneration, molding technique and core making, mold coupling and automatized and/or unique casting, cooling systems for molds and wreaking of castings from mold, cutting of feeder and gating system, sandblasting, grinding and machining. Casting techniques are included with making and preparation of melt. All explanations are combined with seminar work, numerical simulations and planning of project work, material making and analyzing considering foundry technique, material, product, mold material and foundry technology.

Predvideni študijski rezultati:	Intended learning outcomes:
Študent se nauči livarskih tehnik v povezavi s tehnologijo. Poglobljeno spozna stroje za oblikovanje zunanjih in notranjih površin, spozna in razume izdelavo enkratne in trajne forme, ter stroje za izdelavo le teh, zgoščevanje in transport v povezavi s livarsko tehniko. Študent je na osnovi pridobljenih znanj sposoben samostojne objektivne analize in načrtovanja livarske tehnike. Sposoben je uporabljati livarske izračune za trajne in enkratne forme. Študent se nauči povezati različne teoretične in eksperimentalne pristope pri reševanju livarsko tehničnih problemov od izbire postopka do načrtovanja livarne v povezavi z izbiro livne zlitine in materiala forme. Obvladovati mora vse sekvence ki nastopajo v livarni.	Students know foundry technique in correlation with technology. They know machines for making inner and outer surfaces of castings and understands making of unique and permanent mold and also machines for making of them, thickening and transport in foundry technique. With knowledge given, student is capable of individual objective analysis and planning of foundry technique. He is capable to use foundry calculations for permanent and unique molds. Student can connect different theoretical and experimental approach to solve technical foundry problems, like choosing foundry process and planning of foundry with chosen alloy and mold material. He knows all sequences that can be seen in a foundry.

Metode poučevanja in učenja:	Learning and teaching methods:
Predavanja, računske in seminarske vaje ter simulacije, projektno delo.	Lectures, laboratory and calculation work, seminar work, inclusion in the frame of research work.

Načini ocenjevanja:	Delež/Weight	Assessment:
• ustni /pisni izpit – ocena pisnega dela (30 %), ocena pisnega izpita (30 %),	60,00 %	Written and oral examination: 60% of final mark
• Projektno i ocena projektnega dela	40,00 %	Coursework and seminar

Reference nosilca/Lecturer's references:

1. MRVAR, Primož, MEDVED, Jože, KRIŽMAN, Alojz. Control of microstructure during the eutectoid transformation in the As-cast spheroidal graphite cast iron with ˝in-situ˝ dilatation analysis and quenching experiments. Steel research international, 2006, vol. 77, no. 5, 353-361 str. [COBISS.SI-ID 617055]
2. PETRIČ, Mitja, MEDVED, Jože, MRVAR, Primož. Effect of grain refinement, modification and cooling rate on the microstructure of alloy 239 and 226. Giessereiforschung, 2008, vol. 60, no. 2, str. 26-37. [COBISS.SI-ID 823135]
3. MRVAR, Primož, TRBIŽAN, Milan, MEDVED, Jože, KRIŽMAN, Alojz. Study of the eutectoid transformation in the As-cast spherodial graphite cast iron with ˝in-situ˝ dilatation analysis- method for quality control. Mater. sci. forum, 2006, let. 508, zv. 2, 287-293 str. [COBISS.SI-ID 587871]

LIVARSTVO 2

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	Livarstvo 2
Course title:	Casting 2
Članica nosilka/UL Member:	UL NTF

Študijski programi in stopnja	Študijska smer	Letnik	Semestri	Izbirnost
Metalurgija in materiali, druga stopnja, magistrski	Ni členitve (študijski program)	1. letnik	1. semester	obvezen

Univerzitetna koda predmeta/University course code:	0067983
Koda učne enote na članici/UL Member course code:	857

Predavanja /Lectures	Seminar /Seminar	Vaje /Tutorials	Klinične vaje /Clinical tutorials	Druge oblike študija /Other forms of study	Samostojno delo /Individual student work	ECTS
45	15	25	0	5	90	6

Nosilec predmeta/Lecturer:	Primož Mrvar

Izvajalci predavanj:	
Izvajalci seminarjev:	
Izvajalci vaj:	
Izvajalci kliničnih vaj:	
Izvajalci drugih oblik:	
Izvajalci praktičnega usposabljanja:	

Vrsta predmeta/Course type:	Obvezni / Compulsory

Jeziki/Languages:	Predavanja/Lectures:	Slovenščina
	Vaje/Tutorial:	Slovenščina

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	Prerequisites:
Vpis v letnik	Entry in the academic year

Vsebina:	Content (Syllabus outline):
Uvod in ulivanje kot tehnika izdelave delov: razvoj livarstva, pomen livarstva za gospodarstvo, trenutno stanje v svetu in na Slovenskem, trendi, prednosti litja: konstrukcijske, tehnološke, gospodarnostne in ekološke Livarsko tehnološko ustrezno konstruiranje ulitih delov: sodobni trendi, konstruiranje s funkcionalnim in livarsko-tehničnim optimiranjem, lahke konstrukcije, računalniško generiranje geometrije	Introduction and casting as production technique: development of metal casting, metal casting importance to the economy, the current state in the world and in the Slovenia, trends, benefits of casting: the structural, technological, economic and ecological Foundry technology properly cast parts design: new trends, design with functional and foundry-technical optimization, lightweight design, computer-generation of the geometry of castings

ulitka na osnovi trdnostnih zahtev in geometrijskih omejitev Procesi in tehnologije litja: ulivanje v formo, livarski modeli in jedrniki, izdelava form in jeder, napajalniki in ulivni sistemi, tehnološka dokumentacija Polnjenje livne votline-forme s talino, tok taline po ulivnem sistemu in livni votlini, livnost zlitin, zakonitosti toka taline, laminarno in turbulentno gibanje taline, površinska turbulenca, nastanek filmov na površini taline, simulacijski izračuni polnjenja forme Strjevanje ulitka v trajni in v enkratni formi, prehod toplote v ulitku in formi, strjevanje in krčenje, napajanje, usmerjeno strjevanje, kriteriji, samostojna strjevalna področja, simulacijski izračuni toplotnih centrov Nastanek napetosti v ulitku in orodju, krivljenje, vpliv forme in jeder, trajne forme, aktivno hlajenje in/ali ogrevanje, razvoj napetosti, simulacijski izračuni napetosti v ulitku in orodju za vse sekvence izdelave Načrtovanje tehnoloških procesov s simulacijskimi izračuni ter izbira tehnologije: simulacijski paketi, konstruiranje ulitkov z istočasnim optimiranjem litja, strjevanja in napetosti, virtualna livarna Pregled livarskih tehnologij za serijsko in maloserijsko ter posamično izdelavo ulitkov: litje v peščene forme, serijsko in posamično litje, postopki izdelave form in jeder, precizno litje, litje v trajne forme, tlačno in nizkotlačno litje, kokilno, centrifugalno litje, kontinuirno litje, plastno litje, litje s trdo oblo Pregled in značilnosti livnih zlitin: skupina materialov s področja sivih litin, bele in melirane litine, aluminijeve, magnezijeve, bakrove in cinkove zlitine, titanove zlitine	based on strength requirements and geometric constraints Processes and foundry techniques: mould casting, casting models core moulds, mould and core production, feeders and gating system, technological documentation Filling of cavity-mould with melt: metal flow in gating system and in cavity, cast-ability of alloys, metal flow lawfulness, laminar and turbulent metal flow, surface turbulence, formation of oxide films on surface, computer simulation of mould filling Solidification of casting in mould and in permanent mould: heat transfer in casting and in mould, solidification and shrinkage, feeding, directional solidification, separate solidification areas, computer simulation of hot spots Formation of stresses in casting and in die, deformations: influence of mould and cores, permanent moulds, cooling and heating, formation of stresses, computer simulation of stresses in casting and in die during process Technology process planning by computer simulations and choosing of casting process: casting design with simultaneous optimization of filling, solidification and stresses, virtual foundry Survey of casting processes for mass production, small-scale production and single production of castings: sand casting, mass production and single casting production, molding processes and core production processes, investment casting, permanent mould casting, high pressure die casting, low pressure die casting, die casting, centrifugal casting, continuous casting Survey and properties of foundry alloys: cast iron, white and mottled cast iron, aluminium, magnesium, copper, zinc and titanium alloys

Temeljna literatura in viri/Readings:

TRBIŽAN, M.: Livarstvo, skripta, Ljubljana 2003.
MRVAR, P.: Livarski praktikum, skripta, Ljubljana 2006.
CAMBELL, J.: Castings, OBE, Feng, Butterworth Heinemann Ltd, 1991.
SAHM, P.R.: Giessereikunde, Aachen 2003

Cilji in kompetence:	**Objectives and competences:**
Osnovni smotri predmeta so naučiti študente osnov livarstva, ki zajema oblikovanje zunanjih in notranjih površin ulitka, tehnologijo litja in strjevanja, ter poznavanje in razumevanje lastnosti osnovnih livnih materialov, kot tudi materialov forme. Pri predmetu se bodo študentje naučiti osnov izračuna livarskih procesov, uporabe modeliranja ulitkov in določanja materialnih lastnosti forme, ter ulivane zlitine z uporabo pomožnih livarskih sredstev. Vse razlage so združene s seminarskim delom, simulacijami ter projektnim delom načrtovanja, izdelave in karakterizacije materiala, ulitka, mikro in makro strukture na izdelku.	Main competences of students are to learn basics of foundry that concerns the shaping of inner and outer surfaces of casting, casting processes, solidification and understand properties of basic foundry alloys and mould materials as well. They learn to use computer simulation of foundry processes, use of casting modelling and determination of properties of moulding and casting material. All lectures are combined with tutorial work and simulations at project work of designing, production and characterization of material, casting and micro and macrostructure of casting.

Predvideni študijski rezultati:	Intended learning outcomes:
Študent se nauči livarstva in osnovnih pojmov, primerjalnih prednosti litja pred ostalimi izdelovalnimi tehnikami. Spozna osnove konstruiranja livarsko tehnološko ustreznih ulitkov in se seznani s programskim paketom ProCast in CAD/CAM, spozna in razume procese litja v enkratne in trajne forme gravitacijsko in pod tlakom, se nauči zakonitosti strujanja po elementih ulivnega in napajalnega sistema pri polnjenju livne votline in jih izračuna, strjevanje in nastanek notranjih napetosti v ulitku ter odnos s krivljenjem obvladuje za izbrano zlitino s pomočjo ustreznega faznega diagrama, ohlajevalne in dilatometrijske krivulje, nauči se praktične izdelave ulitkov s tehniko gravitacijskega litja v trajne in enkratne forme, spozna in eksperimentira z osnovnimi livarskimi kontrolnimi metodami, Analizira elemente mikro in makrostrukture na ulitkih in se seznani s temeljnimi orodij za izračun livarskih procesov, modeliranjem, simulacijami ter karakterizacijo, ki jih aplikativno uporabi pri projektnem delu izdelave novega materiala in/ali izdelka.	Student learns basic concepts of foundry, comparison of production technologies, advantages of foundry against other technologies. Meets basics of appropriate casting design and computer simulation programs Procast and CAD/CAM programs, understands foundry processes for all casting processes, learns the metal flow laws in gating and feeding system during filling and understands solidification of castings and defects formed during filling and solidification concerning stresses as well. He gets the skills to use phase diagrams and connects them with cooling curves and micro and macrostructures. Finally student considered knowledge used in project work of fabrication of a new material and/or cast part.

Metode poučevanja in učenja:	Learning and teaching methods:
Predavanja, računske in seminarske vaje ter simulacije, projektno delo.	Lectures, laboratory and calculation work, seminar work, inclusion in the frame of research work.

Načini ocenjevanja:	Delež/Weight	Assessment:
• ustni /pisni izpit – ocena pisnega dela	60,00 %	Written and oral examination
• Projektno in seminarsko delo	40,00 %	Coursework and seminar

Reference nosilca/Lecturer's references:

1. MRVAR, Primož, MEDVED, Jože, KRIŽMAN, Alojz. Control of microstructure during the eutectoid transformation in the As-cast spheroidal graphite cast iron with ˝in-situ˝ dilatation analysis and quenching experiments. Steel research international, 2006, vol. 77, no. 5, 353-361 str. [COBISS.SI-ID 617055]

2. PETRIČ, Mitja, MEDVED, Jože, MRVAR, Primož. Effect of grain refinement, modification and cooling rate on the microstructure of alloy 239 and 226. Giessereiforschung, 2008, vol. 60, no. 2, str. 26-37. [COBISS.SI-ID 823135]

3. MRVAR, Primož, TRBIŽAN, Milan, MEDVED, Jože, KRIŽMAN, Alojz. Study of the eutectoid transformation in the As-cast spherodial graphite cast iron with ˝in-situ˝ dilatation analysis- method for quality control. Mater. sci. forum, 2006, let. 508, zv. 2, 287-293 str. [COBISS.SI-ID 587871]

MAGISTRSKO DELO

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	Magistrsko delo
Course title:	Masters Degree
Članica nosilka/UL Member:	UL NTF

Študijski programi in stopnja	Študijska smer	Letnik	Semestri	Izbirnost
Metalurgija in materiali, druga stopnja, magistrski	Ni členitve (študijski program)	2. letnik	2. semester	obvezen

Univerzitetna koda predmeta/University course code:	0067991
Koda učne enote na članici/UL Member course code:	867

Predavanja /Lectures	Seminar /Seminar	Vaje /Tutorials	Klinične vaje /Clinical tutorials	Druge oblike študija /Other forms of study	Samostojno delo /Individual student work	ECTS
0	0	135	0	315	450	30

Nosilec predmeta/Lecturer:	

Izvajalci predavanj:	
Izvajalci seminarjev:	
Izvajalci vaj:	
Izvajalci kliničnih vaj:	
Izvajalci drugih oblik:	
Izvajalci praktičnega usposabljanja:	

Vrsta predmeta/Course type:	Obvezni / Compulsory

Jeziki/Languages:	Predavanja/Lectures:	Slovenščina
	Vaje/Tutorial:	Slovenščina

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	Prerequisites:
/Vpis v letnik.	Entry in the academic year.

Vsebina:	Content (Syllabus outline):
/Vsebina dela je dogovorjena z mentorjem. Temo na predlog kandidata in mentorja potrdi svet Oddelka za materiale in metalurgijo.	Department for materials and metallurgy approves the theme of the Master's degree. The theme is prepared by candidate and mentor.

Temeljna literatura in viri/Readings:

/Tematsko specifična literatura glede na temo magistrske naloge. / Specific thematic literature regarding the theme of master thesis.

Cilji in kompetence:	Objectives and competences:
/Kandidat izdela poročilo (po internih merilih OMM za diplomska dela) in ga predstavi komisiji za zagovor v obliki predavanja. Zaključno delo je preveritev kompetenc, ki jih je študent pridobil med študijem tega študijskega programa, hkrati pa je tudi preveritev komunikacijskih sposobnosti kandidata, katere le ta goji na predhodnih seminarjih posameznih predmetov. Razvije sposobnost zaupanja v pridobljeno znanje in v lastno kreativnost.	The candidate makes a report (according the rules on the OMM for master's degree) and presents it to the commission as a lecture. The final stage of the Master's degree is checking the competences, that student gains during the study of the master's program and to verify the capability of communicational abilities that are earned thru the seminar work. The student must develop the trust in his/her knowledge and in its own creativity.

Predvideni študijski rezultati:	Intended learning outcomes:
/Iskanje literature, sinteza znanj in kompetenc absolviranega študijskega programa, projektni pristop in strokovni zagovor rezultatov dela. Kandidat se nauči lastnega razumevanja teorije in izkušenj v praksi, kritična ocena skladnosti med teoretičnimi načeli in praktičnim ravnanjem, ocena okoljske sprejemljivosti in ekonomskih učinkov.	Literature research, the synthesis of the knowledge and competences, approach to the project and defence of the work results. The candidate learns to understand the theory and practice experience, critic evaluation of this correlation between the theory and practice, assessment of the environmental acceptability end economic effects.

Metode poučevanja in učenja:	Learning and teaching methods:
/Tematsko specifični pristopi pod vodstvom mentorja.	Thematic specific access under the mentor's guidance.

Načini ocenjevanja:	Delež/Weight	Assessment:
povprečje vseh ocen predmetov študijskega programa	70,00 %	the average of all the grades from this study program
ocena diplomskega dela	15,00 %	the estimation of the masters work
ocena predstavitve in zagovora	15,00 %	the estimation of the presentation and the Master's degree defence

Reference nosilca/Lecturer's references:

MATERIALI V ELEKTRONIKI IN ELEKTROTEHNIKI

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	Materiali v elektroniki in elektrotehniki
Course title:	Materials in Electrotechnics and Electronics
Članica nosilka/UL Member:	UL NTF

Študijski programi in stopnja	Študijska smer	Letnik	Semestri	Izbirnost
Metalurgija in materiali, druga stopnja, magistrski	Ni členitve (študijski program)	2. letnik	1. semester	izbirni

Univerzitetna koda predmeta/University course code:	0078007
Koda učne enote na članici/UL Member course code:	873

Predavanja /Lectures	Seminar /Seminar	Vaje /Tutorials	Klinične vaje /Clinical tutorials	Druge oblike študija /Other forms of study	Samostojno delo /Individual student work	ECTS
30	0	30	0	0	60	4

Nosilec predmeta/Lecturer:	Milan Bizjak

Izvajalci predavanj:	
Izvajalci seminarjev:	
Izvajalci vaj:	
Izvajalci kliničnih vaj:	
Izvajalci drugih oblik:	
Izvajalci praktičnega usposabljanja:	

Vrsta predmeta/Course type:	Izbirni / Elective

Jeziki/Languages:	Predavanja/Lectures:	Slovenščina
	Vaje/Tutorial:	Slovenščina

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	**Prerequisites:**
Pogoj za vključitev v delo oziroma za opravljanje študijskih obveznosti je vpis v 2. letnik študija. Izdelana in uspešno predstavljena projektna naloga je pogoj za pristop k pisnemu in ustnemu izpitu.	The condition to attend in the teaching course and to perform study obligations is an entry in the first year of study. Completed and successfully presented project work is required before taking the written and oral examination.

Vsebina:	**Content (Syllabus outline):**
Fizikalne osnove in značilnosti materialov v elektrotehniki in elektroniki. Razdelitev materialov: kovine, keramika, steklo,	Physical basis and characteristics of the materials in electrical engineering and electronics. Classification of materials: metals, ceramics, glass,

polimeri, kompoziti. Fizikalne osnove in značilnosti. Uporaba: materiali za električne vodnike, kontakte, uporovni materiali, materiali za bimetale, tokovna talilna varovala, izolanti... Izolacijski materiali s posebnimi lastnostmi: dielektriki, piezoelektriki, piroelektriki, feroelektriki. Magnetni materiali. Osnovne definicije permeabilnosti, izgub, anizotropije. Mehko in trdo magnetni materiali. Posebne lastnosti magnetnih materialov: magnetostrikcija, magnetoupornost, magnetokalorični pojav. Polprevodniški materiali. Vrste, osnovni mehanizmi prevodnosti. Geometrijsko-snovne lastnosti bipolarnih in unipolarnih struktur. Integrirana vezja. Substrati za monolitne tehnologije. Tehnologije v mikro-elektroniki. Kontrola postopkov: meritve geometrijskih parametrov, kemijske sestave, električnih parametrov. Sekundarna zaščita integriranih vezij. Računalniško podprto modeliranje tehnoloških postopkov. Fotonski elementi: optoelektronski elementi, svetleče diode, polprevodniški laserji, fotodetektorji, sončne celice. Osnovne lastnosti. Reciklaža materialov in vpliv na okolje.	polymers, composites. Physical basis and characteristics. Application: materials for electrical wiring, contacts, resistor materials, materials for the bimetal, current melting guard insulation ... Insulation materials with special properties: dielectrics, piezoelectrics, pyroelectrics, ferroelectrics. Magnetic materials. The basic definition of permeability, magnetic losses, anisotropy. Soft and hard magnetic materials. Specific properties of magnetic materials: magnetostriction, magnetoresistance, magnetocaloric effect. Semiconductor materials. Types, basic mechanisms of conductivity. Geometric-substance properties of bipolar and unipolar structures. Integrated circuits. Substrates for monolithic technology. Technology in micro-electronics. Inspection procedures: measurement of geometrical parameters, chemical composition, electrical parameters. Secondary protection of integrated circuits. Computer-aided modeling of technological processes. Photonic devices: Basic properties, optoelectronic components, LEDs, semiconductor lasers, photo detectors, solar cells… Recycling materials and environmental impact.

Temeljna literatura in viri/Readings:

P. BILJANOVIČ, Mikroelektronika. Školjska knjiga , Zagreb, 1990
S. M. Sze. VLSI Technology. McGraw-Hill, New York, 1988
S. M. Sze. Modern semiconductor device physics. John WileySons, Inc., New York 1998
H. Fredrikson, U. Akerlind, Physics of Functional Materials, John WileySons, Ltd 2008
Funktionwerkstoffe der Elektrotechnik und Elektronik. Uredila NITZSCHE, K. , URLICH, H.J. Leipzig: DVG, 1983
L. M. LEVINSON, Electonic Ceramics. New York. Marcel Dekker Inc., 1988
H. URLICH, Introduction to Industrial Polymers. Second Edition. Hanser Publishers, Munich, Vienna, New York, Barcelona 1993
H. SCHAUMBURG, Polymere. B.G. Teubner, Stuttgart, 1997
D. KOLAR, Tehnična keramika. Ljubljana: ZRS za šolstvo in šport 1993

Cilji in kompetence:	**Objectives and competences:**
Študent se seznani s funkcionalno uporabo materialov v elektrotehniki in elektroniki, električnimi in magnetnimi lastnostmi snovi ter drugimi snovnimi in uporabnimi značilnostmi. Cilj tega predmeta je spoznati materiale in njih izdelavo, ki primerno oblikovani in obdelani z različnimi tehnologijami omogočajo osnovne funkcije. Študent spozna poleg ostalih tehnologij tudi tehnološko opremo in z njo povezanimi tehnološkimi postopki za izdelavo integriranih vezij in mikrosistemov. Uporabo najrazličnejših metod za karakterizacijo, možnosti načrtovanja materialov in vplive na okolje.	Students familiarize themselves with the functional use of materials, their electrical and magnetic properties and other functional characteristics important in electrical engineering. The aim of this course is to acquire knowledge relating to materials and manufacturing technologies of these materials for the needs of electrical engineering. Students learn, among other technologies, also about technology equipment and related technological processes for manufacturing integrated circuits and microsystems, usage of different methods for characterization, material design possibilities, and materials and manufacturing technologies impact on environment.

