TEHNOLOGIJA MONTAŽE

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	Tehnologija montaže
Course title:	Assembly technology
Članica nosilka/UL Member:	UL FS

Študijski programi in stopnja	**Študijska smer**	**Letnik**	**Semestri**	**Izbirnost**
Strojništvo - projektno aplikativni program, prva stopnja, visokošolski strokovni	Proizvodne tehnologije (smer)	2. letnik	2. semester	obvezni

Univerzitetna koda predmeta/University course code:	0563507
Koda učne enote na članici/UL Member course code:	3058-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

Nosilec predmeta/Lecturer:	Marko Šimic, Miha Pipan, Niko Herakovič

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

Vrsta predmeta/Course type:	Izbirni strokovni predmet/Elective specialised course

Jeziki/Languages:	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.

Vsebina:	**Content (Syllabus outline):**
1. Montaža v proizvodnem sistemu - Opredelitev procesa montaže kot dela proizvodnega procesa - Montaža v življenjski dobi izdelka - Vpliv parametrov na izbiro montažnih metod - Povezovanje montaže z ostalimi procesi izdelave	1. Assembly in the production system - Defining the assembly process as part of the production process - Assembly during product life cycle - The influence of parameters on the choice of assembly methods - Connecting assembly to other manufacturing processes
2. Izdelki - Izdelki, končni izdelki, polizdelki, podsestavi, podsklopi, sestavni deli, bazni deli - Struktura izdelkov - Primeri strukture izdelkov - Obvladovanje variantnosti izdelkov - Skupine in družine izdelkov	2. Products - Products, finished products, semi-finished products, subassemblies, subsystems, components, base parts - Product structure - Examples of product structure - Managing product variance - Groups and product families
3. Proces montaže in montažne operacije - Montažni proces, vplivne veličiene, zveze in njihov vpliv na montažni proces - Predmontaža in končna montaža, montažne operacije, kriteriji delitve na predmontažo in končno montažo - Čas montažne operacije, entitetno-relacijski model - Metode določanja časa montažnih operacij	3. The assembly process and assembly operations - The assembly process, the influential parameters, connections and their influence on the assembly process - Pre-assembly and final assembly, assembly operations, division criteria for pre-assembly and final assembly - Time of assembly operations, entity-relational model - Methods of determining the time of assembly operations
4. Struktura montažnega procesa - Struktura montaže in zaporednje montažnih operacij - Primeri strukture montažnega procesa - Skupni čas montaže, takt in delovni cikel, čas montažnega mesta	4. Structure of the assembly process - Assembly structure and sequence of assembly operations - Examples of the assembly process

