IZDELOVALNE TEHNOLOGIJE 2

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	Izdelovalne tehnologije 2
Course title:	MANUFACTURING TECHNOLOGIES 2
Članica nosilka/UL Member:	UL FS

Študijski programi in stopnja	**Študijska smer**	**Letnik**	**Semestri**	**Izbirnost**
Strojništvo - razvojno raziskovalni program, prva stopnja, univerzitetni	Ni členitve (študijski program)	3. letnik	1. semester	obvezen

Univerzitetna koda predmeta/University course code:	0562766
Koda učne enote na članici/UL Member course code:	2029-U

Predavanja /Lectures	**Seminar /Seminar**	**Vaje /Tutorials**	**Klinične vaje /Clinical tutorials**	**Druge oblike študija /Other forms of study**	**Samostojno delo /Individual student work**	**ECTS**
45		30			50	5

Nosilec predmeta/Lecturer:	Damjan Klobčar, Joško Valentinčič

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

Vrsta predmeta/Course	Obvezni splošni predmet / Compulsory general course

type:	

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

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	**Prerequisites:**
Izpolnjevanje pogojev za vpis v Univerzitetni študijski program I. stopnje Strojništvo - Razvojno raziskovalni program.	Meeting the enrollment conditions for the Academic study programme of Mechanical Engineering - Research and Development program.

Vsebina:	**Content (Syllabus outline):**
. Osnove tehnologij spajanja in obločnega varjenja; - pomen tehnologij spajanja in vrste tehnologij, - aktivacijska energije mehanizmov spajanja, - delitev zvarnih spojev, lege pri varjenju, - izkoristki pri obločnem varjenju, - varilni oblok in pihalni učinek, - viri varilnega toka 2. Ročno obločno varjenje, varjenje pod praškom (EPP) in pod žlindro (EPŽ); - principielne sheme postopkov in statične karakteristike virov varilnega obloka, - vžig varilnega obloka, - varilni parametri in njihov izbor, - dodajni in pomožni materiali, - lege pri varjenju, - vrste zvarnih spojev, - uporaba postopkov. 3. Varjenje v zaščiti plinov (MIGMAG in TIG) in varjenje z visoko gostoto energije (plasma, laser in elektronski snop); - principielne sheme postopkov in statične karakteristike virov varilnega obloka, - vžig varilnega obloka, - varilni parametri in njihov izbor, - dodajni in pomožni materiali, - lege pri varjenju, - vrste zvarnih spojev,	1. Fundamentals of joining technologies and arc welding; • the importance of joining technologies and types of technologies, • activation energies of joining mechanisms, • welding joints classification, welding positions, • arc welding efficiency, • welding arc and blowing effect, • welding power sources 1. Shielded metal arc welding, submerged arc welding (SAW) and electroslag welding; • schematic diagrams and static characteristics of welding power sources, • welding arc ignition, • welding parameters and their selection, • filler and auxiliary materials, • welding positions, • types of welding joints, • aplications. 1. Shielding gas welding (GMAW and GTAW) and welding with high energy density (plasma, laser and electron beam); - schematic diagrams and static characteristics of welding power sources, - welding arc ignition,