Predvideni študijski rezultati:	Intended learning outcomes:
Razumevanje pomena materialov v elektrotehniki in elektroniki ter povezave med fizikalnimi lastnostmi in električno funkcijami. Znanje in obvladovanje vsebine zadošča za spremljanje novosti, za pravilno izbiro materiala in je v pomoč pri načrtovanju in sintezi novih materialov ter k reševanju problemov s področja materialov v elektrotehniki in elektroniki. Pridobljena znanja omogočijo študentu slediti spremembam in novostim na področju naprednih materialov in tehnologijah. Obvladuje izdelavo materialov, zna uporabljati tako nove kot že vpeljane materiale, tehnološke procese in opremo. Pozna in obvladuje postopke testiranja in karakterizacije. Sposoben je vodenja in nadzora procesov v industriji. Študent pridobi znanja za samostojno in timsko delo pri načrtovanju, sintezi oziroma pri izbiri materialov za elektrotehniko in elektroniko. Omogoča mu tesno sodelovanje med proizvajalci električnih in elektronskih elementov in naprav, z raziskovalnimi skupinami, dobavitelji osnovnih surovin ter z uporabniki.	Understanding the importance of materials in electrotechnics and electronics as well as links between the physical properties and electrical functions. Acquired knowledge is sufficient to monitor new developments, to correctly select materials, to solve problems related to materials and to assist in the design and synthesis of new materials in electrical engineering and electronics. The course enables students to track changes and new developments in advanced materials and technologies, to manage the test procedures and material characterization and to command and control processes in industry. Students acquire knowledge for individual and team work in the field of design, synthesis and selection of materials for electrical engineering and electronics. It allows them close cooperation between manufacturers of electrical and electronic components and devices, with research groups, raw materials suppliers and final users.

Metode poučevanja in učenja:	Learning and teaching methods:
Predavanja. Timsko in samostojno reševanje problemov. Računalniške simulacije in eksperimentalno delo. Raziskovalno delo in projektna naloga.	Lectures. Team and independent problem solving. Computer simulation and experimental work. Research work and project work.

Načini ocenjevanja:	Delež/Weight	Assessment:
ocena projektnega dela	20,00 %	the mark of project work
ocena pisnega dela izpita	40,00 %	the mark of written examination
ocena ustnega dela izpita	40,00 %	the mark of the oral examination

Reference nosilca/Lecturer's references:

KOSEC, Borut, SOKOVIĆ, Mirko, KOSEC, Ladislav, BIZJAK, Milan, KAMPUŠ, Zlatko. Case of introduction of new ecologically safe material. J. Achiev. Mater. Manuf. Eng., 2006, letn. 17, št. 1/2, str. 85-88.
BIZJAK, Milan, KOSEC, Ladislav, KOSEC, Borut, ANŽEL, Ivan. The characterization of phase transformations in rapidly solidified Al-Fe and Cu-Fe alloys through measurements of the electrical resistance and DSC = Karakterizacija faznih transformacija brzo skrutnutih Al-Fe i Cu-Fe slitine pomoću mjerenja električne otpornosti i diferencijalno skenirajuće kalorimetrije. Metalurgija (Sisak), 2006, let. 45, št. 4, str. 281-286.
BIZJAK, Milan, ZALAR, Anton, PANJAN, Peter, ZORKO, Benjamin, PRAČEK, Borut. Characterization of iron oxide layers using Auger electron spectroscopy. Appl. surf. sci.. [Print ed.], 2007, vol. 253, str. 3977-3981.
KOVAČ, Janez, BIZJAK, Milan, PRAČEK, Borut, ZALAR, Anton. Auger electron spectroscopy depth profiling of Fe-oxide layers on electromagnetic sheets prepared by low temperature oxidation. Appl. surf. sci.. [Print ed.], 2007, vol. 253, str. 4132-4136.
KOSEC, Borut, SOKOVIĆ, Mirko, KOSEC, Ladislav, BIZJAK, Milan, PUŠAVEC, Franci, KAMPUŠ, Zlatko. Introduction of new ecologically safe material for fusible elements of low voltage fuses. Archives of materials science and engineering. [Online ed.], 2007, vol. 28, issue 4, str. 211-216, ilustr.
BIZJAK, Milan, KOSEC, Ladislav, KNEISSL, Albert C., KOSEC, Borut. The characterisation of microstructural changes in rapidly solidified Al-Fe alloys through measurement of their electrical resistance. Int. j. mater. res., 2008, vol. 99, no. 1, str. 101-108.

KOSEC, Ladislav, BIZJAK, Milan, KOSEC, Borut, MARTINČIČ, Viktor. Nizkotaljiva zlitina kositra, bizmuta in antimona za talilne elemente nizkonapetostnih varovalk : št. patenta 21706. Ljubljana: Urad republike Slovenije za intelektualno lastnino: Republika Slovenija, Ministrstvo za gospodarstvo, 2005.
KOSEC, Ladislav, BIZJAK, Milan, KOSEC, Borut, MARTINČIČ, Viktor. Low melting alloy of tin, bismuth and antimony for fusible elements of low voltage fuses = Niedrig schmelzende Legierung aus Zinn, Wismut und Antimon für heissschmelzbare Elemente von Niedrigspannungssicherungen : European patent No. EP1557476 (A1) - 2005-07-27. München: Europäisches Patentamt: = European Patent Office: = Office européen des brevets, 27.7.2005. 1 listina.

MEHANIKA POLIMEROV

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	Mehanika polimerov
Course title:	Mechanics of Polymers
Članica nosilka/UL Member:	UL NTF

Študijski programi in stopnja	Študijska smer	Letnik	Semestri	Izbirnost
Metalurgija in materiali, druga stopnja, magistrski	Ni členitve (študijski program)	2. letnik	1. semester	izbirni

Univerzitetna koda predmeta/University course code:	0078013
Koda učne enote na članici/UL Member course code:	869

Predavanja /Lectures	Seminar /Seminar	Vaje /Tutorials	Klinične vaje /Clinical tutorials	Druge oblike študija /Other forms of study	Samostojno delo /Individual student work	ECTS
30	0	30	0	0	60	4

Nosilec predmeta/Lecturer:	Tomaž Rodič

Izvajalci predavanj:	
Izvajalci seminarjev:	
Izvajalci vaj:	
Izvajalci kliničnih vaj:	
Izvajalci drugih oblik:	
Izvajalci praktičnega usposabljanja:	

Vrsta predmeta/Course type:	Izbirni / Elective

Jeziki/Languages:	Predavanja/Lectures:	Slovenščina
	Vaje/Tutorial:	Slovenščina

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	Prerequisites:
Redno vpisani študentje v letnik. Poznavanje osnov kemije in fizike	Regularly enrolled students in the year. Knowledge of basic chemistry and physics

Vsebina:	Content (Syllabus outline):
I. Osnove 1.1 Polimerne molekule in materiali (definicije, homo in kopolimeri, polimerni materiali, kronologija polimerov, osnovni pojmi) 1.2 Konfiguracija in konformacija makromolekul (cis, trans, gauche, l-sučni, d-sučni, taktičnost, konformacija) 1.3 Gibkost makromolekul (model prosto sklenjene	I Basics 1.1 Polymer molecules and materials (definitions, polymer materials, chronology of polymers, basic concepts). 1.2. Configuration and conformation of molecules (cis, trans, gauche, left rotating, right rotating, tacticity, conformation). 1.3. Flexibility of macromolecules (freely jointed

verige, model prosto vrteče se verige, model molekule z omejenim vrtenjem, model ekvivalentne verige, entropija polimerne molekule, rotacijska izomerija)	chain model, freely rotating chain model, hindered rotation chain model, equivalent chain model, entropy of polymer molecule, rotational isometry).
II. Nadmolekulska struktura polimeriov 2.1 Amorfno stanje (učinkovanja na kratkih in dolgih razdaljah, molekulsko gibanje) 2.1.1 Nadmolekulska struktura amorfnih polimerov (model naključnega klobčiča, model Kargina, model Yeh-a, model klasterjev in drugi) 2.2 Kristalino stanje (osnove kristaline strukture, osnovna celica) 2.2.1 Kristalizacija gibkih in togih molekul (mehanizem zlaganja - lamelni, sferolitni, fibrilni, • šiš-kebabni, napake pri kristalizaciji, kristalizacija v posebnih pogojih (orientacijska v toku raztopin, talin, pod pritiskom) 2.2.2 Kinetika kristalizacije (teorije: Avrami, Keith-Padden, Lauritzen-Hoffman) 2.2.3 Nadmolekulska struktura kristalinih polimerov (opredelitev nadmolekulskih struktur, lamelna, sferolitna struktura, model Hosemanna, model Petrlina) 2.2.4 Sprememba strukture s toplotno obdelavo	II. Supramolecular structure of polymers 2.1 Amorphous state (long-distance and short-distance interactions, molecular motion). 2.1.1. Supramolecular structure of amorphous polymers (random coil model, Kargina model, Yeh's model, cluster model, etc.). 2.2. Crystalline state (basis of crystalline structure, basic cell). 2.2.1. Crystallization of flexible and rigid molecules (arrangement mechanism - lamellar, spherolithic, shish-kebabous, fibrillar, crysta- llization errors, crystallization at special conditions (orientational crystallization in the flow of solutions, melts, under pressure). 2.2.2. Crystallization kinetics (theories: Avrami, Keith-Padden, Lauritzen-Hoffman). 2.2.3. Supramolecular structure of crystalline polymers (definition of supramolecular structures, lamellar, spherolithic structure, Hosemann's model, Petrlin's model). 2.2.4.Structuralmodification by thermal processing.
III. Fizikalna stanja polimerov 3.1 Steklasto amorfno stanje 3.1.1 Steklasti prehod (krivulje prehodov, osnovne mehanske količine) 3.1.2 Teorije steklastega prehoda [prostega volumna, kinetična, termodinamska (Gibbs-DiMarzio)]. 3.1.3 Časovno odvisna elastičnost [pojavni modeli (Maxwell, Voigt-Kelvin, Burger, Eyring, sestavljeni)] 3.2 Visokoelastično (gumi podobno) stanje 3.2.1 Teorije visokoelastičnosti (termodinamična teorija, statistično mehanska, Mooney-Rivlin) 3.3 Tekoče stanje - taline 3.3.1 Osnovne reološ• ke zakonitosti 3.3.2 Polimeri iz gibkih molekul (molekulska razlaga, model Rouse, de Gennes' model plazenja) 3.3.3 Tekoče-kristalini polimeri (kemična in fizikalna struktura, fazni prehodi)	III. Physical states of polymers 3.1 Glassy amorphous stat 3.1.1. Glass transition (curves of transition, basic mechanical quantities). 3.1.2. Theories of glass transition (free volume, kinetic, thermodynamic (Gibbs-Di Marzio)). 3.1.3.Time-dependent elasticity [models (Maxwell's, Voigt-Kelvin, Burger's, Eyring, composed)] 3.2. The rubber-elastic state 3.2.1.Theories of rubber-elasticity (thermodynamic theory, the statistical mechanical theory, Mooney-Rivlin theory). 3.3. Liquid state – melts 3.3.1. Basic rheological principle 3.3.2.Polymers of flexible molecules (molecular explanation, Rouse model, de Gennes' reptation model). 3.3.3. Liquid crystalline polymers (chemical and physical structure, phase transitions).
IV. Lastnosti polimerov 4.1 Orientacija in anizotropija (definicija, metode, lastnosti) 4.2 Mehanske lastnosti (trdnost, polzi□ šče, trajnost, utrujenost, rast razpok, ciklične deformacije, mehanika pretrgov) 4.3 Viskoelastične lastnosti (, E, E*, lezenje, relaksacija, viskoznost) 4.4 Toplotne lastnosti (specifič. toplota, toplotna prevodnost, toplotno raz• irjanje) 4.5 Optične lastnosti (lom, odboj, dvolomnost, sipanje svetlobe) 4.6 Električne lastnosti (dielektrične lastnosti, dielektrične relaksacije, polarizacija, prevodnost) 4.7 Akustične lastnosti (razš• irjanje in absorpcija	IV. Properties of polymers 4.1. Orientation and anisotropy (definition, methods, properties). 4.2. Mechanical properties (strength, yield point, stability, fatigue, increase of ruptures, cyclical deformations, breakage mechanics). 4.3.Viscoelastic properties (-, E, E*, creep, relaxation, viscosity). 4.4.Thermal properties (specific heat, thermal conductivity, thermal expansion). 4.5.Optical properties (refraction, reflectance,

zvoka) 4.8 Magnetne lastnosti (magnetna dovzetnost, magnetna resonanca - jedrska ali elektronska)	birefraction, scattering of light). 4.6.Electric properties (dielectric properties, dielectric relaxations, polarization, conductivity). 4.7. Acoustic properties (expansion and absorption of sound). 4.8. Magnetic properties (magnetic susceptibility, magnetic resonance – nuclear or electronic).

Temeljna literatura in viri/Readings:

1.BUKOŠEK, Vili. Fizika in mehanika polimerov: predavanja, prosojnice. Ljubljana: Naravoslovnotehniška fakulteta, Oddelek za tekstilstvo, 2001. 1 zv. (loč. pag.), ilustr. [COBISS.SI-ID 1310064]

2. Gedde UW.: Polymer Physics, Chapman & Hall, London 1995, ISBN 0-412-59020-4.

3. Strobl G.: The Physics of Polymers, Concepts for Understanding their Structures and Behavior, Springer-Verlag, Berlin 1996, ISBN 3-540-60768-4.

4. Grosberg A.Yu., Hohlov A.R.: Giant Molecules, Here, there, and Evrywhere..., Academic Press, 1997, ISBN 0-12-304130-9.

5. I.M.Ward, D.W.Hadley: An Introduction to the Mechanical Properties of Solid Polymers, John Wiley & Sons, Chichester 1993, ISBN 0-417-93887-4.

Cilji in kompetence:	**Objectives and competences:**
Predmet nudi temeljna teoretična znanja in osnovna načela na področju fizike in mehanike trdnega stanja polimerov, ki so potrebni za razumevanje njihovih lastnosti in obnašanja. Glavni namen predmeta je predstaviti nekaj pomembnih teorij (steklastega prehoda, visooelastično stanje, elastičnost, kristalizacija) in osnovna načela fizike polimerov strukturno in na zanimiv način pokazati, kako je poskus lahko povezati s teorijo. Cilj predmeta je podati temeljna teoretična znanja, da študent in ga seznanili z osnovnimi načeli na področju polimerne fizike in mehanike, ki so potrebni za razumevanje njihovih lastnosti in obnašanja. Študent razširi teoretična znanja s področja polimerov. Glavni namen in cilj predmeta je predstaviti osnovne principe polimerne fizike strukturno in informativno, povezati rezultateposkusov s teorijo, in predstaviti nekaj pomembnih teorij (steklastega prehoda, visokoelastičnosti, kristalizacije). Vsebine so temeljnega pomena za študij orientiranih polimerov in tehnologije kot tudi za razumevanje njihovih lastnosti. Posebna znanja: - Poznavanje različnih fizikalnih stanj in pojavov značilnih za polimere, - Znanje o eksperimentalnih tehnikah v polimerni fiziki, - Seznanjanje s sodobnim znanjem delno kristalinih polimerov, - Sposobnost uporabe teoretičnega znanja fizike polimerov na področju strukture, morfologije in	The course provides basic theoretical knowledge and basic principles in the field of solid polymer physics and mechanics, which are required to understand their properties and behaviour. Main purpose of the course is to present several important theories (glass transition, rubber-elasticity, crystallization) and basic principles of the polymer physics structurally and in an interesting way, and to present how the experiment can be linked to the theory. The objective of the course is to provide basic theoretical knowledge to the student and to familiarize him with basic principles in the field of polymer physics and mechanics, which are required to understand their properties and behaviour. The student extends the theoretical knowledge of polymers. The main purpose and objective of the course is to present basic principles of the polymer physics structurally and informatively, to link experiments to theory, and to present several important theories (glass transition, rubberelastic state, crystallization). The course contents are fundamental to the study of oriented polymers and technology as well as to the understanding of their properties. Specific knowledge: - knowledge of various physical states and phenomena characteristic of polymers, - knowledge of experimental techniques in the polymer physics, - familiarity with the up-to-date knowledge of partly crystalline polymers, - ability to apply the theoretical knowledge of the

lastnosti pri razlagi obnašanja materijalov na različne okoliške pogoje, - Sposobnost povezovanja lastnosti polimerov z nadmolekulsko in morfološko strukturo pod vplivom dejavnikov, ki nastane med proizvodnjo in uporabo polimerov in končnih izdelkov, - Poznavanje različnih možnosti uporabe orientiranih polimerov, na različnih področjih, - Sposobnost kritične ocene strokovne literature,	polymer physics in the field of structure, morphology and properties in the interpretation of the behaviour of materials at various environmental conditions, - ability to link the properties of polymers to the supramolecular and morphological structure under the influence of factors arising during the production and use of polymers and end products, - familiarity with various application possibilities of oriented polymers in different areas, - ability to critically estimate the professional literature,

Predvideni študijski rezultati:	**Intended learning outcomes:**
Znanje in razumevanje: Predmet omogoča sistematični pregled znanja osnov fizike polimerov in njihovih fizikalnih stanj. Študent pridobi poglobljeno znanje o orientiranih delno kristalinih polimerih, molekulski, nadmolekulski, mikrofibrilni strukturi in morfologiji v povezavi z njihovimi lastnostmi. Ima znanje o zakonitostih in spremembah lastnosti ter obnašanju polimerov v različnih okoliških pogojih, kakor tudi znanje o uporabi polimerov v tehnologijah sedanjosti. Pridobljeno znanje na področju fizike polimerov omogoča razumevanje odvisnosti struktura – lastnosti in pojasnitev le-teh s teoretičnega stališča, teorij in drugih zakonitosti. Razumevanje in poznavanje osnovnih zakonitosti fizike polimerov ustvarja možnost razumevanja obnašanja v specifično zahtevnih ali ekstremnih pogojih uporabe polimerov, kakor tudi na osnovi tega znanja njihovo ustrezno pravilno izbiro za končni izdelek.	Knowledge and understanding: The course provides a systematic overview of basic knowledge of physics of polymers and their physical conditions. Students acquire advanced knowledge of partially oriented crystalline polymers, molecular, supramolecular, microfibrillar structure and morphology in relation to their properties. Have knowledge of laws and amendments to the properties and behavior of polymers in different environmental conditions, as well as knowledge of the use of polymers in the present technologies. Acquired knowledge in the field of polymer physics allows to understand the structure - properties and clarify these with theoretical views, theories and other laws. Understanding and knowledge of basic laws of polymer physics creates the possibility of understanding the behavior of a specific complex or extreme conditions of polymers, as well as on the knowledge of their proper right choice for the final product.

Metode poučevanja in učenja:	**Learning and teaching methods:**
Predavanja, individualni razgovori in pojasnjevanje vsebine predmeta,	Lectures, individual interviews and clarification of the course,

Načini ocenjevanja:	**Delež/Weight**	**Assessment:**
Pisni izpit	70,00 %	written examination
Laboratorijsko delo	30,00 %	lab work examination

Reference nosilca/Lecturer's references:

RODIČ, Tomaž, ŠUŠTAR, Tomaž, ŠUŠTARIČ, Primož, KORELC, Jože. Efficient numerical implementation of pressure, time and temperature superposition for elasto-visco-plastic material model by using a symbolic approach. Int. j. numer. methods eng., okt. 2010, letn. 84, št. 4, str. 470-484, ilustr., doi: 10.1002/nme.2903. [COBISS.SI-ID 5006433]

LANGUS, Janez, ŠUŠTARIČ, Primož, RODIČ, Tomaž. Impact response of polymer-coated grinding spheres. Eng. comput., 2011, vol. 28, no. 7, str. 792-801, doi: 10.1108/02644401111165095. [COBISS.SI-ID 1175903]

GIAVAZZI, Silvia, GANATEA, Marco Francesco, ŠUŠTARIČ, Primož, RODIČ, Tomaž. Inverse determination of viscoelastic properties of human fingertip skin = Inverzno določanje viskoelastičnih lastnosti človeške kože na prstu. RMZ-mater. geoenviron., 2010, let. 57, št. 1, str. 1-16. [COBISS.SI-ID 1011039]

MERITVE IN OBDELAVA PODATKOV

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	Meritve in obdelava podatkov
Course title:	Measuring and Analysis of Data
Članica nosilka/UL Member:	UL NTF

Študijski programi in stopnja	Študijska smer	Letnik	Semestri	Izbirnost
Metalurgija in materiali, druga stopnja, magistrski	Ni členitve (študijski program)	2. letnik	1. semester	izbirni

Univerzitetna koda predmeta/University course code:	0067976
Koda učne enote na članici/UL Member course code:	880

Predavanja /Lectures	Seminar /Seminar	Vaje /Tutorials	Klinične vaje /Clinical tutorials	Druge oblike študija /Other forms of study	Samostojno delo /Individual student work	ECTS
30	10	20	0	0	60	4

Nosilec predmeta/Lecturer:	Dr. David Bombač, Matjaž Knap, Peter Fajfar

Izvajalci predavanj:	
Izvajalci seminarjev:	
Izvajalci vaj:	
Izvajalci kliničnih vaj:	
Izvajalci drugih oblik:	
Izvajalci praktičnega usposabljanja:	

Vrsta predmeta/Course type:	Izbirni / Elective

Jeziki/Languages:	Predavanja/Lectures:	Slovenščina
	Vaje/Tutorial:	Slovenščina

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	Prerequisites:
Pogoj za pristop k pisnem in ustnem izpitu so opravljene laboratorijske vaje in opravljena ter uspešno predstavljena seminarska naloga.	Completed of laboratory works and completed and successfully presented seminar work is required before taking the written and oral exam.