□ Balansiranje montažnega procesa □ Skupine in družine izdelkov 5. Montažni sistemi (MS) □ Opredelitev in načini gradnje MS, montažni podsistemi □ Tipi avtomatizacije MS, hibridni MS □ Montažni sistemi in fleksibilnost □ Organiziranost in povezanost MS ter koncepti □ Vplivne veličine na izbiro koncepta montažnega sistema 6. Ročni montažni sistemi □ Ergonomsko oblikovanje delovnega mesta □ Ukrepi za lažje delo □ Skrajšanje časov montažni operacij □ Metode virtualnega oblikovanja ročnih montažnih mest in modeliranje človeka □ Primeri ergonomsko oblikovanih ročnih montažnih mest □ Ročna montaža v virtualnem okolju, uporaba modeliranja in simulacije 7. Organiziranost ročnih montažnih sistemov □ Posamična montažna mesta □ Ročna montaža na več mestih – pretočna montaža z ročnim podajanjem □ Pretočna montaža z mehanskim podajanjem izdelkov v urejenem stanju □ Paletni sistemi, postavitev ročnih montažnih mest ob paletni sistem 8. Cenena inteligenta ročna montaža □ Načini za povečanje učinkovitosti ročnih montažnih sistemov □ U-celice □ Implementacija cenenih konceptov Poka-yoke in enostavnih, inteligentnih ter učinkovitih montažnih pripomočkov 9. Ročna montaža in Industrija 5.0 □ Metodologija Industrije 5.0 za povečanje učinkovitosti ročnih montažnih mest □ Tehnologije 5.0 in povezanost z delavcem □ Virtualno usposabljanje in trening delavcev, VR in AR □ Uporaba simulacije in tehnologije digitalnih dvojčkov montažnega procesa 10. Avtomatizirani montažni sistemi	structure □ Total assembly time, tact and duty cycle, assembly station time □ Balancing the assembly process □ Groups and product families 5. Assembly systems (AS) □ Definition and construction methods of AS, assembly subsystems □ Types of AS automation, hybrid AS □ Assembly systems and flexibility □ Organization and connection of AS and concepts □ Effective parameters for the selection of the concept of the assembly system 6. Manual assembly systems □ Ergonomic workplace design □ Measures for easier work □ Reducing the assembly operations times □ Methods of virtual design of manual assembly workplaces and human modelling □ Examples of ergonomically designed manual assembly workplaces □ Manual assembly in virtual environment, use of modelling and simulation 7. Organization of manual assembly systems □ Individual assembly workplaces □ Multiple assembly workplaces - Flow assembly with manual feeding □ Flow assembly with mechanical feeding of the products in an ordered condition □ Pallet systems, setting of manual assembly workplaces next to the pallet system 8. Low-cost intelligent manual assembly □ Ways to increase the efficiency of manual assembly systems □ U-cells □ Implementation of low-cost Poka-yoke concepts and simple, intelligent and efficient assembly accessories 9. Manual assembly and the Industry 5.0 □ Industry 5.0 methodology for the increase of the efficiency of manual assembly workplaces

 Opredelitev, tehnično ekonomski in sociološki razlogi za avtomatizacijo montaže
 Pogoji za uspešno uvajanje avtomatizirane montaže
 Diagram uvajanja novega avtomatiziranega montažnega sistema
 Vrste avtomatiziranih montažnih sistemov

11. Togi avtomatizirani montažni sistemi
 Značilnosti, pogoji in kriteriji implementacije
 Enopostajni avtomati
 Krožni avtomati
 Linijski avtomati
 Povezovanje togih avtomatov med seboj
 Možnosti vključitve ročnih montažnih mest v toge avtomatizirane sisteme

12. Fleksibilni avtomatizirani montažni sistemi
 Opredelitev fleksibilnosti, produktivnosti in cene, vrste fleksibilnosti, sposobnost prilagajanja obsegu proizvodnje
 Modularna gradnja fleksibilnih montažnih sistemov ter ponovna uporaba (Re-use)
 Vrste fleksibilnih avtomatiziranih montažnih sistemov in njihove značilnosti
 Vključevanje ročnih montažnih mest v fleksibilne avtomatizirane montažne sisteme
 Flesibilni montažni sistemi s paletnim prenosom in avtomatsko vodenimi vozički

13. Avtomatizacija operacij sestavljanja in urejanje ter urejevalne naprave
 Vrste zvez in postopkov sestavljanja
 Vijačenje, značilnosti, kriteriji avtomatizacije vijačenja, napake
 Kovičenje, značilnosti, kriteriji avtomatizacije kovičenja, napake
 Toge in fleksibilne urejevalne naprave
 Povezovanje urejevalnih naprav z montažnimi mesti in sistemi
 Veličine, ki vplivajo na izbiro urejevalnih naprav

14. Oblikovanje izdelkov za montažo

 Technologies 5.0 and connections with the employee
 Virtual training and employee training, VR and AR
 The use of simulation and digital twin technology of assembly process

10. Automated assembly systems
 Definition, technical, economic and sociological reasons for assembly automation
 Conditions for successful introduction of automated assembly
 Diagram of the introduction of a new automated assembly system
 Types of automated assembly systems

11. Rigid automated assembly systems
 Characteristics, conditions and criteria of implementation
 One-station automated machines
 Circular automated machines
 Automated line machines
 Connecting rigid automated machines to each other
 Possibilities of including manual assembly workplaces in rigid automated systems