- uporaba postopkov 4. Uporovno varjenje; - principielne sheme postopkov: točkovno, bradavično, sočelno, obžigalno, visokofrekvenčno; - osnovni fizikalni principi, - vrste zvarnih spojev, - lastnosti elektrod za varjenje, - uporaba postopkov 5. Varjenje s kemično energijo in z mehansko energijo; - fizikalne osnove postopkov spajanja: plamensko varjenje, aluminotermično varjenje, eksplozijsko varjenje, kovaško varjenje, varjenje s trenjem, FSW, ultrazvočno varjenje, difuzijsko varjenje, - načini izvedbe, - vrste zvarnih spojev in primernost materialov, - prednosti in omejitve, - uporaba postopkov. 6. Spajkanje, lepljenje in hibridno spajanje; - osnovni fizikalni principi (omočljivost, difuzija, kapilarni učinek, površinska napetost, adhezijske in kohezijske sile), - delitve postopkov in načini ogrevanja pri spajkanju, - vrste spojev, - dodajni materiali in lastnosti spojev, - priprava površin, - uporaba postopkov. 7. Tehnike mehanskega spajanja, metalizacije in navarjanja ter 3D navarjanje kovin; - pregled in fizikalno ozadje postopkov mehanskega spajanja: kovičenja, samokovičenje, robljenje, - delitev postopkov metalizacije, - pregled in fizikalno ozadje postopkov nabrizgavanja (plamensko, plazemsko, lasersko), pregled in fizikalno ozadje postopkov navarjanja, - vrste in posebnosti spojev ter lastnosti, - oprema za izvedbo spojev, - uporaba postopkov mehanskega spajanja, nabrizgavanja in navarjanja. 8. Tehnologije spajanja polimernih materialov; - delitev postopkov spajanja polimerov,	- welding parameters and their selection, - filler and auxiliary materials, - welding positions, - types of welding joints, - aplications. 4. Resistance welding; - schematic diagrams of procedures: spot, projection, butt, flash, high frequency; - basic physical principles, - types of welding joints, - welding electrode properties, - aplications. 5. Welding with chemical and mechanical energy; - the physics of the joining process: oxi-fuel welding, aluminothermic welding, explosion welding, forge welding, friction welding, FSW, ultrasonic welding, diffusion welding, - the implementation types, - the types of welding joints and the suitability of the materials, - advantages and limitations, - aplications. 6. Soldering, adhesive bonding and hybrid joining; - basic physical principles (wettability, diffusion, capillary effect, surface tension, adhesion and cohesion forces), - the classification of processes and the methods of heating during soldering, - types of joints, - filler materials and joint properties, - surface preparation, - aplications. 7. Technologies of mechanical joining, metallization, cladding and 3D cladding of metals; - overview and physical background of

- posebnosti postopkov in fizikalno ozadje nastanka spojev, - vrste zvarnih spojev in lastnosti mesta spajanja, - prednosti in omejitve postopkov, - uporaba postopkov, - varivost polimernih materialov. 9. Osnove varivosti materialov; - varivost jekel in barvnih kovin, - ogljikov ekvivalent za jeklo, pomen temperature predgrevanja in medvarkovne temperature, - TTT diagrami in hitrosti ohlajanja zvarov, - Shaefflerjev diagram za nerjavno jeklo, - izbor dodajnih materialov in izbor tehnologij za spajanje določenih materialov in izdelkov, - varivost različnih materialov med seboj. 10. Toplotno rezanje materialov ter mehanizacija in robotizacija varjenja; - plamensko, plazemsko in lasersko rezanje materialov, - fizikalno ozadje pri toplotnem rezanju materialov, - sheme robotskih in CNC sistemov za varjenje in rezanje, - pomožne naprave za varjenje (vrtljive mize, sistemi za pozicioniranje, senzorji za uporabo v varilstvu) 11. Nekonvencionalni obdelovalni postopki in aditivne tehnologije; - primerjava procesov odrezavanja in odnašanja, - delitev postopkov odnašanja materiala glede na energijo in njihova primerjava, - uvod v adititvne tehnologije. 12. Delitev aditivnih tehnologij po standardu ISO/ASTM 52900-2015; - fotopolimerizacija v kadi, - brizganje veziva, - brizganje materiala, - ekstrudiranje materiala, - spajanje slojev praškastega materiala, - nalaganje krojenih plasti, - direktno energijsko odlaganje. 13. Potopna in žična elektroerozija:	mechanical joining processes: riveting, self-riveting, roller hemming, - classification of metallization processes, - overview and physical background of the spraying processes (oxi-flame, plasma, laser), overview and physical background of the weld cladding processes, - types and specificities of joints and properties, - equipment for joining tecnologies, - aplications of mechanical joining, thermal spraying and weld cladding. 8. Joining technologies of polymers; - classification of polymer joining processes, - the specificities of the procedures and the physical background of the joint formations, - welding joints types and characteristics of the joining area, - advantages and limitations of procedures, - aplications, - weldability of polymers. 9. Material weldability fundamentals; - weldability of steels and non-ferrous metals, - carbon equivalent for steel, the importance of preheating and inter-pass temperature, - TTT diagrams and weld cooling rates, - Shaeffler diagram for stainless steel, - the selection of filler materials and joining technologies for the materials and products, - weldability of dissimilar materials. 10. Thermal cutting of materials and mechanization and robotization of welding; - oxi-fuel, plasma and laser cutting of