Vsebina:	Content (Syllabus outline):
Osnove merilnih metod. Osnovni merski sistem. Načrtovanje preizkusov. Kalibracija. Standardi. Statične in dinamične karakteristike signalov. Analiza signala. Amplituda in frekvenca. Fouriereva transformacija. Pogreški pri merjenju in merilna negotovost.	Basic concept of measurement methods. General measurement system. Experimental test plan. Calibration. Standards. Static and dynamic characteristic of signal. Signal analysis. Amplitude and frequency. Fourier transforms.

Statistična teorija merjenja. Merilni pogreški. Vzroki pogreškov. Sistematični in naključni pogreški. Analogno in digitalno merjenje. Analogne in digitalne naprave. Digitalno merjenje. D/A (A/D) pretvorniki. Sistem za zajemanje podatkov. Električno merjenje fizikalnih veličin. Temperatura. Deformacija. Tlak. Hitrost.	Probability and uncertainty analysis. Statistical measurement theory. Measurement errors. Error sources. Systematic and random errors. Analog and digital measurement. Analog and digital devices. Digital measurement. D/A (A/D) converter. Data –acquisition system. Electrical measurements of physical quantity. Temperature. Strain. Pressure. Velocity. Force. Torque. Weight. Displacement.

Temeljna literatura in viri/Readings:

FIGOLA, R. S., Beasley, D. E. Theory and Design for Mechanical Measurements. 4th ed. John Wiley & Sons, Inc., 2006. HOFFMANN, J. Taschenbuch der Messtechnik. Carel Hanser Verlag München Vien, 2004.

Cilji in kompetence:	**Objectives and competences:**
Študentje bodo pridobili osnovna znanja s področja inženirskih meritev. Sposobni bodo izbrati ustrezno merilno metodo ali sistem ter interpretirati rezultate. Pridobljeno znanje bodo sposobni uporabiti pri svojem delu.	Students will get familiar with the background in the theory of engineering measurements. They will be able to select the proper measurement method or system and to interpret the results obtained from such measurements. They will gain the ability to apply fundamental knowledge of engineering measurements in praxis.

Predvideni študijski rezultati:	**Intended learning outcomes:**
Znanje in razumevanje: Študent bo pridobil osnovna znanja iz teorije inženirskih meritev. Naučil se bo načrtovanja in organizacije industrijskih meritev. Spoznal bo teorijo pogreškov in merilne negotovosti, statične in dinamične karakteristike signalov, analogno in digitalno merjenje. Poudarek bo na električnem merjenju fizikalnih veličin kot so: temperatura, deformacija, hitrost, tlak, pomik, sila, moment itd.	Knowledge and understanding: Student will get well-founded background in the theory of engineering measurements. They will have skill to plan and organize industrial measurements. They will learn the theory of probability and uncertainty analysis, about static and dynamic characteristic of signal, analog and digital measurements. The emphasis is on electrical measurements of physical quantity such as temperature, strain, velocity, pressure, displacement, force, torque etc.

Metode poučevanja in učenja:	**Learning and teaching methods:**
Predavanja, računske vaje, laboratorijske vaje, seminarska naloga.	Lectures, exercises solving, laboratory works, seminar work.

Načini ocenjevanja:	**Delež/Weight**	**Assessment:**
ocena pisnega dela izpita	30,00 %	the mark of written examination
ocena ustnega dela izpita	30,00 %	the mark of the oral examination (
ocena seminarske naloge	40,00 %	the mark of seminar work

Reference nosilca/Lecturer's references:

TERČELJ, Milan, KUGLER, Goran, TURK, Radomir, CVAHTE, Peter, FAJFAR, Peter. Measurement of temperature on the bearing surface of an industrial die and assessment of the heat transfer coefficient in hot extrusion of aluminium: a case study. Int. j. veh. des., 2005, vol. 39, nos. 1/2, str. 93-109. [COBISS.SI-ID 532575]

FAJFAR, Peter, TURK, Radomir. Meritve in kontrola tehnoloških parametrov valjanja = Measurements and control of technological rolling parameters. Kovine zlit. tehnol., 1999, letn. 33, št. 5, str. 299-301, ilustr. [COBISS.SI-ID 162986]

FAJFAR, Peter, BARBIČ, Rok. Meritev sil na vlečnem stroju EJP I (stroj 7136). Ljubljana: Univerza v Ljubljani, NTF, Oddelek za materiale in metalurgijo, 2008. 11 f., ilustr., graf. prikazi. [COBISS.SI-ID 917599]

EHOVNIK, Franc, BURJA, Jaka, ARH, Boštjan, KNAP, Matjaž. Submerged entry nozzle clogging during continuous casting of Al-killed steel. Metalurgija. 2015, vol. 54, no. 2, str. 371-374, ilustr. ISSN 0543-5846. http://hrcak.srce.hr/file/190507. [COBISS.SI-ID 1101994]

KNAP, Matjaž, FALKUS, Jan, ROZMAN, Alojz, KONOPKA, Krysztof, LAMUT, Jakob. The prediction of hardenability using neural networks = Modelowanie hartowności stali z wykorzystaniem sztucznych sieci neuronowych. Archives of metallurgy and materials. 2014, vol. 59, no. 1, str. 133-136. ISSN 1733-3490. http://www.imim.pl/archives. [COBISS.SI-ID 1448799]

KNAP, Matjaž, ROZMAN, Alojz, LAMUT, Jakob. Influence of process parameters on hydrogen content in steel melt = Vpliv procesnih parametrov na vsebnost vodika v jekleni talini. RMZ - Materials and geoenvironment : periodical for mining, metallurgy and geology. [Tiskana izd.]. dec. 2013, vol. 60, no. 4, str. 233-238, ilustr. ISSN 1408-7073. [COBISS.SI-ID 1426527]

BOMBAČ, David, GINTALAS, Marius, KUGLER, Goran, TERČELJ, Milan. Thermal fatigue behaviour of Fe-1.7C-11.3Cr-1.9Ni-1.2Mo roller steel in temperature range 500 - 700 °C. International journal of fatigue. 2019, vol. 121, str. 98-111.

BOMBAČ, David, CVAHTE, Peter, BALOG, Martin, KUGLER, Goran, TERČELJ, Milan. In-depth comparison of an industrially extruded powder and ingot al alloys. Metals. 2020, vol. 10, iss. 11, str. 1-18.

BOMBAČ, David, LAMUT, Martin, MRVAR, Primož, ŠIROK, Brane, BIZJAN, Benjamin. Physical properties of mineral fibers depending on the mineralogical composition. Materials. 2021, vol. 14, iss. 20, str. 1-12.

METALURGIJA PRAHOV

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	Metalurgija prahov
Course title:	Powder Metallurgy
Članica nosilka/UL Member:	UL NTF

Študijski programi in stopnja	Študijska smer	Letnik	Semestri	Izbirnost
Metalurgija in materiali, druga stopnja, magistrski	Ni členitve (študijski program)	2. letnik	1. semester	izbirni

Univerzitetna koda predmeta/University course code:	0078009
Koda učne enote na članici/UL Member course code:	879

Predavanja /Lectures	Seminar /Seminar	Vaje /Tutorials	Klinične vaje /Clinical tutorials	Druge oblike študija /Other forms of study	Samostojno delo /Individual student work	ECTS
30	15	15	0	0	60	4

Nosilec predmeta/Lecturer:	Milan Bizjak

Izvajalci predavanj:	
Izvajalci seminarjev:	
Izvajalci vaj:	
Izvajalci kliničnih vaj:	
Izvajalci drugih oblik:	
Izvajalci praktičnega usposabljanja:	

Vrsta predmeta/Course type:	Izbirni / Elective

Jeziki/Languages:	Predavanja/Lectures:	Slovenščina
	Vaje/Tutorial:	Slovenščina

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	**Prerequisites:**
Pogoj za vključitev v delo oziroma za opravljanje študijskih obveznosti je vpis v 1. letnik študija.	The condition for attending the programme is enrolment in 1st year of study.

Vsebina:	**Content (Syllabus outline):**
Postopki izdelave prahov. Karakterizacija prahov. Priprava prahov za oblikovanje in konsolidacijo. Oblikovanje in stiskanje prahov v togih matricah. Drugi postopki oblikovanja. Sintranje; dogodki v posameznih stopnjah;	Powder production technology Powder characterisation Powder preparation for shape forming and consolidation Shape forming and pressing of powders in dies Other processes of shape forming

aktivacijsko sintranje, sintranje s talino; sintranje pod tlakom; reaktivno in reakcijsko sintranje, supersolid sintranje, razvoj mikrostrukture. Sekundarne operacije. Primeri izdelave materialov in izdelkov po postopkih metalurgije prahov. Povezava metalurgije prahov z drugimi procesnimi tehnikami.	Sintering: processes in different stages of sintering; activated sintering, liquid phase sintering, press sintering; reactive sintering, supersolid sintering, microstructure development. Secondary operations, Case studies of the material production and products made by powder metallurgy route Relation between powder metallurgy and other processing techniques.

Temeljna literatura in viri/Readings:

THIMMLER, F. in OBERACHER, R. Introduction to Powder Metallurgy. Cambridge: Cambridge University Press, 1993.
GERMAN, R.M. Sintering Theory and Practice. New York: John Wiley and Sons, 1996.

Cilji in kompetence:	**Objectives and competences:**
Cilj predmeta je spoznati študente s teoretičnimi osnovami, načrtovanjem, postopki izdelave izhodnih surovin, sinteze materialov in izdelkov, karakterizacije materialov in izdelovalnimi tehnologijami metalurgije prahov.	The scope of the course is to introduce to the students theoretical bases, planning, production of raw materials, material synthesis and products development, material characterisation and technologies of powder metallurgy production

Predvideni študijski rezultati:	**Intended learning outcomes:**
Znanje in razumevanje: Metalurgija prahov je eden izmed zaključnih predmetov študija. Razvoj znanja izhaja iz termodinamike materialov, materialografije, fizikalne metalurgije, preiskav materialov ter predmetov procesne tehnike.	Knowledge and understanding: Powder metallurgy is one of the last courses of the study. The knowledge arises from thermodynamics of the materials, materialography, physical metallurgy, materials testing as well as processing techniques.

Metode poučevanja in učenja:	**Learning and teaching methods:**
Predavanja, računske in eksperimentalne vaje, seminarsko delo.	Lectures, calculation tasks, laboratory work and seminar.

Načini ocenjevanja:	**Delež/Weight**	**Assessment:**
Teoretični del	50,00 %	oral examination
pisni izpit	40,00 %	written examination
seminarsko delo	10,00 %	seminar

Reference nosilca/Lecturer's references:

Bizjak, Milan: The characterization of phase transformations in rapidly solidified Al-Fe and Cu-Fe alloys trough measurements of the electrical resistance and DSC. Metalurgija, 2006, le. 45, št. 4, str, 281-286
Bizjak, Milan., Kosec L., Kneissl A.C., Kosec B.: The characterisation of microstructural changes in rapidly solidified Al-Fe alloys through measurement of their electrical resistance, International Journal of Materials Research, Vol. 99, No. 1, 101 – 108, 2008
Bizjak, Milan, KOSEC Borut, NAGODE Aleš, BLAŽ, Karpe: The Influence of Si and V on the Kinetics of Phase Transformation and Microstructure of Rapidly Solidified Al-Fe-Zr Alloys, Journal of Ming and Metallurgy (v objavi)

NAČRTOVANJE MATERIALOV

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	Načrtovanje materialov
Course title:	Materials Design
Članica nosilka/UL Member:	UL NTF

Študijski programi in stopnja	Študijska smer	Letnik	Semestri	Izbirnost
Metalurgija in materiali, druga stopnja, magistrski	Ni členitve (študijski program)	2. letnik	1. semester	obvezen

Univerzitetna koda predmeta/University course code:	0067992
Koda učne enote na članici/UL Member course code:	864

Predavanja /Lectures	Seminar /Seminar	Vaje /Tutorials	Klinične vaje /Clinical tutorials	Druge oblike študija /Other forms of study	Samostojno delo /Individual student work	ECTS
45	0	45	0	0	90	6

Nosilec predmeta/Lecturer:	Boštjan Markoli

Izvajalci predavanj:	
Izvajalci seminarjev:	
Izvajalci vaj:	
Izvajalci kliničnih vaj:	
Izvajalci drugih oblik:	
Izvajalci praktičnega usposabljanja:	

Vrsta predmeta/Course type:	Obvezni / Compulsory

Jeziki/Languages:	Predavanja/Lectures:	Slovenščina
	Vaje/Tutorial:	Slovenščina

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	Prerequisites:
Obvezna prisotnost pri laboratorijskih vajah. Prisotnost pri predavanjih in seminarskih vajah v skladu s pravili UL. Do frekvence so upravičeni vsi, ki glede prisotnosti izpolnjujejo predpise UL. K ustnemu izpitu lahko pristopijo tisti z izpolnjenimi seminarskimi in laboratorijskimi obveznostmi.	Attendance at the lab. Attendance at lectures and tutorials in accordance with the rules of University of Ljubljana (UL). The professor´s signature is awarded to all students who comply with regulations regarding the lecture and laboratory presence at UL. The oral examination may be given access to those with completed seminar and laboratory obligations.

Vsebina:	Content (Syllabus outline):
Razvoj in načrtovanje materialov: cilji, področja uporabe in zanesljivost materialov, sistematika in selekcija materialov, metodologija načrtovanja.	Development and designing of materials: objectives, scope and reliability of the materials, the scheme and selection of materials, design methodology.

Zgradba materialov: nastanek, definicija in analiza, osnovni tipi dvofaznih in večfaznih mikrostruktur; disperzija, mrežasta zgradba, dupleks in dualna mikrostruktura, prehod enega tipa mikrostrukture v drugega in fizikalne lastnosti, nanostruktura, steklasto stanje. Stabilnost mikrostrukture: vzroki in mehanizmi sprememb, laminati in vlaknate tvorbe, deformacijske in rekristalizacijske teksture, metode utrjevanja in zaviranja sprememb mikro- in nanostruktrunih sestavin. Fizikalno-kemične osnove načrtovanja: interakcija elementov, konstitucijski kriteriji izbire komponent, vloga faznih diagramov; definicija osnove, dodatkov in primesi, principi poizkusov. Opredelitev nalog načrtovanja kovinskih in keramičnih materialov: izbira zlitinskih komponent ter legirna sistematika in tehnika, izhodišča za izbiro zlitin, funkcionalna in konstrukcijska keramika, mikrostruktura-lastnosti kot podlaga za razvoj. Polimerne snovi: zgradba in lastnosti, termoplasti, amorfne in kristalne strukture, kompozitni polimerni materiali.	Materials structure: origin, definition and analysis, basic types of two-phase and multiphase microstructures; dispersion, net structure, duplex and dual microstructure, the transition of one type to another microstructure and physical properties, nanostructures, glassy state. The stability of the microstructure: the causes and mechanisms of change, laminates and fibril formation, deformation and recrystallization textures, the method of strengthening and inhibition of micro-changes and nanostructural ingredients. Physico-chemical basics of designing: the interaction of elements, constitutional criteria of selection of components, application of phase diagrams, the definition of the matrix, additions and ingredients, principles of experimentation. Definition of the functions of planning metal and ceramic materials: choice of alloying constituents and alloying logic and technique, guidelines for the selection of alloys, functional and structural ceramics, microstructure-property as a basis for development. Polymeric materials: structure and properties, thermoplastics, amorphous and crystalline structures, composite polymeric materials.

Temeljna literatura in viri/Readings:

B.D. Fahlman: Materials Chemistry, Springer, 2007
W.F. Hosford: Materials Science, Cambridge University Press, 2008
R.F. Gibson: Principles of Composite Materials 2nd ed., CRC Press, 2007
R.J. Naumann:Physics and Chemistry of Materials, CRC Press, 2009
B. Markoli: Struktura in lastnosti materialov: interna skripta, NTF, Ljubljana 2005
B. MARKOLI: Struktura in lastnosti materialov : električna in toplotna prevodnost, izolatorji, magneti, polprevodniki : interna skripta. 1. izd. Ljubljana: Naravoslovnotehniška fakulteta, Oddelek za materiale in metalurgijo, 2008.
B. MARKOLI: Fizikalna metalurgija I : ternarni in kvaterni sistemi. 2. izd. Ljubljana: Naravoslovnotehniška fakulteta, Oddelek za materiale in metalurgijo, 2009.
R.J.D. Tilley: Understanding solids, John Wiley Sons Ltd. 2004
M.F. Ashbey: Materials selection and materials design, London-Butterworth-Heinemann, 1997
S. Spaić: Osnove načrtovanja zlitin I. in II. del, interna skripta, Ljubljana, NTF, Univerza v Ljubljani, 1995

Cilji in kompetence:	**Objectives and competences:**
Študent se seznani s sistematiko, zgradbo in parametri materialov, kar omogoča razumevanje metodologije načrtovanja. Spozna načrtovanje konstitucije, njen nastanek, razvoj in stabilnost makro-, mikro- in nanostrukture v povezavi z lastnostmi in obnašanjem materialov. Pridobljeno znanje je osnova za inovativno preverjanje obstoječih materialov in načrtovanje ter razvoj kovinskih in nekovinskih materialov. Pridobi kompetence pri uvajanju in usmerjanju v sodobno razvojno delo na področju selekcije materialov v povezavi zgradba-lastnosti-namembnost.	Students become acquainted with the systematic, structure and parameters of materials, enabling understanding of the methodology of materials designing. They learn to design a constitution, its origins, development and stability of macro-, micro- and nano-structures in relation to the properties and behavior of materials. This knowledge is the basis for validation of existing innovative materials and design and development of metal and nonmetal materials. Get skills in establishing and directing a modern development work in the selection of materials in relation to structure-property-purpose.

Predvideni študijski rezultati:	Intended learning outcomes:
Znanje in razumevanje: Deklarativno znanje: Osnove zgradbe materialov in njeni tipi na mikro- in nanonivoju. Stabilnost strukturnih sestavin. Razumevanje značilnosti napak ali defektov v zgradbi materialov in vplivu le-teh na lastnosti ter interakcija kemijskih elementov. Samostojna priprava seminarja iz tematike povezane s sodelovanjem pri aktualnih projektih.	Knowledge and understanding: Declarative knowledge: Basics of the structure of materials and its types in micro-and nanolevel. The stability of structural components. Understanding the nature of disorders or defects in structure of materials and the impact thereof on the properties and interaction of chemical elements. Students prepare and independant seminar related to their involvement in the current projects.

Metode poučevanja in učenja:	Learning and teaching methods:
Predavanja, seminarji, raziskovalni seminarji, laboratorijske vaje, simulacije, nastopi, vključevanje v projektno delo.	Lecturing, seminars, research seminars, laboratory exercises, simulations, oral presentations, cooperation on projects.

Načini ocenjevanja:	Delež/Weight	Assessment:
ocena ustnega dela izpita	40,00 %	evaluation of oral examination
ocena pisnega dela izpita	40,00 %	assessment of the written examination
ocena seminarja	20,00 %	seminar assessment

Reference nosilca/Lecturer's references:

1) ZUPANIČ, Franc, BONČINA, Tonica, ROZMAN, Niko, ANŽEL, Ivan, GROGGER, Werner, GSPAN, Christian, HOFER, Ferdinand, MARKOLI, Boštjan. Development of an Al-Mn-Be-Cu alloy with improved quasicrystalline forming ability. Z. Kristallogr., str. 735-738.
2) MARKOLI, Boštjan, BONČINA, Tonica, ZUPANIČ, Franc. The solidification path of the complex metallic Al-Mn-Be alloy. Croat. chem. acta, Apr. 2010, vol. 83, no. 1, str. 49-54.
3) PODMILJŠAK, Benjamin, ŠKULJ, Iztok, MARKOLI, Boštjan, ŽUŽEK ROŽMAN, Kristina, MCGUINESS, Paul J., KOBE, Spomenka. Microstructural changes in Fe-doped Gd[sub]5Si[sub]2G[sub]2. J. magn. magn. mater.. [Print ed.], 2008, vol. 321, no. 4, str. 300-304.
4) ŽUŽEK ROŽMAN, Kristina, KOVAČ, Janez, MCGUINESS, Paul J., SAMARDŽIJA, Zoran, MARKOLI, Boštjan, KOBE, Spomenka. Microstructural, compositional and magnetic characterization of electrodeposited and annealed Co-Pt-based thin films. Thin solid films. [Print ed.], 2010, vol. 518, no. 6, str. 1751-1755.
5) S. Šturm, K. Žužek Rožman, B. Markoli, E. Sarantopoulou, Z. Kollia, A.C. Cefalas and S.Kobe. Formation of core–shell and hollow nanospheres through the nanoscale melt-solidification effect in the Sm–Fe(Ta)–N system, Nanotechnology (Bristol), 2010, vol. 21, no. 48, str. 485603-1-485603-8

PRAKSA

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	Praksa
Course title:	Practical Work
Članica nosilka/UL Member:	UL NTF

Študijski programi in stopnja	Študijska smer	Letnik	Semestri	Izbirnost
Metalurgija in materiali, druga stopnja, magistrski	Ni členitve (študijski program)	2. letnik	1. semester	izbirni

Univerzitetna koda predmeta/University course code:	0067977
Koda učne enote na članici/UL Member course code:	881

Predavanja /Lectures	Seminar /Seminar	Vaje /Tutorials	Klinične vaje /Clinical tutorials	Druge oblike študija /Other forms of study	Samostojno delo /Individual student work	ECTS
0	0	60	0	0	60	4

Nosilec predmeta/Lecturer:	Peter Fajfar

Izvajalci predavanj:	
Izvajalci seminarjev:	
Izvajalci vaj:	
Izvajalci kliničnih vaj:	
Izvajalci drugih oblik:	
Izvajalci praktičnega usposabljanja:	

Vrsta predmeta/Course type:	Izbirni / Elective

Jeziki/Languages:	Predavanja/Lectures:	Slovenščina
	Vaje/Tutorial:	Slovenščina

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	Prerequisites:
/Vpis v letnik.	Entry in the academic year.

