VARJENJE, REZANJE IN NAVARJANJE Z VISOKO GOSTOTO ENERGIJE

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	VARJENJE, REZANJE IN NAVARJANJE Z VISOKO GOSTOTO ENERGIJE
Course title:	WELDING, CUTTING AND SURFACING WITH HIGH ENERGY DENSITY
Članica nosilka/UL Member:	UL FS

Študijski programi in stopnja	**Študijska smer**	**Letnik**	**Semestri**	**Izbirnost**
Strojništvo, tretja stopnja, doktorski	Proizvodno inženirske znanosti, kibernetika in mehatronika (smer)		Celoletni	izbirni

Univerzitetna koda predmeta/University course code:	0033474
Koda učne enote na članici/UL Member course code:	7319

Predavanja /Lectures	**Seminar /Seminar**	**Vaje /Tutorials**	**Klinične vaje /Clinical tutorials**	**Druge oblike študija /Other forms of study**	**Samostojno delo /Individual student work**	**ECTS**
90					160	10

Nosilec predmeta/Lecturer:	Damjan Klobčar

Izvajalci predavanj:	Damjan Klobčar
Izvajalci seminarjev:	
Izvajalci vaj:	
Izvajalci kliničnih vaj:	
Izvajalci drugih oblik:	

Izvajalci praktičnega usposabljanja:	
Vrsta predmeta/Course type:	Izbirni predmet /Elective course

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

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	**Prerequisites:**
Veljajo splošni pogoji za doktorski študij.	General prerequisites for the third level studies.

Vsebina:	**Content (Syllabus outline):**
Fizikalne, kemijske in metalurške osnove varjenja in rezanja z visoko gostoto energije (električni oblok, elektronski in svetlobni snop, plazma). Teorija varjenja in toplotnega rezanja z električnim oblokom, s plazmo, z elektronskim snopom in svetlobnim snopom. Key-hole efekt, marangonijev efekt. Metalurški in tehnični pojavi v zvaru in rezu. Tehnologije, stroji in naprave oz. sistemi za varjenje in rezanje s plazmo, z elektronskim snopom in laserjem. Osnovni in dodajni materiali, vplivni parametri v procesih. Kombinirani postopki varjenja (hibridno varjenje) in rezanja z visoko gostoto energije. Stanje in tendence razvoja varjenja in rezanja z visoko gostoto energije. Teorija obnavljanja in oplemenitenja površinskih slojev s postopki navarjanja in nabrizgavanja. Primernost dodajnih materialov za določen osnovni material pri obnovi obrabljenih strojnih elementov. Naprave in sistemi. Stanje in tendence razvoja. Fizikalno kemijske in metalurške osnove procesov nanašanja zaščitnih površinskih slojev po različnih postopkih navarjanja in nabrizgavanja. Elektroiskrno navarjanje, navarjanje z lasarjem, elektronskim snopom, plazmo,	Physical, chemical and metallurgical phenomena of welding and cutting with a high energy density (electric arc, electron and laser beam, plasma arc). The theory of thermal cutting and welding with electric arc, plasma arc, the electron beam and the beam of light. Key-hole effect, Marangony effect. Metallurgical and technical phenomena in weld and cut. Technologies, machines and apparatus or systems for welding and cutting with plasma arc, the electron beam and laser beam. Basic materials and consumables, influential parameters in the welding processes. Combined welding processes (hybrid welding) and cutting with the high energy density. Status and trends of developments in welding and cutting processes with a high energy density. The theory of regeneration and processing of surface layers with surfacing and metallization. The suitability of consumable materials for a particular base material in the reconstruction of worn-out mechanical elements. The devices and systems. Status and trends of development. Physical, chemical and metallurgical processes basics of processing of

navarjanje v hladnem. Toplotne obdelave nanosov. Možnosti in prednosti kombiniranja raznih postopkov obnavljanja in oplemenitenja površin pri vzdrževanju in izdelavi novih orodij in obrabno obremenjenih strojnih elementov.	protective surface layers using different surfacing and metallization processes. Electro-spark surfacing, laser beam surfacing, electron beam, plasma arc, and surfacing at room temperatures. Surface layers heat treatment. Opportunities and advantages of combining the various processes for surface renewal at the maintenance and construction of the new tools and wear loaded mechanical elements.

Temeljna literatura in viri/Readings:

[1] Boxman, R.L.: Handbook of vacuum, arc science and technology, Noyes Publication, Park Ridge, New Jersey, ZDA, 1995

[2] The Physics of welding /ed. by J.F. Lancaster.- 1st ed.- Oxford et al.: Pergamon Press, 1986.

