

## UČNI NAČRT PREDMETA/COURSE SYLLABUS

<b>Predmet:</b>	Tehnologije v proizvodnji 2
<b>Course title:</b>	Production technologies 2
<b>Članica nosilka/UL Member:</b>	UL FS

Študijski programi in stopnja	Študijska smer	Letnik	Semestri
Strojništvo - projektno aplikativni program, prva stopnja, visokošolski strokovni	Mehatronika (smer)	2. letnik	1. semester
Strojništvo - projektno aplikativni program, prva stopnja, visokošolski strokovni	Energetsko strojništvo (smer)	2. letnik	1. semester
Strojništvo - projektno aplikativni program, prva stopnja, visokošolski strokovni	Procesno strojništvo (smer)	2. letnik	1. semester
Strojništvo - projektno aplikativni program, prva stopnja, visokošolski strokovni	Konstruiranje strojev in naprav (smer)	2. letnik	1. semester
Strojništvo - projektno aplikativni program, prva stopnja, visokošolski strokovni	Konstruiranje industrijskih sistemov (smer)	2. letnik	1. semester
Strojništvo - projektno aplikativni program, prva stopnja, visokošolski strokovni	Proizvodne tehnologije (smer)	2. letnik	1. semester
Strojništvo - projektno aplikativni program, prva stopnja, visokošolski strokovni	Industrijsko inženirstvo (smer)	2. letnik	1. semester
Strojništvo - projektno aplikativni program, prva stopnja, visokošolski strokovni	Prometni pilot letala/helikopterja (smer)	2. letnik	1. semester
Strojništvo - projektno aplikativni program, prva stopnja, visokošolski strokovni	Snovanje in vzdrževanje letal (smer)	2. letnik	1. semester

<b>Univerzitetna koda predmeta/University course code:</b>	0562714
<b>Koda učne enote na članici/UL Member course code:</b>	3017-V

Predavanja	Seminar	Vaje	Klinične vaje	Druge oblike študija	Samostojno delo	ECTS
45		45			35	5

**Nosilec predmeta/Lecturer:** Damjan Klobčar, Tomaž Pepelnjak

**Vrsta predmeta/Course type:** Obvezni splošni predmet /Compulsory general course

<b>Jeziki/Languages:</b>	Predavanja/Lectures:	Slovenščina
	Vaje/Tutorial:	Slovenščina

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

Izpolnjevanje pogojev za vpis v Visokošolski strokovni študijski program I. stopnje Strojništvo - Projektno aplikativni program.

**Prerequisites:**

Meeting the enrollment conditions for the MECHANICAL ENGINEERING - Project Oriented Applied Programme.

**Vsebina:**

1. Osnove tehnologij spajanja in obločnega varjenja;
  - pomen tehnologij spajanja in vrste tehnologij,
  - delitev zvarnih spojev in lege pri varjenju,
  - varilni oblok, pihalni učinek in izkoristki pri obločnem varjenju,
  - viri varilnega toka.
2. Ročno obločno varjenje, varjenje pod praškom (EPP) in pod žlindro (EPŽ);
  - principieline sheme postopkov in statične karakteristike virov varilnega obloka,
  - varilni parametri in njihov izbor,
  - dodatni in pomožni materiali,
  - vrste zvarnih spojev, lege pri varjenju in uporaba postopkov.
3. Varjenje v zaščiti plinov (MIGMAG in TIG) in varjenje z visoko gostoto energije (plasma, laser in elektronski snop);
  - principieline sheme postopkov in statične karakteristike virov varilnega obloka,
  - varilni parametri in njihov izbor,
  - dodatni in pomožni materiali ter lastnosti zaščitnih plinov, ki so pomembne pri spajanju,
  - lege pri varjenju, vrste zvarnih spojev in uporaba postopkov.
4. Uporovno varjenje;
  - principieline sheme postopkov: točkovno, bradavično, sočelno, obžigalno, visokofrekvenčno;
  - osnovni fizikalni principi,
  - lastnosti elektrod za varjenje,
  - vrste zvarnih spojev in posebnosti pri varjenju različnih materialov ter 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 spajanja,
  - vrste zvarnih spojev in primernost materialov,
  - prednosti in omejitve ter 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 glede na različne vire energije,