Vsebina:	Content (Syllabus outline):
/V okviru praktičnega usposabljanja se študent seznani z organizacijo podjetja, varnostnimi ukrepi in spozna tehnološki proces. Vsebine prakse so prilagojene konkretnemu mestu, kjer se opravlja. Področja opravljanja prakse so: - uvajanje v delo magistra metalurgije in materialov, - zasledovanje tehnoloških procesov, - zasledovanje toka materiala, - nadzor proizvodnega procesa,	During the practice qualification the student is acquainted with the organisation of the industry, security measurements and gets to know with the technological process. The practical work is adapted to the industry where the practice work is executed. The fields of practice are: - work responsibilities of master of metallurgy and materials, - following the technological processes,

- karakterizacija materialov, - osvojitev pravil varnosti pri delu, - varstvo okolja, - vzdrževanje strojev in naprav	- following of the flow material, - supervision of the fabrication processes, - characterization of the materials, - safety regulations, - maintenance of the production equipment and devices

Temeljna literatura in viri/Readings:

/Literatura je odvisna od strokovnega področja in vsebine prakse. / Literature depends on the field of the research and content of the practice.

Cilji in kompetence:	**Objectives and competences:**
/Cilj praktičnega usposabljanja je narediti most med teoretičnim delom izobraževanja in konkretnim delovnim okoljem, kjer študent pridobi praktična znanja in izkušnje.	The main goal of practice is to bridge the theoretical part of the education and real production environment, where the student gains the practical knowledge and experiences.

Predvideni študijski rezultati:	**Intended learning outcomes:**
/Študent zna povezati teoretična znanja in realno delovno okolje. Seznani se z reševanjem različnih problemov s področja metalurgije in materialov. Nauči se strokovnega sporazumevanja in delovanja v timu.	The student learns how to connect the theoretical knowledge and real production environment. He is acquainted with the solving of various problems from the field of metallurgy and materials. He gains the professional communication skills and how to work as a member of a team.

Metode poučevanja in učenja:	**Learning and teaching methods:**
/Študent v okviru prakse izdela poročilo o opravljeni praksi. Potrdita ga mentor v podjetju in mentor na fakulteti.	The student is obligated to in the frame of practice writes a report about the performed practice. This must be confirmed by both, mentor in the industry and at the faculty.

Načini ocenjevanja:	**Delež/Weight**	**Assessment:**

Reference nosilca/Lecturer's references:

PREISKAVA MATERIALOV

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	Preiskava materialov
Course title:	Materials Testing
Članica nosilka/UL Member:	UL NTF

Študijski programi in stopnja	Študijska smer	Letnik	Semestri	Izbirnost
Metalurgija in materiali, druga stopnja, magistrski	Ni členitve (študijski program)	1. letnik	2. semester	obvezen

Univerzitetna koda predmeta/University course code:	0067985
Koda učne enote na članici/UL Member course code:	859

Predavanja /Lectures	Seminar /Seminar	Vaje /Tutorials	Klinične vaje /Clinical tutorials	Druge oblike študija /Other forms of study	Samostojno delo /Individual student work	ECTS
30	0	30	0	0	60	4

Nosilec predmeta/Lecturer:	Milan Bizjak

Izvajalci predavanj:	
Izvajalci seminarjev:	
Izvajalci vaj:	
Izvajalci kliničnih vaj:	
Izvajalci drugih oblik:	
Izvajalci praktičnega usposabljanja:	

Vrsta predmeta/Course type:	Obvezni / Compulsory

Jeziki/Languages:	Predavanja/Lectures:	Slovenščina
	Vaje/Tutorial:	Slovenščina

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	Prerequisites:
Vpisan v 1. letnik magistrskega študija.	Enrolled in 1st year of master degree.

Vsebina:	Content (Syllabus outline):
1) Fizikalne osnove metod neporušnih preiskav 2) Metode, aparature, načini in možnosti vizualnih preiskav brez porušitve: vizualna kontrola, preiskave z laserjem, meritve oblik in dimenzij, robotizacija preiskav in kontrole 3) Načini preiskav brez porušitve (PBP) materiala oz elementa: izbira PBP; metode metalografskih preiskav BP (tehnike replik), preizkušanje tesnosti, preiskave s penetranti, preiskave z magnetnimi prahovi, preiskave	1) Physical bases of non-destructive testing methods 2) Methods, devices, ways of visual non-destructive testing: visual control, laser testing, measuring of shape and dimensions, robotisation of testing and controlling 3) The ways of non-destructive testing (NDT) of material: selection; metalographic investigation (replica), sealing test, penetration test, magnetic powder test, Eddy current test, ultrasonic test,

z vrtinčnimi tokovi, preiskave z ultrazvokom, akustična emisija, radiografija; industrijske CT, kotrola temperaturnih polj; optična in akustična holografija; 4) Merjenje notranjih napetosti 5) PBP specifičnih izdelkov: ulitki, odkovki, polizdelek, cevi, zvari in spoji, izdelki MP, zlepi, posode z nadtlakom 6) Kvantitativna PBP: kontrola porušitev, kontrola zanesljivosti sistemov zanesljivost rezultatov kontrole PBP, modeliranje na področju PBP; Statistične metode v podporo PBP.	acoustic emission, radiographic test, temperature field control, optic and acoustic holography 4) Internal stress measurements 5) NDT of specific products: castings, forgings, tubes, weldings, joints, products of powder metallurgy, vessels. 6) Quantitative NDT: failure control, reliability control of systems, reliability of results of NDT, modelling, NDT supporting statistical methods

Temeljna literatura in viri/Readings:

1) Nondestructive Evaluation and Quality Control, 1991, ASM International;
2) P.E. Mix: Introduction to nondestructive testing; A training guide; 1987, J. Wiley and Sons;
3) Nondestructive Testing Handbook, Vol. 1-10, 1987, American Society for Nondestructive testing inc.
4) J. Krautkrämär, H. Krautkrämär: Werkstoffprüfung mit Ultraschall; 1986, Springer-Verlag;
5) Failure Analysis and Prevention, Metals Handbook, Vol. 11, 2002, ASM international;
6) H. Chicos, T. Saito, L. Smith; Springer Handbook of Materials Measurement Methods, 2006, Springer-Verlag;

Cilji in kompetence:	**Objectives and competences:**
Spoznanje fizikalnih, eksperimentalnih in materialnih osnov preiskav materialov brez porušitve; eksperimentalne tehnike in metodike, rokovanja z instrumenti, postopkov in načinov analize rezultatov, pisanje poročil in zapisnikov, standardi in sodelovanje pri raziskavah realnih problemov; kontrola kvalitete;	Knowledge about physical, experimental as well as material bases of non-destructive testing; experimental techniques and methods; instrument handling, procedures and ways of analysis of the results; writing reports and notes, standards and cooperation at investigations of real problems; quality control;

Predvideni študijski rezultati:	**Intended learning outcomes:**
Znanje in razumevanje: Razumevanje metod in načrtovanje meritev neporušnih preiskav in meritev določenih fizikalnih in kemičnih lastnosti materialov.	Knowledge and understanding: Understanding the methods and planning NDT as well as monitoring certain physical and chemical properties of the material

Metode poučevanja in učenja:	**Learning and teaching methods:**
Predavanje, laboratorijske vaje, seminar	Lectures, laboratory work, tutorials

Načini ocenjevanja:	**Delež/Weight**	**Assessment:**
pisni izpit,	50,00 %	examination,
ustno izpraševanje,	40,00 %	oral,
naloge, projekt	10,00 %	coursework, project

Reference nosilca/Lecturer's references:

LOJEN, Gorazd, ANŽEL, Ivan, KNEISSL, Albert C., UNTERWEGER, E., KOSEC, Borut, BIZJAK, Milan. Microstructure of rapidly solidified Cu-Al-Ni shape memory alloy ribbons. J. mater. process. technol.. [Print ed.], May 2005, vol. 162/163, str. 220-229.
BIZJAK, Milan, KOSEC, Ladislav, KOSEC, Borut, ANŽEL, Ivan. The characterization of phase transformations in rapidly solidified Al-Fe and Cu-Fe alloys through measurements of the electrical resistance

and DSC = Karakterizacija faznih transformacija brzo skrutnutih Al-Fe i Cu-Fe slitine pomoću mjerenja električne otpornosti i diferencijalno skenirajuće kalorimetrije. Metalurgija (Sisak), 2006, let. 45, št. 4, str. 281-286, ilustr

BIZJAK, Milan, KOSEC, Ladislav, KNEISSL, Albert C., KOSEC, Borut. The characterisation of microstructural changes in rapidly solidified Al-Fe alloys through measurement of their electrical resistance. Int. j. mater. res., 2008, vol. 99, no. 1, str. 101-108.

PREOBLIKOVANJE 2

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	Preoblikovanje 2
Course title:	Forming 2
Članica nosilka/UL Member:	UL NTF

Študijski programi in stopnja	Študijska smer	Letnik	Semestri	Izbirnost
Metalurgija in materiali, druga stopnja, magistrski	Ni členitve (študijski program)	1. letnik	2. semester	obvezen

Univerzitetna koda predmeta/University course code:	0067986
Koda učne enote na članici/UL Member course code:	860

Predavanja /Lectures	Seminar /Seminar	Vaje /Tutorials	Klinične vaje /Clinical tutorials	Druge oblike študija /Other forms of study	Samostojno delo /Individual student work	ECTS
45	10	35	0	0	90	6

Nosilec predmeta/Lecturer:	Tomaž Rodič

Izvajalci predavanj:	
Izvajalci seminarjev:	
Izvajalci vaj:	
Izvajalci kliničnih vaj:	
Izvajalci drugih oblik:	
Izvajalci praktičnega usposabljanja:	

Vrsta predmeta/Course type:	Obvezni / Compulsory

Jeziki/Languages:	Predavanja/Lectures:	Slovenščina
	Vaje/Tutorial:	Slovenščina

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	Prerequisites:
Vpis na magisterski študij	Entry in the academic year

Vsebina:	Content (Syllabus outline):
UVOD: Pregled preoblikovalnih postopkov in njihovih tipčnih fizikalnih odzivov, parametri procesov ter njihova občutljivost, tipične namenske funkcije in omejitve, optimiranje in inverzne analize. TEORETIČNI DEL PRIMARNE ANALIZE preoblikovalnih procesov, mehanske analize napetostno-deformacijskih polj, temperaturna polja med preoblikovalnimi procesi,	INTRODUCTION: Overview of material forming processes and their typical physical responses, process parameters and their sensitivities, typical objective functions and constraints, optimisation and inverse analyses. THEORETICAL PART PRIMAL ANALYSES of material forming processes, mechanical analyses of stress-strain fields,

preoblikovanje ob prisotnosti elektromagnetnih polj, analize vezanih termomehanskih in magnetno-temperaturno-mehanskih polj med preoblikovalnimi procesi OBČUTLJIVOST PROCESOV, definicija odzivnih funkcionalov, občutljivost stacionarnih, časovno odvisnih in vezanih polj, metode posrednega in neposrednega odvajanja za izračun občutljivosti procesov OPTIMIRANJE NELINEARNIH PROCESOV: formulacije namenskih funkcij in omejitev, metode reševanja, optimizacija brez omejitev (Metode konjugiranih vrednosti, Kvazi-Newtonove metode), optimizacija z omejitvami (pogoji za lokalni minimum z omejitvami, kazenske metode, zaporedno kvadratno programiranje TEHNOLOŠKI DEL PREOBLIKOVANEC: napetosto-deformacijska polja v preoblikovancu, tok snovi, analize napak v polju pomikov, kriteriji preoblikovalnosti za masivno preoblikovanje, mejne deformacije pločevin, načrtovanje predoblik ORODJA: napetostno-deformacijska polja v orodjih, zanesljivost orodij, mikromehanska napetostna stanja v tipičnih orodnih materialih, mehanika poškodb, analize stohastičnih vplivov na vzdržljivost orodij TRIBOLOŠKI SISTEMI v preoblikovalnih procesih, mikromehanika hrapavih površin ob prisotnosti maziv, temperaturne razmere in prenos toplote na stiku med preoblikovancem in orodjem, hidrodinamika tekočih maziv, analize obrabe površin PREOBLIKOVALNI STROJI: osnovni parametri preoblikovalnih strojev ter njihov vpliv na natančnost izdelkov in vzdržljivost orodij, mehanizmi in togost stiskalnic M5 PREOBLIKOVALNI SISTEMI	temperature fields during material forming processes, forming in the presence of electromagnetic fields, inverse analyses of coupled thermomechanical and mechanical-thermal-magnetic fields during material forming PROCES SENSITIVITIES, definition of response functionals, sensitivity of stationary, transient and coupled fields, direct differentiation and adjoint methods to determine process sensitivities. OPTIMISATION OF NON-LINEAR PROCESSES: formulation of objective functions and constraints, optimisation methods without constraints (Conjugated methods, kvazi Nweton methods), optimisation with constraints (conditions for local minimum with constraints, penalty methods, sequential quadratic programming. TECHNOLOGICAL PART WORKPIECE: stress-strain fields in a workpiece, material flow, analyses of defects in displacement fields, formability limits for bulk and sheet forming operations, design of preforms and forming sequences. TOOLS: stress-strain fields in tools, reliability of tools, micromechanical stress-strain fields in typical tool materials, damage mechanics, stochastic influences on service life of tools. TRIBOLOGICAL SYSTEMS in material forming processes, micromechanics of rough surfacess with lubricants, temperature evolution and heat transfer at the tool-workpiece contact interface, hydrodynamics of liquid lubricants, surface wear. FORMING MACHINES: basic parameters of forming machines and their influence on tool service life and product tolerances, mechanisms and stiffness of forming machines M5 FORMING SYSTEMS

Temeljna literatura in viri/Readings:

T. Rodič, Preoblikovanje II, Naravoslovnotehniška fakulteta, Oddelek za materiale in metalurgijo, 2005 ISBN 961-6047-32-9

Cilji in kompetence:	**Objectives and competences:**
Cilj predmeta je naučiti študente povezovati temeljna znanja iz nauka o materialih, mehanike, numeričnih analiz in računalništva pri načtrovanju kompleksnih tehnologij na področju plastičnega preoblikovanja materialov. Za učinkovito soočanje z bodočimi tehnološkimi izzivi na področju plastičnega preoblikovanja materialov bomo študente naučili kako uporabiti sodobne M5 metode za analize preoblikovalnih procesov, ki vključujejo obravnavanje vezanih termomehanskih problemov ob upoštevanju različnih fizikalnih polj na različnih časovnih in dimenzijskih skalah; analize kontaktnih problemov med	Main objective of this subject is to teach students how to integrate fundamental knowledge about materials, mechanics, numerical analyses and computer sciences in the design of complex forming technologies based on plastic deformation of materials. For efficient solutions of future technological challenges in the area of material forming we will teach students how to apply modern M5 methods for analyses of forming processes that include treatment of coupled thermomechanical problems by taking into account different physical fields at various time and length scales; analyses of contact problems

deformabilnimi telesi; občutljivosne analize M5 procesov; inverzno modeliranje; formulacije namenskih funkcij in omejitev za M5 procese ter metode optimiranja. Praktične M5 probleme povezane s preoblikovanci, orodji, kontaktnimi površinami in preoblikovalnimi stroji bodo študenti reševali z virtualnimi modeli po metodi končnih elementov in v okviru laboratorijskih vaj. Predmet bo vključen v mednarodne povezave, ki jih razvijamo v okviru projektov TEMPUS in mednarodnega sodelovanja z državami na področju Sredozemlja, Alp in Zahodnega Balkanana.	between deformable bodies; sensitivity analyses of M5 processes; inverse modelling; formulations of objective and constraint functions for M5 processes and methods for their optimisation. Students will be solving practical M5 problems related to workpieces, tools, contact surfaces and forming machnices with virtual models based on finite element method and in the scope of laboratory exercises. The subject will be integrated into international network, that is being developed in the scope of TEMPUS projects and international collaboration with Mediteranean countries, Alpine region and Western Balkan.

Predvideni študijski rezultati:	**Intended learning outcomes:**
Znanje in razumevanje: Celostne analize M5 problemov. Poimenovanje M5 izvira iz angleščine (Multi-field, Multi-scale, Multi-body, Multi-phase & Multi-objective)	Knowledge and understanding: Holistic analyses of M5 problems where the term M5 denotes their Multi-field, Multi-scale, Multi-body, Multi-phase and Multi-objective aspects

Metode poučevanja in učenja:	**Learning and teaching methods:**
Predavanja, vaje v učilnici, računalniškem in eksperimentalnem laboratoriju, seminarji	Lectures, exercises in the classroom as well as in computer and experimental laboratories; seminars

Načini ocenjevanja:	**Delež/Weight**	**Assessment:**
pisni izpit,	50,00 %	examination,
ustno izpraševanje,	40,00 %	oral,
naloge, projekt	10,00 %	coursework, project

Reference nosilca/Lecturer's references:

STUPKIEWICZ, Stanislaw, KORELC, Jože, DUTKO, Martin, RODIČ, Tomaž. Shape sensitivity analysis of large deformation frictional contact problems. Comput. methods appl. mech. eng.. [Print ed.], 2002, vol. 191, issue 33, str. 3555-3581, ilustr. [COBISS.SI-ID 1658977]

IBRAHIMBEGOVIĆ, Adnan, GREŠOVNIK, Igor, MARKOVIČ, Damijan, MELNYK, Sergiy, RODIČ, Tomaž. Shape optimization of two-phase inelastic material with microstructure. Eng. comput., 2005, letn. 22, no. 5/6, str. 606-645. [COBISS.SI-ID 556639]

RODIČ, Tomaž, CUKJATI, Domen, GREŠOVNIK, Igor. Optimal design of perform geometry and tribological conditions in can forming. Eng. comput., 2005, letn. 22, no. 7/8, str. 972-979. [COBISS.SI-ID 639839]

RODIČ, Tomaž, KORELC, Jože, PRISTOVŠEK, Anton. A micro-macro analysis of the tool damage in precision forming = Mikro-makroanaliza poškodb orodja za natančno kovanje. Mater. tehnol., 2006, letn. 40, št. 6, str. 243-246. [COBISS.SI-ID 579242]

KRUŠIČ, Vid, MAŠERA, Sebastjan, PEPELNJAK, Tomaž, KUZMAN, Karl, RODIČ, Tomaž, PRISTOVŠEK, Anton. The impact of the forming system parameters on tool service life and product accuracy in cold forming. International Journal of Microstructure and Materials Properties, 2009, vol. 4, no. 5/6, str. 547-561, ilustr. [COBISS.SI-ID 11288091]

KRUŠIČ, Vid, MAŠERA, Sebastjan, PRISTOVŠEK, Anton, RODIČ, Tomaž. Adjustment of stohastic responses of typical cold forging systems. J. mater. process. technol.. [Print ed.], 2009, vol. 209, iss. 11, str. 4983-4993. [COBISS.SI-ID 1007711]

RODIČ, Tomaž, LANGUS, Janez. Advanced M5 modeling of stirred media milling. Chem. eng. technol., 2010, vol. 33, no. 9, str. 1427-1432. http://dx.doi.org/10.1002/ceat.201000065, doi: 10.1002/ceat.201000065. [COBISS.SI-ID 1093215]

CVAHTE, Peter, KUGLER, Goran, RODIČ, Tomaž. Prediction of statically recrystallized microstructure

during extrusion of aluminium alloys. Inform. Technol. Mater., 2010, vol. 10, no. 4, str. 294-306. [COBISS.SI-ID 1092959]

RODIČ, Tomaž, ŠUŠTAR, Tomaž, ŠUŠTARIČ, Primož, KORELC, Jože. Efficient numerical implementation of pressure, time and temperature superposition for elasto-visco-plastic material model by using a symbolic approach. Int. j. numer. methods eng., okt. 2010, letn. 84, št. 4, str. 470-484, ilustr., doi: 10.1002/nme.2903. [COBISS.SI-ID 5006433]

RAČUNALNIŠKA ZNANOST O MATERIALIH

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	Računalniška znanost o materialih
Course title:	Computational Materials Science
Članica nosilka/UL Member:	UL NTF

Študijski programi in stopnja	Študijska smer	Letnik	Semestri	Izbirnost
Metalurgija in materiali, druga stopnja, magistrski	Ni členitve (študijski program)	1. letnik	1. semester	obvezen

Univerzitetna koda predmeta/University course code:	0067987
Koda učne enote na članici/UL Member course code:	855

Predavanja /Lectures	Seminar /Seminar	Vaje /Tutorials	Klinične vaje /Clinical tutorials	Druge oblike študija /Other forms of study	Samostojno delo /Individual student work	ECTS
45	15	30	0	0	90	6

Nosilec predmeta/Lecturer:	Dr. David Bombač, Goran Kugler

Izvajalci predavanj:	
Izvajalci seminarjev:	
Izvajalci vaj:	
Izvajalci kliničnih vaj:	
Izvajalci drugih oblik:	
Izvajalci praktičnega usposabljanja:	

Vrsta predmeta/Course type:	Obvezni / Compulsory

Jeziki/Languages:	Predavanja/Lectures:	Slovenščina
	Vaje/Tutorial:	Slovenščina

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	Prerequisites:
vpis v letnik študija in znanje osnov: programiranja, fizikalne metalurgije in termodinamike.	entry in the academic year and basic knowledge of: programming, physical metallurgy and thermodynamics.

