

# NAČRTOVANJE TEHNOLOGIJ PREOBLIKOVANJA

## UČNI NAČRT PREDMETA/COURSE SYLLABUS

<b>Predmet:</b>	Načrtovanje tehnologij preoblikovanja
<b>Course title:</b>	Design on forming technologies
<b>Članica nosilka/UL Member:</b>	UL FS

Študijski programi in stopnja	Študijska smer	Letnik	Semestri	Izbirnost
Strojništvo - projektno aplikativni program, prva stopnja, visokošolski strokovni	Proizvodne tehnologije (smer)	3. letnik	1. semester	obvezno

<b>Univerzitetna koda predmeta/University course code:</b>	0563510
<b>Koda učne enote na članici/UL Member course code:</b>	3059-V

Predavanja /Lectures	Seminar /Seminar	Vaje /Tutorials	Klinične vaje /Clinical tutorials	Druge oblike študija /Other forms of study	Samostojno delo /Individual student work	ECTS
30		30			40	4

<b>Nosilec predmeta/Lecturer:</b>	Tomaž Pepelnjak
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<b>Vrsta predmeta/Course type:</b>	Izbirni strokovni predmet/Elective specialised course
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<b>Jeziki/Languages:</b>	Predavanja/Lectures:	Slovenščina
	Vaje/Tutorial:	Slovenščina

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

Izpolnjevanje pogojev za vpis v Visokošolski strokovni študijski program I. stopnje Strojništvo - Projektno aplikativni program.	Meeting the enrollment conditions for the MECHANICAL ENGINEERING - Project Oriented Applied Programme.
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### **Vsebina:**