**Content (Syllabus outline):**

1. Fundamentals of joining and arc welding technologies;
  - the importance and types of joining technologies,
  - welding joints and welding position classification,
  - welding arc, blowing effect and arc welding efficiency,
  - welding power sources.
2. Shielded metal arc welding, submerged arc welding (SAW);
  - schematic diagrams and static characteristics of welding power sources,
  - welding parameters and their selection,
  - filler and auxiliary materials,
  - weld types, welding positions and applications.
3. 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 parameters and their selection,
  - filler and auxiliary materials and properties of the shielding gases important in welding,
  - welding positions, welding joints types and applications.
4. Resistance welding;
  - schematic diagrams of the process: spot, projection, butt, flash, high frequency;
  - basic physical principles,
  - welding electrode properties,
  - welding joint types and special features in welding different materials and applications.
5. Welding with chemical energy and mechanical energy;
  - the physical basis of the joining process: oxi-fuel welding, aluminothermic welding, explosion welding, forge welding, friction welding, FSW, ultrasonic welding, diffusion welding,
  - ways of perform the joining,
  - welding joint types and the suitability of the materials,
  - advantages and limitations and applications.
6. Soldering, adhesive bonding and hybrid bonding;
  - basic physical principles (wettability, diffusion, capillary effect, surface tension, adhesion and cohesion forces),

