OBRATOVALNA TRDNOST

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	OBRATOVALNA TRDNOST
Course title:	OPERATIONAL STRENGTH
Članica nosilka/UL Member:	UL FS

Študijski programi in stopnja	Študijska smer	Letnik	Semestri	Izbirnost
Strojništvo, tretja stopnja, doktorski	Konstrukcijsko mehanske inženirske znanosti (smer)	1. letnik, 2. letnik	Celoletni	izbirni

Univerzitetna koda predmeta/University course code:	0033436
Koda učne enote na članici/UL Member course code:	7111

Predavanja /Lectures	Seminar /Seminar	Vaje /Tutorials	Klinične vaje /Clinical tutorials	Druge oblike študija /Other forms of study	Samostojno delo /Individual student work	ECTS
90					160	10

Nosilec predmeta/Lecturer:	Jernej Klemenc, Marko Nagode

Izvajalci predavanj:	Jernej Klemenc, Marko Nagode
Izvajalci seminarjev:	
Izvajalci vaj:	
Izvajalci kliničnih vaj:	
Izvajalci drugih oblik:	
Izvajalci praktičnega usposabljanja:	

Vrsta predmeta/Course type:	Izbirni predmet /Elective course

Jeziki/Languages:		
	Predavanja/Lectures:	Angleščina, Slovenščina
	Vaje/Tutorial:	Angleščina, Slovenščina

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	**Prerequisites:**
Veljajo splošni pogoji za doktorski študij.	General prerequisites for the third level studies.

Vsebina:	**Content (Syllabus outline):**
• Obratovalna trdnost v razvojnem, izdelovalnem, obratovalnem, vzdrževalnem in reciklažnem tehniškem sistemu. • Obratovalno stanje (konstrukcija, obremenitve, vpliv okolja, zdržljivost, zanesljivost). • Razvojni postopek (oblikovanje, vrednotenje). • Obremenitve (mehanske, termo-mehanske, toplotne, nevtronsko sevanje, kemične). • Obremenitve v časovnem in frekvenčnem prostoru (deterministične, naključne, stacionarne, ergodične, spektri itn.). • Vrednotenje obremenitev (števne metode, obremenitveni kolektivi, spektri energijske gostote, verjetnost realizacije, teorija maksimumov, perioda vračanja). • Poškodbe (mehanske, mehansko-termične, toplotne itn.). • Trenutne poškodbe in poškodbe zaradi utrujanja. • Poškodbeni fenomeni, kriteriji. • Trenutne poškodbe (zlomi, trki, ekstremni dogodki). • Utrujanje (malociklično, časovno-velikociklično, trajnodinamično). • Hipoteze o akumulaciji poškodb. • Poškodbe (do nastanka tehnične poškodbe, rast poškodbe). • Malociklično in časovno utrujanje (napetostni in deformacijski pristop, modeli utrujanja, parametrični in	• Operational strength in R&D, production, operational, maintenance and recycling technical systems. • Operational condition (structure, loads, environmental influences, durability, reliability). • R&D process (design, evaluation) • Loads (mechanical, thermo-mechanical, thermal, neutron radiation, chemical). • Loads in time and frequency domain (deterministic, random, stationary, ergodic, spectra etc.). • Evaluation of loads (counting methods, loading spectra, power spectrum density, probability of realisation, extreme-value theory, period of return). • Damage (mechanical, thermo-mechanical, thermal etc.). • Instantaneous damage and fatigue damage. • Damage phenomena and criteria. • Instantaneous damage (rupture, crash, extreme events). • Fatigue damage (low-cycle, medium-cycle fatigue, high-cycle fatigue and durability). • Damage accumulation hypotheses. • Fatigue damage (until the technical crack, crack growth). • Low-cycle and medium-cycle fatigue (stress-based and strain-based approach, fatigue damage models, parametric and non-parametric description of states and influential

neparametrični popisi stanj in vplivnih parametrov). • Trajnodinamično utrujanje (metode za ugotavljanje zdržljivosti, Palmgreen-Minerjeve hipoteze: originalna, modificirana, Haibachova itn.). • Obratovalna trdnost (raztrosi obremenitvenih in zdržljivostnih stanj, verjetnost okvare). • Kriteriji za vrednotenje razvojnih rešitev (RMS kriteriji). • Efektivnost izdelkov in sistemov (pripravljenost za obratovanje, zanesljivost, elastičnost). • Zanesljivost (presek verjetnostnih prostorov, metode opredeljevanja, ugotavljanja in merjenja). • Modeliranje zanesljivosti (vpliv strukture, modeli). • Računalniška podpora modeliranju zanesljivosti (standardna, specifična, komercialna). • Metode verifikacije modelov. • Eksperimenti v obratovalni trdnosti (preskusi za ugotavljanje obremenitvenih in obratovalnih stanj, preskusi materialnih parametrov, preskusi za podporo modeliranju in simulacijam, preskusi za ugotavljanje poškodb). • Preskuševališča (standardna, specifična). • Merilne tehnike v obratovalni trdnosti.	parameters). • High-cycle fatigue and durability (methods for evaluating durability, Palmgreen-Miner hypotheses: original, modified, Haibach's etc.). • Operational strength (scatter of load states and durability, probability of fault). • Criteria for evaluation of R&D solutions (RMS criteria). • Effectiveness of products and systems (readiness for operation, reliability, elasticity). • Reliability (cross-section of probability spaces, methods for definition, determination and measurement). • Reliability models (influence of structure, models). • Computer aided reliability modelling (standard, specific and commercial software equipment). • Methods for validation of models. • Experiments in operational strength (test for determination of loading and operating conditions, test of materials, test for supporting modelling and simulations, fatigue damage tests). • Test stands (standard, specific). • Experimental techniques in operational strength.