<p>1. Predavanje: Karakterizacija predelave polimerov</p> <ul style="list-style-type: none"> <li>□ Opredelitve terminologije pri predelavi polimerov</li> <li>□ Predstavitev procesnih lastnosti polimerov ključnih za uspešno predelavo s preoblikovanjem</li> <li>□ Opredelitev glavnih procesov predelave, predstavitev tipičnih izdelkov</li> </ul> <p>2. Predavanje: Brizganje polimerov in napake procesa</p> <ul style="list-style-type: none"> <li>□ Ključni parametri procesa in faze brizganja</li> <li>□ Vpliv parametrov procesa na kakovost izdelka</li> <li>□ Predstavitev napak pri procesu brizganja</li> <li>□ Opredelitev ključnih parametrov, ki vodijo do napak pri brizganju</li> <li>□ Odpravljanje napak pri brizganju</li> </ul> <p>3. Predavanje: Orodja za brizganje polimerov</p> <ul style="list-style-type: none"> <li>□ Glavne komponente orodja za brizganje, delovanje orodja in njihova vloga v preoblikovalnem procesu</li> <li>□ Glavne komponente gravure orodja</li> <li>□ Stranska jedra</li> <li>□ Delitev orodij glede na število izdelkov v orodju</li> </ul> <p>4. Predavanje: Stroji za brizganje polimerov</p> <ul style="list-style-type: none"> <li>□ Predstavitev tipov strojev za brizganje</li> <li>□ Delovanje stroja za brizganje in njihova vloga pri procesu brizganja, kinematika strojev</li> <li>□ Pomožna oprema pri procesu brizganja (sušilna enota, temperirna enota, mešalniki, dozatorji ...)</li> </ul> <p>5. Predavanje: Iztiskavanje polimerov</p> <ul style="list-style-type: none"> <li>□ Koncepti iztiskavanja, namen uporabe, vrste mešanja polimerov</li> <li>□ Stroji za iztiskavanje</li> </ul>	<p><b>Content (Syllabus outline):</b></p> <p>1. Lecture: Characterization of polymer processing</p> <ul style="list-style-type: none"> <li>□ Definitions of terminology for polymer processing</li> <li>□ Presentation of the process properties of polymers, which are decisive for successful processing by forming</li> <li>□ Identification of the most important processing processes, presentation of typical products</li> </ul> <p>2. Lecture: Polymer injection molding and process defects</p> <ul style="list-style-type: none"> <li>□ Key parameters and phases of the injection molding process</li> <li>□ Influence of the process parameters on the product quality</li> <li>□ Presentation of defects in the injection molding process</li> <li>□ Identification of key parameters that lead to injection molding errors</li> <li>□ Troubleshooting injection molding</li> </ul> <p>3. Lecture: Polymer injection moulding tools</p> <ul style="list-style-type: none"> <li>□ The main components of the injection moulding tool, how the tool works and its role in the moulding process</li> <li>□ Main components of the mould</li> <li>□ Side cores</li> <li>□ Division of the tools according to the number of products in the tool</li> </ul> <p>4. Lecture: Polymer injection moulding machines</p> <ul style="list-style-type: none"> <li>□ Introduction of injection moulding machine types</li> <li>□ Functionality of injection moulding machines and their role in the injection moulding process, kinematics of the machines</li> <li>□ Auxiliary equipment for the injection process (drying unit, temperature control unit, mixers, dispensers ...)</li> </ul> <p>5. Lecture: Polymer extrusion</p>
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<p>□ Izvedbe iztiskavanja, njihove prednosti in slabosti</p> <p>6. Predavanje: Termoformiranje in pihanje</p> <p>□ Predstavitev tehnologije, omejitve, zahteve za material</p> <p>□ Prednosti in slabosti termoformiranja pred ostalimi postopki predelave termoplastov</p> <p>□ Glavne vrste termoformiranja: predstavitev posamezne izvedbe tehnologije, prednosti in slabosti</p> <p>□ Glavne vrste pihanja: predstavitev posamezne izvedbe, prednosti in slabosti</p> <p>7. Predavanje: Nizkotlačni postopki predelave polimerov</p> <p>□ Karakterizacija postopkov nizkotlačne predelave polimerov: rotacijski liv in centrifugalni liv</p> <p>□ Proces kalandiranja; namen uporabe in karakteristike</p> <p>□ Potek hladnega preoblikovanja polimerov, področja uporabe, prednosti pred termoformiranjem, omejitve procesa</p> <p>8. Predavanje: Preoblikovanje duroplastov</p> <p>□ Karakterizacija postopkov predelave duroplastov</p> <p>□ Predstavitev postopkov, njihovih prednosti in slabosti</p> <p>□ Prešanje</p> <p>□ Nizkotlačno reakcijsko brizganje</p> <p>□ Brizganje in brizgalno prešanje</p> <p>□ Litje</p> <p>9. Predavanje: Opredelitev preoblikovanja kovinskih materialov</p> <p>□ Napetosti in plastične deformacije materiala, povzročene preoblikovalne sile in njihova delitev glede na preoblikovalni postopek, opredelitev deformacijskega dela</p> <p>□ Enostopenjsko in večstopenjsko preoblikovanje, vplivi na deformacijsko delo</p> <p>□ Pomen sile in dela za izbiro procesa in preoblikovalnega stroja</p> <p>10. Predavanje: Globoki vlek pločevinskih surovcev</p>	<p>□ Extrusion concepts, intended use, type of polymer blending</p> <p>□ Extruder Machines</p> <p>□ Variants of extrusion, their advantages and disadvantages</p> <p>6. Lecture: Thermoforming and blow moulding</p> <p>□ Technology presentation, limitations, material requirements</p> <p>□ Advantages and disadvantages of thermoforming compared to other thermoplastic processing methods</p> <p>□ Main types of thermoforming: presentation of the individual technology implementation, advantages and disadvantages</p> <p>□ Main types of blow moulding: presentation of individual performance, strengths and weaknesses</p> <p>7. Lecture: Low pressure polymer processing</p> <p>□ Characterization of low pressure polymer processing: rotary casting and centrifugal casting</p> <p>□ Calender process; intended use and characteristics</p> <p>□ Cold polymer forming process, scope, advantages over thermoforming, process limits</p> <p>8. Lecture: Forming of thermosets</p> <p>□ Characterization of thermoset processing operations</p> <p>□ Presentation of the processes, their advantages and disadvantages</p> <p>□ Compression forming</p> <p>□ Low pressure reaction injection moulding</p> <p>□ Injection moulding and injection compression moulding</p> <p>□ Casting</p> <p>9. Lecture: Definition of forming of metallic materials</p> <p>□ Stresses and plastic strains of the material, induced forming forces and their determination according to the forming process, definition of the deformation work</p> <p>□ Single-stage and multi-stage forming, effects on the deformation work</p> <p>□ The importance of force and</p>
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<ul style="list-style-type: none"> <li>□ Karakterizacija postopka in ključne veličine, analitična analiza postopka</li> <li>□ Globoki vlek okroglih in neokroglih izdelkov</li> <li>□ Ključni tehnološki parametri procesa in ukrepi za njihovo obvladovanje</li> <li>□ Enostopenjski in večstopenjski vlek; smernice za izbiro in snovanje procesa</li> </ul> <p>11. Predavanje: Upogibanje pločevine</p> <ul style="list-style-type: none"> <li>□ Karakterizacija postopka in ključne veličine</li> <li>□ Določitev potrebnih dimenzij surovca</li> <li>□ Analiza pojava elastičnega izravnavanja in ukrepi za njegovo zmanjševanje</li> </ul> <p>12. Predavanje: Rezanje in fino rezanje pločevine</p> <ul style="list-style-type: none"> <li>□ Koncepti preoblikovanja s strižno deformacijo – potek postopka, robni pogoji, oblike orodja</li> <li>□ Razlike med rezanjem in finim rezanjem, vpliv rezalne zračnosti</li> <li>□ Natančnost procesa rezanja</li> <li>□ Ukrepi pri postopkih strižnega preoblikovanja za izboljševanje stabilnosti in kakovosti procesa</li> </ul> <p>13. Predavanje: Kovanje</p> <ul style="list-style-type: none"> <li>□ Vrste kovanja</li> <li>□ Vplivni parametri postopka kovanja in optimizacija procesnih parametrov</li> <li>□ Natančnost procesa kovanja</li> </ul> <p>14. Predavanje: Kombinirani postopki preoblikovanja kovin in dosegljiva izdelovalna natančnost</p> <ul style="list-style-type: none"> <li>□ Predstavitev možnih kombinacij postopkov</li> <li>□ Opredelitev izdelovalne natančnosti preoblikovalnih postopkov</li> <li>□ Integracija preoblikovalnih postopkov za skrajševanje proizvodnih verig</li> </ul> <p>15. Predavanje: Orodja, stroji in sistemi za preoblikovanje kovin</p> <ul style="list-style-type: none"> <li>□ Opredelitev vloge orodij in strojev za preoblikovanje kovin na kakovost preoblikovalnega procesa</li> <li>□ Predstavitev tipične sestave preoblikovalnega orodja in njegovih komponent</li> <li>□ Predstavitev sodobnih strojev za</li> </ul>	<p>deformation work in the choice of process and forming machine</p> <p>10. Lecture: Deep drawing of sheet metal</p> <ul style="list-style-type: none"> <li>□ Process characterization and key parameters, analytical process analysis</li> <li>□ Deep drawing of round and non-round products</li> <li>□ Key technological parameters of the process and measures to control them</li> <li>□ Single-step and multi-step deep drawing; process selection and design guidelines</li> </ul> <p>11. Lecture: Sheet metal bending</p> <ul style="list-style-type: none"> <li>□ Process characterization and key parameters</li> <li>□ Determining the required dimensions of the blank</li> <li>□ Analysis of the phenomenon of elastic springback and measures to reduce it</li> </ul> <p>12. Lecture: Cutting and fine blanking of sheet metal</p> <ul style="list-style-type: none"> <li>□ Concepts for shear deformation - process course, boundary conditions, tool shapes</li> <li>□ Differences between cutting and fine blanking, the influence of the cutting clearance</li> <li>□ The precision of the cutting process</li> <li>□ Measures in shear forming processes to improve process stability and quality</li> </ul> <p>13. Lecture: Forging</p> <ul style="list-style-type: none"> <li>□ Types of forging</li> <li>□ Influential parameters of the forging process and optimization of process parameters</li> <li>□ The accuracy of the forging process</li> </ul> <p>14. Lecture: Combined metal forming processes and achievable manufacturing accuracy</p> <ul style="list-style-type: none"> <li>□ Presentation of possible process combinations</li> <li>□ Definition of the manufacturing accuracy of forming processes</li> <li>□ Integration of forming processes to shorten production chains</li> </ul> <p>15. Lecture: Tools, machines and systems for metal forming</p> <ul style="list-style-type: none"> <li>□ Definition of the role of tools and</li> </ul>
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preoblikovanje kovin	machines for metal forming on the quality of the forming process ☐ Representation of the typical design of the forming tool and its components ☐ Presentation of modern metal forming machines
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### Temeljna literatura in viri/Readings:

1. S. Kalpakjian, S.R. Schmidt: Manufacturing Engineering and Technology, Prentice Hall, Singapore, 7. izdaja, 2013.
2. Skupina avtorjev: Moderno proizvodno inženirstvo – priročnik, K. Kuzman (Edt.), Grafis trade,d.o.o, Grosuplje, 2010.
3. Z. Kampuš: Osnove tehnologije preoblikovanja kovin : preoblikovanje pločevine, masivno preoblikovanje : učbenik, Ljubljana : Fakulteta za strojništvo, 2014.
4. Kampuš, Z.; Kuzman, K.: Priporočila preoblikovanja, Fakulteta za strojništvo Univerze v Ljubljani, Ljubljana, 201
5. J. Navodnik, M. Kopčič: Plastik-orodjar : priročnik, 3. dopolnjena izdaja, Velenje : Navodnik, 1998.
6. Schuler GmbH: Metal Forming Handbook, Springer Science & Business Media, 2012.
7. T. Pepelnjak: Preoblikovalni stroji, elektronski vir, Ljubljana, Fakulteta za strojništvo, 2012.

### Cilji in kompetence:

#### Cilji:

1. Spoznati primernost posameznega preoblikovalnega postopka za proizvodnjo izdelkov s specifičnimi lastnostmi.
2. Spoznati izdelovalne tolerance preoblikovalnih postopkov in detektirati napake in motnje v izdelovalnem procesu.
3. Spoznati tehnološke parametre posameznih preoblikovalnih procesov in opredeliti njihove vrednosti za kakovostno in stabilno preoblikovanje.
4. Spoznati načine in koncepte za opredelitev ustreznih kombinacij preoblikovalnih postopkov in opredeliti kako izbrane postopke združiti v celovit izdelovalni proces.
5. Spoznati, kako snovati, konstruirati in testirati preoblikovalno orodje skladno s ključnimi obremenitvami ter kako nastaviti ustrezne obratovalne parametre na izbranem

### Objectives and competences:

#### Objectives:

1. To understand the suitability of each forming process for the production of products with specific characteristics.
2. To know the manufacturing tolerances of forming processes and to detect defects and disturbances in the manufacturing process.
3. Become familiar with the technological parameters of the individual forming processes and define their values for quality and stable forming.
4. To learn ways and concepts to identify the appropriate combinations of forming processes and define how the selected processes can be combined to form a complete manufacturing process.
5. Learn how to design, construct and test a forming tool according to the main loads and how to set the corresponding operating parameters