- mehanizmi odnašanja materiala (fizikalni opis enotskega dogodka), - nadzor in krmiljenje procesa, - obdelovalni parametri, - značilnosti obdelave, - stroji koncepti in pregled trga, - trendi razvoja. 14. Rezanje z vodnim in abrazivnim curkom: - oblikovanje visokohitrostnega vodnega in abrazivnega vodnega curka, - energija curka in mehanizmi odnašanja materiala (fizikalni opis enotskega dogodka), - obdelovalni parametri - značilnosti obdelave (standard SN 214001), - 5-osna obdelava, področja uporabe, - stroji: koncepti in pregled trga, - trendi razvoja. 15. Ekonomika nekonvencionalnih postopkov obdelave; - izračun časa obdelave, - cene strojne ure in stroškov izdelave, - analiza postavk v ceni strojne ure za potopno in žično elektroerozijo, rezanje z abrazivnim vodnim curkom in lasersko rezanje.	materials, - physical background in thermal cutting of materials, - schematics of the robotic and CNC systems for welding and cutting, - Welding auxiliaries (rotary tables, positioning systems, sensors for welding) 11. Non-conventional machining processes and additive manufacturing: • comparison of conventional and non-conventional machining processes, • classification of non-conventional machining processes according to the energy used in material removal, brief comparison, • introduction to additive manufacturing. 12. Classification of additive technologies according to the standard ISO/ASTM 52900-2015: • vat photopolymerisation, • binder jetting, • material jetting, • material extrusion, • powder bed fusion, • sheet lamination, • direct energy deposition. 13. Die-sinking EDM: • material removal mechanisms (physical description of the unit event), • monitor and control of the process, • machining parameters, • machining characteristics, • machine tools: concepts and market overview, • development trends. 14. Water jet and abrasive water jet machining: • formation of high-speed water and and abrasive water jet, • jet energy and material removal mechanisms (physical description of the unit event), • machining parameters, • machining characteristics (standard

	SN 214001), • 5-axis machining, applications, • machine tools: concepts and market overview. 15. Economics of non-conventional machining processes: • calculation of the machining time, • cost of machining hour and manufacturing costs, • analysis of machining hour costs for die-sinking EDM, wire EDM, abrasive water jet machining, and laser beam machining.

Temeljna literatura in viri/Readings:

1. J. Tušek: Varjenje in sorodne tehnike spajanja materialov v neločljivo zvezo, Fakulteta za strojništvo, 2014,
2. L. Jeffus: Welding: Principles and applications, seventh edition, Delmar, Cengage Learning, 2012
3. R. W. Messler: Principles of Welding; Wiley.vch, Verlag GmbH & Co. KgaA, Weinheim, 2004
4. I. Rak: Tehnologija varjenja; Modrijan, d.o.o., Ljubljana 2008
5. J. Tušek: Praktične in računske vaje iz tehnike spajanja, 2006
6. D. Klobčar: Dodatno študijsko gradivo pri predmetu Tehnologija spajanja in toplotnega rezanja: Ljubljana: Fakulteta za strojništvo, 2018.
7. D. Klobčar: Laboratorijske vaje pri predmetu Tehnologije spajanja: delovni učbenik za laboratorijske vaje: Ljubljana: Fakulteta za strojništvo, 2018.
8. I. Hrivnjak: Theory of weldability of metals and alloys. Amsterdam: Elsevier Science, 1992.
9. ASM Handbook: Welding, brazing and soldering, vol. 6, ASM International, 1993.
10. A O'Brien, C. Guzman: Welding handbook, American Welding Society, 2007
11. M. Beckert: Kompendum der Schweißtechnik, Band 3: Eigenung mettalischer Werksffe zum Schweißen, DVS –Verlag, Band 128/1, 1997
12. H.J. Fahrewaldt, V. Schuler: Praxiswissen; Schweißtechnik, Friedr. Vieweg & Sohn Verlag/ GWV Fachwerlage GmbH Wiesbaden, 2006
13. J. Valentinčič idr.: Alternativne tehnologije, učbenik za tretji letnik visokošolskega strokovnega študijskega programa I. stopnje, Fakulteta za strojništvo, Ljubljanan 2012.
14. M.P. Groover: Fundamentals of Modern Manufacturing - Materials, Processes, and Systems, 4th edition, John Willey and Sons, 2010.
15. B. Guitrau, E.: The Electrical Discharge Machining Handbook. - Hanser Gardner Publications, Cincinnati, OH, USA, 1997.
16. A.W. Momber and R. Kovačević: Principles of Abrasive Water Jet Machining - Sprnger-Verlag London, 1998
17. J. Powel: CO2 Laser Cutting, Springer, 1993.
18. VALENTINČIČ, Joško, KLOBČAR, Damjan, LEBAR, Andrej. Nekonvencionalne tehnologije in tehnologije spajanja : izdelovalne tehnologije 2 : gradivo za vaje. Ljubljana: Fakulteta za strojništvo, 2014.

