Fakulteta za industrijski inženiring
Faculty of Industrial Engineering

UČNI NAČRT PREDMETA / COURSE SYLLABUS	
Predmet: ***Course title:***	Inteligentno vzdrževanje procesov in naprav
	Advanced maintenance of processes and devices

Študijski program ***Study programme and level***	**Študijska smer** ***Study field***	**Letnik** ***Academic year***	**Semester** ***Semester***
Inženiring in avtomobilska industrija		drugi	
Engineering and Automotive Industry		second	

Vrsta predmeta / ***Course type***	Izbirni	Optional

Univerzitetna koda predmeta / ***University course code:***	**MAG_21012**

Predavanja ***Lectures***	**Seminar** ***Seminar***	**Sem. vaje** ***Tutorial***	**Lab. vaje** ***Laboratory work***	**Teren. vaje** ***Field work***	**Samost. delo** ***Individ. work***	**ECTS**
45	-	30		-	135	7

Nosilec predmeta / ***Lecturer:***	**Prof. dr. Rudi Pušenjak**

Jeziki / ***Languages:***	**Predavanja /** ***Lectures*****:**	**Vaje /** ***Tutorial:***
	Slovenski	Slovenski
	Slovenian	Slovenian

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	***Prerequisits:***
– vpis v drugi letnik študija	– enrolment in the second year of the study

Vsebina: ***Content (Syllabus outline):***

– Razčlenitev vzdrževanja. Nenačrtovano in načrtovano vzdrževanje. Preventivno in prediktivno vzdrževanje. Vzdrževanje po stanju, nadzor pogojev delovanja. – Vibracijska analiza. Uporaba FFT analize v diagnostiki. Časovno-frekvenčna analiza. Valčna analiza. – Ultrazvočna diagnostika napak z akustično emisijo. – Diagnostika napak na osnovi merjenja temperature. – Infrardeča termografija. – Detekcija razpok – Analiza maziv – Nadzorovanje korozije – Nadzorovanje iztekanja	– Classification of maintenance. Reactive and proactive maintenance. Preventive and predictive maintenance. Condition monitoring maintenance. – Vibration analysis. Application of FFT analysis in diagnostics. Joint Time-frequency analysis. Wavelet analysis. – Ultrasonic fault diagnostics with acoustic emission. – Temperature monitoring fault diagnostics. – Infrared termography. – Crack detection. – Lubricant analysis. – Corrosion monitoring. – Leak monitoring.

Temeljni literatura in viri / *Readings:*

E-gradiva predmeta | E-Course material

- R. Pušenjak. *Inteligentno vzdrževanje procesov in naprav.* Učno gradivo magistrskega študija. Fakulteta za industrijski inženiring Novo mesto, 2019.

Priporočljiva literatura / *Recomended Textbooks*

- Scheffer, C., Girdhar, P. (2004). *Practical Machinery Vibration Analysis and Predictive Maintenance*. Elsevier, Linacre House, Jordan Hill, Oxford OX2 8DP: Burlington. MA 01803, 2004. ISBN 0 7506 6275 1.
- Ebeling, C. E. (2009*). An Introduction to Reliability and Maintainability Engineering*. Waveland Press. ISBN 1577666259.
- Isermann, R. 2011) *Fault-Diagnosis Applications Model-Based Condition Monitoring: Actuators, Drives, Machinery, Plants, Sensors, and Fault-tolerant Systems*. Springer-Verlag, Berlin: Heidelberg. ISBN 978-3-642-12766-3.
- Qian, S., Chen, D. (1996). *Joint Time-Frequency Analysis: Methods and Applications*. Prentice Hall. ISBN 978-0132543842.
- Goswami, J. C., Chan, A. K. (1999). *Fundamentals of Wavelets: Theory, Algorithms, and Applications*. John Wiley&Sons, Inc.