<p>preoblikovalnem stroju.</p> <p>Kompetence:</p> <ol style="list-style-type: none"> <li>1. S2-PAP+P1-PAP+P3-PAP: Sposobnost opredelitve primernosti izbire preoblikovalnega procesa skladno s performansami izdelka.</li> <li>2. S8-PAP+P1-PAP+P4-PAP: Sposobnost prepoznavanja izdelovalnih toleranc, napak in motenj obravnavanega preoblikovalnega procesa.</li> <li>3. S7-PAP+P6-PAP: Sposobnost opredelitve tehnoloških parametrov za kakovosten in stabilen potek preoblikovalnega procesa.</li> <li>4. S1-PAP+S12-PAP+P8-PAP: Sposobnost samostojne opredelitve kombinacij preoblikovalnih postopkov in njihova integracija v celovit izdelovalni proces.</li> <li>5. S13-PAP+P9-PAP: Sposobnost snovanja, konstrukcije in preverjanja preoblikovalnega orodja skladno s ključnimi obremenitvenimi in obratovalnimi parametri na izbranem preoblikovalnem stroju.</li> </ol>	<p>on the selected forming machine.</p> <p>Competences:</p> <ol style="list-style-type: none"> <li>1. S2-PAP+P1-PAP+P3-PAP: Ability to determine the appropriateness of the choice of a forming process in relation to the performance of the product.</li> <li>2. S8-PAP+P1-PAP+P4-PAP: Ability to identify the manufacturing tolerances, defects and disturbances of the forming process under consideration.</li> <li>3. S7-PAP+P6-PAP: Ability to define technological parameters for a quality and stable course of the forming process.</li> <li>4. S1-PAP+S12-PAP+P8-PAP: Ability to independently identify combinations of forming processes and integrate them into a complete manufacturing process.</li> <li>5. S13-PAP+P9-PAP: Ability to design, construct, and validate forming tools according to the main loads and operating parameters on the selected forming machine.</li> </ol>
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### **Predvideni študijski rezultati:**

<p>Znanja:</p> <p>Z1: Poglobljeno strokovno in teoretično znanje na področju načrtovanja tehnologij preoblikovanja, podprto s širšo teoretično in metodološko osnovo:</p> <ul style="list-style-type: none"> <li>• poglobljeno strokovno teoretično in praktično znanje o procesih in tehnologijah preoblikovanja kovinskih in nekovinskih gradiv.</li> <li>• Razumevanje osnovnih zakonitosti preoblikovalnih postopkov.</li> <li>• Razumevanje problemov preoblikovalnosti glede na material, preoblikovalni sistem.</li> <li>• Znanje potrebno za opredelitev omejitev pri izbiri posamezne tehnologije in zanjo potrebne opreme ter za določitev ustreznega preoblikovalnega postopka po</li> </ul>	<p>Knowledge:</p> <p>Z1: In-depth technical and theoretical expertise in the design of forming technology, supported by a broader theoretical and methodological basis:</p> <ul style="list-style-type: none"> <li>- In-depth technical theoretical and practical knowledge of processes and technologies for forming metallic and non-metallic materials.</li> <li>- Understanding of the basic principles of forming processes.</li> <li>- Understanding the problems of formability in relation to the material, the forming system.</li> <li>- The knowledge required to identify the limitations in the choice of technology and equipment and to determine the appropriate forming process according</li> </ul>
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<p>različnih kriterijih.</p> <p><b>Spretnosti:</b></p> <p>S1.1 Izvajanje kompleksnih operativno-strokovnih nalog izbire tehnologije preoblikovanja, ki vključujejo ustrezno uporabo analitičnih, numeričnih in računalniško podprtih metodoloških orodij.</p> <p>S1.2 Obvladovanje zahtevnih, kompleksnih delovnih procesov preoblikovanja kovinskih, nekovinskih ali integrirano mešanih komponent ob samostojni uporabi znanja v novih delovnih situacijah.</p> <p>S1.3 Diagnosticiranje in reševanje problemov v specifičnih delovnih okoljih proizvodnih obratov, povezanih s področjem usposabljanja za kakovostno preoblikovanje materialov.</p>	<p>to various criteria.</p> <p><b>Skills:</b></p> <p>S1.1 Perform complex operational and technical tasks in the selection of forming technology with appropriate use of analytical, numerical and computer-aided methodological tools.</p> <p>S1.2 Master demanding, complex work processes in the forming of metallic, non-metallic or integrated mixed components with independent application of the knowledge in new work situations.</p> <p>S1.3 Diagnosis and problem solving in specific working environments of production facilities related to the field of training in forming of quality materials.</p>
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#### **Metode poučevanja in učenja:**

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.