Vsebina:	Content (Syllabus outline):
Pri predavanjih bodo obravnavane naslednje teme: • Uvod: Zakaj modeliranje • Koncept posplošenih funkcij stanja • Numerično modeliranje in simulacije • Kategorije modelov • Atomistični modeli • Ab initio metode	The topics that will be covered in this course are: • Introduction: Why modelling • The Generalized State Variable Concept • Numerical Modeling and Simulation • Categories of Models • Modelling on atomistic spatial scale • Ab initio methods

• Molekularna dinamika • Monte Carlo metode • Kinetična Monte Carlo metoda • Analiza in vrednotenje rezultatov atomističnih simulacij • Modeliranje na mikroskopski in mezoskopski prostorski skali • Pottsova Monte Carlo metoda • Metoda faznega polja • Metode sledenja meje • Level set metoda • Celični avtomati • Dislokacijski modeli • Združevanje simulacij na različnih prostorskih in časovnih skalah Pri vajah bodo dobili študentje napisane kode za simulacije, ki jo bodo na vajah uporabljali in jo tudi spreminjali. V okviru vaj in seminarja bomo diskutirali tudi o aktualnih in pomembnih znanstvenih člankih s področja modeliranja in jih tudi ovrednotili.	• Molecular dynamics • Monte Carlo methods • Kinetic Monte Carlo method • Analysis and evaluation of results of atomistic simulations • Modeling on microscopic and mesoscopic spatial scale • Potts Monte Carlo method • Phase field method • Front tracking method • Level set method • Cellular automata • Discrete Dislocation Statics and Dynamics • Multiscale modeling At tutorial the students will use and modify prewritten computer codes. Recent important research articles from the area of modeling will be discussed and evaluated at tutorials and seminars.

Temeljna literatura in viri/Readings:

• D. Raabe: Computational Materials Science: The Simulation of Materials Microstructures and Properties, Wiley-VCH, Weinheim, 1998
• Z. H. Barber: Introduction to Materials Modelling, Maney, London, 2005
• D. C. Rapaport: The Art of Molecular Dynamic Simulation, Cambridge University Press, 1995
• D.P. Landau, K. Binder: A Guide to Monte Carlo Simulations in Statistical Physics, Cambridge University Press, Cambridge, 2000.
• B. Chophard, M. Droz: Cellular Automata modeling of Physical Systems, Cambridge Universitry Press, Cambridge, 1998.
• K. Ohno, K. Esfarjani, and Y. Kawazoe: Introduction to computational materials science: from ab initio to Monte Carlo methods, Springer-Verlag: Berlin, New York, 1999.
• Handbook of Materials Modeling, edited by Sidney Yip, Springer, Berlin, New York, 2005.
• Znanstveni članki, ki jih bo razdelil predavatelj (scientific articles, provided by the instructor)

Cilji in kompetence:	**Objectives and competences:**
Cilji: Študent dobi pregled nad metodami računalniškega modeliranja v metalurgiji in znanosti o materialih in se jih nauči uporabljati. Seznani se z metodami modeliranja in simulacij na atomistični, mikroskopski in mezoskopski prostorski skali in s konceptom večnivojskega pristopa in jih razume. Predmetno specifične kompetence: Študenti bodo spoznali tako prednosti kot tudi slabosti obravnavanih metod. Velik poudarek bo na pridobivanju praktičnih izkušenj pri oblikovanju in izvajanju računalniških simulacij.	Objectives: Learn key concepts and major topics in computer modeling through which materials scientists and metallurgists study and apply these methods on atomistic, microscopic and mesoscopic spatial scales to understand and predict phenomena and properties of materials. Competences: Students will get familiar with computational methods and will learn of their strengths and limitations. They will gain the ability to apply fundamental knowledge on materials modeling via computer simulations.

Predvideni študijski rezultati:	**Intended learning outcomes:**
V okviru predmeta bodo študenti pridobili sposobnost pravilne izbire modelov in simulacijskih orodij za specifično aplikacijo ter zmožnost prenosa spoznanj iz enega področja znanosti o materialih in metalurgije na drugo. Nadalje bodo poglobili njihovo razumevanje fizikalno	By the end of this course students will obtain ability to select a computational method that are appropriate for a given materials study and to transfer the knowledge between different fields of materials science and metallurgy. Further, they will deepen their understanding of physical and metallurgical processes

metalurških procesov, ki potekajo v materialih. Pridobljeno znanje s področja računalniške znanosti o materialih jim bo omogočilo poiskati tako podobnosti, kot tudi razlike med raznimi metodami. Sposobni bodo reševanja širokega spektra praktičnih nalog in kritičnega ovrednotenja rezultatov simulacij in njihove natančnosti. Znali bodo obdelati rezultate računalniških eksperimentov z različnimi matematičnimi in fizikalnimi orodji ter jih tudi predstaviti v različnih formatih. Študentje se bodo naučili analizirati novejše študije v znanstveni periodiki in ovrednotiti kvaliteto in pomembnost objavljenih člankov s teh področij.	that takes place in materials. They will demonstrate knowledge of topics in computational materials science that enable the comparison of similarities and differences among available methods. They will have capability to solve a wide range of practical problems and to critically evaluate results of simulations and their accuracy. They will be able to process the results of computer experiments employing different mathematical and physical tools and present them in various formats. Students will learn to analyze contemporary modeling studies in journals and to evaluate the quality and significance of works published in international journals from these fields.

Metode poučevanja in učenja:	**Learning and teaching methods:**
Predavanja, vaje in domače naloge (praktična raba algoritmov), projektno delo.	Lectures. Exercises and homework's (practical use of algorithms). Project work.

Načini ocenjevanja:	**Delež/Weight**	**Assessment:**
• ocena domačih nalog	50,00 %	• mark of homework's
• ocena projektnega dela	25,00 %	• mark of project work
• ocena ustnega izpita	25,00 %	• mark of the oral exam

Reference nosilca/Lecturer's references:

G. Kugler, R. Turk: Modeling the dynamic recrystallization under multi-stage hot deformation, Acta Mater., 52 (2004), 4659-4668

G. Kugler, R. Turk: Study of the influence of initial microstructure topology on the kinetics of static recrystallization using a cellular automata model, Comp. Mater. Sci., 37, (2006), 284-291

M. Terčelj, R. Turk, G. Kugler, I. Peruš: Neural network analysis of the influence of chemical composition on surface cracking during hot rolling of AISI D2 tool steel, Comp. Mater. Sci., 42 (2008), 625-637

A. Turk, S. Pu, D. Bombač, P.E.J. Rivera-Díaz-del-Castillo, E.I. Galindo-Nava: Quantification of hydrogen trapping in multiphase steels : part II - effect of austenite morphology, *Acta Mater.*, 197(2020), 253-268

D. Bombač, I.H. Katzarov, D.L. Pashov, A.T. Paxton: Theoretical evaluation of the role of crystal defects on local equilibrium and effective diffusivity of hydrogen in iron, *Mater. Sci. Technol.*, 33(2017), 1505-1514

D. Bombač, G. Kugler: Influence of diffusion asymmetry on kinetic pathways in binary Fe-Cu alloy: a kinetic Monte Carlo study, *J. Mater. Eng. Perform.*, 24(2015), 2382-2389

SPECIALNE JEKLARSKE TEHNOLOGIJE

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	Specialne jeklarske tehnologije
Course title:	Special Steelmaking Technologies
Članica nosilka/UL Member:	UL NTF

Študijski programi in stopnja	Študijska smer	Letnik	Semestri	Izbirnost
Metalurgija in materiali, druga stopnja, magistrski	Ni členitve (študijski program)	2. letnik	1. semester	izbirni

Univerzitetna koda predmeta/University course code:	0078011
Koda učne enote na članici/UL Member course code:	877

Predavanja /Lectures	Seminar /Seminar	Vaje /Tutorials	Klinične vaje /Clinical tutorials	Druge oblike študija /Other forms of study	Samostojno delo /Individual student work	ECTS
15	15	20	0	10	60	4

Nosilec predmeta/Lecturer:	Matjaž Knap

Izvajalci predavanj:	
Izvajalci seminarjev:	
Izvajalci vaj:	
Izvajalci kliničnih vaj:	
Izvajalci drugih oblik:	
Izvajalci praktičnega usposabljanja:	

Vrsta predmeta/Course type:	Izbirni / Elective

Jeziki/Languages:	Predavanja/Lectures:	Slovenščina
	Vaje/Tutorial:	Slovenščina

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	Prerequisites:
Opravljanje študijskih obveznosti je opredeljeno v pravilniku o preverjanju in ocenjevanju študentov na UL NTF. Za pozitivno in uspešno opravljanje študijskih obveznosti ter vključevanje v študijsko delo se priporoča redno obiskovanje predavanj, reševanje dodatnih domačih bolj zahtevnih nalog in ustrezna predpriprava pred izvajanjem laboratorijskih vaj ter izkazana aktivnost in vsaj 80 % prisotnost na vajah.	Liabilities are defined in the regulations on examination and evaluation of students at ULNTF. For a positive and successful attendance of their duties students are encourage to regular attendance of lectures, additional domestic more complex work more and appropriate preparing to laboratory work. At least 80% attendance at tutorials is needed.

Vsebina:	Content (Syllabus outline):
Večfazni sistemi pri proizvodnji jekla: Tvorba trdnih, tekočih in plinastih delcev v večfaznih	Multiphase systems in steel: Formation of solid, liquid and gaseous particles in

sistemih. Tvorba kompleksnih vključkov pri proizvodnji jekla: - Tvorba kompleksnih oksidnih vključkov; - Tvorba sulfidov in njihova topnost Prenos snovi pri metalurgiji jekla in zlitin: Gibanje taline in žlindre v različnih metalurških reaktorjih. Gibanje trdnih delcev v talini in staljeni žlindri. Tvorba skupkov (cluster) dezoksidacijskih in rafinacijskih produktov in gibanje v talini. Prenos trdnih delcev iz toka plina v talino. Gibanje mehurjev plina v talini in tekoči žlindri: gibanje mehurjev inertnega plina, gibanje mehurjev plina, ki reagira s talino oz. žlindro. Kinetika metalurških reakcij in taljenja: Kinetika reakcij pri taljenju kovinskega vložka. Kinetika reakcij pri taljenju ferozlitin. Taljenje in raztapljanje homogenih poroznih snovi v talini jekla: - Stalni fazni kontakt - Prehodni fazni kontakt Metalurška keramika, ognjevzdržni materiali in obzidava metalurških reaktorjev Reakcije na fazni meji ognjevzdržna gradiva – talina. Reakcije na fazni meji ognjevzdržna gradiva - tekoča žlindra. Reakcije na fazni meji ognjevzdržna gradiva – plini. Obraba ognjevzdržnih materialov. Mehanizmi korozije ognjevzdržnih materialov. Modeliranje metalurških procesov Modeliranje prenosa snovi v metalurških reaktorjih. Modeliranje raztapljanja in taljenja v metalurških reaktorjih. Uporaba vodnih modelov pri raziskavah. intenzitete in mesta vpihavanja plinov (kisika, inertnega plina) v modele talilnih agregatov. Numerično modeliranje toka taline: - laminarni tok - turbolentni tok Modeliranje dvofaznega toka - dve tekočini (talina in tekoča žlindra) - kovinska talina in trdni delci - gibanje mehurčkov v kovinski talini Izbira procesov, tehnologij in reaktorjev glede na vrsto in količino izdelane jeklene taline: Elektro pretaljevanje pod žlindro (EPŽ) Priprava elektrode za pretaljevanje, kinetika taljenja elektrode, rafinacijske žlindre, hlajenje kristalizatorja in rafinacijski učinek žlinder. Tvorba kaplje, potovanje kaplje skozi tekočo žlindro. Elektro pretaljevanje pod žlindro pri povečanem tlaku (PEPŽ) Vliv tlaka na potek metalurških reakcij in kakovost izdelkov. Elektro obločna peč z vpihavanjem kisika od zgoraj in skozi dno peči (EAF-BTO) Prednosti EAF-BTO v primerjavi z EAF, razvoj tehnologije izdelave jekla v EOP in njen vliv na	multiphase systems. Formation of complex inclusions in steel making: - the formation of complex oxide inclusions; - the formation of sulphides and their solubility Mass transfer in metallurgy of steel making and alloys: Melt and slag flow in various metallurgical reactors. Movement of solid particles in the melt and in the molten slag. The formation of clusters of deoxidized and refining products and their movement in the melt. Transfer of solid particles from the gas flow into the melt. Gas bubble movement in the melt and in liquid slag: the movement of inert gas bubbles, the movement of gas bubbles, which react with the melt or slag. Kinetics of metallurgical reactions and melting: Kinetics of reactions at smelting of metallic charge. Kinetics of reactions at smelting of ferro-alloys. Melting and solving of homogeneous porous. substance in liquid steel: - Constant phase contact - Transitional phase contact Metallurgical ceramics, refractory materials and lining of metallurgical reactors Reactions at the phase boundary of the refractory materials – melt. Reaction at the phase boundary of liquid slag – refractory materials. Reactions to the phase boundary of the refractory materials – gases. Wear of refractory materials. Corrosion mechanisms of the refractory materials. Modelling of metallurgical processes Modelling of mass transfer in metallurgical reactors. Modelling of solving and melting in metallurgy reactors. The use of water models in research of intensity and injection points of gases (oxygen, inert gas) into models of smelting aggregates. Numerical modeling of melt flow: - the laminar flow - the turbulent flow Modelling of two phase flow: - two fluids (liquid melt and slag) - metal melt and solid particles - the movement of bubbles in the metal melt Selection of processes, technologies and reactors with regard to the type and quantity of steel melt: ESA Electric Slag Remelting The preparation of electrodes for remelting, the kinetics of electrode melting, refining slag, mould cooling and the effect of refining slags. The formation of drops, drop movement through the liquid slag. PESR Pressure Electric Slag Remelting Pressure influence on the course of metallurgical reactions and quality of products. EAF-BTO Electric Arc Furnace - Bottom Top

kvaliteto izdelanega jekla, produktivnost, energetiko in varstvo okolja. Indukcijsko taljenje in vlivanje v vakuumu (VIM Vacuum Induction Melting) Tehnologija izdelave in vlivanja jekla v indukcijskih vakuumskih napravah. Vakuumska obločna peč (VAF) Prednosti in slabosti izdelave jekla pri znižanem ali nizkem tlaku v pečeh z obločnim ogrevanjem. Pred začetkom predavanj in vaj bo študentom razdeljeno študijsko gradivo.	Oxygen The benefits of EAF-BTO in comparison with the EAF, the development of steelmaking technology in the EOP and its influence on the quality of produced steel, productivity, energy and environmental protection VIM Vacuum Induction Melting Steelmaking and casting in vacuum induction devices. VAF Vacuum Arc Furnace The advantages and disadvantages of steel production at reduced or low pressure in the arc furnace heating. Prior to the beginning of lectures and tutorials literature will be distributed.

Temeljna literatura in viri/Readings:

Ghosh A., Chatterjee A.: IRONMAKING AND STEELMAKING THEORY AND PRACTICE, PHI, 2008
U. K. Mudali, B. Raj: HIGH NITROGEN STEELS AND STAINLESS STEELS, Alpha Science International Ltd., UK, 2004
Ahindra Ghosh: SECONDARY STEELMAKING; CRC Press, (2001)

Cilji in kompetence:	**Objectives and competences:**
Za sodoben in sonaraven razvoj sta železo in jeklo najbolj raziskovan in najpomembnejši kovinski material. Za reševanje energetskih, okoljevarstvenih, transportnih, konstrukcijskih in podobnih problemov želijo naročniki vedno nove vrste jekla, ki jim zagotavljajo želene uporabne lastnosti. To je vzrok za nenehen razvoj novih inovativnih procesov proizvodnje jekla in drugih zlitin železz z višjo in visoko vsebnostjo legirnih elementov. Študenti bodo na osnovi primerov izdelave specialnih vrst jekel, s povišanimi mehanskimi, korozijskimi, elektromagnetnimi in podobnimi lastnostmi, spoznali procese in tehnologije, ki omogočajo izdelavo teh vrst jekel. Namen tega predmeta je, da bodo študenti sposobni izbrati primerno tehnologijo in proces, ki bo prilagojen oz. optimalen za izdelavo izbrane vrste jekla.	Iron and steel are the most researched and important metallic material for a modern and sustainable development. For the energy, environmental, transportation, construction and other issues users always demands new types of steel, which provide the desired application properties. This is the reason for the continued development of new innovative processes of production of steel and other ferroalloys with a high content of alloying elements. Students will learn on the bases of examples about the processes and technologies that enable the production of special steels, with increased mechanical, corrosion, electromagnetic and similar properties. The purpose of this course is that students will be able to choose appropriate i.e. optimal technology and process for production of selected of steel type.

Predvideni študijski rezultati:	**Intended learning outcomes:**
Znanje in razumevanje: Študenti bodo nadgradili znanje, ki so ga dobili pri predmetih s področja izdelave jekla in železovih zlitin. Naučili se bodo kako z uporabo termodinamičnih orodij obvladovati vodenje metalurških reakcij, ki nastopajo v postopku izdelave jekla. Ta znanja so potrebna za izdelavo kvalitetnih vrst jekla. Spoznali bodo specialne agregate potrebne za izdelavo specialnih jekel in temu prilagojene postopke in tehnologije.	Knowledge and understanding: Students will build upon the knowledge they obtained from subjects in the field of steel making and ferroalloys making. Students will learn how to usage of thermodynamic tools help by governing metallurgical reactions and thus influence steel making. This knowledge is needed for production of high-quality steel grades. They will study the special aggregates required for the production of special steels and the processes and

Znanje, ki ga bo pridobil pri tem predmetu je nadgradnja oz. poglobljen študij posameznih faz v procesu izdelave jekla. Razumeli bodo, da je poznavanje osnovnih termodinamičnih in metalurških reakcije, ki nastopajo v postopku izdelave jekla, pomembno za optimalno vodenje izdelave specialnih jekel.	technologies connected with it. Acquired knowledge is an advancement or. even deeper study of various stages in the steel making process. They will understand that the base knowledge of thermodynamics and metallurgical reactions that occurs in the steel making is important for optimal control of special steel production.

Metode poučevanja in učenja:	**Learning and teaching methods:**
Predavanja, seminarji, seminarske in laboratorijske vaje, terenske vaje, samostojno delo	Lectures, seminars, tutorial and laboratory work, fieldwork, individual work

Načini ocenjevanja:	**Delež/Weight**	**Assessment:**
ustni izpit	60,00 %	oral exam
pisni izpit	20,00 %	examination
seminarska naloga in poročilo laboratorijskih vaj	20,00 %	seminar work and the report of the laboratory work

Reference nosilca/Lecturer's references:

- BURJA, Jaka, TEHOVNIK, Franc, LAMUT, Jakob, KNAP, Matjaž. Alumothermic reduction of ilmenite in a steel melt = Alumotermična redukcija ilmenita v jekleni talini. Mater. tehnol., 2013, letn. 47, št. 2, str. 217-222. [COBISS.SI-ID 976298]
- LAMUT, Jakob, FALKUS, Jan, JURJEVEC, Beno, KNAP, Matjaž. Influence of inclusions modification on nozzle clogging = Wpływ modyfikacji wtrąceń niemetalicznych na zarastanie wylewów zanurzeniowych. Archives of metallurgy and materials, 2012, vol. 57, no. 1, str. 319-324. [COBISS.SI-ID 1211231]
- LAMUT, J., KNAP, M., TOLAR, M., ROZMAN, A.. Slag composition in making alloyed steel. V: MARKOVIĆ, Zoran S. (ur.). Proceedings. Bor: Technical Faculty, 2004, 2004, str. 618-626 [COBISS.SI-ID 528735]

STRUKTURNA KERAMIKA

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	Strukturna keramika
Course title:	Structural Ceramics
Članica nosilka/UL Member:	UL NTF

Študijski programi in stopnja	Študijska smer	Letnik	Semestri	Izbirnost
Metalurgija in materiali, druga stopnja, magistrski	Ni členitve (študijski program)	2. letnik	1. semester	izbirni

Univerzitetna koda predmeta/University course code:	0078014
Koda učne enote na članici/UL Member course code:	871

Predavanja /Lectures	Seminar /Seminar	Vaje /Tutorials	Klinične vaje /Clinical tutorials	Druge oblike študija /Other forms of study	Samostojno delo /Individual student work	ECTS
30	0	30	0	0	60	4

Nosilec predmeta/Lecturer:	

Izvajalci predavanj:	
Izvajalci seminarjev:	
Izvajalci vaj:	
Izvajalci kliničnih vaj:	
Izvajalci drugih oblik:	
Izvajalci praktičnega usposabljanja:	

Vrsta predmeta/Course type:	Izbirni / Elective

Jeziki/Languages:	Predavanja/Lectures:	Slovenščina
	Vaje/Tutorial:	Slovenščina

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	Prerequisites:
Vpis v letnik.	Entry in the academic year.