Cilji in kompetence: ***Objectives and competences:***

Cilji	**Objectives**
– Predmet je namenjen pridobitvi znanj o posameznih vrstah vzdrževanja in različnih metodah diagnostike pri odkrivanju in odpravljanju napak v tehniških procesih ter delovanju strojev in naprav. V obravnavi metod diagnostike je pozornost posvečena uporabnosti metod na posameznih področjih.	– The subject is intended to acquiring of knowledge on maintenance types as well as various methods of fault detection in engineering processes and operation of machines and devices. Treatment of fault detection methods includes classification of methods in terms of their usefulness in specific areas.
Kompetence	**Competences**
– *Učna enota prispeva predvsem k razvoju naslednjih splošnih in specifičnih kompetenc:* – sposobnost določitve vrste problema vzdrževanja in njegove analize, – sposobnost uporabe naprednih programov vzdrževanja procesov in naprav – sposobnost uporabe pridobljenega teoretičnega znanja v praksi, – avtonomnost v strokovnem delu na področju diagnostike napak procesov in naprav, – sposobnost razumevanja in uporabe sodobnih teorij na področju vzdrževanja sistemov in procesov, – sposobnost uporabe matematičnih metod na področju diagnostike napak v sistemih in procesih, – sposobnost uporabe merilnih, informacijskih in komunikacijskih tehnologija področju vzdrževanja	– The subject contributes to the development of the following common and specific competences, respectively: – ability to identify and analyze problems of maintenance, – ability to use advanced conceptsof maintenance of processes and devices, – ability to apply acquired theoretical knowledge in practice, – professional autonomy in the field of maintenance by performing fault diagnosis of processes and devices, – the ability to understand and use modern theoriesof maintenance, – ability to use the mathematical methods in fault diagnosis of systems and processes, – ability to use the modern measurement, information and communication technologies in the field of maintenance.

Predvideni študijski rezultati:	***Intended learning outcomes:***
Študent/študentka: – *pozna hierarhično strukturo vzdrževanja,* – *pozna in razume posamezne vrste industrijske diagnostike,* – *obvlada najvažnejše matematične metode vibracijske analize v diagnostiki,* – *pozna merilne metode industrijske diagnostike, procese zajemanja, shranjevanja in obdelave merilnih signalov,* – *pozna osnovna orodja za analizo in vrednotenje izmerjenih signalov in jih pri določanju napak zna uporabljati,* – *pozna postopke in metode vrednotenja in razvrščanja dobljenih vrednosti,* – *zna načrtovati, uporabljati standarde, predpise in literaturo.*	***Student:*** – *knows the hierarchy of maintenance,* – *knows and understands kinds of the industrial diagnostics,* – *is mastering the most important methods of vibration analysis in diagnostics,* – *knows the measurement techniques of industrial diagnostics as well as acquisition, storage, and processing of measuring signals,* – *knows basic tools of analysis and evaluation of measuring signalsand knows how use them* – *knows evaluation methods and how to perform the classification of measuring values* – *knows how to perform plan, to use standards, regulations and literature.*

Metode poučevanja in učenja:	***Learning and teaching methods*:**
– *predavanja z aktivno udeležbo študentov, ki vsebujejo razprave, diskusije, odgovore na vprašanja in reševanje nalog ob pomoči sodobnih pedagoških pripomočkov,* – *seminarska naloga iz posamezne vrste vzdrževanja oziroma iz določenega področja diagnostike napak, ki jo študentje izdelajo v skladu z usmeritvami in pomočjo predavatelja* – *laboratorijske vaje, ki potekajo v ustrezno opremljenem laboratoriju.* Predmet je oblikovan na kombinirani način študija, ki vključuje aktivnosti preko elektronskega (on-line) okolja: te aktivnosti so sestavljene iz samostojnih in skupinskih aktivnosti z uporabo učnega okolja Moodle in drugih elektronskih vsebin. Praviloma vključujejo diskusije v forumih, spletne strani, ogled posnetih predavanj in vaj, preverjanje znanja, odgovori na vprašanja, iskanje po spletu (bazah) itd.	– *lectures with active attendance of students, which incorporate discussions, answers on the questions and solving of exercises with application of the contemporary pedagogical aids* – *seminar work on some art of maintenance or method of fault diagnostics on the selected area of practice, which is performed under supervision of the lecturer* – *laboratory work, which is performed in a suitable* – *equipped laboratory.* The course is designed as blended learning that includes online activities: Online activities consist of independent and group activities using the LMS Moodle and other electronic or online content. Activities usually include discussions in forums, websites, viewing of recorded lectures and tutorials, assessments, answering questions, searching the web (databases), etc.