<ul style="list-style-type: none"> <li>- vrste spojev, ki so primerne za te načine spajanja in lege pri varjenju,</li> <li>- osnovni, dodajni materiali in pomožni materiali ter lastnosti spojev,</li> <li>- pomen priprave površin in uporaba postopkov.</li> </ul> <p>7. Tehnike mehanskega spajanja, metalizacije in navarjanja Tehnike mehanskega spajanja, metalizacije in navarjanja ter 3D navarjanje kovin;</p> <ul style="list-style-type: none"> <li>- pregled in fizikalno ozadje postopkov mehanskega spajanja: kovičenja, samokovičenje, robljenje,</li> <li>- delitev postopkov metalizacije,</li> <li>- pregled in fizikalno ozadje postopkov nabrizgavanja (plamensko, plazemsko, lasersko), pregled in fizikalno ozadje postopkov navarjanja,</li> <li>- vrste in posebnosti spojev ter lastnosti spojev in plasti,</li> <li>- oprema za izvedbo spojev ter uporaba postopkov mehanskega spajanja, nabrizgavanja in navarjanja.</li> </ul> <p>8. Tehnologije spajanja polimernih materialov;</p> <ul style="list-style-type: none"> <li>- delitev postopkov spajanja polimerov,</li> <li>- posebnosti postopkov in fizikalno ozadje nastanka spojev,</li> <li>- vrste zvarnih spojev in lastnosti mesta spajanja,</li> <li>- prednosti in omejitve postopkov ter varivost polimernih materialov,</li> <li>- uporaba postopkov glede na omejitve.</li> </ul> <p>9. Osnove varivosti materialov;</p> <ul style="list-style-type: none"> <li>- varivost jekel in barvnih kovin,</li> <li>- ogljikov ekvivalent za jeklo, pomen temperature predgrevanja in medvarkovne temperature,</li> <li>- TTT diagrami in hitrosti ohlajanja zvarov,</li> <li>- Shaefflerjev diagram za nerjavno jeklo,</li> <li>- izbor dodajnih materialov in izbor tehnologij za spajanje določenih materialov in izdelkov,</li> <li>- varivost različnih materialov med seboj.</li> </ul> <p>10. Toplotno rezanje materialov ter mehanizacija in robotizacija varjenja;</p> <ul style="list-style-type: none"> <li>- fizikalno ozadje pri toplotnem rezanju (plamensko, plazemsko in lasersko) materialov,</li> <li>- sheme robotskih in CNC sistemov za varjenje in rezanje,</li> <li>- pomožne naprave za varjenje (vpenjalni sistemi, vrtljive mize, sistemi za pozicioniranje, senzorji za uporabo v varilstvu)</li> </ul> <p>11. Osnove preoblikovanja in delitev preoblikovalnih postopkov</p> <ul style="list-style-type: none"> <li>- Koncepti postopkov preoblikovanja, ključne prednosti tehnologije</li> <li>- Ključni delitev preoblikovalnih postopkov in predstavitev sistemov delitve na konkretnih industrijskih primerih</li> <li>- Opredelitev parametrov izbire posamezne tehnologije preoblikovanja</li> <li>- Primerjalno vrednotenje izbranih tehnologij</li> </ul>	<ul style="list-style-type: none"> <li>- the classification of processes and the methods of heating during soldering,</li> <li>- the welding joint types and welding positions,</li> <li>- basic, filler and auxiliary materials and properties of welding joints,</li> <li>- the importance of surface preparation and applications.</li> </ul> <p>7. Mechanical joining, metallization and welding techniques and 3D weld cladding;</p> <ul style="list-style-type: none"> <li>- overview and physical background of mechanical joining processes: riveting, self-riveting, roller hemming,</li> <li>- metallization processes classification,</li> <li>- overview and physical background of the spraying processes (oxy-fuel, plasma, laser), overview and physical background of the welding operations,</li> <li>- types and characteristics of joints and properties of joints and layers,</li> <li>- equipment for making joints and applications of mechanical joining, thermal spraying and weld cladding.</li> </ul> <p>8. Joining technologies of polymers;</p> <ul style="list-style-type: none"> <li>- classification of polymer joining processes,</li> <li>- the specificities of the procedures and the physical background of the joint formations,</li> <li>- welding joints types and characteristics of the joining area,</li> <li>- advantages and limitations of processes and weldability of polymers,</li> <li>- applications and limitations of processes.</li> </ul> <p>9. Fundamentals of weldability of materials;</p> <ul style="list-style-type: none"> <li>- weldability of steels and non-ferrous metals,</li> <li>- carbon equivalent for steel, the importance of preheating and interpass temperature,</li> <li>- TTT diagrams and weld cooling rates,</li> <li>- Shaeffler diagram for stainless steel,</li> <li>- the selection of filler materials and joining technologies for materials and products,</li> <li>- weldability of dissimilar materials.</li> </ul> <p>10. Thermal cutting of materials and mechanization and robotization of welding;</p> <ul style="list-style-type: none"> <li>- physical background in thermal cutting (oxy-fuel, plasma and laser) of materials,</li> <li>- schematics of the robotic and CNC systems for welding and cutting,</li> <li>- Welding auxiliaries (clamping systems, rotary tables, positioning systems, sensors for welding).</li> </ul> <p>11. Fundamentals of forming and division of forming processes</p> <ul style="list-style-type: none"> <li>- Concepts of forming processes, key advantages of the technology</li> <li>- The keys to the division of forming processes and the representation of division systems in selected industrial cases</li> <li>- Definition of the parameters of the selected forming technology</li> </ul>
