Fakulteta za industrijski inženiring
Faculty of Industrial Engineering

UČNI NAČRT PREDMETA / COURSE SYLLABUS	
Predmet:	Toplotna obdelava in inženiring površin kovinskihmaterialov
Course title:	Heat treatment and surface engineering of metals

Študijski program Study programme and level	Študijska smer Study field	Letnik Academic year	Semester Semester
Inženiring in avtomobilska industrija	Razvoj novih proizvodov/tehnologij	2017/2018	1. (zimski)
Engineering and automotive industry, masters	Development of new products/technologies	2017/2018	1. (winter)

Vrsta predmeta / Course type Izbirni / optional

Univerzitetna koda predmeta / University course code: **31025**

Predavanja Lectures	Seminar Seminar	Sem. vaje Tutorial	Lab. vaje Laboratory work	Teren. vaje Field work	Samost. delo Individ. work	ECTS
60		30			180	10

Nosilec predmeta / Lecturer: Izr. prof. dr. Vojteh Leskovšek

Jeziki / Languages:	
Predavanja / Lectures:	slovenski/Slovenian angleški/english
Vaje / Tutorial:	slovenski/Slovenian angleški/english

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	Prerequisits:
– Zaključen univerzitetni študij na eni od naravoslovnih ali tehniških fakultet, študij 2. stopnje (magistrski) po Bolonjskem programu.	– University study on one of the natural science or engineering faculties finished, second grade ofBolognian study.

Vsebina:	Content (Syllabus outline):
– **Faze in strukture:** - Perlit, ferit, in cementit, avstenit, martenzit in bainit – **Pretvorbe pri segrevanju:** - Premena □□□□□ - Toplotna obdelava na ferit in perlit - Trdota in kaljivost - Avstenit v jeklih – **Popuščanje jekel** – **Posebne toplotne obdelave:** - Nerjavna jekla - Orodna in hitrorezna jekla - Jeklene litine – **Toplotna obdelava neželeznih zlitin** Al, Cu, Mg, Ni in Ti – **Postopki modificiranja površin** - Mehansko modificiranje: - Toplotno modificiranje - Toplotno-kemijsko modificiranje – **Postopki za prekrivanje površin:** - Toplotno prekrivanje - Mehansko prekrivanje - Toplotno-mehansko prekrivanje - Kemično prekrivanje - Elektrokemično prekrivanje - Prekrivanje v parni fazi – **Mejni postopki:** - Ionska implantacija - Anodna oksidacija - Toplotno-kemično difuzijsko prekrivanje	– **Phases and Structures:** - Perlite, ferite, cementite and austenite, martesite and bainite – **Transformation on heating:** - Transformation □□□□□ - Heat treatments to produce ferrite and pearlite - Hardness and Hardenability - Austenite in Steels – **Tempering of Steels** – **Special Heat Treatments:** - Stainless Steels - Tool and HSS Steels - Cast Irons – **Heat Treatment of non ferrous alloys** o Al, Cu, Mg, Ni and Ti – **Modification of surfaces:** - Mechanical modification - Surface hardening - Thermo-chemical modification – **Surface deposition processes:** - Heat deposition - Mechanical deposition - Thermo-mechanical deposition - Chemical deposition - Electrochemical deposition - Vapour deposition – **Boundary Processes:** - Ion Implantation - Anodic oxidation - Thermo-chemical diffusion deposition

Temeljni literatura in viri / Readings:

- George Krauss, Steels: Heat treatment and processing principles, ASM International, Materials park,Ohio,1997
- A. Constant, G. Henry,J.-C. Charbonnier, Priciples de base des tratements thermiques thermomechaniques et thermochimiques des aciers, PYC Edition, Verdun 1992
- Heat treating, Metals handbook, Ninth edition, Volume 4, ASM International, Materials park, Ohio, 1997
- K.E. Thelning, Steel and its Heat treatment, Bofors Handbook, Bofors1974
- Roger Fabian, Vacuum Technology (Practical Heat treating and Brazing), ASM International Materials Park,OH 44073-0002, 1993
- S. Grainger, Engineering coatings – design and application, Ablington Publishing,
- Chambrige, 1989
- H.K.D.H. Bhaeshia, Steels, Microstructure and Properties, Third edition 2006 Butterworth-Heinemann, Oxford OX2 8DP, UK
- Mladen Stupnišek, Franjo Cajner, Osnove toplinske obrade metala, Sveučitelište u Zagrebu, Fakultet strojarstva i brodogradnje, 1996

