

## UČNI NAČRT PREDMETA/COURSE SYLLABUS

<b>Predmet:</b>	Krmiljenje in statistični nadzor proizvodnje
<b>Course title:</b>	CONTROL AND STATISTICAL SUPERVISION IN MANUFACTURING
<b>Članica nosilka/UL Member:</b>	UL FS

Študijski programi in stopnja	Študijska smer	Letnik	Semestri
Strojništvo - projektno aplikativni program, prva stopnja, visokošolski strokovni	Industrijsko inženirstvo (smer)	2. letnik	2. semester

<b>Univerzitetna koda predmeta/University course code:</b>	0563546
<b>Koda učne enote na članici/UL Member course code:</b>	3063-V

Predavanja	Seminar	Vaje	Klinične vaje	Druge oblike študija	Samostojno delo	ECTS
30		30			40	4

<b>Nosilec predmeta/Lecturer:</b>	Drago Bračun, Edvard Govekar
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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

<b>Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:</b>	<b>Prerequisites:</b>
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.

<b>Vsebina:</b>	<b>Content (Syllabus outline):</b>
<p>1. Predavanje: Proizvodnja kot kompleksni delovni sistem</p> <ul style="list-style-type: none"> <li>- Kompleksnost v proizvodnji</li> <li>- Pomen subjekta, vloga avtomatizacije, primeri iz prakse</li> <li>- Grafični opis kompleksnih delovnih sistemov po IDEF0 metodologiji (na primerih iz prakse)</li> </ul> <p>2. Predavanje: Sistemi za vodenje in nadzor delovnih sistemov</p> <ul style="list-style-type: none"> <li>- Namen, gradniki, tipične arhitekture SCADA sistemov</li> </ul>	<p>1. Lecture: Manufacturing as a complex work system</p> <ul style="list-style-type: none"> <li>- Manufacturing complexity</li> <li>- The importance of the subject, the role of automation, practical examples</li> <li>- Graphic description of complex work systems according to IDEF0 methodology (based on examples)</li> </ul> <p>2. Lecture: Manufacturing execution and process monitoring systems</p> <ul style="list-style-type: none"> <li>- Purpose, building blocks, typical architectures of SCADA systems</li> </ul>