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<p>preoblikovanja in konkurenčnosti izdelkov narejenih z različnimi izdelovalnimi procesi</p> <p>12. Izbira postopka preoblikovanja pločevinskih izdelkov</p> <ul style="list-style-type: none"> <li>- Predstavitev glavnih postopkov preoblikovanja pločevine ; delitev glede na napetostno-deformacijsko stanje v materialu</li> <li>- Predstavitev postopkov dodelave preoblikovancev (vlečenje vratov, uvaljanje navojev ...)</li> <li>- Alternativni postopki preoblikovanja pločevine (postopno preoblikovanje, potisno oblikovanje, superplastično preoblikovanje, eksplozijsko preoblikovanje, elektro-magnetno preoblikovanje)</li> <li>- Štancanje pločevinskih izdelkov v večstopenjskih orodjih</li> </ul> <p>13. Opredelitev postopkov preoblikovanja masivnih surovcev</p> <ul style="list-style-type: none"> <li>- Delitev postopkov predelave masivnih surovcev</li> <li>- Priprava surovcev pred masivnim preoblikovanjem</li> <li>- Predstavitev glavnih skupin postopkov (valjanje, iztiskavanje, vlečenje profilov in palic...)</li> </ul> <p>14. Pregled postopkov preoblikovanja polimerov</p> <ul style="list-style-type: none"> <li>- Primerjava preoblikovanja kovinskih in polimernih preoblikovancev</li> <li>- Potrebni tehnološki pogoji za preoblikovanje polimernih materialov glede na lastnosti posameznih skupin polimerov (durpolasti, termoplasti)</li> <li>- Predstavitev osnov glavnih postopkov preoblikovanja polimernih materialov</li> <li>- Opredelitev izbire tehnologije preoblikovanja polimerov glede na oblikovno-mehanske zahteve izdelka</li> </ul> <p>15. Oprema za izvedbo preoblikovalnih postopkov</p> <ul style="list-style-type: none"> <li>- Tipične potrebne karakteristike opreme za izvedbo posameznih preoblikovalnih postopkov</li> <li>- Ključne lastnosti preoblikovalnih orodij za velike, srednje in male serije izdelkov</li> <li>- Oprema za posluževanje preoblikovalnim strojem (velikoserijska in maloserijska proizvodnja)</li> </ul>	<ul style="list-style-type: none"> <li>- Comparative evaluation of selected technologies of forming and competitiveness of products produced by different manufacturing processes</li> </ul> <p>12. Selection a process for the forming of sheet metal products</p> <ul style="list-style-type: none"> <li>- Presentation of the most important sheet metal forming processes; classification according to the stress-strain state in the material</li> <li>- Presentation of the processes for finishing the workpieces (collar drawing, thread rolling...)</li> <li>- Alternative sheet metal forming processes (incremental forming, flow forming, superplastic forming, explosion forming, electromagnetic forming)</li> <li>- Stamping of sheet metal products in multi-stage tools</li> </ul> <p>13. Definition of bulk forming processes</p> <ul style="list-style-type: none"> <li>- Classification of the processing of bulk materials</li> <li>- Preparation of billets before bulk forming</li> <li>- Presentation of the main process groups (rolling, extrusion, drawing of profiles and bars, etc.)</li> </ul> <p>14. Overview of the polymer moulding processes</p> <ul style="list-style-type: none"> <li>- Comparison of metal and polymer forming</li> <li>- The necessary technological conditions for the forming of polymeric materials according to the properties of individual polymer groups (thermosets, thermoplastics)</li> <li>- Presentation of the basics of the main processes of polymer material forming</li> <li>- Definition of the selection of polymer forming technology according to the mechanical and shape requirements of the product</li> </ul> <p>15. Equipment for performing forming operations</p> <ul style="list-style-type: none"> <li>- Typical equipment characteristics required to perform the individual forming operations</li> <li>- Key features of forming tools for large, medium and small product series</li> <li>- Equipment for handling the forming machines (large and small series production)</li> </ul>
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#### 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. D. Klobčar: Dodatno študijsko gradivo pri predmetu Tehnologija spajanja in toplotnega rezanja: Ljubljana: Fakulteta za strojništvo, 2018.
6. D. Klobčar: Laboratorijske vaje pri predmetu Tehnologije spajanja: delovni učbenik za laboratorijske vaje: Ljubljana: Fakulteta za strojništvo, 2018.
7. I. Hrivnjak: Theory of weldability of metals and alloys. Amsterdam: Elsevier Science, 1992.
8. ASM Handbook: Welding, brazing and soldering, vol. 6, ASM International, 1993.
9. A O'Brien, C. Guzman: Welding handbook, American Welding Society, 2007