Priporočljiva literatura / Recomended Textbooks

- Ray W. Reynoldson, Heat treatment in Fluidzed Bed Furnaces, ASM International Materials Park,OH 44073-0002,
- 1993
- S. L. Semiatin and D.E. Stutz, Induction Heat Treatment of Steel,ASM American Society for Metals, Metals Park, Ohio 44073, 1986
- L. J. Durney, Electroplating engineering handbook, Fourth ed.,Chapman&Hall,London, 1996
- R.F. Bunshah, Handbook of hard coatings, Deposition technologies, properties and applications, Noyes Publications, Park Ridge, 2001
- R. Fabian, Vacuum Technology, Practical Heat Treatment and Brazing, ASM International, Metals Park, Ohio 44073-0002, 1998
- F. Vodopivec, Kovine in zlitine, Inštitut za kovinske material in tehnologije Ljubljana, 2002

Cilji in kompetence:	**Objectives and competences:**
Cilji	***Objectives***
– Podiplomski študij tega predmeta bo organiziran za znanstveno izpopolnjevanje iz področja tehnologij toplotne obdelave in inženiringa površin kovinskih materialov, – modeliranja procesov in proizvodnega management, – pridobljeno znanje bo omogočilo uporabo znanstvenih metod za reševanje kompleksnih znanstveno-raziskovalnih nalog,	– Post-graduate study of this object will be organised for scientific perfecting from field of technologies of heat treatment and surface engineering of metallic materials, – modelling of processes and production management, – gained knowledge will allowed using of scientific methods for solving of complex scientifically-research tasks, – guidance of developmental and of research programmes, as also for development and

– vodenja razvojnih in raziskovalnih programov, kot tudi za razvoj in uporabo novih tehnologija s ciljem revitalizacije in modernizacije proizvodnje.	use of new technology with goal of revitalisation and modernizations of production.
Kompetence	***Competences***
Učna enota prispeva predvsem k razvoju naslednjih splošnih in specifičnih kompetenc:	Course unit contributes mainly to the development of generic and specific competences:
– usposobiti študente za razumevanje, načrtovanje in izvedbo postopkov toplotne obdelave pri katerih kovinske dele namerno izpostavimo temperaturno-časovnem ciklusu, da dosežemo želeno mikrostrukturo in s tem želene mehanske, fizikalne in kemijske lastnosti. – usposobiti študente za razumevanje in načrtovanje ter izvajanje postopkov inženiringa površin, ki temeljijo na novih spoznanjih v okviru fizike trdne snovi in termodinamike procesov, na razvoju senzorjev in na razvoju in uporabi matematičnih modelov in programske opreme za vodenje procesov. – veliko število obstoječih postopkov toplotne obdelave, modificiranja in prekrivanja površin, ki jih koristimo s ciljem povečati odpornost proti obrabi in trajni dinamični trdnosti strojnih elementov in orodij, se vse bolj uveljavljajo v industrijski praksi, pojavljajo pa se tudi novih postopki. – vsak od postopkov je specifičen tako z vidika podobnosti mehanizmov in pogojev obrabe, kot tudi z vidika uporabnosti obdelovanih materialov in tehnoloških posebnosti uporabe. Zato je pravilni izbor postopka vedno povezan s celovito analizo vseh vplivnih dejavnikov. – doktorand bo usposobljen za delo: v raziskovalnih laboratorijih za materiale, na inštitutih in centrih za razvoj proizvodov in tehnologije v industriji, – kot predavatelj na fakultetah in srednjih šolah, v proizvodnji, v oddelkih za karakterizacijo materialov v kontroli kakovosti v industriji, – kot podjetnik v ustanavljanju in	– to educate students for understanding and planning and conducting of processes of heat treatment at which metallic parts intentionally emphasise temperature-time cycle, that we achieve desired microstructure and mechanical, physical and chemical characteristics wanted with this. – to educate students for understanding and planning and implementing of processes of surface engineering that based upon on new findings in frame of solid-state physics and of thermodynamics of processes, on development of sensors and on development and uses of mathematical models and software for direction of processes. – namely, extensive number of existent procedures of heat treatment, modifications and coverings of surfaces, which them serve with goal to increase resistance against wear out and fatigue strength of machine elements and of tools, all are asserting oneself more in industrial practice, and new procedures also occur. – each of procedures is specific so from point of view of similarity of mechanisms and of conditions of wear out, as also from point of view of usability of treated materials and of technological specialities of use. That is why correct selection of procedure is connected with complete analysis of all influential factors always. – doctor of this direction is trained for work: in research laboratories for materials, on institutes and centres for development of products and technology in industry, as lecturer on faculties and

vodenju podjetja temelječega na znanju. – aktivno in kritično spremljanje razvoja novih metod uporabe materialov na področju avtomobilizma, energije in ekologije.	secondary schools, – in production, in departments for characterization of materials in control of quality in industry, as entrepreneur in establishing and direction of company based on knowledge. – actively and critically monitoring the development of new methods of using materials in the automotive, energy and ecology field.