12. Flexible automated assembly systems
 Defining flexibility, productivity and price, types of flexibility, ability to adapt to production volume
 Modular design of flexible assembly systems and re-use
 Types of flexible automated assembly systems and their characteristics
 Inclusion of manual assembly workplaces in flexible automated assembly systems
 Flexible assembly systems with pallet transport and automatic guided wehicles

13. Automation of assembly operations, arrangement and arrangement devices
 Types of joining technichs and assembly procedures
 Screwing, characteristics, criteria for screwing automation, errors
 Riveting, characteristics, criteria for automation of riveting, errors
 Rigid and flexible arrangement devices
 Connecting handling devices to

□ Oblikovanje izdelkov za ročno montažo in smernice □ Oblikovanje izdelkov za avtomatizirano montažo in smernice □ Izboljšanje organiziranosti montaže □ Virtualna montaža in oblikovanje izdelkov 15. Planiranje montažnih procesov in sistemov □ Opredelitev, izhodišča, vplivni parametri □ Metodologija planiranja montažnih sistemov in procesov, osem korakov, časovni vidik aktivnosti □ Cilji in metode načrtovanja montažnih procesov in sistemov □ Računalniško podprte metode načrtovanja montažnih in strežnih procesov in sistemov □ Koraki pri izdelavi koncepta, integralni model načrtovanja	assembly workplaces and systems □ Parameters that influence the choice of handling devices 14. Design of products for assembly □ Designing products for manual assembly and guidelines □ Designing products for automated assembly and guidelines □ Improving the organization of assembly □ Virtual assembly and product design 15. Planning of assembly processes and systems □ Definition, starting points, impact parameters □ Methodology of planning of assembly systems and processes, eight steps, time aspect of activities □ Objectives and design methods for assembly processes and systems □ Computer aided design methods for assembly and handling processes and systems □ Concept design steps, integral design model

Temeljna literatura in viri/Readings:

Boothroyd, G.: Assembly Automation and Product Design, Second edition, CRC Press, 2005

Herakovič, N.: Tehnologija montaže, Učno gradivo, UL FS, 2019

Groover, Mikell P.: Automation, Production Systems, and Computer-Integrated Manufacturing, 2007

Takeda, H.: LCIA – Low Cost Intelligent Automation, 2. Auflage, SPS, 2006

Nof, S. Y., Wilhelm W.I., Warnecke H.-J.:Industrial Assembly, Chapman & Hall, London, 1997

Kopač., J., Noe, D.: Strega in montaža, UL FS, 1989

Cilji in kompetence:	**Objectives and competences:**
Cilji: Usvojiti osnovna znanja in tehnike strukturiranja izdelkov in montažnih procesov Usvojiti osnovna znanja in tehnologije ergonomskega oblikovanja ročnih delovnih mest in oblikovanja izdelkov za	Objectives: To gain basic knowledge and techniques of product structuring and assembly processes To acquire basic knowledge and technologies of ergonomic design of manual workplaces and design of

montažo	products for assembly
Usvojiti osnove avtomatizacije montaže in osnovne tehnologije montažnih procesov	To gain the basics of assembly automation and basic technologies of assembly processes
Spoznati osnovna znanja in tehnike za optimizacijo montažnih procesov in sistemov	To gain basic knowledge and techniques for optimizing assembly processes and systems
Spoznati načine in tehnike načrtovanja montažnih procesov in sistemov	To learn the ways and techniques of designing assembly processes and systems
Kompetence:	Competencies:
Izdelava montažno orientirane strukture izdelka in procesa, ki omogoča načrtovanje učinkovitih montažnih procesov in sistemov	Creation of assembly-oriented product and process structure that enables the design of efficient assembly processes and systems
Načrtovanje ergonomsko oblikovanih ročnih in hibridnih montanih mest ter oblikovanje izdelkov za enostavno in učinkovito montažo	Design of ergonomic manual and hybrid assembly workplaces and design of products for simple and efficient assembly
Sprejemanje odločitev o stopnji, načinu in tipu avtomatizacije montažnih procesov	Making decisions about the degree, manner and type of automation of assembly processes
Sposobnost analize in optimiranja montažnih procesov in sistemov	Ability to analyze and optimize assembly processes and systems
Sposobnost načrtovanja učinkovitih in cenenih ter naprednih montažnih procesov in sistemov	Ability to design efficient and inexpensive and advanced assembly processes and systems