Temeljna literatura in viri/Readings:

[1] Betriebsfestigkeit : sichere und wirtschafliche Bemessung schwingbruchgefährdeter Bauteile
Buxbaum, Otto, Düsseldorf : Strahleisen, 1988 [COBISS.SI-ID - 4426523]
[2] Reliability and risk assessment ,Andrews, J. D. ; Moss, T. R., Essex : Longman Scientific & Technical, 1993 [COBISS.SI-ID - 858139]
[3] An introduction to reliability and maintainability engineeringEbeling, Charles E. Long Grove, IL : Waveland Press, cop. 2010 [COBISS.SI-ID - 11713819]
[4] Fatigue of materials Suresh, Subra, Cambridge ; New York ; Melbourne ; Madrid : Cambridge University Press, 2004 [COBISS.SI-ID - 9388827]
[5] Mechanical behavior of materials : engineering methods for deformation, fracture, and fatigue
Dowling, Norman E., Upper Saddle River, NJ : Prentice Hall, cop. 1999 [COBISS.SI-ID – 44474625]

[6] Fatigue and fracture mechanics of high risk parts : application of LEFM & FMDM theory
Farahmand, Bahram ; Bockrath, George ; Glassco, James , New York [etc.] : Chapman & Hall, cop. 1997 [COBISS.SI-ID - 18108677]
[7] The mechanics of constitutive modeling Ottosen, Niels Saabye ; Ristinmaa, Matti, Amsterdam [etc.] : Elsevier, 2005 [COBISS.SI-ID - 3810401]
[8] RMS ; Reliability, maintainability, and supportability guidebook, Warrendale : SAE, Society of Automotive Engineers, cop. 1995 [COBISS.SI-ID - 1222427]
[9] Modeling for reliability analysis : Markov modeling for reliability, maintainability, safety, and supportability analyses of complex systems COBISS.SI-ID : 2860051

Cilji in kompetence:	**Objectives and competences:**
Cilji: Izbira relevantnega področja Obratovalne trdnosti, pregled bazične in specifične literature, strukturiran pristop k uporabi osvojenih znanj na izbrani aplikaciji ter izdelava seminarja. **Kompetence**: Študenti osvojijo znanja za samostojno aplikativno in raziskovalno delo s področja razvojnih vrednotenj glede na izbrane vsebine. Poleg tega osvojijo tudi znanja za vodenje postopkov razvojnih vrednotenj.	**Goals:** The selection of the relevant field of Operational strength, survey of basic and specific literature, structured approach to the use of the acquired on a selected application and elaboration of a seminar. **Competences**: Students master the knowledge to work applicative and scientifically on their own in the field of development evaluations according to the selected topics. Apart from this they get the knowledge of how to manage the development evaluation procedures.

Predvideni študijski rezultati:	**Intended learning outcomes:**
Znanje in razumevanje: Izbira relevantnega področja Obratovalne trdnosti, pregled bazične in specifične literature, strukturiran pristop k uporabi osvojenih znanj na izbrani aplikaciji ter izdelava seminarja. Študenti osvojijo znanja za samostojno aplikativno in raziskovalno delo s področja razvojnih vrednotenj glede na izbrane vsebine. Poleg tega osvojijo tudi znanja za vodenje postopkov razvojnih vrednotenj.	**Knowledge and understanding:** The selection of the relevant field of Operational strength, survey of basic and specific literature, structured approach to the use of the acquired on a selected application and elaboration of a seminar. Students master the knowledge to work applicative and scientifically on their own in the field of development evaluations according to the selected topics. Apart from this they get the knowledge of how to manage the development evaluation procedures.

Metode poučevanja in učenja:	**Learning and teaching methods:**

Predavanja, laboratorijske vaje, seminarsko delo, e-izobraževanje, konzultacije. Seminarsko delo v čim večji meri navezujoče se na področje doktorskega raziskovanja. Študij z uporabo priporočene literature.	Lectures, laboratory practice & seminar work, e-education, consulting. The seminar work is related, as much as possible, to the student's doctoral research field. Study on a recommended literature basis.