Predvideni študijski rezultati:	**Intended learning outcomes:**
Znanje in razumevanje: *Študent/študentka:* – pozna in razume osnovne zakonitosti materialov, – pozna delitev tehnoloških postopkov ter njihovo uporabo, – pozna delitev ostalih železnih in neželeznih zlitin in njihovo uporabo v avtomobilski industriji, – se seznani s tehnologijo pridobivanja sintanih gradiv, njihovo toplotno obdelavo in uporabo teh gradiv, – zna uporabljati kompozitne materiale, – zna uporabljat nanomateriale v avtomobilski industriji, – pozna lastnosti kombiniranih materialov v avtomobilski industriji (MMM princip) in jih zna uporabljat, – sposoben bo oceniti in izbrati najugodnejši material za konstrukcije, orodja, izdelke itd., – na osnovi preiskave materiala in laboratorijskih vaj zna oceniti obnašanje materiala vgrajenega v izdelek, – zna načrtovati, uporabiti standarde, uporabiti literaturo in samostojno načrtovati proizvodni proces s področja in uporabe postopkov toplotne obdelave in inženiringa površin za različne materiale.	Knowledge and understanding: *Student / student:* – know and understand the basic principles of materials – knows the sharing of technological processes and their application, – familiar with the division of other ferrous and non ferrous alloys and their use in the automotive industry, – become acquainted with the technology of obtaining sintered materials, their heat treatment and application of these materials, – knows how to use composite materials, – knows how to use nanomaterials in the automotive industry, – knows the characteristics of the combined materials in the automotive industry (MMM principle) and knows how to use, – be able to evaluate and select the best material for construction, tools, products, etc., – on the basis of the investigation of the material and lab exercises be able to assess the behavior of the material incorporated in the product, – be able to plan, apply standards used literature and independent planning of the production process with the scope and procedures of heat treatment and surface engineering for various materials.

Metode poučevanja in učenja:	Learning and teaching methods:
– predavanja z aktivno udeležbo študentov (razlaga, diskusija, vprašanja, reševanje nalog) ob pomoči sodobnih pedagoških pripomočkov, – avditorne vaje za poglabljanje teoretičnih osnov, – individualne in skupinske konzultacije, – laboratorijske vaje, ki potekajo v ustrezno opremljenem laboratoriju.	– lectures with active participation of students (explanation, discussion, questions, problem solving) with the help of modern pedagogical tools, – tutorial for deepening the theoretical bases, – individual and group consultations, – laboratory exercises, which take place in a properly equipped laboratory

Načini ocenjevanja:	Delež (v %) / Weight (in%)	Assessment:
– Pogoj za opravljanje pisnega izpita so pozitivno ocenjene laboratorijske vaje in seminarji. – Končna ocena izpita je povprečje rezultata pisnega dela in ustnega zagovora.		– The condition for passing a written examination are positively evaluated laboratory work and seminars. – Final exam evaluation is the average of the results of the written work and oral examination.

Reference nosilca / Lecturer's references:

- LESKOVŠEK, Vojteh, PODGORNIK, Bojan. Tool Steels : Fracture Toughness. V: COLAS, Rafael (ur.), TOTTEN, George E. (ur.). *Encyclopedia of iron, steel, and their alloys*, (Metals and Alloys Encyclopedia Collection). Boca Raton: CRC Press: Taylor & Francis group, 2016, str. 3687-3719, ilustr., doi: 10.108/E-EISA-120049739. [COBISS.SI-ID 1212842]
- PODGORNIK, Bojan, LESKOVŠEK, Vojteh, GODEC, Matjaž, SENČIČ, Bojan. Microstructure refinement and its effect on properties of spring steel. *Materials Science & Engineering. A, Structural materials: Properties, Microstructure and Processing*, ISSN 0921-5093. [Print ed.], 2014, vol. 599, str. 81-86, ilustr. [COBISS.SI-ID 1015210], [JCR, SNIP]
- LESKOVŠEK, Vojteh, PODGORNIK, Bojan. Vacuum heat treatment, deep cryogenic treatment and simultaneous pulse plasma nitriding and tempering of P/M S390MC steel. *Materials Science & Engineering. A, Structural materials: Properties, Microstructure and Processing*, ISSN 0921-5093. [Print ed.], 1. jan. 2012, vol. 531, str. 119-129, doi: 10.1016/j.msea.2011.10.044. [COBISS.SI-ID 890794], [JCR, SNIP]
- LESKOVŠEK, Vojteh, PODGORNIK, Bojan, JENKO, Monika. A PACVD duplex coating for hot-forging applications. *Wear*, ISSN 0043-1648. [Print ed.], 2009, vol. 266, iss. 3/4, str. 453-460. [COBISS.SI-ID 717738], [JCR, SNIP]
- LESKOVŠEK, Vojteh, GODEC, Matjaž, KOGEJ, Peter. Strengthening via the formation of strain-induced martensite and the effects of laser marking on the microstructure of austenitic stainless steel. *Metallurgical and materials transactions. A, Physical metallurgy and materials science*, ISSN 1073-5623, June 2014, vol. 45, iss. 6, str. 2819-2826, ilustr., doi: 10.1007/s11661-014-2213-5. [COBISS.SI-ID 13377307], [JCR, SNIP]
- NOLAN, James David, HUANG, S.W., LESKOVŠEK, Vojteh, BRAUN, S. Sliding wear of titanium nitride thin films deposited on Ti-6Al-4V alloy by PVD and plasma nitriding processes. *Surface & coatings technology*, ISSN 0257-8972. [Print ed.], 2006, vol. 200, no. 20-21, str. 5698-5705. [COBISS.SI-ID