Predvideni študijski rezultati:	**Intended learning outcomes:**
Znanja:	Knowledge:
Poznavanje in razumevanje osnov ročnih in avtomatiziranih ter robotiziranih montažnih procesov in sistemov, oblikovanja izdelkov za montažo (DFA), ter osnov strukturiranja izdelka in montažnega procesa na način, da bo montažni proces najbolj učinkovit.	Knowledge and understanding of the basics of manual and automated and robotic assembly processes and systems, product design for assembly (DFA), and the basics of structuring of product and assembly process in such a way that the assembly process will be most effective.
Spretnosti:	Skills:
Izdelava strukture izdelka in procesa na način, da bo možno razviti učinkovit in sledljiv ter tansparenten montažni proces in sistem	Designing the product and process structure in such a way that it is possible to develop an efficient, traceable and transparent assembly process and system
Uporaba računalniško podprtih programskih orodij za razvoj in analizo	Using computer-aided software tools for

montažnih procesov in sistemov Programiranje robotov in izvajanje simulacij gibanj robotske roke Izbira montažnemu procesu ustreznih in učinkovitih tehnologij avtomatizacije in robotizacije	the development and analysis of assembly processes and systems Programming robots and performing simulations of robot arm movements Choosing efficient automation and robotization technologies that are appropriate for the assembly process

Metode poučevanja in učenja:	**Learning and teaching methods:**
P1, P2 Avditorna predavanja podprta z interaktivnim prikazom praktičnih primerov P3 Avditorne vaje z reševanjem praktičnih primerov P4 Laboratorijske vaje s timskim reševanjem aplikativnih problemov in uporabo programske opreme ter njihova predstavitev z razpravo. P5 Uporaba študijskega gradiva v e-obliki, skripta in e-verzija predavanj. P6 Interaktivna predavanja	P1, P2 Lectures supported by interactive presentation of practical examples P3 Tutorials solving practical examples P4 Laboratory exercises with team solving of application problems, using software and presenting them with discussion. P5 Use of study material in e-form, lecture notes and e-version of lectures. P6 Interactive lectures

Načini ocenjevanja:	**Delež/ Weight**	**Assessment:**
Teoretične vsebine (predavanja): Kolokviji, pisni in/ali ustni izpit	50,00 %	Theoretical contents (lectures): Clloquium, writing and/or oral exam
Samostojno delo na avditornih in laboratorijskih vajah (vključno s poročili):	50,00 %	Individual work in exercises, individual laboratory work (including reports):

Reference nosilca/Lecturer's references:

Niko Herakovič:

1. PIPAN, Miha, KOS, Andrej, HERAKOVIČ, Niko. Adaptive algorithm for the quality control of braided sleeving : Miha Pipan, Andrej Kos, and Niko Herakovic. *Advances in mechanical engineering*, ISSN 1687-8132. [Printed ed.], 2014, str. 1-8, ilustr., doi: 10.1155/2014/812060. [COBISS.SI-ID 13667611], [JCR, SNIP, WoS, Scopus]
2. GACEVA, Gordana Bogoeva, HERAKOVIČ, Niko, DIMESKI, Dimko, STEFOV, Viktor. Ultrasound assisted process for enhanced interlaminar shear strength of carbon fiber/epoxy resin composites. *Macedonian journal of chemistry and chemical engineering*, ISSN 1857-5552, 2010, vol. 29, no. 2, str. 149-155. [COBISS.SI-ID 11851291], [JCR, SNIP, WoS, Scopus]
3. HERAKOVIČ, Niko. Flow-force analysis in a hydraulic sliding-spool valve.