Načini ocenjevanja:	**Delež/Weight (%)**	**Assessment:**
Pogoj za pristop k izpitu sta pozitivno ocenjena seminarska naloga in poročilo o laboratorijskih vajah.		The prerequisite for accession to the exam is positive grade of the seminar work
– laboratorijske vaje – seminarska naloga – pisni/usrni izpit	20% 50% 30%	– laboratory work – seminar work – written/oral exam
Ocenjevalna lestvica je skladna z ECTS in Pravilnikom o preverjanju in ocenjevanju znanja FINI NM.		Evaluation scale in accordance with ECTS and the Rules on the Evaluation and Assessment of Knowledge FINI NM.

Reference nosilca / *Lecturer's references:*

- PUŠENJAK, Rudi, OBLAK, Maks. Finite element method using continous elements with constant geometries. V: ROBINSON, John (ur.). *Quality assurance in FEM technology : [proceedings of the Fifth world congress sponsored by ISTEL England]*. Okehampton: Robinson and Associates. cop. 1987, str. 369-378. [COBISS.SI-ID 443140]
- PUŠENJAK, Rudi, OBLAK, Maks. Design of axisymmetric electron optical systems with use of continuous and fully discretized finite elements. V: *FEMCAD-88 : proceedings of the Fourth SAS-World Conference, Paris, 17-19 October 1988*, (Technology transfer series). Gournay-sur-Marne: IITT-International. 1988, str. 256-263. [COBISS.SI-ID 7316484]
- PUŠENJAK, Rudi, OBLAK, Maks. The use of continuous finite elements in electron optics. V: TANAKA, Masataka (ur.), CRUSE, Thomas A. (ur.). *Boundary element methods in applied mechanics : proceedings of the First Joint Japan/US Symposium on Boundary Element Methods, Tokyo, Japan, 3-6 October 1988*. Oxford [etc.]: Pergamon Press. 1988, str. 47-52. [COBISS.SI-ID 7315972]
- PUŠENJAK, Rudi, OBLAK, Maks. Continuous finite element model for solution of paraxial ray equation in electron optics. V: *Proceedings*. [S.l.]: American Academy of Mechanics. 1989, str. 316-319. [COBISS.SI-ID 7333636]
- PUŠENJAK, Rudi. Nonlinear almost periodic analysis of FET amplifiers by incremental harmonic balance and multiple time scales. V: BARTOLIĆ, Juraj (ur.). *ICECOM '99 : proceedings*. Zagreb: KoREMA, 1999, str. 130-134. [COBISS.SI-ID 4870422]
- PUŠENJAK, Rudi. Computation of electromagnetic waveguide transverse resonances by using continuous finite elements. V: BONEFAČIĆ, Davor (ur.). 16th International Conference on Applied Electromagnetics and Communications, 1-3 October 2001, Dubrovnik, Croatia. *ICECOM 2001 : conference proceedings*. Zagreb: KoREMA, 2001, str. 257-264. [COBISS.SI-ID 6596630]
- PUŠENJAK, Rudi. Razvejitve pri Van der Pol-Duffingovem nihalu = Bifurcations of the Van der Pol-Duffing oscillator. *Stroj. vestn.*, 2003, letn. 49, št. 7/8, str. 370-384. [COBISS.SI-ID 8489750] JCR IF: 0.048, SE (99/106), engineering, mechanical, x: 0.61
- PUŠENJAK, Rudi, OBLAK, Maks. Incremental harmonic balance method with multiple time variables for dynamical systems with cubic non-linearities. *Int. j. numer. methods eng.*, Jan. 2004, vol. 59, iss. 2, str. 255-292. [COBISS.SI-ID 8442134] JCR IF: 1.501, SE (3/61), engineering, multidisciplinary, x: 0.57, SE (7/162), mathematics, applied, x: 0.698
- KASTREVC, Mitja, PUŠENJAK, Rudi. Fuzzy pressure control of hydraulic system with gear pump driven by variable speed induction electro-motor. *Exp. tech. (Westport Conn.)*, May/June 2005, vol. 29, no. 3, str. 57-62. [COBISS.SI-ID 9576470] JCR IF: 0.363, SE (64/104), engineering, mechanical, x: 0.644, SE (92/110), mechanics, x: 0.96, SE (19/25), materials science, characterization & testing, x: 0.575
- PUŠENJAK, Rudi. Extended Lindstedt-Poincare method for non-stationary resonances of dynamical systems with cubic nonlinearit. *J. Sound Vib.*, July 2008, vol. 314, iss. 1/2, str. 194-216. http://dx.doi.org/10.1016/j.jsv.2008.01.002. [COBISS.SI-ID 12081430] JCR IF (2007): 1.024, SE (11/28), acoustics, x: 1.012, SE (23/107), engineering, mechanical, x: 0.706, SE (39/112), mechanics, x: 1.049