<ul style="list-style-type: none"> <li>- Komunikacije in uporabniški vmesniki</li> <li>- Nadzorni sistemi</li> <li>- MES in ERP sistemi</li> </ul> <p>3. Predavanje: Avtomatska identifikacija</p> <ul style="list-style-type: none"> <li>- Pregled tehnologij</li> <li>- Črtne in QR kode, RFID</li> <li>- Industrijski internet stvari (IIS)</li> <li>- Osnovni koncepti in senzorska omrežja IIS</li> </ul> <p>4. Predavanje: Avtomatizirana kontrola procesov</p> <ul style="list-style-type: none"> <li>- Procesi in variabilnost</li> <li>- 100% vs. statistična kontrola</li> <li>- Končna vs. porazdeljena kontrola</li> <li>- Primeri iz prakse</li> </ul> <p>5. Predavanje: Metode kontrole procesov</p> <ul style="list-style-type: none"> <li>- 100% nadzor izdelkov</li> <li>- pregled kontrolnih metod (dotične/brezdotične)</li> <li>- avtomatizirana preizkuševališča in kalibri</li> <li>- primeri iz prakse</li> </ul> <p>6. Predavanje: Strojni vid (SV) v kontroli izdelkov in procesov; 100% nadzor</p> <ul style="list-style-type: none"> <li>- tipične aplikacije</li> <li>- splošna struktura sistemov SV</li> <li>- merilne lastnosti in umeritev sistema</li> <li>- integracija</li> </ul> <p>7. Predavanje: Koordinatni merilni stroji (KMS) – visoko natančne meritve izdelkov; vzorčni nadzor procesov</p> <ul style="list-style-type: none"> <li>- namen in princip merjenja</li> <li>- izdelava merilnega programa</li> <li>- interpretacija meritev</li> <li>- primer merjenja izdelka</li> </ul> <p>8. Predavanje: Urejanje in predstavitev variabilnih podatkov</p> <ul style="list-style-type: none"> <li>- Vrste in primeri variabilnih podatkov v strojništvu</li> <li>- Tabele in grafi podatkov</li> <li>- Sipalni diagram</li> <li>- Stolpični diagram (Histogram)</li> <li>- Stebelni in listni diagram</li> </ul> <p>9. Predavanje: Osnovne opisne statistike</p> <ul style="list-style-type: none"> <li>- Opisne karakteristike podatkov</li> <li>- Mere centralne tendence (srednja vrednost, mediana, mod)</li> <li>- Mere variabilnosti (min – max, kvartili, varianca, standardni odklon)</li> <li>- Škatljčni diagram</li> </ul> <p>10. Predavanje: Osnovne verjetnosti</p> <ul style="list-style-type: none"> <li>- Relativna pogostost, verjetnost in uporaba verjetnosti pri opisu naključnosti</li> <li>- Povezana verjetnost</li> <li>- Pogojna verjetnost</li> <li>- Primeri v strojništvu</li> </ul>	<ul style="list-style-type: none"> <li>- Communications and user interfaces</li> <li>- Monitoring systems</li> <li>- MES and ERP systems</li> </ul> <p>3. Lecture: Automatic identification</p> <ul style="list-style-type: none"> <li>- Technology overview</li> <li>- Bar and QR code, RFID</li> <li>- Industrial internet of things (IIS)</li> <li>- Basic concepts and sensor networks of IIS</li> </ul> <p>4. Lecture: Automated process control</p> <ul style="list-style-type: none"> <li>- Processes and variability</li> <li>- 100% vs. statistical control</li> <li>- Final vs. distributed control</li> <li>- Case studies</li> </ul> <p>5. Lecture: Process control methods</p> <ul style="list-style-type: none"> <li>- 100% inspection</li> <li>- review of inspection methods (touch / non-contact)</li> <li>- automated testing devices</li> <li>- case studies</li> </ul> <p>6. Lecture: Machine vision (MV) in product and process control; 100% inspection</p> <ul style="list-style-type: none"> <li>- typical applications</li> <li>- general structure of MV system</li> <li>- MV system properties and calibration</li> <li>- integration</li> </ul> <p>7. Lecture: Coordinate measuring machines (CMM) – high accurate inspection of parts; sampling control of processes</p> <ul style="list-style-type: none"> <li>- purpose and principle of measurement</li> <li>- measuring program development</li> <li>- interpretation of measurements</li> <li>- an example of measuring a part</li> </ul> <p>8. Lecture: Editing and presenting variable data</p> <ul style="list-style-type: none"> <li>- Types and examples of variable data in mechanical engineering</li> <li>- Tables and graphs of data</li> <li>- Scatter diagram</li> <li>- Bar chart (Histogram)</li> <li>- Stem and leaf diagram</li> </ul> <p>9. Lecture: Editing and presenting variable data</p> <ul style="list-style-type: none"> <li>- Types and examples of variable data in mechanical engineering</li> <li>- Tables and graphs of data</li> <li>- Scatter diagram</li> <li>- Bar chart (Histogram)</li> <li>- Stem and leaf diagram</li> </ul> <p>10. Lecture: Basic of Probability</p> <ul style="list-style-type: none"> <li>- Relative frequency, probability and use of probability in describing randomness</li> <li>- Joint probability</li> <li>- Conditional probability</li> </ul>
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<p>11. Predavanje: Porazdelitev verjetnosti</p> <ul style="list-style-type: none"> <li>- Histogram in porazdelitev verjetnosti</li> <li>- Binomska porazdelitev in primeri v strojništvu</li> <li>- Gaussova porazdelitev in primeri v strojništvu</li> <li>- Pravilo seštevanja Gaussovih spremenljivk</li> </ul> <p>12. Predavanje: Osnovne sklepne statistike</p> <ul style="list-style-type: none"> <li>- Osnovni pojmi (populacija, vzorec, statistično sklepanje)</li> <li>- Gaussova populacija</li> <li>- Ocena parametrov gaussove populacije</li> <li>- Primerjava dveh Gaussovih populacij s praktičnimi primeri uporabe v proizvodnji</li> </ul> <p>13. Predavanje: Avtomatsko spremljanje stanja procesov</p> <ul style="list-style-type: none"> <li>- Osnovni gradniki sistema</li> <li>- Značilke podatkov</li> <li>- Vrste in izbira modelov</li> </ul> <p>14. Predavanje: Izgradnja modela</p> <ul style="list-style-type: none"> <li>- Statistični pragovni model</li> <li>- Sipalni diagram in korelacijski koeficient</li> <li>- Linearni parametrični model</li> </ul> <p>15. Predavanje: Praktična primera spremljanje stanja proizvodnih procesov</p> <ul style="list-style-type: none"> <li>- Vtiskovanje ojnice</li> <li>- Vibroakustična končna kontrola kompresorjev</li> </ul>	<p>- Mechanical engineering cases</p> <p>11. Lecture: Probability distributions</p> <ul style="list-style-type: none"> <li>- Histogram and probability distribution</li> <li>- Binomial distribution and cases in mechanical engineering</li> <li>- Gaussian distribution and examples in mechanical engineering</li> <li>- The rule of summation of Gaussian variables</li> </ul> <p>12. Lecture: Basic inferential statistics</p> <ul style="list-style-type: none"> <li>- Basic concepts (population, sample, statistical reasoning)</li> <li>- Gaussian population</li> <li>- Estimation of parameters of a Gaussian population</li> <li>- Comparison of two Gaussian populations with practical use cases in production</li> </ul> <p>13. Lecture: Automatic process state monitoring</p> <ul style="list-style-type: none"> <li>- The basic building blocks of the system</li> <li>- Data features</li> <li>- Types and selection of models</li> </ul> <p>14. Lecture: Model Building</p> <ul style="list-style-type: none"> <li>- Statistical threshold model</li> <li>- Scattering diagram and correlation coefficient</li> <li>- Linear parametric model</li> </ul> <p>15. Lecture: A practical example of monitoring the state of production processes</p> <ul style="list-style-type: none"> <li>- Monitoring of crankshaft stamping</li> <li>- Vibro-acoustic final control of compressors</li> </ul>
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#### Temeljna literatura in viri/Readings:

1. Fundamentals of Industrial Instrumentation and Process Control, William C. Dunn, McGraw-Hill Education; 2 edition, 2018
2. Condition Monitoring and Control for Intelligent Manufacturing, L. Wang, Springer London, 2006.
3. Machine Vision: Automated Visual Inspection: Theory, Practice and Applications, J.Beyerer, Springer-Verlag Berlin Heidelberg, 2016.
4. Douglas C. MONTGOMERY, George C. RUNGER, *Applied statistic and probability for engineers*, Third edition, 2003, John Wiley and Sons.
5. Edvard GOVEKAR, *Naključni pojavi : elektronski zapiski in interaktivni učbenik*. Univerza v Ljubljani, Fakulteta za strojništvo, 2005. <http://lab.fs.uni-lj.si/lasin/www/teaching/np/predavanja.htm>. [COBISS.SI-ID [11321371](#)]

#### Cilji in kompetence:

- Cilji:
1. Spoznati sisteme za krmiljenje in nadzor proizvodnje.
  2. Spoznati metode avtomatiziranega nadzora izdelkov.
  3. Spoznati osnovne metode statistike za spremljanje in vrednotenje proizvodnih procesov

#### Objectives and competences:

- Objectives:
1. Understand manufacturing execution, monitoring and control systems.
  2. Learn the methods of automated product control.
  3. To learn basic methods of statistics for monitoring and evaluation of production processes
- Competences:

<b>Kompetence:</b> 1. S1-PAP + P4-PAP: Sposobnost razumevanja in uporabe sistemov vodenja in nadzora proizvodnje. 2. S1-PAP + P4-PAP: Sposobnost razumevanja in uporabe metod nadzora izdelkov in procesov v praksi. 3. S1-PAP + P4-PAP: Sposobnost uporabe pridobljenega znanja osnov statistike pri spremljanju, vrednotenju in krmiljenju proizvodnih procesov.	1. S1-PAP + P4-PAP: The ability to understand and to use monitoring and control systems in production processes 2. S1-PAP + P4-PAP: The ability to understand and to use product and process inspection methods in practice. 3. S1-PAP + P4-PAP: The ability to use the knowledge of the basics statistics in monitoring, evaluation and control of production processes.
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#### **Predvideni študijski rezultati:**

<b>Znanja:</b> Z1: Predmet je obravnava različne sisteme za krmiljenje in nadzor proizvodnje, kot tudi metode zbiranja in analize proizvodnih podatkov. S pridobljenimi kompetencami bodo študenti v praksi sposobni uporabljati različne sisteme za krmiljenje in nadzor proizvodnje ter analizirati in interpretirati proizvodne podatke. <b>Spretnosti:</b> S1.1: Osnovno razumevanje kompleksnosti in variabilnosti v proizvodnji. S1.1: Uporaba sistemov krmiljenja in nadzora proizvodnje. S1.2: Analiza in interpretacija variabilnih proizvodnih podatkov.	<b>Knowledge:</b> Z1: The course deals with various systems for monitoring and control of production process, as well as with methods for collecting and analyzing of manufacturing data. With the acquired competences, students will be able in practice to use different systems for monitoring and control of production process and to analyze and interpret production data. <b>Skills:</b> S1.1: Basic understanding of complexity and variability in production. S1.1: Use of manufacturing control and monitoring systems. S1.2: Analysis and interpretation of variable production data.
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#### **Metode poučevanja in učenja:**