Strojarstvo : časopis za teoriju i praksu u strojarstvu, ISSN 0562-1887, 2009, vol. 51, no. 6, str. 555-564. http://hrcak.srce.hr/index.php?show=clanak&id_clanak_jezik=77620. [COBISS.SI-ID 11989787], [JCR, SNIP]

4. HERAKOVIČ, Niko, NOE, Dragica. Experimental analysis of conditions for machine vision control in EM stator assembly process. V: *IFAC Workshop on Intelligent Assembly and Disassembly, IAD'07, Alicante, Spain, May 23-25, 2007*. [Alicante]: [Universidad de Alicante]. 2007, str. 110-115. [COBISS.SI-ID 10336795], [Scopus]
5. HERAKOVIČ, Niko, ZUPAN, Hugo, DEBEVEC, Mihael. *FMS simulation model and analysis of the factory : report of the project (done in year 2017)*. Ljubljana: Fakulteta za strojništvo, Laboratorij LASIM, 2017. 12 f., ilustr. [COBISS.SI-ID 16025883]

Marko Šimic:

1. TURK, Maja, **ŠIMIC, Marko**, PIPAN, Miha, HERAKOVIČ, Niko. Multi-criterial algorithm for the efficient and ergonomic manual assembly process. *International journal of environmental research and public health*. [Online ed.]. Mar. 2022, vol. 19, iss. 6, str. 1-17, ilustr. ISSN 1660-4601. https://www.mdpi.com/1660-4601/19/6/3496, DOI: 10.3390/ijerph19063496. [COBISS.SI-ID 101798659], [JCR, SNIP, WoS do 25. 2. 2023: št. citatov (TC): 4, čistih citatov (CI): 4, čistih citatov na avtorja (CIAu): 1,00, Scopus do 22. 1. 2023: št. citatov (TC): 4, čistih citatov (CI): 4, čistih citatov na avtorja (CIAu): 1,00]
2. TURK, Maja, PIPAN, Miha, **ŠIMIC, Marko**, HERAKOVIČ, Niko. Simulation-based time evaluation of basic manual assembly tasks. *Advances in production engineering & management*. Sep. 2020, vol. 15, no. 3, str. 331-344, ilustr. ISSN 1854-6250. http://www.apem-journal.org/Archives/2020/Abstract-APEM15-3_331-344.html, DOI: 10.14743/apem2020.3.369. [COBISS.SI-ID 40044035], [JCR, SNIP, WoS do 3. 11. 2022: št. citatov (TC): 6, čistih citatov (CI): 6, čistih citatov na avtorja (CIAu): 1,50, Scopus do 12. 11. 2022: št. citatov (TC): 8, čistih citatov (CI): 8, čistih citatov na avtorja (CIAu): 2,00]
3. TURK, Maja, PIPAN, Miha, **ŠIMIC, Marko**, HERAKOVIČ, Niko. A smart algorithm for personalizing the workstation in the assembly process. *Applied sciences*. Dec. 2020, vol. 10, iss. 23, f. 1-19, ilustr. ISSN 2076-3417. https://www.mdpi.com/2076-3417/10/23/8624/htm, DOI: 10.3390/app10238624. [COBISS.SI-ID 40663299], [JCR, SNIP, WoS do 12. 1. 2023: št. citatov (TC): 5, čistih citatov (CI): 4, čistih citatov na avtorja (CIAu): 1,00, Scopus do 14. 2. 2023: št. citatov (TC): 5, čistih citatov (CI): 4, čistih citatov na avtorja (CIAu): 1,00]
4. **ŠIMIC, Marko**, HERAKOVIČ, Niko. Advanced spool materials for friction reduction in pneumatic valves. V: LOVREC, Darko (ur.), TIČ, Vito (ur.). Conference proceedings. International Conference Fluid Power 2019. 1st ed. Maribor: University of Maribor Press, Faculty of Mechanical Engineering, 2019. Str. [75]-87, ilustr. ISBN 978-961-286-301-2. [COBISS.SI-ID 16798491]
5. JANKOVIČ, Denis, NOVAK, Rok, **ŠIMIC, Marko**, HERAKOVIČ, Niko. The concept of automatic generation of hydraulic press cycle. V: LOVREC, Darko (ur.), TIČ, Vito (ur.). International Conference Fluid Power 2021 : conference proceedings : Maribor, Slovenia, 16. - 17. September 2021. 1st ed. Maribor: University of Maribor, University Press, 2021. Str. 285-300, ilustr. ISBN 978-961-286-513-9. DOI: 10.18690/978-961-286-513-9.24. [COBISS.SI-ID 77602051]