Vsebina:	Content (Syllabus outline):
• Pregled razvoja keramičnih materialov • Tipi keramičnih materialov; njihove lastnosti in uporaba. • Osnovne zakonitosti potrebne za razumevanje lastnosti in priprave keramičnih materialov. • Izdelava keramičnih materialov;surovine, oblikovanje, sintranje in razvoj mikrostrukture, karakterizacija. • Mehanske, električne, termične in optične lastnosti	• History and Development of Ceramic Materials (Ceramics) • Types of Ceramics and their Application • Background Needed to Understand Properties and Processing of Ceramics • Processing of Ceramics; Raw Materials, Shaping and Forming, Sintering, Microstructure, Characterization • Mechanical, Electrical, Thermal and Optical Properties and Weaknesses

in slabosti • Visokotemperaturna keramika. • Nano-keramični kompoziti. • Biokeramika	• High-Temperature Ceramics. • Nanoceramic Composites. • Bioceramics.

Temeljna literatura in viri/Readings:

• C.B. CARTER, M.G. NORTON, Ceramic Materials, Science and Engineering, Springer 2007
• W. D. KINGERY, H. K. BOWEN, D. K. UHLMANN, Introduction to Ceramics; Ed. 2, Wiley 1976
• SUK-JONG L.KANG, Sintering:Densification, Grain Growth &Microstructure, Elsevier 2005
• D. KOLAR, Tehnična keramika, ZRS za šolstvo in šport, Ljubljana, 1993

Cilji in kompetence:	**Objectives and competences:**
Cilji: i) Posredovati osnovno znanje o sestavi, zgradbi in lastnostih keramičnih materialov ter njihovi uporabnosti na različnih področjih naravoslovja, tehnike in medicine. ii) Doseči razumevanje mehanizmov v materialih na mikro nivoju, ki so pomembni za razumevanje obnašanja materiala. iii) Predstaviti pojave, ki potekajo med materialom in okolico med uporabo. iv) Seznaniti študente z naprednimi keramičnimi materiali. Kompetence slušatelja: • Pozna lastnosti keramičnih materialov in razume pojave, ki potekajo med materialom in okolico med uporabo; • Zna izbrati in uporabljati keramične konstrukcijske materiale na različnih področjih naravoslovja, tehnike in medicine. • Obvlada napredne keramične materiale.	Objectives: i) To explain the fundamental knowledge about the composition, structure and properties of ceramic materials and its applicability in various fields of nature, technique and medicine. ii) To achieve the understanding of mechanisms in the material on micro-level, which are important for the understanding of materials behaviour. iii) To present the phenomenon that occur during exploitation between the material and its surroundings. iv) To acquaint the students with the advanced ceramic materials. Competences: • Student is familiar with the properties of the ceramic materials and understands the phenomenon that can occur during exploitation between the material and its surroundings. • Knows how to select and use ceramics for construction applications in various fields of science, engineering and medicine. • Is competent in the field of advanced ceramic materials.

Predvideni študijski rezultati:	**Intended learning outcomes:**
• Zna izbrati in uporabljati keramične konstrukcijske materiale za različne uporab • Razume lastnosti in tehnologije izdelave drugih materialov in uporablja pridobljeno znanje na področju inženirstva • Obvlada napredne keramične materiale.	• Knows how to select and use ceramics for various applications in different fields of application. • Understands the properties and technologies of manufacture of other materials and uses this knowledge on the engineering field • Is competent in the field of advanced ceramic materials.

Metode poučevanja in učenja:	**Learning and teaching methods:**
Predavanja, vaje, individualne naloge, samostojni študij.	Lectures, exercise, individual work, independent study.

Načini ocenjevanja:	**Delež/Weight**	**Assessment:**
Pisni izpit in ustno izpraševanje	50,00 %	Written and oral examination and oral
Računske in laboratorijske vaje	50,00 %	Coursework

Reference nosilca/Lecturer's references:

1. DOMINKO, Robert, BELE, Marjan, GABERŠČEK, Miran, REMŠKAR, Maja, HANŽEL, Darko, PEJOVNIK, Stane, JAMNIK, Janko. Impact of the carbon coating thickness on the electrochemical performance of LiFePO[sub]4/C composites. J. Electrochem. Soc., 2005, vol. 152, str. A607-A610. [COBISS.SI-ID 18788391]
2. PEJOVNIK, Stane, DOMINKO, Robert, BELE, Marjan, GABERŠČEK, Miran, JAMNIK, Janko. Electrochemical binding and wiring in battery materials. J. power sources. [Print ed.], 2008, vol. 184, no. 2, str. 593-597. [COBISS.SI-ID 3987994]
3. PEJOVNIK, Stane, KOLAR, Drago, HUPPMANN, W. J., PETZOW, G. Sintering of Al[sub]2O[sub]3 in presence of liquid phase. Sci. sinter., 1978, vol. 10, str. 87-95. [COBISS.SI-ID 10039591]
4. PEJOVNIK, Stane, BELE, Marjan, DOMINKO, Robert, DROFENIK, Jernej, GABERŠČEK, Miran. Use of materials science principles in battery design: gelatin in lithium batteries = Uporaba
5. GENORIO, Boštjan, STRMČNIK, Dušan, SUBBARAMAN, Ram, TRIPKOVIC, Dusan, KARAPETROV, Goran, STAMENKOVIC, Vojislav, PEJOVNIK, Stane, MARKOVIC, Nenad M. Selective catalysts for the hydrogen oxidation and oxygen reduction reactions by patterning of platinum with calix[4]arene molecules. Nature materials, 2010, vol. 9, no. 12, str. 998-1003, doi: 10.1038/NMAT2883. [COBISS.SI-ID 34569477]

TEHNOLOGIJA ALUMINIJA

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	Tehnologija aluminija
Course title:	Aluminium Technology
Članica nosilka/UL Member:	UL NTF

Študijski programi in stopnja	Študijska smer	Letnik	Semestri	Izbirnost
Metalurgija in materiali, druga stopnja, magistrski	Ni členitve (študijski program)	2. letnik	1. semester	obvezen

Univerzitetna koda predmeta/University course code:	0067993
Koda učne enote na članici/UL Member course code:	865

Predavanja /Lectures	Seminar /Seminar	Vaje /Tutorials	Klinične vaje /Clinical tutorials	Druge oblike študija /Other forms of study	Samostojno delo /Individual student work	ECTS
45	10	30	0	5	90	6

Nosilec predmeta/Lecturer:	Aleš Nagode, Jožef Medved

Izvajalci predavanj:	
Izvajalci seminarjev:	
Izvajalci vaj:	
Izvajalci kliničnih vaj:	
Izvajalci drugih oblik:	
Izvajalci praktičnega usposabljanja:	

Vrsta predmeta/Course type:	Obvezni / Compulsory

Jeziki/Languages:	Predavanja/Lectures:	Slovenščina
	Vaje/Tutorial:	Slovenščina

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	Prerequisites:
Vpis v letnik.	Entry in the academic year.

Vsebina:	Content (Syllabus outline):
Pridobivanje aluminija: Boksit; Glinica; Bayerjev postopek; Elektroliza glinice (Hall-Heroult postopek); Termodinamika elektrolizne redukcije; Alternativne metode pridobivanja; Primarni (tehnični) aluminij; Obdelava taline (rafinacija, udrobnjevanje, modifikacija) Proizvodnja zlitin iz primarnih in sekundarnih surovin. Postopki litja aluminija in zlitin (klasično, polkontinuirno, kontinuirno). ***Recikliranje sekundarnih surovin:***	***Production of aluminium:*** Bauxite; Alumina; Bayer process; Electrolytic reduction /Hall-Heroult process); Thermodynamics of electrolytic reduction; Alternative methods of producing aluminium; primary (commercial) aluminium; Superpurity aluminium; Production of Aluminium alloys from primary and secondary materials. Aluminium and alloy casting processes (classical, semi-continuous, continuous).

Recikliranje sekundarnih surovin iz ekološkega in energijskega vidika; Razvrščanje in priprava sekundarnih surovin za taljenje; Taljenje sekundarnih surovin; Naprave za pripravo in taljenje; Vpliv nečistoč na lastnosti sekundarnega aluminija. ***Fizikalna metalurgija Al in Al-zlitin:*** Lastnosti aluminija; Konstitucija Al-zlitin; Mikrostruktura Al in Al-zlitin; Deformacijsko utrjevanje; Poprava rekristalizacija in rast zrn; Toplotna obdelava in mehanizmi izločevalnega utrjevanja; Vpliv zlitinskih elementov in nečistoč na lastnosti Al-zlitin; Korozija. ***Ulivanje, mehanska predelava, toplotna obdelava:*** Taljenje; Polkontinuirno ulivanje in ulivno-valjarniški postopki; Homogenizacija; Vroča predelava (valjanje, iztiskovanje, kovanje); Hladna predelava (hladno valjanje, izdelava folij, vlečenje); Mikrostrukturne, mehanske in tehnološke lastnosti polizdelkov v odvisnosti od postopkov mehanske predelave; Praksa toplotne obdelave in termomehanske obdelav (Mikrostrukturne, mehanske in tehnološke lastnosti polizdelkov v odvisnosti od postopkov toplotne obdelave)- ***Gnete zlitine, ki se toplotno ne utrjujejo:*** Al-Mn; Al-Mg; Al-Mg-Mn; Al-Fe-Si (posebnost, lastnosti, standardizacija, uporabnost). ***Gnetne, toplotno utrjevalne zlitine:*** Al-Cu; Al-Cu-Mg; Al-Mg-Si; Al-Zn-Mg; Al-Zn-Mg-Cu; Al-Li-X; (posebnosti, lastnosti standardizacija, uporabnost). ***Aluminijeve zlitine za posebne namene:*** Zlitine za letalstvo, Karoserijska pločevina; Embalaža; Avtomatne zlitine; Superplastične zlitine; Električni vodniki; Ležajne zlitine; Temperaturno obstojne zlitine; Zlitine za varjenje in spajkanje; Metalurgija prahov. ***Posebna poglavja:*** Razvojne tendence aluminijskih materialov in tehnoloških postopkov; Aluminiju konkurenčni materiali, Aluminij in ekologija; Aluminijska industrija v svetu in Sloveniji. Izdelava kovinskih pen na osnovi aluminija; Korozija in protikorozijska zaščita aluminija in zlitin; Kompoziti na osnovi aluminija. Projektno delo.	***Recycling of secondary raw materials:*** Recycling of scrap from an ecological and energy point of view; Sorting and preparation of secondary raw materials for smelting; Melting of secondary raw materials; Preparation and melting equipment; Influence of impurities on the properties of secondary aluminium. ***Physical metallurgy of Al and Al-alloys***: Properties of aluminium; Constitution of aluminium alloys, Microstructure of Al and Al-alloys; Hardening mechanisms; Recovery, recrystallization and grain growth; Heat treatment and principles of age hardening; Influence of alloying elements and impurities on the properties of Al-alloys, Corrosion. ***Casting, hot and cold working, thermal treatment:*** Melting; Direct Chill casting process; Continuous casting; Homogenization; Hot working (hot rolling, extrusion, forging); Cold working, foil production, drawing); Microstructural, mechanical and technological properties of semi products in dependence on the mechanical and thermomechanical processes; Practical work of heat- and thermomechanical treatments (microstructural, mechanical and technological properties of semi products in dependence on heat treatment processes. ***Wrought non-heat-treatable alloys:*** Al-Mn; Al-Mg; Al-Mg-Mn; Al-Fe-Si; (speciality, properties, designation, application). ***Wrought heat-treatable alloys:*** Al-Cu; Al-Cu-Mg; Al-Mg-Si; Al-Zn-Mg; Al-Zn-Mg-Cu; Al-Li-X; (speciality, properties, designation, application). ***Aluminium alloys for special products:*** Aircraft alloys; Automotive sheet and structural alloys; Packaging; Aluminium free-cutting alloys; Superplastic alloys; Electrical conductor alloys; Aluminium alloy bearings; Temperature resistance alloys; Alloys for joining and welding, Powder metallurgy products. **Special chapters:** Development of Al-materials and technological processes in the future; Competition of alternative lightweight materials; Aluminium industry in the world and in Slovenia. Manufacture of metal foams based on aluminium; Corrosion and anti-corrosion protection of aluminium and alloys; Aluminium based composites. Project work.

Temeljna literatura in viri/Readings:

Polmear I.J.: Light alloys: Metallurgy of the Light Metals, Arnold, London, 1995

Aluminium Properties and Physical Metallurgy, Ed. Hatch J.E., American Society for Metals, Metals Park, Ohio, 1984

Kaufman J.G.: Introduction to Aluminium Alloys and Tempers, ASM International, Materials Park, Ohio, 2000

Altenpohl D. Aluminium von Innen, Aluminium-Verlag, Düsseldorf, 1994

Sheppard T.: Extrusion of Aluminium Alloys, Kluwer Academic Publishers, Dordrecht-Boston_-London, 1999

Cilji in kompetence:	Objectives and competences:
Aluminij je za železom druga tehnično najbolj uporabna kovina. Lastnosti aluminija in zlitin kot so majhna specifična gostota, visoke trdnostne lastnosti zlitin, ugodno razmerje, trdnost/specifična gostota, električna in toplotna prevodnost, korozijska odpornost in lahka ter cenena reciklaža omogočajo njegovo uporabo v vseh tehnično pomembnih panogah kot so transport, gradbeništvo, strojegradnja, elektrotehnika, embalaža, in predmeti široke potrošnje. Zaradi naraščajoče porabe in stalnega izboljševanja lastnosti ter izdelovalnih postopkov se je podobno kot pri železu pojavila potreba po poglobljenem obravnavanju tematike s področja aluminija kot samostojen predmet. Študentje bodo v okviru predmeta detajlno spoznali lastnosti aluminijskih materialov in postopke od izdelave do finalizacije ter uporabnost. Diplomanti s tega področja imajo možnost zaposlitve v podjetjih za izdelavo in predelavo aluminija, livarnah, kovinsko predelovalni industriji in znanstvenih ustanovah.	Aluminium is beside iron the second technically most useful metal. The properties of aluminium and its alloys like: small specific density, high strength, an advantageous relationship between strength and specific density, electrical and thermical conductivity, excellent formability, corrosion resistance and a simple and cheap recycling – enable its application in the all technically important sectors like: transport, building, construction, machinery, electrical, packaging, and consumer durable objects. Because of the increasing use and the constant improvements of the properties and manufacturing processes there appears, like at iron, a need to a deeper treatment of the topics in the research of aluminium as an independent subject. In the frame of this subject the student will get the knowledge about properties of aluminium materials in details and about the processes from the production to finalization and its application. The post-graduate bachelors of this field will have the possibility to get the employment in the firms producing and working aluminium, in the foundries in the metal-working industry and scientific institution.

Predvideni študijski rezultati:	Intended learning outcomes:
Znanje in razumevanje: Študent je na osnovi pridobljenih znanj sposoben samostojne, objektivne analize in načrtovanja novih materialov in tehnologij. Študent pridobi spretnosti uporabe strokovne literature in drugih sodobnih virov informacij. Nauči se zbiranja, selekcioniranja in interpretacije podatkov in rezultate analiz. Sposoben je samostojnega reševanja zastavljenih problemov.	Knowledge and understanding: The student is on the base of the new knowledge able independently and objectively to analyse and to plan new materials and technologies. The student gets the skills of using the technical literature and other modern sources of information. He/she learns to collect, select and interpret the data and the results of the analyses. HeIshe is capable of identification and how to solve the set up of problems.

Metode poučevanja in učenja:	Learning and teaching methods:
Predavanje, računske in laboratorijske vaje, seminarsko delo, simulacije, vključevanje v raziskovalne projekte.	Lectures, laboratory work, calculation work, seminar work, inclusion in the frame of research work.

Načini ocenjevanja:	Delež/Weight	Assessment:
Pisni izpit in ustno izpraševanje	50,00 %	Written and oral examination and oral
Računske in laboratorijske vaje	40,00 %	Coursework
Seminarska naloga	10,00 %	Seminar

Reference nosilca/Lecturer's references:

MEDVED, Jože, KORES, Stanislav, VONČINA, Maja. Development of innovative Al-Si-Mn-Mg alloys with high mechanical properties. V: OLIVER, Martin (ur.). *Light Metals 2018*, (The minerals, metals & materials series) Cham: Springer. 2018, str. 373-380.

JERINA, Lina, **MEDVED, Jože**, GODEC, Matjaž, VONČINA, Maja. Influence of the specific surface area of secondary material on the solidification process and microstructure of aluminium alloy AA7075. *Journal of thermal analysis and calorimetry*, 2018, str. 1-8.

ARBEITER, Jože, VONČINA, Maja, ŠETINA, Barbara, **MEDVED, Jože**. Transformation of the metastable Al6Fe intermetallic phase during homogenization of a binary Al-Fe alloy. Materials, ISSN 1996-1944, 2021, vol. 14, iss. 23, str. 1-9.

REČNIK, Simon, BIZJAK, Milan, MEDVED, Jože, CVAHTE, Peter, KARPE, Blaž, **NAGODE, Aleš**. Mechanism of the Mg3Bi2 phase formation in Pb-Free aluminum 6xxx alloy with bismuth addition. Crystals. 2021, vol. 11, iss. 4, str. 1-12. ISSN 2073-4352. DOI: 10.3390/cryst11040424.
VONČINA, Maja, **NAGODE, Aleš,** MEDVED, Jože, PAULIN, Irena, ŽUŽEK, Borut, BALAŠKO, Tilen. Homogenisation effciency assessed with microstructure analysis and hardness measurements in the EN AW 2011 aluminium alloy. *Metals*. 2021, vol. 11, iss. 8, str. 1-11. ISSN 2075-4701. DOI: 10.3390/met11081211.
SMOLEJ, Anton, KLOBČAR, Damjan, SKAZA, Branko, **NAGODE, Aleš,** SLAČEK, Edvard, DRAGOJEVIČ, Vukašin, SMOLEJ, Samo. Superplasticity of the rolled and friction stir processed Al-4.5 Mg-0.35Sc-0.15Zr alloy. Materials Science & Engineering. A, Structural materials: Properties, Microstructure and Processing. [Print ed.]. Jan. 2014, vol. 590, str. 239-245, ilustr. ISSN 0921-5093. DOI: 10.1016/j.msea.2013.10.027

TERMODINAMIKA MATERIALOV 2

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	Termodinamika materialov 2
Course title:	Thermodynamics of Materials 2
Članica nosilka/UL Member:	UL NTF

Študijski programi in stopnja	Študijska smer	Letnik	Semestri	Izbirnost
Metalurgija in materiali, druga stopnja, magistrski	Ni členitve (študijski program)	1. letnik	1. semester	obvezen

Univerzitetna koda predmeta/University course code:	0067988
Koda učne enote na članici/UL Member course code:	853

Predavanja /Lectures	Seminar /Seminar	Vaje /Tutorials	Klinične vaje /Clinical tutorials	Druge oblike študija /Other forms of study	Samostojno delo /Individual student work	ECTS
45	15	30	0	0	90	6

Nosilec predmeta/Lecturer:	Jožef Medved

Izvajalci predavanj:	
Izvajalci seminarjev:	
Izvajalci vaj:	
Izvajalci kliničnih vaj:	
Izvajalci drugih oblik:	
Izvajalci praktičnega usposabljanja:	

Vrsta predmeta/Course type:	Obvezni / Compulsory

Jeziki/Languages:	Predavanja/Lectures:	Slovenščina
	Vaje/Tutorial:	Slovenščina

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	Prerequisites:
Pogoj za vključitev v delo oziroma za opravljanje študijskih obveznosti je vpis v 1. letnik študija. Opravljeno in uspešno predstavljeno projektno delo ter seminar je pogoj za pristop k pisnemu in ustnemu izpitu.	The condition to attend in the teaching course and to perform study obligations is an entry in the first year of study. Completed and successfully presented project work is required before taking the written and oral exam.

Vsebina:	Content (Syllabus outline):
Fazna ravnotežja: trdno-trdno, trdno-tekoče, trdno-plinasto, tekoče-tekoče, tekoče-plinasto, termodinamika talin, raztopine, vpliv temperature na topnost v trdnem, nukleacija, strjevanje.	Phase equilibrium: solid-solid, solid-liquid, solid-gas, liquid-liquid, liquid-gas, thermodynamics of liquids, solutions, influence of temperature on solubility in solid state, nucleation, solidification.

Termodinamika faznih diagramov: primerjalne G-X krivulje, modeliranje faznih diagramov (dvo in tri fazno polje, vmesne faze, idealne raztopine, model regularne raztopine, CALPHAD, model faznega polja). Termodinamika površin: površinska energija,meritve površinske energije, topnost majhnih delcev, omočenje površin, adsorpcija. Kinetika procesov v raztopinah: reakcijska kinetika heterogenih reakcij, aktivacijska energija, homogene in heterogene reakcije, hitrost homogenih reakcij, geometrija reakcijske površine, mejne plasti; Difuzija: termodinamika difuzije, termodinamična sila koncentracijskega gradienta, prvi in drugi Fickov zakon; Termodinamika metalurških procesov: kovinski sistemi v tekočem in trdnem stanju, oksidni sistemi, metalurške žlindre, oksidacija, Seminarsko delo. Projektno delo.	Thermodynamics of phase diagrams: G-X curves, modelling of phase diagrams (two and three phase field, semi phases, ideal solutions, a model of regular solution, CALPHAD, a model of phase field). Thermodynamics of surfaces: surface energy, measuring of surface energy, solubility of small particles, wettability of surfaces, adsorption. Kinetics of processes in solutions: reaction kinetics of heterogeneous reactions, activation energy, homogenous and heterogeneous reactions, speed of homogeneous reactions, geometry of reaction surfaces, surface of grain boundaries; Diffusion: thermodynamics of diffusion, thermodynamic force of concentration gradient, first and second Fick law; Thermodynamics of metallurgical processes: metal systems in liquid and solid state, oxide systems, metallurgical slags, oxidation, Seminary work. Project work.