Cilji in kompetence:	**Objectives and competences:**
Cilji: 1. Identificirati in izbirati procese spajanja materialov in nekonvencionalnih izdelovalnih postopkov glede na zahtevane lastnosti materiala izdelka in njegovih obremenitev. 2. Spoznati načine za opredelitev in izbiro osnovnih parametrov procesov spajanja materialov in nekonvencionalnih izdelovalnih postopkov ter izvedbe aplikativnih tehnoloških rešitev. 3. Razumevati specifike tehnoloških procesov spajanja materialov ter njihovo ustrezno umeščanje v obstoječe proizvodne procese. 4. Spoznati ustrezne stroškovno-tehnološko učinkovite izbire procesov spajanja materialov in nekonvencionalnih izdelovalnih postopkov. Kompetence: 1. S1-RRP+ S2-RRP+P2- RRP: Sposobnost identifikacije in izbire procesa spajanja materialov in nekonvencionalnih izdelovalnih postopkov skladno z zahtevanimi lastnostmi materiala izdelka, okolja delovanja in obremenitev ter namena uporabe 2. S4-RRP+ S5-RRP+P3- RRP: Sposobnost opredelitve osnovnih tehnoloških parametrov posameznega procesa spajanja materialov in nekonvencionalnih izdelovalnih postopkov izdelave na osnovi strokovnega sporazumevanja in pisnega izražanja tudi v tujem jeziku 3. S6-RRP+ S7-RRP+P5- RRP: Sposobnost umestitve procesov spajanja v tehnološki proces proizvodnje na osnovi samostojnega pridobivanja znanj in kritične presoje informacij	Goals: 1. Identification and selection of the joining processes and unconventional fabrication processes according to the required material properties of the product and its loads. 2. Learn ways to define and select the basic parameters of materials joining processes and unconventional manufacturing processes and implementation of applied technological solutions. 3. Understand the specifics of technological processes for joining materials and their proper placement in existing production processes. 4. Learn the appropriate cost-technologically efficient choices of materials joining processes and unconventional manufacturing processes. Competencies: 1. S1-RRP + S2-RRP + P2-RRP: Ability to identify and select the process of joining materials and unconventional fabrication processes in accordance with the required material characteristics of the product, the operating environment and the load and purpose of use 2. S4-RRP + S5-RRP + P3- RRP: Ability to define the basic technological parameters of an individual process of joining materials and unconventional manufacturing processes based on professional communication and written expression even in a foreign language 3. S6-RRP + S7-RRP + P5-RRP: Ability to integrate joining processes into a technological production process based on independent knowledge acquisition and critical information assessment

Predvideni študijski rezultati:	**Intended learning outcomes:**
Znanja: Poglobljeno strokovno teoretično in praktično znanje na področju tehnologij spajanja materialov in nekonvencionalnih izdelovalnih postopkov, podprto s širšo teoretično in metodološko osnovo. Spretnosti: S1.1 Izvajanje kompleksnih operativno-strokovnih opravil s področja tehnologij spajanja materialov in nekonvencionalnih izdelovalnih postopkov, ki vključujejo tudi uporabo metodoloških orodij. S1.3 Diagnosticiranje in reševanje izzivov v različnih specifičnih delovnih okoljih, povezanih s področjem tehnologij spajanja materialov in nekonvencionalnih izdelovalnih postopkov pridobljenih med izobraževanja in usposabljanja.	Knowledge: In-depth professional theoretical and practical knowledge in the field of materials joining technologies and unconventional manufacturing processes, supported by a broader theoretical and methodological basis. Skills: S1.1 Performing complex operational and technical tasks in the field of materials joining technologies and unconventional manufacturing processes, which also include the use of methodological tools. S1.3 Diagnosing and solving challenges in a variety of specific work environments related to the field of materials joining technologies and unconventional manufacturing processes acquired during education and training.