Miha Pipan:

1. TURK, Maja, ŠIMIC, Marko, **PIPAN, Miha**, HERAKOVIČ, Niko. Multi-criterial algorithm for the efficient and ergonomic manual assembly process. *International journal of environmental research and public health*. [Online ed.]. Mar. 2022, vol. 19, iss. 6, str. 1-17, ilustr. ISSN 1660-4601. https://www.mdpi.com/1660-4601/19/6/3496, DOI: 10.3390/ijerph19063496. [COBISS.SI-ID 101798659], [JCR, SNIP, WoS do 25. 2. 2023: št. citatov (TC): 4, čistih citatov (CI): 4, čistih citatov na avtorja (CIAu): 1,00, Scopus do 22. 1. 2023: št. citatov (TC): 4, čistih citatov (CI): 4, čistih citatov na avtorja (CIAu): 1,00]
2. DEBEVEC, Mihael, **PIPAN, Miha**, ZUPAN, Hugo, HERAKOVIČ, Niko. An innovative training of production planners through virtual production performing. *Tehnički vjesnik : znanstveno-stručni časopis tehničkih fakulteta Sveučilišta u Osijeku*. Apr. 2016, vol. 23, nr. 2, str. 363-369, ilustr. ISSN 1330-3651. DOI: 10.17559/TV-20150130124330. [COBISS.SI-ID 14633499], [JCR, SNIP, WoS do 26. 10. 2022: št. citatov (TC): 3, čistih citatov (CI): 3, čistih citatov na avtorja (CIAu): 0,75, Scopus do 14. 2. 2023: št. citatov (TC): 5, čistih citatov (CI): 4, čistih citatov na avtorja (CIAu): 1,00]
3. **PIPAN, Miha**, PROTNER, Jernej, HERAKOVIČ, Niko. Distributed manufacturing node control with digital twin. V: ZADNIK STIRN, Lidija (ur.), et al. *SOR '19 proceedings*. Ljubljana: Slovenian Society Informatika, Section for Operational Research, 2019. Str. 257-262, ilustr. ISBN 978-961-6165-55-6. [COBISS.SI-ID 16810523], [Scopus]
4. **PIPAN, Miha**, KOS, Andrej, HERAKOVIČ, Niko. Adaptive algorithm for the quality control of braided sleeving : Miha Pipan, Andrej Kos, and Niko Herakovic. *Advances in mechanical engineering*. [Printed ed.]. 2014, str. 1-8, ilustr. ISSN 1687-8132. DOI: 10.1155/2014/812060. [COBISS.SI-ID 13667611], [JCR, SNIP, WoS do 26. 10. 2022: št. citatov (TC): 1, čistih citatov (CI): 1, čistih citatov na avtorja (CIAu): 0,33, Scopus do 10. 8. 2020: št. citatov (TC): 2, čistih citatov (CI): 2, čistih citatov na avtorja (CIAu): 0,67]
5. DEBEVEC, Mihael, ZUPAN, Hugo, **PIPAN, Miha**, ŠIMIC, Marko, KOS, Andrej, ADROVIĆ, Edo, TURK, Maja, RESMAN, Matevž, HERAKOVIČ, Niko. *Študija proizvodnih zmogljivosti linije za barvanje robotov : razvito za podjetje YASKAWA Europe Robotics d.o.o.* Ljubljana: Fakulteta za strojništvo, Laboratorij za strego, montažo in pnevmatiko, 2017. 7 str., graf. prikazi. [COBISS.SI-ID 15547675]