Temeljna literatura in viri/Readings:

- V. Gontarev. Termodinamika materialov, učbenik, Univerza v Ljubljani, NTF, Ljubljana, 2005.
- V. Gontarev. Teorija metalurških procesov, učbenik, Univerza v Ljubljani, NTF, Ljubljana, 2005.
- D. R. Gaskell, D. E. Laughlin. Introduction to the Thermodynamics of Materials, Taylor & Francis Group, 2018.
- R. DeHoff. Thermodynamics in Materials Science, Second Edition, CRC Press, Taylor & Francis Group, 2006.
- M.Hillert: Phase equilibriaCambridge University Press, Cambridge, New York, 1998.
- S.Seetharaman. Fundamentals of metallurgy, Woodhead Publishing, 2005

Cilji in kompetence:	**Objectives and competences:**
Osnovni smotri predmeta so naučiti študente osnov termodinamike v tekočih in trdnih raztopin, kemijska in fazna ravnotežja v materialih, termodinamika in kinetika procesov v raztopinah, ki omogočajo boljše razumevanje procesov v materialih. Pri predmetu se bodo študentje naučili osnov termodinamike faznih diagramov, kinetike ter difuzije ter elektrokemije. Vse razlage so združene z seminarskim delom, simulacijami ter projektnim delom načrtovanja, izdelave in termodinamične karakterizacije materiala.	The basis of the course is to teach the student basics of the thermodynamics in liquid and solid solutions, chemistry and phase equilibrium in materials, thermodynamics and kinetics of processes in solutions, that enables better understanding of processes in the materials. The students will learn about the thermodynamic basics of the phase diagrams, kinetics and diffusion and also chemistry. The lectures are complemented with seminar work, simulations and project work of planning, manufacturing and thermodynamic characterization of the materials.

Predvideni študijski rezultati:	**Intended learning outcomes:**
Znanje in razumevanje: Pri predmetu Termodinamika materialov II nadgradi študent znanja Termodinamike materialov I na I stopnji. Nauči se obravnavati večkomponentne in večfazne sisteme na področju anorganskih materialov. Seznani se z temeljnimi orodij za termodinamično modeliranje in simuliranje ter karakterizacijo, ki jih aplikativno uporabi pri projektnem delu izdelave novega materiala.	Knowledge and understanding: At this course Thermodynamics of materials II the student will complement the knowledge of the Thermodynamics of materials I from I level. It learns to precede multicomponent and multiphase systems from inorganic fields of the materials. It acquaints with basic tools for thermodynamic modelling and simulation and characterisation which it brings to use in the project work of making of a new material.

Metode poučevanja in učenja:	Learning and teaching methods:
Predavanja, računske in seminarske vaje ter simulacije, projektno delo.	Lectures. Exercises solving. Laboratory. Numerical simulations. Project work.

Načini ocenjevanja:	Delež/Weight	Assessment:
ocena projektnega dela in seminarja	30,00 %	the mark of project work
ocena pisnega dela izpita	30,00 %	the mark of written examination
ocena ustnega dela izpita	40,00 %	the mark of the oral examination

Reference nosilca/Lecturer's references:

MEDVED, Jože, VONČINA, Maja, KLANČNIK, Grega, MRVAR, Primož. Termodinamično modeliranje kot pomoč pri optimiranju aluminijevih materialov in tehnologij = Thermodynamic modeling as a support for optimization of aluminium materials and technologies. *Livar. vestn.*, 2013, vol. 60, no. 1, str. 31-51.
MEDVED, Jože, LAMUT, Jakob, ZDOVC, Miro, MRVAR, Primož. Influence of SiO2 addition on the properties of Al2O3-CaO-CaF2 slag. Steel research international, 2008, vol. 79, no. 12, str. 908-912.
MEDVED, Jože, MRVAR, Primož, VONČINA, Maja. Oxidation resistance of cast magnesium alloys. Oxid. met., 2009, vol. 71, no. 5/6, str. 257-270.
VONČINA, Maja, KRESNIK, Kristijan, VOLŠAK, Darja, **MEDVED, Jože**. Effects of homogenization conditions on the microstructure evolution of aluminium alloy EN AW 8006. Metals, 2020, vol. 10, iss. 3, str. 1-12. [COBISS.SI-ID 1859167]

TERMOMEHANSKA PREDELAVA MATERIALOV

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	Termomehanska predelava materialov
Course title:	Thermomechanical Processing of Materials
Članica nosilka/UL Member:	UL NTF

Študijski programi in stopnja	Študijska smer	Letnik	Semestri	Izbirnost
Metalurgija in materiali, druga stopnja, magistrski	Ni členitve (študijski program)	1. letnik	2. semester	obvezen

Univerzitetna koda predmeta/University course code:	0554928
Koda učne enote na članici/UL Member course code:	863

Predavanja /Lectures	Seminar /Seminar	Vaje /Tutorials	Klinične vaje /Clinical tutorials	Druge oblike študija /Other forms of study	Samostojno delo /Individual student work	ECTS
30	15	15	0	0	60	4

Nosilec predmeta/Lecturer:	Milan Terčelj, Peter Fajfar

Izvajalci predavanj:	
Izvajalci seminarjev:	
Izvajalci vaj:	
Izvajalci kliničnih vaj:	
Izvajalci drugih oblik:	
Izvajalci praktičnega usposabljanja:	

Vrsta predmeta/Course type:	Obvezni / Compulsory

Jeziki/Languages:	Predavanja/Lectures:	Slovenščina
	Vaje/Tutorial:	Slovenščina

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	Prerequisites:
Vpis v letnik študija.	Entry in the academic year.

Vsebina:	Content (Syllabus outline):
• Definicija in namen termomehanske predelave • Vroča, topla in hladna mehanska predelava kovinskih materialov • Utrjevanje in mehčanje med termomehansko predelavo materialov • Razvoj mikrostrukture med termomehansko predelavo materialov: • Matematični modeli za izračun procesov med vročo predelavo	• Definitions and aim of thermomechanical processing • Hot, warm and cold deformation of metalic materials • Hardening and softening during thermomechanical processing of materials: • Development of microstructure during thermomechanical processing of materials:

• Laboratorijske simulacije vroče predelave • Izračun in časovni potek in vrednosti relevantni preoblikovalnih parametri v industrijski praksi • Relevantni vplivi kemične sestave in processnih parametrov na termomehansko predelavo • Potrebni pogoji za termomehansko predelavo v industriji • Razvoj tekstur med termomehansko predelavo materialov • Preoblikovalnost in načrtovanje tehnologij • Določanje preoblikovalnosti materialov • Tehnologije preoblikovanja: • Valjanje • Iztiskavanje • Kovanje • Vlečenje žice, palic in cevi • Preoblikovanje pločevine • Preoblikovanje PM materialov • Termomehanska predelava aluminijevih zlitin • Termomehanska predelava jekel • Termomehanska predelava heksagonalnih materialov • Termomehanska predelava nikljevih, titanovih in drugih relevantnih zlitin • Orodja in stroji za preoblikovanje: • Načtovanje oblik in dimenzij orodij • Vzdržljivost orodij, modeli za obrabo in rast razpok na orodjih • Laboratorijsko testiranje na odpornost na termično in mehansko utrujanje ter obrabo orodij za preoblikovanje • Vpliv karakteristik orodij in strojev na dosežene lastnosti in kvaliteto izdelkov • Procesne verige pri izdelavi materialov: • Definicija procesnih verig • Tvorbe baze podatkov pri procesnih verigah • Metode za analizo podatkov ter napovedovanje dobljenih lastnosti materialov Optimiranje procesnih verig	• Mathematical models for calculation of relevant proceses during hot working • Laboratorij simulation of hot working • Calculation and time course of deformation parameters in industrial practice, • Relevant influences of chemical composition and processing parameters on thermo-mechanical procesing • Conditions for thermonechanical procesing in industrial practice • Development of texturs during thermomechanical processing of materials, • Workability of materials and design of technology of deformation process, • Determination of workability of materials, • Introduction in technologies of metal forming: • Rolling, • Drawing • Forging, • Drawing of wire, rods, tubes • Sheet metal forming, • Deformation of PM materials, • Termomechanical processing of Al alloys, • Termomechanical processing of steels, • Termomechanical processing of hexagonal materials. • Thermomechanical procesing of Ni, Ti and other relevant alloys • Dies and machines for metal forming: • Design of shape and dimensions of dies • Endurance of dies, models for prediction of wear, cracks growth on dies • Laboratory testing on thermal and mechanical fatigue resistance and wear resistance of dies for metal forming • Influence of characteristics of dies and machines on obtained properties and quality of products · Procesing chains at materials processing: • Definition of processing chains • Formation of data base and prediction of obtained properties of materials Optimization of processing chanins

Temeljna literatura in viri/Readings:

- Verlinden B., Driver R., Samajdar I., Doherty R. D., Thermo-Mechanical processing of Metallic Materials, Elsevier, London 2007.
- Dieter G. E., Kuhn H. A., Semiatan S. L., Handbook of Workability and Process Design, ASM International, NY, 2003.
- Sheppard T., Extrusion of Aluminium Alloys, Dordrecht : Kluwer Academic Publishers, 1999.
- Lenard J. G., Primer on Flat Rolling, Elsevier, London 2007.
- A. Weronski, Therma Fatigue of Metals, CRC Press, 2019, ISBN 9780367402952
- ASM Handbook Volume 19 : Fatigue and Fracture, **ISBN:** 0871703858 / 9780871703859
- Taylan Altan, Erman Tekkaya. Sheet Metal Forming: Process and Applications, ASM International, 2012, ISBN: 1615038442,978-1-61503-844-2

Cilji in kompetence: **Objectives and competences:**

Cilj predmeta je podati orodja za načrtovanje tehnologije plastične predelave materialov ob upoštevanju postopka plastične predelave, procesov v materialu med plastično predelavo ter predhodnih procesnih parametrov izdelave ter želenimi končnimi lastnostmi po celem volumnu preoblikovancev. V celoto se povezuje procesne parametre izdelave materiala, tehnologije preoblikovanja, stroje in orodja, t.j. vpliv procesnih parametrov izdelava materiala, deformacijskih parametrov, načrtovanja oblik in dimenzij orodij, karakteristike strojev na dosežene lastnosti ter kvaliteto izdelkov. Na vse to se navezujejo procesi degradacije (obraba in rast razpok) materialov za orodja njihovo vzdržljivost.	Aim of the subject is to give tools for planning material forming processes with the respect of plastic deformation, processes in material during plastic deformation and the history of process parameters and final properties in the whole volume of deformed workpiece. In whole are linked processing parameters of material production, technology of metal forming, dies and machines, i.e. influence of processing parameters of material production, deformation parameters, characteristics of forming machines and dies on obtained properties and quality of products. Processes of degradation (wear and cracks growth) of die materials are related with previous content. .

Predvideni študijski rezultati:	**Intended learning outcomes:**
Znanje in razumevanje: Zna povezati parametre izdelave materiala z dobljenimi lastnostmi, razume procese, ki vplivajo na preoblikovalnost materialov, zna ovrednotiti in opredeliti vzroke za neuspešno predelavo ter sprejeti ukrepe za izboljšanje. Študent razume tudi vpliv orodij, strojev, kemične sestave in procesnih parametrov izdelave materiala ter deformacijskih parametrov na dosežene lastnosti in kvaliteto izdelka.	Knowledge and understanding: He is able to link the material forming parameters with the gained properties, he understands processes which influence the material workability, he can value and define reasons for abortive technology and he can take measure to improve it. Student understand also influence of dies, forming machines, chemical composition and parameters of materials processing as well as deformation parameters on obtained quality and properties of products.

Metode poučevanja in učenja:	**Learning and teaching methods:**
Predavanja, vaje, laboratorijsko delo, seminarji, projektno delo.	Lectures, exercises and laboratory work, seminar work, project work.

Načini ocenjevanja:	**Delež/Weight**	**Assessment:**
ocena projektnega dela	30,00 %	the mark of project work
ocena pisnega dela izpita	30,00 %	the mark of written examination
ocena ustnega dela izpita	40,00 %	the mark of the oral examination

Reference nosilca/Lecturer's references:

izr.prof.dr. Milan Tečelj:

• TERČELJ M., FAZARINC M., BOMBAČ D., KUGLER G., Conditions for the efficient crushing of the as-cast microstructure of 30Cr10Ni duplex stainless steel. Metall. mater. trans., B, Proc. metall. mater. proc. sci., 2010, vol. 41, no. 6, str. 1328-1337, kategorija: 1A1 (Z1);

• VEČKO PIRTOVŠEK, Tatjana, PERUŠ, Iztok, KUGLER, Goran, TERČELJ, Milan. Towards improved reliability of the analysis of factors influencing the properties on steel in industrial practice. ISIJ int., 2009, vol. 49, no. 3, str. 395-401. [COBISS.SI-ID 894815], [JCR, WoS, št. citatov do 7. 5. 2009: 0, brez avtocitatov: 0, normirano št. citatov: 0] kategorija: 1A1 (Z1);

• VEČKO PIRTOVŠEK, Tatjana, KUGLER, Goran, GODEC, Matjaž, TERČELJ, Milan. Microstructural characterization during the hot deformation of 1.17C-11.3Cr-1.48V-2.24W-1.35Mo ledeburitic tool steel. Mater. charact.. [Print ed.], 2010, 31 str. http://dx.doi.org/10.1016/j.matchar.2010.11.016, doi: 10.1016/j.matchar.2010.11.016. [COBISS.SI-ID 1091167], [JCR], kategorija: 1A1 (Z1);

• FAZARINC, Matevž, TERČELJ, Milan, BOMBAČ, David, KUGLER, Goran. Transformation and precipitation kinetics in 30Cr10Ni duplex stailess steel. Metall. mater. trans., A Phys. metall. mater. sci., 2010, vol. 41A, september, str. 2197-2207. http://dx.doi.org/10.1007/s11661-010-0317-0, doi: 10.1007/s11661-010-0317-0. [COBISS.SI-ID 1039199], [JCR, WoS, št. citatov do 6. 2. 2011: 1, brez avtocitatov: 0, normirano št. citatov: 0], kategorija: 1A1 (Z1);

;• BRADAŠKJA, Boštjan, PIRNAR, Boštjan, FAZARINC, Matevž, FAJFAR, Peter. Deformation Behaviour and Microstructural Evolution During Hot Compression of AISI 904L. Steel research international, doi: 10.1002/srin.201000036. [COBISS.SI-ID 880222], [JCR] kategorija: 1A3 (Z1);
• TERČELJ M., KUGLER G., TURK R., CVAHTE P., FAJFAR P., Measurement of temperature on the bearing surface of an industrial die and assessment of the heat transfer coefficient in hot extrusion of aluminium: a case study. Int. j. veh. des., 2005, vol. 39, nos. 1/2, str. 93-109
• PERUŠ I., FAZARINC M., KUGLER G., FAJFAR P.. On the influence of human factor on mechanical properties in aluminium hot extrusion process. Metalurgija, 2010, vol. 49, br. 2, str. 87-90.

VARJENJE

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	Varjenje
Course title:	Welding
Članica nosilka/UL Member:	UL NTF

Študijski programi in stopnja	Študijska smer	Letnik	Semestri	Izbirnost
Metalurgija in materiali, druga stopnja, magistrski	Ni členitve (študijski program)	1. letnik	2. semester	obvezen

Univerzitetna koda predmeta/University course code:	0067989
Koda učne enote na članici/UL Member course code:	862

Predavanja /Lectures	Seminar /Seminar	Vaje /Tutorials	Klinične vaje /Clinical tutorials	Druge oblike študija /Other forms of study	Samostojno delo /Individual student work	ECTS
30	0	30	0	0	60	4

Nosilec predmeta/Lecturer:	Borut Zorc

Izvajalci predavanj:	
Izvajalci seminarjev:	
Izvajalci vaj:	
Izvajalci kliničnih vaj:	
Izvajalci drugih oblik:	
Izvajalci praktičnega usposabljanja:	

Vrsta predmeta/Course type:	Obvezni / Compulsory

Jeziki/Languages:	Predavanja/Lectures:	Slovenščina
	Vaje/Tutorial:	Slovenščina

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	Prerequisites:
Vpis v letnik in predhodno ali vzporedno obiskovanje predavanj in vaj iz matematike, fizike, kemije, računalništva, metalografije, strojništva, toplotne tehnike, termodinamike	Enrolment in 1st year of study and attending lectures from mathematics, physics, chemistry, computer science, metalography, mechanical engineering, heat engineering, thermodynamics. The student who has already listened to above mentioned lectures may also taking the study programme

Vsebina:	Content (Syllabus outline):
Uvod Opis tehnologij spajanja, mehanizmov nastanka spojev, uporabe toplote in vpliva na material. Toplotni izvori	Introduction Description of joining technology, mechanism of joining occurrences, heat application and the influence of heat on material.

- različne vrste energije, uporabljene pri spajanju in njihovo pretvorbo v toploto. - Fizikalni modeli toplotnih izvorov in varjencev za obravnavo širjenja toplote v varjencu. - temperaturna polja za različne modele toplotni izvorov in varjencev ter vplivne parametre na temperaturno polje. Termični varilni ciklus - termični varilni ciklus (enovarkovni in večvarkovni zvar) - dogajanja v materialu med ogrevanjem, v varilni kopeli in med ohlajanjem (fazne transformacije v toplotno vplivani coni, nastanek plinov in nekovinskih vključkov v varu, strjevanje. Specifičnost različnih dodajnih materialov. - vplivni parametri na termični varilni ciklus s primerjavo varilnih postopkov. - praktična uporaba termičnega varilnega cikla. Zaostale napetosti in deformacije - vzroki in mehanizmi nastanka zaostalih napetosti in deformacij. - vrste, tipi in razporeditev napetosti v različnih zvarnih spojih ter vplivni faktorji na razporeditev in velikost zaostalih napetosti. - deformacije v zvarjencih in vplivni faktorji na nastanek in velikost deformacij. - metode zmanjševanja zaostalih napetosti in deformacij. Vpliv dovedene toplote in zaostalih napetosti na nosilnost zvarjenega spoja - napake v zvarih (poroznost, vključki žlindre, zlepi, razpoke) - povezava med mikrostrukturo zvara in osnovnega materiala ter zaostalih napetosti na nastanek razpok v zvarnih spojih - zveza med dovedeno toploto in mehanskimi lastnostmi zvarnega spoja	Heat sources - Different kind of energy applied for joining and its transformation in the heat. - Physical models of heat sources and workpieces for discussing about heat conduction in the welding workpieces - temperature fields for different kinds of heat sources and workpieces models and affected parameters on temperature field Thermal Cycle in welding - welding thermal cycle of single pass and multipass welds - phenomena in base material and in weld pool during heating and cooling (microstructrural transformation in heat-affected zone, arising of gases and non-metallic inclusions in the weld pool, weld metal solidification, specific properties of different kinds of filler materials) - essential parameters on thermal cycle in different welding technology - practical uses of welding thermal cycle Welding residual stresses and distortions - Causes and mechanisms for the origin of residual stresses and distortions - Kinds, types and arranging of residual stresses in different kinds of welds and essential factors an arranging and size of residual stresses - Distortions in welds and essential parameters for origin and size of distortions - Methods of reduction of welding residual stresses and distortion Effect of heat input and residual stresses on mechanical properties of welds - welding defects (porosity, slag inclusions, lack of fusion, cracks) - connection between microstructure of weld metal heat-affected zone and residual stresses on forming of weld cracks - connection between heat input and mechanical properties of welds

Temeljna literatura in viri/Readings:

- B. Zorc: Zapiski za predavanja
- I. Rak: Tehnologija varjenja, Modrijan založba d.o.o., Ljubljana, 2008
- Granjon H.: Metalurške osnove varjenja (prevod Štular P.) Ljubljana ZDVT, 1996
- Zavarivanje u četiri knjige, Inženjersko tehnički priročnik, Rad Beograd, 1980
- I. Hrivnak: Zavarljivost čelika, IRO ˝Građevinska knjiga˝, Beograd, 1982
- I. Hrivnak: Theory of weldability of metals and alloys, Elsevier, 1992
- D. Radaj: Heat effects of welding, Springer-Verlag, 1992 (tudi v Nemščini /also available in German)

Cilji in kompetence:	**Objectives and competences:**
Razumevanje vpliva dovedene toplote na nastanek zvarnega in spajkanega spoja, napak v zvarih, napetosti in deformacij, sprememb mikrostrukture in mehanskih lastnosti v območju spoja. Študent spozna	Understanding the influence of heat input on occurrence of welding and soldering joints, failures in welds, stresses and strains, changing in the microstructure and mechanical properties in the areas

uporabnost osvojenega znanja pri načrtovanju spojev v praksi.	of weld. The student obtains knowledge for planning the joints in practical applications

Predvideni študijski rezultati:	**Intended learning outcomes:**
Znanje in razumevanje: Študent mora spoznati in razumeti vpliv dovedene toplote na pojave v zvarni kopeli in osnovnem materialu med ogrevanjem in ohlajanjem (spremembe mikrostrukture, nastanek zaostalih notranjih napetosti in deformacij) ter njihov vpliv na mehanske lastnosti zvara, Spoznati mora ukrepe za zmanjševanje negativnih efektov in kako računsko oceniti vpliv toplote na varjeni material ter kako pridobljeno znanje uporabiti v praksi pri izdelavi zvarnih spojev.	Knowledge and understanding: The student must recognize and understand the influence of heat input on phenomena in weld pool and base material during the heating and cooling (microstructure changing, the occurrence of residual internal stresses and distortions) as well as their influence on mechanical properties of weld. The student must get to know taking measures for decreasing negative effects and estimate the influence of the heat on welding material as well as using the obtained knowledge for making welding joints in the practical applications.

Metode poučevanja in učenja:	**Learning and teaching methods:**
predavanja, računske vaje, laboratorijske vaje, programiranje in modeliranje z računalnikom s programsko opremo SolidWorks in Sys Weld	Lectures, calculation tasks, laboratory work, programming and modelling by using Solid Works and SysWeld.