[3] Ninth Edition, Volumen 1, Welding Science and Technology; Welding Handbook AWS 550 N. W. Lejeeune road Miami FL 33126, 2006

[4] Ninth Edition, Volumen 2, Welding Processes Part 1; Welding Handbook AWS 550 N. W. Lejeeune road Miami FL 33126, 2006

[5] N. N.: Ninth Edition, Volumen 3, Welding Processes Part 2; Welding Handbook AWS 550 N. W. Lejeeune road Miami FL 33126, 2008

[6] Mohler, R.: Practical Welding Technology, Industrial pressinc, 200 Madison Avenue, New York, 2006

[7] Steen, W.M.: Laser material welding.- 2nd ed.- London, 1998

[8] Marfels, W.: Der Lichtbogenschweißer: Leitfaden für Ausbildung und Praxis / Marfels, Orth.- 9.- überarbeitete und erweiterte Aufl.- Düsseldorf: DVS-Verlag, 1997 (Die schwiesstechnische Praxis; Band 2,

[9] Schultz, H.: Elektronenstrahlschweißen.- 2., vollständig überarb. und erw. Aufl.- Düsseldorf: DVS-Verlag, 2000 (Fachbuchreihe Schweisstechnik; Bd. 93)

[10] Welding of aluminium: 250 references from the METADEX database / prepared by the editors of Materials Information in cooperation with ASM International & the Institute of Materials.- London: Materials Information; Bethesda, MD: Cambridge Scientific Abstracts, 2005.- (Search-in-print report; ALU006)

[11] Welding of dissimilar metals: 250 references from the METADEX database / prepared by the editors of Materials Information in cooperation with ASM International & the Institute of Welding.

Cilji in kompetence:	**Objectives and competences:**
Cilji:	**Goals**:
Študentu prikazati vlogo, pomen, lastnosti in uporabnost vseh procesov rezanja, varjenja in navarjanja z visoko	The role, meaning, properties and application of all cutting processes, welding processes and surfacing with

gostoto energije v splošni industriji in v znanosti. Pojasniti pomen navarjanja in toplotnega rezanja v industriji in znanosti. Razjasniti uporabnost posameznih procesov pri učinkovanju visoke gostote energije na material za vse vrste materialov. Pojasniti delo z laserskim žarkom, elektronskim snopom in s plazmo. **Kompetence:** Študent osvoji znanja iz procesov toplotnega rezanja in navarjanja z visoko gostoto energije, samostojno odloča o raziskavah in o metodah raziskovalnega dela pri posameznih procesih rezanja in navarjanja z visoko gostoto energije. Študent mora imeti sposobnost uporabe pridobljenega znanja v praksi in pri raziskovalnem delu, pri iskanje novih znanj iz različnih virov, ima sposobnost za samostojno raziskovalno in znanstveno delo ter za svoje delo prevzemati odgovornost, ima sposobnost za delo v skupini in je sposoben odločanja in vodenja.	high energy density in general industry and science are shown to the student. The meaning of surfacing and thermal cutting in the industry and science is explained. The applicability of individual processes on interaction of high energy density on material for all material types is clarified. The manipulation with the laser beam, the electron beam and the plasma arc is explained. **Competences**: Student conquers the knowledge of thermal cutting and surfacing with high energy density, independently decides about research and methods of research work at particular thermal cutting and surfacing with high energy density. A student has to be able to use the acquired knowledge in practice, at research work, at searching of new knowledge from different sources, has the ability for independent research and scientific research as well as to contract an obligation, has the ability to work in a team and the ability of making decisions and leadership, is ethical and knows to critically and fairly judge the coworkers, knows to manage the time, is able to communicate orally and in writing, knows the professional terminology in English and German language.

Predvideni študijski rezultati:	**Intended learning outcomes:**
Študent osvoji znanja iz procesov toplotnega rezanja in navarjanja z visoko gostoto energije, samostojno odloča o raziskavah in o metodah raziskovalnega dela pri posameznih procesih rezanja in navarjanja z visoko gostoto energije. Študent mora imeti sposobnost uporabe pridobljenega znanja v praksi in pri raziskovalnem delu, pri iskanje novih znanj iz različnih virov, ima sposobnost za samostojno raziskovalno in znanstveno delo ter za svoje delo prevzemati odgovornost, ima sposobnost za delo v skupini in je sposoben odločanja in vodenja.	Student conquers the knowledge of thermal cutting and surfacing with high energy density, independently decides about research and methods of research work at particular thermal cutting and surfacing with high energy density. A student has to be able to use the acquired knowledge in practice, at research work, at searching of new knowledge from different sources, has the ability for independent research and scientific research as well as to contract an obligation, has the ability to work in a team and the ability of making decisions and leadership, is ethical and knows to critically and fairly judge the coworkers,

	knows to manage the time, is able to communicate orally and in writing, knows the professional terminology in English and German language.