10. S. Kalpakjian, S.R. Schmidt: Manufacturing Engineering and Technology, Prentice Hall, Singapore, 7. izdaja, 2013.
11. Skupina avtorjev: Moderno proizvodno inženirstvo – priročnik, K. Kuzman (Edt.), Grafis trade,d.o.o, Grosuplje, 2010.
12. Z. Kampuš: Osnove tehnologije preoblikovanja kovin : preoblikovanje pločevine, masivno preoblikovanje : učbenik, Ljubljana : Fakulteta za strojništvo, 2014.
13. Skupina avtorjev: Sheet Metal Forming – Fundamentals, ASM international, Materials Park Ohio, 2012.

#### **Cilji in kompetence:**

##### **Cilji:**

Identificirati in izbirati procese preoblikovanja in spajanja materialov glede na zahtevane lastnosti materiala izdelka in njegovih obremenitev.

Spoznati načine za opredelitev in izbiro osnovnih parametrov procesov spajanja in preoblikovanja in izvedbe aplikativnih tehnoloških rešitev.

Razumevati specifične procesov spajanja materialov in preoblikovanja in njihovo ustrezno umeščanje v tehnologije obstoječih proizvodnih procesov.

Spoznati ustrezne stroškovno-tehnološko učinkovite izbire procesov preoblikovanja in spajanja materialov.

##### **Kompetence:**

Sposobnost identifikacije in izbire procesa spajanja materialov in preoblikovanja skladno z zahtevanimi lastnostmi materiala izdelka in namena uporabe (S1-PAP+P3-PAP)

Sposobnost opredelitve osnovnih tehnoloških parametrov posameznega procesa spajanja materialov in preoblikovanja (S13-PAP+P8-PAP)

Sposobnost umestitve procesa preoblikovanja in spajanja materialov v tehnološki proces proizvodnje (S7-PAP+P9-PAP)

Sposobnost ovrednotenja primernosti uporabe procesov spajanja materialov in/ali preoblikovanja skladno z velikostjo serije izdelave (S12-PAP+P9-PAP)

#### **Objectives and competences:**

##### **Objectives:**

Identification and selection the processes of material transformation and joining technologies according to the required material properties of the product and its loads.

Learn ways to define and choose the basic parameters of joining and transformation processes and implementations of applied technological solutions.

Understand the specifics of materials joining and transformation processes and their proper placement in the technologies of existing production processes.

Learn the appropriate cost-technologically efficient choices of processes of material transformation and joining.

##### **Competencies:**

Ability to identify and select the process of material joining and transformation according to the required material properties of the product and the intended use (S1-PAP + P3-PAP)

Ability to define the basic technological parameters of each material joining and transformation process (S13-PAP + P8-PAP)

Ability to integrate the process of transformation and joining of materials in the technological process of production (S7-PAP + P9-PAP)

Ability to evaluate the suitability of the use of material joining and / or transformation processes according to the batch size of manufacture (S12-PAP + P9-PAP)

#### **Predvideni študijski rezultati:**

##### **Znanja:**

Poglobljeno strokovno teoretično in praktično znanje na področju tehnologij spajanja in preoblikovanja materialov, podprto s širšo teoretično in metodološko osnovo.

##### **Spretnosti:**

S1.1 Izvajanje kompleksnih operativno-strokovnih

#### **Intended learning outcomes:**

##### **Knowledge:**

In-depth professional theoretical and practical knowledge in the field of materials joining and transformation technologies, supported by a broader theoretical and methodological basis.