Metode poučevanja in učenja:	**Learning and teaching methods:**
P1 Avditorna predavanja z reševanjem izbranih - za področje značilnih - teoretičnih in praktično uporabnih primerov. P2 Obravnava snovi po urejeni in vnaprej razloženi sistematiki. P3 Avditorne vaje, kjer se teoretično znanje s predavanj podkrepi z računskimi primeri. P5 Uporaba študijskega gradiva v obliki: knjige, e-verzija predstavitve predavanj. P6 Interaktivna predavanja P7 Študij literature in razprava P8 Izdelava in predstavitev aplikativnih seminarskih nalog P10 Uporaba anket v realnem času P15 Uporaba video vsebin kot priprava na predavanja in vaje	P1 Lectures by solving selected – typical for the field - theoretical and practical examples. P2 Subject matter treatment according to an orderly and pre-explained systematics. P3 Practical classes where theoretical knowledge from lectures is backing by computational examples. P5 Use of study materials in the form of: books, e-version of lecture presentation. P6 Interactive Lectures P7 Literature studies and discussion P8 Design and presentation of applied seminar papers P10 Use of surveys in real time P15 Use of video content to prepare for lectures and tutorials

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

	Weight	
- Teoretične vsebine (predavanja)	50,00 %	- Theoretical content (lectures)
- Delo na laboratorijskih vajah (vključno s poročili)	30,00 %	- Laboratory work (including reports)
- Seminar	20,00 %	- Seminar

Reference nosilca/Lecturer's references:

Damjan Klobčar:

1. **KLOBČAR, Damjan**, TUŠEK, Janez, SMOLEJ, Anton, SIMONČIČ, Samo. Parametric study of FSSW of aluminium alloy 5754 using a pinless tool. Welding in the world, Mar. 2015, vol. 59, iss. 2, str. 269-281, doi: 10.1007/s40194-014-0208-x. [COBISS.SI-ID 13806875]
2. BALOŠ, Sebastian, DRAMIĆANIN, Miroslav D., JANJATOVIC, Petar, ZABUNOV, Ivan, **KLOBČAR, Damjan**, BUŠIĆ, Matija, GRILLI, Maria Luisa. Metal oxide nanoparticle-based coating as a catalyzer for A-TIG welding : critical raw material perspective. Metals, 2019, vol. 9, iss. 5, f. 1-12, doi: 10.3390/met9050567. [COBISS.SI-ID 16623131],
3. 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, Jan. 2014, vol. 590, str. 239-245, doi: 10.1016/j.msea.20110.027. [COBISS.SI-ID 1315679],
4. **KLOBČAR, Damjan**, KOSEC, Ladislav, PEPELNJAK, Tomaž, TUŠEK, Janez. Microstructure and mechanical properties of friction stir welded AlMg5Mn alloy. Engineering review, 2012, vol. 32, iss. 2, str. 104-110, [COBISS.SI-ID 12401435],
5. **KLOBČAR, Damjan**, TUŠEK, Janez, BIZJAK, Milan, SIMONČIČ, Samo, LEŠER, Vladka. Active flux tungsten inert gas welding of austenitic stainless steel AISI 304. Metalurgija, lis. 2016, vol. 55, nr. 4, str. 617-620, http://hrcak.srce.hr/index.php?show=clanak&id_clanak_jezik=231945. [COBISS.SI-ID 14709787]

Joško Valentinčič:

1. **VALENTINČIČ, Joško**, JUNKAR, Mihael. Detection of the eroding surface in the EDM process based on the current signal in the gap. *International journal of advanced manufacturing technology*, ISSN 0268-3768, 2007, vol. 33, no. 7/8, str. 698-705.
2. **VALENTINČIČ, Joško**, BRISSAUD, Daniel, JUNKAR, Mihael. EDM process adaptation system in toolmaking industry. Journal of materials processing technology, ISSN 0924-0136. [Print ed.], 2006, vol. 172, št. 2, str. 291-298.
3. BISSACCO, Giuliano, HANSEN, H.N., TRISTO, Gianluca, **VALENTINČIČ, Joško**. Feasibility of wear compensation in micro EDM milling based on discharge counting and discharge population characterization. CIRP annals, ISSN 0007-8506, 2011, vol. 60, iss. 1, str. 231-234.
4. PRIJATELJ, Miha, JERMAN, Marko, ORBANIĆ, Henri, SABOTIN, Izidor, **VALENTINČIČ, Joško**, LEBAR, Andrej. Determining focusing nozzle wear by measuring AWJ diameter. Strojniški vestnik, ISSN 0039-2480, Oct. 2017, vol. 63,

no. 10, str. 597-605.
5. PARTHIBAN, M., KRISHNARAJ, V., SINDHUMATHI, R., **VALENTINČIČ, Joško**. Investigation on manufacturing of microtools made of tungsten carbide using wire electric discharge grinding (WEDG). *Journal of the Brazilian Society of Mechanical Sciences and Engineering*, ISSN 1678-5878. [Print ed.], Sept. 2017, vol. 39, iss. 9, str. 3571-3580.