442538], [JCR, SNIP]

- NOLAN, James David, LESKOVŠEK, Vojteh, JENKO, Monika. Estimation of fracture toughness of nitride compound layers on tool steel by application of the Vickers indentation method. *Surface & coatings technology*, ISSN 0257-8972. [Print ed.], 2006, vol. 201, 1-2, str. 182-188. [COBISS.SI-ID 442026], [JCR, SNIP]
- LESKOVŠEK, Vojteh, ULE, Boris. Influence of deep cryogenic treatment on microstructure, mechanical properties and dimensional changes of vacuum heat-treated high-speed steel. *Heat treatment of metals*, ISSN 0305-4829, 2002, no. 3, str. 72-76. [COBISS.SI-ID 381279], [JCR, SNIP]
- LESKOVŠEK, Vojteh, ULE, Boris. Fracture toughness as a criterion for optimising the heat treatment of high-speed steel. *Heat treatment of metals*, ISSN 0305-4829, 2001, vol. 28, št. 4, str. 39-45, graf. prikazi. [COBISS.SI-ID 304991], [JCR, SNIP]
- LESKOVŠEK, Vojteh, ŠUŠTARŠIČ, Borivoj, JUTRIŠA, Gorazd. The influence of austenitizing and tempering temperature on the hardness and fracture toughness of hot-worked H11 tool steel. *Journal of materials processing technology*, ISSN 0924-0136. [Print ed.], sep. 2006, vol. 1/3, iss. 1/3, str. 328-334. [COBISS.SI-ID 442282], [JCR, SNIP]
- LESKOVŠEK, Vojteh, PODGORNIK, Bojan, NOLAN, D. Modelling of residual stress profiles in plasma nitrided tool steel. *Materials characterization*, ISSN 1044-5803. [Print ed.], 2008, vol. 59, no. 4, str. 454-461. http://dx.doi.org/10.1016/j.matchar.2007.03.009. [COBISS.SI-ID 10380571], [JCR, SNIP]
- LESKOVŠEK, Vojteh, ULE, Boris, LIŠČIĆ, B. Relations between fracture toughness, hardness and microstructure of vacuum heat-treated high-speed steel. *Journal of materials processing technology*, ISSN 0924-0136. [Print ed.], 2002, vol. 127, str. 298-308, ilustr. [COBISS.SI-ID 338090], [JCR, SNIP]
- LESKOVŠEK, Vojteh. Modelling of high-speed steels fracture toughness. *Materials and manufacturing processes*, ISSN 1042-6914, 2009, vol. 24, no. 6, str. 603-609, doi: 10.1080/10426910902768881. [COBISS.SI-ID 726442], [JCR, SNIP]
- LESKOVŠEK, Vojteh, KALIN, Mitjan, VIŽINTIN, Jože. Influence of deep-cryogenic treatment on wear resistance of vacuum heat-treated HSS. *Vacuum*, ISSN 0042-207X. [Print ed.], 2006, letn. 80, št. 6, str. 507-518. [COBISS.SI-ID 8999195], [JCR, SNIP]
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- LESKOVŠEK, Vojteh, JENKO, Monika, PODGORNIK, Bojan. PACVD duplex coating for hot forging of high strength steels for automotive applications = PACVD duplex prevlake za toplo kovanje visoko čvrstih čelika za automobilsku primjenu. *Strojarstvo*, ISSN 0562-1887, 2011, letn. 53, št. 1, str. 39-44. [COBISS.SI-ID 898986], [SNIP]
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