Metode poučevanja in učenja:	**Learning and teaching methods:**
Predavanja, laboratorijske vaje, seminarsko delo, e-izobraževanje, konzultacije. Seminarsko delo v čim večji meri navezujoče se na področje doktorskega raziskovanja. Študij z uporabo priporočene literature.	Lectures, laboratory practice & seminar work, e-education, consulting. The seminar work is related, as much as possible, to the student's doctoral research field. Study on a recommended literature basis.

Načini ocenjevanja:	**Delež/ Weight**	**Assessment:**
Ustni izpit, poročilo o seminarskem delu. Pogoj za opravljanje ustnega izpita je uspešno izdelano in pozitivno ocenjeno seminarsko delo. Način (pisni izpit, ustno izpraševanje, naloge, projekt): • naloge 25% • projektno delo 25% • ustno zagovor 50%.		Oral exam, report on seminar work. The condition for admission to oral exam is successful completion of seminar work, rewarded with a passing grade. Method (written exam, oral examination, assignments, project): • assignments (25%) • project seminar (25%) • oral examination (50%)

Reference nosilca/Lecturer's references:

doc.dr. Damjan KLOBČAR

1. KLOBČAR, Damjan, TUŠEK, Janez, BIZJAK, Milan, SIMONČIČ, Samo, LEŠER, Vladka. Active flux tungsten inert gas welding of austenitic stainless steel AISI 304. *Metalurgija*, ISSN 0543-5846, lis. 2016, vol. 55, nr. 4, str. 617-620, ilustr. http://hrcak.srce.hr/index.php?show=clanak&id_clanak_jezik=231945. [COBISS.SI-ID 14709787], [SNIP, WoS do 5. 7. 2016: št. citatov (TC): 0, čistih citatov (CI): 0, Scopus do 29. 1. 2017: št. citatov (TC): 1, čistih citatov (CI): 1]

2. SKUMAVC, Andrej, TUŠEK, Janez, NAGODE, Aleš, KLOBČAR, Damjan. Thermal fatigue study of tungsten alloy WNi28Fe15 cladded on AISI H13 hot work tool steel. *Surface & coatings technology*, ISSN 0257-8972. [Print ed.], Jan. 2016, vol. 285, str. 304-311, ilustr., doi: 10.1016/j.surfcoat.2015.09.044. [COBISS.SI-ID 14404123], [JCR, SNIP, WoS do 24. 12. 2017: št. citatov (TC): 4, čistih citatov (CI): 4, Scopus do 12. 11. 2017: št. citatov (TC): 5, čistih citatov (CI): 5]

3. TUŠEK, Janez, LEŠNJAK, Andrej, PLETERSKI, Matej, KLOBČAR, Damjan. The weld-pool solidification mode of ferritic stainless steels. *Metalurgija*, ISSN 0543-5846, Apr.-Jun. 2012, vol. 51, no. 2, str. 175-178. [COBISS.SI-ID 12107803], [JCR, SNIP, WoS do 5. 4. 2012: št. citatov (TC): 0, čistih citatov (CI): 0, Scopus do 22. 11. 2012: št. citatov (TC): 0, čistih citatov (CI): 0]

4. KLOBČAR, Damjan, TUŠEK, Janez, SMOLEJ, Anton, SIMONČIČ, Samo.

Parametric study of FSSW of aluminium alloy 5754 using a pinless tool. *Welding in the world*, ISSN 0043-2288, Mar. 2015, vol. 59, iss. 2, str. 269-281, ilustr., doi: 10.1007/s40194-014-0208-x. [COBISS.SI-ID 13806875], [JCR, SNIP, WoS do 28. 1. 2018: št. citatov (TC): 7, čistih citatov (CI): 7, Scopus do 27. 10. 2017: št. citatov (TC): 8, čistih citatov (CI): 8]

5. SMOLEJ, Anton, KLOBČAR, Damjan, SKAZA, Branko, NAGODE, Aleš, SLAČEK, Edvard, DRAGOJEVIČ, Vukašin, SMOLEJ, Samo. The superplasticity of friction stir processed Al-5Mg alloy with additions of scandium and zirconium. *International journal of materials research : Zeitschrift für Metallkunde*, ISSN 1862-5282, 2014, vol. 105, no. 12, str. 1218-1225. [COBISS.SI-ID 1507423], [JCR, SNIP, WoS do 28. 1. 2018: št. citatov (TC): 2, čistih citatov (CI): 2, Scopus do 27. 1. 2018: št. citatov (TC): 2, čistih citatov (CI): 2]

6. 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*, ISSN 0921-5093. [Print ed.], Jan. 2014, vol. 590, str. 239-245, ilustr., doi: 10.1016/j.msea.2013.10.027. [COBISS.SI-ID 1315679], [JCR, SNIP, WoS do 28. 1. 2018: št. citatov (TC): 18, čistih citatov (CI): 15, Scopus do 27. 1. 2018: št. citatov (TC): 18, čistih citatov (CI): 15]