##### **Skills:**

S1.1 Performing complex operational and technical

opravi s področja tehnologij spajanja in preoblikovanja kovinskih in nekovinskih materialov, ki vključujejo tudi uporabo metodoloških orodij in modelov.  S1.2 Obvladovanje zahtevnih, kompleksnih delovnih procesov ob samostojni uporabi znanja s področja tehnologij spajanja in preoblikovanja materialov v novih delovnih situacijah.	tasks in the field of joining and transformation technologies of metallic and non-metallic materials, which also include the use of methodological tools and models.  S1.2 Mastering difficult, complex workflows with the independent use of knowledge in the field of joining and material transformation technologies in new work situations.
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#### Metode poučevanja in učenja:

#### Learning and teaching methods:

Klasične oblike poučevanja:  P1 Avditorna predavanja z reševanjem izbranih - za področje značilnih - teoretičnih in praktično uporabnih primerov.  P3 Avditorne vaje, kjer se teoretično znanje s predavanj podkrepi z računskimi primeri.  P5 Uporaba študijskega gradiva v obliki: knjige, e-verzija predstavitev predavanj.  Moderne in prožne oblike poučevanja:  P6 Interaktivna predavanja  P7 Študij literature in razprava  P8 Izdelava in predstavitev aplikativnih seminarskih nalog  P15 Uporaba video vsebin kot priprava na predavanja in vaje	Classical forms of teaching:  P1 Lectures by solving selected – typical for the field - theoretical and practical examples.  P3 Practical classes where theoretical knowledge from lectures is supported by computational examples.  P5 Use of study materials in the form of: books, e-version of lecture presentation.  Modern and flexible forms of teaching:  P6 Interactive Lectures  P7 Literature studies and discussion  P8 Design and presentation of applied seminar papers  P15 Use video content to prepare for lectures and tutorials
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#### Načini ocenjevanja:

#### Delež/Weight

#### Assessment:

- 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:

**KLOBČAR, Damjan**, TUŠEK, Janez, TALJAT, Boštjan, KOSEC, Ladislav, PLETESKI, Matej. Aging of maraging steel welds during aluminium alloy die casting. Computational materials science, 2008, letn. 44, št. 2, str. 515-522. <http://dx.doi.org/10.1016/j.commatsci.2008.04.011>. [COBISS.SI-ID]

**KLOBČAR, Damjan**, TUŠEK, Janez, BIZJAK, Milan, LEŠER, Vladka. Micro friction stir welding of copper electrical contacts. Metalurgija, 2014, vol. 53, no. 4, str. 509-512, [COBISS.SI-ID [13473819](#)],

BUŠIĆ, Matija, KOŽUH, Zoran, **KLOBČAR, Damjan**. Influence of the tool travel speed on friction stir processing of aluminium alloy AlCu4Mg1. Analele Universit  ii "Dun  area de Jos" Galaţi = : Annals of "Dun  area de Jos" University of Galaţi. Fascicle XII, Welding Equipment and Technology. Fascicula XII, Utilajul  i tehnologia sud  arii, 2017, vol. 28, str. 11-15,. <https://search.proquest.com/docview/1987360277?pq-origsite=gscholar>. [COBISS.SI-ID

[15820827](#)],

TUŠEK, Janez, SKUMAVC, Andrej, **KLOBČAR, Damjan**. Vacuum brazing of tools with a thin foil. Metalurgija, 2015, vol. 54, no.1, str. 67-70, [COBISS.SI-ID [13675291](#)],

PODRŽAJ, Primož, JERMAN, Boris, **KLOBČAR, Damjan**. Welding defects at friction stir welding. Metalurgija, Apr./Jun. 2015, vol. 54, no. 2, str. 387-389, [COBISS.SI-ID [13744411](#)],

Tomaž Pepelnjak:

BARIŠIČ, Branimir, **PEPELNJAK, Tomaž**, MATH, Miljenko D. Predicting of the Lüder's bands in the processing of TH material in computer environment by means of stochastic modeling. Journal of materials processing technology, ISSN 0924-0136. [Print ed.], 2008, vol. 203, no. 1/3, str. 154-165.

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