P4 Laboratorijske vaje z namenski didaktičnimi pripomočki:

- Hidravlična stiskalnica z orodjem za preoblikovanje pločevine
- Univerzalni preizkuševalni stroj z orodji za štančanje in upogibanje
- Stroj za brizganje polimerov

P7 Študij literature in razprava

P8 Izdelava in predstavitev aplikativnih seminarskih nalog

P12 Individualizirane domače naloge v spletni učilnici

P15 Uporaba video vsebin kot priprava na predavanja in vaje

#### **Learning and teaching methods:**

P4 Laboratory exercises with special-purpose didactic devices:

- Hydraulic press with tooling for sheet metal forming
- Hydraulic testing machine with tools for stamping and bending
- Injection moulding machine

P7 Literature study and discussion.

P8 Making and presenting applied seminar exercises.

P12 Individualised homeworks in a web classroom.

P15 Application of videos for preparations to the lectures and exercises.

**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)
Projektno delo	20,00 %	Project work

**Reference nosilca/Lecturer's references:**

Tomaž Pepelnjak:

1. **PEPELNJAK, Tomaž**, ŠAŠEK, Patricia, KUDLÁČEK, Jan. Upsetting analysis of high-strength tubular specimens with the Taguchi method. *Metals*, ISSN 2075-4701, Nov. 2016, vol. 6, iss. 11, f. 1-14, ilustr. <http://www.mdpi.com/2075-4701/6/11/257/html>, doi: [10.3390/met6110257](https://doi.org/10.3390/met6110257). [COBISS.SI-ID [15008283](#)]
2. **PEPELNJAK, Tomaž**, BARIŠIČ, Branimir. Computer-assisted engineering determination of the formability limit for thin sheet metals by a modified Marciniak method. *Journal of strain analysis for engineering design*, ISSN 0309-3247, 2009, vol. 44, iss. 6, str. 459-47 <http://dx.doi.org/10.1243/03093247JSA503>, doi: 10.1243/03093247JSA503. [COBISS.SI-ID 11002907]
3. BALOŠ, Sebastian, MILUTINOVIĆ, Mladomir, POTRAN, Michal, VULETIĆ, Jelena, PUŠKAR, Tatjana, **PEPELNJAK, Tomaž**. The mechanical properties of moulded and thermoformed denture resins. *Strojniški vestnik*, ISSN 0039-2480, Feb. 2015, vol. 61, no. 2, str. 138-145, SI 25, ilustr., doi: [10.5545/sv-jme.2014.2249](https://doi.org/10.5545/sv-jme.2014.2249). [COBISS.SI-ID [13894939](#)]
4. BORIČ, Andrej, **PEPELNJAK, Tomaž**, JURKOVIĆ, Zoran. Single point incremental forming of polymers : a review of process parameters. V: **PEPELNJAK, Tomaž** (ur.), CAR, Zlatan (ur.), KUDLÁČEK, Jan (ur.). *IN-TECH 2017 : proceedings*, International Conference on Innovative Technologies, Ljubljana, [11. - 13. 9.] 2017, (Proceedings (International Conference on Innovative Technologies), ISSN 1849-0662). Rijeka: Faculty of Engineering. 2017, str. 255-258, ilustr. [COBISS.SI-ID [15649307](#)]
5. KOBOLD, Dominik, **PEPELNJAK, Tomaž**, HANČIČ, Aleš. Magnesium anisotropic material flow at applied plastic deformation. V: HANČIČ, Aleš (ur.), et al. *Conference proceedings*, 9th International Conference on Industrial Tools and Material Processing Technologies [also] ICIT & MPT, Ljubljana, Slovenia, April 9th - 11th 2014. Celje: TECOS, Slovenian Tool and Die Development Centre. 2014, str. 361-364, ilustr. [COBISS.SI-ID [13413147](#)]