Načini ocenjevanja:	**Delež/Weight**	**Assessment:**
Ustni izpit, poročilo o seminarskem delu. Pogoj za opravljanje ustnega izpita je uspešno izdelano in pozitivno ocenjeno seminarsko delo. Način (pisni izpit, ustno izpraševanje, naloge, projekt) • projekt (seminarska naloga) (70%) • ustno izpraševanje (30%)		Oral exam, report on seminar work. The condition for admission to oral exam is successful completion of seminar work, rewarded with a passing grade. Method (written exam, oral examination, assignments, project) • project (seminar work) (70%) • oral examination (30%)

Ocenjevalna lestvica:	**Grading system:**
5 - 10, pri čemer velja, da je pozitivna ocena od 6 - 10	5 - 10, a student passes the exam if he is graded from 6 to 10

Reference nosilca/Lecturer's references:

prof. dr. Marko NAGODE

NAGODE, Marko, OMAN, Simon, KLEMENC, Jernej, PANIĆ, Branislav. Gumbel mixture modelling for multiple failure data. Reliability engineering & systems safety. [Print ed.]. Feb. 2023, vol. 230, str. 1-12, ilustr. ISSN 0951-8320. https://www.sciencedirect.com/science/article/pii/S0951832022005610, DOI: 10.1016/j.ress.2022.108946. [COBISS.SI-ID 129890307]

NAGODE, Marko, KLEMENC, Jernej, OMAN, Simon, ŠERUGA, Domen. A closed-form solution for temperature-dependent elastoplastic problems using the Prandtl operator approach. Communications in Nonlinear Science and Numerical Simulation. Aug. 2021, vol. 99, str. 1-24, ilustr. ISSN 1007-5704. https://www.sciencedirect.com/science/article/pii/S1007570421001519?via%3Dihub, https://repozitorij.uni-lj.si/IzpisGradiva.php?id=126176, DOI: 10.1016/j.cnsns.2021.105839. [COBISS.SI-ID 59481091]

NAGODE, Marko, KLEMENC, Jernej. Modelling of load spectra containing clusters of less probable load cycles. International journal of fatigue. Feb. 2021, vol. 143, str. 1-10, ilustr. ISSN 0142-1123. https://www.sciencedirect.com/science/article/abs/pii/S0142112320305387, DOI:

10.1016/j.ijfatigue.2020.106006. [COBISS.SI-ID 35679235]

NAGODE, Marko, GOSAR, Aleš, SWEENEY, Caoimhe A., JAGUEMONT, Joris, MIERLO, Joeri Van, ŠERUGA, Domen. Mechanistic modelling of cyclic voltage-capacity response for lithium-ion batteries. Energy. Nov. 2019, vol. 186, str. 1-12, ilustr. ISSN 0360-5442. https://www.sciencedirect.com/science/article/pii/S036054421931463X?via%3Dihub#!, DOI: 10.1016/j.energy.2019.07.121. [COBISS.SI-ID 16771099]

GOSAR, Aleš, EMRI, Igor, KLEMENC, Jernej, NAGODE, Marko, OMAN, Simon. On the vibration-damping properties of the prestressed polyurethane granular material. Polymers. 2023, vol. 15, iss. 5, str. 1-22, ilustr. ISSN 2073-4360. https://www.mdpi.com/2073-4360/15/5/1299, DOI: 10.3390/polym15051299. [COBISS.SI-ID 145104131]

prof. dr. Jernej KLEMENC

KLEMENC, Jernej, HUMAR, Miha, FAJDIGA, Gorazd. Influence of insect damage to the fatigue life of an old larch wood. *Construction & building materials*. [Online ed.]. 2023, vol. 375, 1 spletni vir (1 datoteka pdf ([13] str.)). ISSN 1879-0526. https://www.sciencedirect.com/science/article/pii/S0950061823006888, DOI: 10.1016/j.conbuildmat.2023.130976. [COBISS.SI-ID 145016835]

ZUPANIČ, Franc, KLEMENC, Jernej, STEINACHER, Matej, GLODEŽ, Srečko. Microstructure, mechanical properties and fatigue behaviour of a new high-strength aluminium alloy AA 6086. *Journal of alloys and compounds*. [Print ed.]. April 2023, vol. 941, [atricle no.] 168976, 13 str. ISSN 0925-8388. DOI: 10.1016/j.jallcom.2023.168976. [COBISS.SI-ID 139639811]

BARTOŠÁK, Michal, NAGODE, Marko, KLEMENC, Jernej, DOUBRAVA, Karel, ŠERUGA, Domen. Use of Prandtl operators in simulating the cyclic softening of Inconel 718 under isothermal low-cycle fatigue loading. *International journal of mechanical sciences*. May 2022, vol. 222, str. 1-11, ilustr. ISSN 0020-7403. https://www.sciencedirect.com/science/article/pii/S0020740322001072, DOI: 10.1016/j.ijmecsci.2022.107182. [COBISS.SI-ID 102892035]

ZOBEC, Peter, KLEMENC, Jernej. Application of a nonlinear kinematic-isotropic material model for the prediction of residual stress relaxation under a cyclic load. *International journal of fatigue*. Sep. 2021, vol. 150, str. 1-11, ilustr. ISSN 0142-1123. https://www.sciencedirect.com/science/article/pii/S014211232100150X, DOI: 10.1016/j.ijfatigue.2021.106290. [COBISS.SI-ID 89708547],