Načini ocenjevanja:	**Delež/Weight**	**Assessment:**
Pisni izpit	40,00 %	Writing exam
Teoretični del	60,00 %	Theory part

Reference nosilca/Lecturer's references:

ZORC, Borut, KOSEC, Ladislav. A new approach to improving the properties of brazed joints. Weld. j., 2000, vol. 79, no. 1, str. 24s-31s.
ZORC, Borut. Chemical and microstructural diversity of steel grades 355 = Differencisa en la constitución química y la microstructura de aceros calidad 355. Rev. metal. (Madr.), 2002, vol. 38, no. 6, str. 451-456.
ZORC, Borut, KOSEC, Ladislav. Metallurgical reactions in the coalescence zone between a reinforcement and a parent metal in reinforced brazed joints. Metall (Berl. West), 2004, jahrg. 58, no. 5, str. 290-294.
ZORC, Borut, KOSEC, Ladislav. Metallurgical reactions in the coalescence zone between a reinforcement and a base metal in reinforced brazed joints. Rev. metal. (Madr.), 2004, vol. 40, no. 6, str. 458 - 466.

VLIVANJE INGOTOV IN KONTINUIRANO VLIVANJE

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	Vlivanje ingotov in kontinuirano vlivanje
Course title:	Ingots and Continuous Casting
Članica nosilka/UL Member:	UL NTF

Študijski programi in stopnja	Študijska smer	Letnik	Semestri	Izbirnost
Metalurgija in materiali, druga stopnja, magistrski	Ni členitve (študijski program)	2. letnik	1. semester	izbirni

Univerzitetna koda predmeta/University course code:	0067978
Koda učne enote na članici/UL Member course code:	876

Predavanja /Lectures	Seminar /Seminar	Vaje /Tutorials	Klinične vaje /Clinical tutorials	Druge oblike študija /Other forms of study	Samostojno delo /Individual student work	ECTS
30	10	20	0	0	60	4

Nosilec predmeta/Lecturer:	Matjaž Knap

Izvajalci predavanj:	
Izvajalci seminarjev:	
Izvajalci vaj:	
Izvajalci kliničnih vaj:	
Izvajalci drugih oblik:	
Izvajalci praktičnega usposabljanja:	

Vrsta predmeta/Course type:	Izbirni / Elective

Jeziki/Languages:	Predavanja/Lectures:	Slovenščina
	Vaje/Tutorial:	Slovenščina

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	**Prerequisites:**
Opravljanje študijskih obveznosti je opredeljeno v pravilniku o preverjanju in ocenjevanju študentov na UL NTF. Za pozitivno in uspešno opravljanje študijskih obveznosti ter vključevanje v študijsko delo se priporoča redno obiskovanje predavanj, reševanje dodatnih domačih bolj zahtevnih nalog in ustrezna predpriprava pred izvajanjem laboratorijskih vaj ter izkazana aktivnost in vsaj 80 % prisotnost na vajah.	Liabilities are defined in the regulations on examination and evaluation of students at ULNTF. For a positive and successful attendance of their duties students are encourage to regular attendance of lectures, additional domestic more complex work more and appropriate preparing to laboratory work. At least 80% attendance at tutorials is needed.

Vsebina:	**Content (Syllabus outline):**
Obdelava taline: Doseganje načrtovane kemijske sestave; Kontrola temperature v loncu in vmesni	Melt processing: Reaching the planned chemical composition; Temperature control in the ladle and

ponovci; Rafinacijski procesi v vmesni ponovci. Vlivanje ingotov za velike izdelke: Usmerjeno strjevanje; Nastajanje lunkerjev in poroznosti; Segregacije; Topnost vodika in tvorba kosmičev; Uporaba izolacijskih in termičnih posipov za preprečevanje poroznosti in tvorbe lunkerjev. Transport taline: Tok taline na prehodu med loncem in vmesno ponovco; Tok taline v vmesni ponovci; Tok taline na prehodu med vmesno ponovco in kristalizatorjem. Konstrukcija kristalizatorja: Geometrija in material kristalizatorja; Osciliranje, Kristalizatorji z spremenljivo širino. Odvod toplote v kristalizatorju: Vpliv hladilne vode; Vpliv mazanja; Vpliv vsebnosti ogljika; Vpliv hitrosti vlivanja. Livni praški: Fizikalne lastnosti livnih praškov; Taljenje livnega praška; Strjevanje livnega praška; Rafinacijski učinek livnega praška; Mazalne sposobnosti livnega praška. Sekundarno ohlajanje in sistem za vlivanje: Naprave za kontinuirano vlivanje; Sekundarno hlajenje (ohlajanje z vodo, ohlajanje z mešanico vode in zraka); Sistemi za vodenje vlitega traku. Strjevanje: Termodinamika strjevanja; Makro nivo (nastanek mikrostrukture, prenos mase in energije, modeliranje strjevanja); Mikro nivo (nastanek nukleusov in rast dendritov; Evtetsko, peritekstsko strjevanje in strjevanje v prisotnosti tretje faze. Vpliv parametrov vlivanja na površinske napake: Tipi površinskih napak; Vpliv kemijske sestave taline ter procesno-tehnoloških parametrov na površinske napake; Vpliv parametrov v kristalizatorju; Vpliv sekundarnega hlajenja; Vpliv geometrije livne naprave. Vpliv parametrov vlivanja na napake v notranjosti: Klasifikacija napak v materialu; Vpliv kemijske sestave taline; Vpliv temperature; Uporaba elektromagnetnega mešanje; Vpliv parametrov v kristalizatorju; Vpliv sekundarnega hlajenja; Vpliv geometrije livne naprave. Posebni procesi vlivanje: Horizontalno vlivanje; Vlivanje tankih slabov; Vlivanje trakov.	tundish; Refining processes in the tundish. Casting ingots for massive products: Directional solidification; Shrinkage and porosity; Segregation; Solubility of hydrogen and formation of flakes; Use of thermal insulation for prevention of porosity and shrinkage. Melt transport: The melt flow in region between the ladle and tundish; Melt flow in tundish; The melt flow in region between tundish and mould. Construction of mould: Geometry and material of mould; Oscillation, Moulds with variable width. Heat sink in mould: Effect of cooling water; Effect of lubrication; Effect of carbon content; Influence of casting speed. Casting flux: Physical properties of casting fluxes; Melting of casting fluxes; Casting flux curing; Refining effect of casting flux; Lubricating capability of casting flux. Secondary cooling and casting system: Continuous casting machine; Secondary cooling (cooling water, cooling mixture of water and air) Systems for strip casting. Solidification: Thermodynamics of solidification; Macro level (the formation of the microstructure, mass and energy transport, modelling of solidification); Micro level (the formation of nucleus and dendrite growth; Eutectic and peritectic solidification and solidification in the presence of the third phase. The influence of casting parameters on surface defects: Types of surface defects; Influence of chemical composition of the melt and process-technological parameters on the surface defects; The parameters of the mould; Effect of secondary cooling; Influence of casting devices geometry. The influence of casting parameters on internal defects: The classification of defects in materials; Influence of melt chemical composition; Influence of temperature; Use of electromagnetic stirring (EMS); Influence of mould parameters; Influence of secondary cooling; Influence of casting devices geometry. Special casting processes: Horizontal casting; Thin slab casting, Strip casting.

Temeljna literatura in viri/Readings:

Ahindra Ghosh: SECONDARY STEELMAKING; CRC Press, (2001)
Duru Michael Stefanescu: SCIENCE AND ENGINEERING OF CASTING SOLIDIFICATION; Kluwer Academic, (2002)
W.R. Irving: CONTINIOUS CASTING OF STEEL; The Institut of Materials, London, (1993)
Kurz Fisher: FUNDAMENTALS OF SOLIDIFICATION 4th Ed.; Trans Tech Publications Ltd., (1998)

Cilji in kompetence:	**Objectives and competences:**
Večino izdelanega jekla, tako v Sloveniji kot v svetu, je vlitega po postopku kontinuiranega vlivanja.	The majority of steel produced in Slovenia and in the world is continuous casted. Special steels and ingots

Specialna jekla in ingoti za izdelavo posebnih izdelkov pa se vlivajo v bloke. Za dobro kvaliteto vlitega polizdelka je nujna dobra kvaliteta taline. Študenti bodo znali izdelati talino primerno za nadaljnje kontinuirano vlivanje in vlivanje v bloke. Na osnovi kemijskih in fizikalnih lastnosti teline bodo sposobni pripraviti tehnologijo vlivanja, ki bo zagotovila izdelavo polizdelkov z zahtevanimi lastnostmi. Študent se navaja na timsko in projektno delo, uporabo strokovne literature in sodobnih virov informacij.	for special products are cast in blocks. For good quality of casted semi product a good quality melt is needed. Students will be able to prepare melt appropriate for further continuous or block casting. On the basis of chemical and physical properties of melt they will be able to organize casting technology for fabrication of semi products with the required properties. Students will be accustomed to teamwork and project work, usage of specialized literature and up-to-date sources of information.

Predvideni študijski rezultati:	**Intended learning outcomes:**
Znanje in razumevanje: Pri predmetu Vlivanje v bloke in kontinuirano vlivanje pridobi študent znanja o tehnoloških postopkih potrebnih za kvalitetno izdelane polizdelke. Nauči se pravilnih postopkov priprave taline, pravilnega načrtovanja in vodenja tehnologije kontinuiranega vlivanja in optimiranja proizvodnega procesa. Študenti dobijo vpogled v pomembnost posameznih vplivnih parametrov kar jim omogoča, da se pravilno odločajo tudi v primerih, ko je potrebno razvijati izdelavo novih, še ne osvojenih izdelkov, materialov in dimenzij. Pridobil bo znanje s področja strjevanja. Izdelavo polizdelkov bo lahko načrtoval tako, da bodo imeli v naprej določene metalurške lastnosti, ki bodo ustrezale zahtevam nadaljnjih uporabnikov.	Knowledge and understanding: Course Block and continuous casting will give students knowledge about technologies which are needed for production of high quality half products. They will learn right procedure in melt preparation, right planning and controlling of continuous casting and optimal production process. Students get insight into relevance of particular influential parameter which enables them to make right decisions even if they have to develop new technology, for new not yet acknowledged products, materials and dimensions. They will get knowledge about solidification. Production of half products will be carried in such way that demands of end users could be fulfilled.

Metode poučevanja in učenja:	**Learning and teaching methods:**
Predavanja, seminarji, seminarske in laboratorijske vaje, terenske vaje, samostojno delo	Lectures, seminars, tutorial and laboratory work, fieldwork, individual work

Načini ocenjevanja:	**Delež/Weight**	**Assessment:**
ustni izpit	60,00 %	oral exam
pisni izpit	20,00 %	examination
seminarska naloga in poročilo laboratorijskih vaj	20,00 %	seminar work and the report of the laboratory work

Reference nosilca/Lecturer's references:

LAMUT, Jakob, FALKUS, Jan, JURJEVEC, Beno, KNAP, Matjaž. Influence of inclusions modification on nozzle clogging = Wpływ modyfikacji wtrąceń niemetalicznych na zarastanie wylewów zanurzeniowych. Archives of metallurgy and materials, 2012, vol. 57, no. 1, str. 319-324. [COBISS.SI-ID 1211231]
LAMUT, Jakob, KLANČNIK, Grega, JURJOVEC, Beno, DEBELAK, Martin, KNAP, Matjaž. Influence of the inclusion composition on continues casting of steel melt. V: IVANOV, Svetlana (ur.), ŽIVKOVIĆ, Dragana (ur.). 42nd International October Conference on Mining and Metallurgy - IOCMM 2010, October 10-13 2010, Kladovo. Proceedings. Bor: Technical Faculty, 2010, str. 330-335. [COBISS.SI-ID 1081183]
KNAP, Matjaž, FALKUS, Jan, ROZMAN, Alojz, LAMUT, Jakob. Hardenability prediction based on chemical composition of steel = Napovedovanje prekaljivosti na osnovi kemične sestave jekla. RMZ-mater. geoenviron., 2009, let. 56, št. 2, str. 108-117. [COBISS.SI-ID 952159]

VZDRŽLJIVOST MATERIALOV

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	Vzdržljivost materialov
Course title:	Endurace of Materials
Članica nosilka/UL Member:	UL NTF

Študijski programi in stopnja	Študijska smer	Letnik	Semestri	Izbirnost
Metalurgija in materiali, druga stopnja, magistrski	Ni členitve (študijski program)	2. letnik	1. semester	izbirni

Univerzitetna koda predmeta/University course code:	0078015
Koda učne enote na članici/UL Member course code:	874

Predavanja /Lectures	Seminar /Seminar	Vaje /Tutorials	Klinične vaje /Clinical tutorials	Druge oblike študija /Other forms of study	Samostojno delo /Individual student work	ECTS
30	15	15	0	0	60	4

Nosilec predmeta/Lecturer:	Milan Terčelj

Izvajalci predavanj:	
Izvajalci seminarjev:	
Izvajalci vaj:	
Izvajalci kliničnih vaj:	
Izvajalci drugih oblik:	
Izvajalci praktičnega usposabljanja:	

Vrsta predmeta/Course type:	Izbirni / Elective

Jeziki/Languages:	Predavanja/Lectures:	Slovenščina
	Vaje/Tutorial:	Slovenščina

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	Prerequisites:
Vpis v letnik študija.	Entry in the academic year.

Vsebina:	Content (Syllabus outline):
Pri predavanjih bodo obravnavane naslednje teme: - Osnovne triboloških, temperaturnih, mehanskih in kemičnih obremenitev materialov, - Načini degradacije materialov pri različnih obremenitvah, - Splošni vplivi lastnosti materilov, mikrostrukture in kemične sestave na njihovo vzdržljivost, - Procesi v materialih med njihovo življensko dobo pri različnih načinih obremenjevanja. Aplikacija	The topics that will be covered in this course are: - Basic of tribological, thermal, mechanical and chemical loads of materials, - Modes of degradation of materials at various loads, - General influences of material properties, microstructure and chemical composition on endurance, - Processes in materials during their service time at various types of loading. Applications of materials

materialov in procesi v materialih v ekstremnih pogojih (temperaturnih, triboloških, kemičnih, mehanskih in termomehanskih obremenitvah), - Skupne osnove procesov v materialu pri različnih mehanizmih poslabšanja lastnosti materialov ter razlike med njimi, - Nastale poškodbe na površinski plasti in notranjosti materiala med različnimi načinih obremenjevanja, - Metode za sledenje procesov in poškodb v materialu in na njegovi površinski plasti med degradacijo, - Metode za določitev (oceno) obremenitev v materialu na različnih prostorskih skalah, - Tribološki sistemi pri izdelavi materialov, - Matematični modeli za opis degradacije materialov, - Laboratorijski testi za fizikalno simulacijo degradacije materialov, - Osnovnih vplivi procesnih parametrov izdelave materialov na njihovo vzdržljivost, - Izbira materialov za specifične pogojih obratovanja, - Matematična predstavitev procesnih verig pri izdelavi materialov, zbrane baze podatkov procesnih parametrov ter analiza in optimiranje parametrov na določeno vzdržljivostno lastnost materiala, - Ukrepi za izboljšanje vzdržljivosti materialov.	and processes in materials at extreme working conditions (temperature, mechanical, tribological, chemical and thermomechanical), - Common base of proccesses in materials at various modes of degradation of material properties and difference between them, - Occurence of damages on surface layer of materials and in matereial internal at various type of loadings, - Methods for tracing of processes in materials and their surface layers during process of degradation, - Methods for determination (assessment) of loads in materials on various spatial scales, - Tribological systems at materials production, - Mathematical models for description of degradation of materials, - Laboratory tests for physical simulation of degradation of materials, - General influences of processing parameters of material production on their endurance, - Selection of materials for specific working conditions, - Mathematical presentation of processing chains of material production, colected data base of process parameters, analyse and optimisation of parameters considering selected endurance characteristics of material, - Measures for increasing of endurance of materials.

Temeljna literatura in viri/Readings:

1. G. W. Stahowiak, A. W. Batchelor, Engineering Tribology, Elsevier Inc., 2005.
2. A. Saxena, Comprenhensive Structural Intergrity, Elsevier Pergamon 2003.
3. J. Skrzypek, A. W. Ganzarski, E. Halina, F. Rusticelli, Advanced Materials and Structures for extreme operating condition, Springer Verlag 2008.
3. M.C. Ashby, Materials selection in mechanical design, Elsvier 2007.
4. R. Buergel, Handbuch Hochtemperatur Werkstofftechnik, Vieweg 2004.
5. K. Holmberg, A. Matthews, Coatings Tribology, Elsevier 2009
6. T. F.J. Quinn, Physical analysis for Tribology, Cambridge university press 1991.
7. A. Weronski, T. Hejwowski, Thermal fatigue of metals, Marcel Decker Inc. 1991

Cilji in kompetence:	**Objectives and competences:**
Cilj predmeta je podati skupne osnove za študij vzdržljivostni materialov, t.j. obrabna obstojnost, odpornost proti termičnemu utrujanju, odpornost na temperaturne šoke, mehansko utrujanje in odpornost na nastanek razpok med plastično deformacijo materiala (plastična sposobnost). Študent pridobi sposobnost za oceno vzdržljivosti v laboratoriju kot tudi z znanimi motematičnimi modeli računsko napovedati vzdržljivosti, nadalje pridobi znanje najpomembnejših procesih v materialu v času njegove življenske dobe ter transfer laboratorijskih rezultatov v prakso, izbiri materiala za določeno aplikacijo. Nadalje študent pridobi tudi sposobnost bolj integralnega obravnavanja vpliva procesnih parametrov pri izdelavi materialov na omenjene vzdržljivostne karakteristike materialov.	The aim of the course is to establish common base for study of endurance of materials, i.e. wear resistance, thermal fatigue resistance, resistance on mechanical and thermomechanical fatigue resistance, and plasticity of materials. Student is able to carry out laboratory assessment of material endurance as well as for forcasting (assessment) of material service time using known mathematical models, moreover student acquires knowledge about most important processes in materials during their service time, transfer of laboratory results in practice, and selection material for specific application. Furthermore, student is acquiries ability of integral consideration of influence of process parameters at material production on endurance characteristics of materials.

Predvideni študijski rezultati:	Intended learning outcomes:
V okviru predmeta bodo študenti pridobili sposobnost o pravilni izbiri materiala za specično aplikacijo povezano z vzdržljivostjo, zna načrtovati eksperiment za preizkušanje določene vzdržljivosti, zna napovedati (oceniti) življensko dobo določenega predmeta (materiala) v izbrani aplikaciji. Nadalje bodo poglobili njihovo razumevanje fizikalno metalurških procesov, ki potekajo v materialih, in so povezani z vzdržljivostjo ter zna uporabiti metode za detekcijo teh procesov. Študentje bodo tudi pridobili sposobnost reševanja problemov sistemske narave. Znanje in razumevanje: Zna povezati parametre izdelave materiala z dobljenimi vzdržljivostnimi karakteristikami, razume procese, ki pospešujejo kinetiko poslabšanja lastnosti materialov in s tem tudi nastanek poškodb, zna ovrednotiti in opredeliti vzroke za nastale poškodbe ter sprejeti ukrepe za izboljšanje vzdržljivosti, zna napovedati (oceniti) življenjsko dobo in izbirati pravi material za specifično aplikacijo, razume pomen sistemskega pristopa pri problemih vzdržljivosti materialov. Študent pridobi sposobnost na reševanju problemov, ki so na videz težko rešljivi in so sistemske narave. Kombinacija uporabe laboratorijskega dela za fizikalno simuliranje degradacije materialov, matematičnih modelov za degradacijo, metod za sledenje procesov degradacije in nastalih poškodb ter ob upoštevanju parametrov izdelave materiala omogoča celovito obravnavanje problema vzdržljivosti in s tem tudi v razumevanju povezave med vzroki in posledicami.	By the end of this course students will obtain ability to select appropriate material for specific application reffering to endurance of material, ability to design of experiment for investigation of specific endurance characteristic, ability for forecasting (assesment) of service time of material in selected aplcation. Further, they will deepen their understanding of physical and metallurgical processes that takes place in materials and are related to endurance as well as to apply methods needed for detection of these processes in material. Students will be able also to solve complex problems. Knowledge and understanding: Student is able to connect process parameters of material production with obtained endurance characteristics, he/she understand the kinetic of degradation processes in materials leading to damages, he/she is able to assess reasons for occurrence of various type of damages and to make a decisions for improving of endurance, he is able to forecast (assess) service time and to select appropriate material for specific application, and understand importance of system approach at problems of endurance of materials. Student is able at solving of problems which are apparently hard to solve and for which systematic approach is needed. Applying of combination of laboratory work for physical simulation, mathematical models for description of degradation of materials, methods for tracing of degradation processes as well as occurrence of damages considering process parameters of material production enables integral considering of problem of endurance. This also enables understanding of reasons and consequences at endurance of materials.

Metode poučevanja in učenja:	Learning and teaching methods:
Predavanja, vaje, laboratorijsko delo, seminarji, projektno delo.	Lectures, exercises and laboratory work, project work.

Načini ocenjevanja:	Delež/Weight	Assessment:
• ocena domačih nalog	25,00 %	• mark of homework's
• ocena projektnega dela	25,00 %	• mark of project work
• ocena ustnega izpita	50,00 %	• mark of the oral exam

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2. LAVTAR, Lejla, MUHIČ, Tadej, KUGLER, Goran, TERČELJ, Milan. Analysis of the main types on damage on a pair of industrial dies for hot forging car stering mechanisems. Eng fail. anal.. [Print ed.], 24 str. http://dx.doi.org/10.1016/j.engfailanal.2010.11.002, doi: 10.1016/j.engfailanal.201011.002. [COBISS.SI-ID 1088351], [JCR] kategorija: 1A2 (Z1);

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