- PUŠENJAK, Rudi, OBLAK, Maks. Discussion on: "Analysis of control relevant coupled nonlinear oscillatory systems". *Eur. j. control*, 2008, vol. 14, 4, str. 283-285. http://dx.doi.org/10.3166/ejc.14.283-285. [COBISS.SI-ID 12640790] JCR IF (2007): 1.153, SE (20/52), automation & control systems, x: 0.927
- PUŠENJAK, Rudi, OBLAK, Maks, TIČAR, Igor. Nonstationary Vibration and Transition through Fundamental Resonance of Electromechanical Systems Forced by a Nonideal Energy Source. *Int. J. of Nonl. Sci. Num. Sim.*, May 2009, vol. 10, iss. 5, str. 635-657. JCR IF (2007): 5.099, SE(1/67), engineering, multidisciplinary, SE(1/165),mathematics,applied, SE(2/112) mechanics, (1/43), physics, mathematical
- PUŠENJAK, Rudi, OBLAK, Maks, TIČAR, Igor. Modified Lindstedt-Poincare method with multiple time scales for combination resonance of damped dynamical systems with strong linearities. *Int. J. of Nonl. Sci. Num. Sim.*, May 2010, vol. 11, no. 3, str. 173-201. [COBISS.SI-ID 13917718], [JCR, SNIP, WoS].
- PUŠENJAK, Rudi, OBLAK, Maks, The Control of Nonlinear Oscillatory Systems with Delay – Upravljanje nelinearnih nihajočih sistemov z zakasnitvami, *Anali PAZU*, 2013, vol. **3**(1), str. 15-24. [COBISS.SI-ID 554230]
- PUŠENJAK, Rudi, TIČAR, Igor, OBLAK, Maks.Self-excited oscillations and Fuel Control of a Combustion Process in a Rijke Tube. *International Journal for Nonlinear Sciences and Numerical Simulation*, 2014, vol. 15(2), str. 87-106. [COBISS.SI-ID 17621526], [JCR, SNIP, WoS].
- PUŠENJAK, Rudi, TIČAR, Igor. Combustion processes with external harmonic excitation using extended Lindstedt-Poincare method with multiple time scales. V: G. KYPRIANIDIS, Konstantinos (ur.), SKVARIL, Jan (ur.). *Developments in combustion technology*. Rijeka: InTech. 2016, str. 372-396. [COBISS.SI-ID 19938838]