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. P4 Laboratorijske vaje z namenski didaktični pripomočki: merilnimi sistemi, kamerami, prenosnimi računalniki in odprtokodno programsko opremo. P5 Uporaba študijskega gradiva v obliki e-zapiskov P8 Izdelava in predstavitev aplikativnih seminarskih nalog.	<b>Learning and teaching methods:</b> P1 Auditorial lectures with solving selected field-specific theoretical and applied use cases. P2 Presenting the content according to the explained system. P3 Auditorial exercises, in which theoretical content from the lectures is supplemented with practical examples. P4 Laboratory exercises with special-purpose didactic devices: measuring systems, cameras, laptops and open source software. P5 Application of study material: books, e-version of lecture presentation. P8 Making and presenting applied seminar exercises.
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#### **Načini ocenjevanja:**

#### **Delež/Weight Assessment:**

Teoretična snov (predavanja).	50,00 %	Theoretical matter (lectures).
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Laboratorijsko delo na vajah (vključno s poročili).	40,00 %	Laboratory work in exercises (including reports).
Projektni seminar.	10,00 %	Project seminar.

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

Drago Bračun:

1. **BRAČUN Drago**, LEKŠE Igor. A visual inspection system for KTL coatings. Procedia CIRP, ISSN 2212-8271, vol. 81, 2019, vol. 81, 771-774.
2. **BRAČUN Drago**, PERDAN Boštjan, DIACI Janez. Surface defect detection on power transmission belts using laser profilometry. Strojniški vestnik. mar. 2011, vol. 57, no. 3, str. 257-266.
3. VUKAŠINOVIĆ Nikola, **BRAČUN Drago**, MOŽINA Janez, DUHOVNIK Jože. The influence of incident angle, object colour and distance on CNC laser scanning. The international journal of advanced manufacturing technology, ISSN 0268-3768, Sep. 2010, vol. 50, iss. 1/4, str. 265-274.
4. **BRAČUN Drago**, GRUDEN Valter, MOŽINA Janez. A method for surface quality assessment of die-castings based on laser triangulation. Measurement science & technology, ISSN 0957-0233. 2008, letn. 19, št. 4, 8.
5. PERHAVEC Tadej, GORKIČ Aleš, **BRAČUN Drago**, DIACI Janez. A method for rapid measurement of laser ablation rate of hard dental tissue. Optics and laser technology, ISSN 0030-3992, 2009, vol. 41, issue 4, str. 397-402.

Edvard Govekar:

1. THALER, Tilén, POTOČNIK, Primož, BRIC, Ivan, **GOVEKAR, Edvard**. Chatter detection in band sawing based on discriminant analysis of sound features. Applied acoustics, ISSN 0003-682X, 2014, letn. 77, str. 114-121
2. THALER, Tilén, BRIC, Ivan, BRIC, Rudi, POTOČNIK, Primož, MUŽIČ, Peter, **GOVEKAR, Edvard**. Characterization of band sawing based on cutting forces. Journal of machine engineering, ISSN 1895-7595, 2012, vol. 12, no. 1, str. [41]-54, ilustr
3. POTOČNIK, Primož, **GOVEKAR, Edvard**, GRABEC, Igor. Application of psychoacoustic filtering for machine fault detection. International journal of materials & product technology, ISSN 0268-1900, 2006, letn. 27, št. 3/4, str. 229-237
4. POTOČNIK, Primož, SOKLIČ, Dejan, MUŽIČ, Peter, ABSEC, Matija, STRMEC, Tomaž, **GOVEKAR, Edvard**. Automatic detection of spring faults during assembly of reciprocating compressors. Strojniški vestnik, 2009, letn. 55, št. 7/8, str. 444-45
5. KLEMENČIČ, Jure, KOKALJ, Tadej, MUŽIČ, Peter, GRABEC, Igor, **GOVEKAR, Edvard**. Characterization of laser droplet formation by reflected light. Optics and lasers in engineering, 2006, letn. 44, št. 5, str. 398-410.