

# DINAMIKA IN VIBRACIJE

## UČNI NAČRT PREDMETA/COURSE SYLLABUS

<b>Predmet:</b>	DINAMIKA IN VIBRACIJE
<b>Course title:</b>	DYNAMICS AND VIBRATIONS
<b>Članica nosilka/UL Member:</b>	UL FS

<b>Študijski programi in stopnja</b>	<b>Študijska smer</b>	<b>Letnik</b>	<b>Semestri</b>	<b>Izbirnost</b>
Strojništvo, tretja stopnja, doktorski	Konstruktivsko mehanske inženirske znanosti (smer)		Celoletni	izbirni

<b>Univerzitetna koda predmeta/University course code:</b>	0033428
<b>Koda učne enote na članici/UL Member course code:</b>	7102

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

<b>Nosilec predmeta/Lecturer:</b>	Miha Boltežar
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<b>Izvajalci predavanj:</b>	Miha Boltežar, Gregor Čepon, Janko Slavič
<b>Izvajalci seminarjev:</b>	
<b>Izvajalci vaj:</b>	
<b>Izvajalci kliničnih vaj:</b>	
<b>Izvajalci drugih oblik:</b>	
<b>Izvajalci praktičnega usposabljanja:</b>	

<b>Vrsta predmeta/Course</b>	Izbirni predmet /Elective course
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**type:**

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**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.
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**Vsebina:**

**Content (Syllabus outline):**

<p>Nihanja linearnih sistemov z več prostostnimi stopnjami. Modalna transformacija. Odziv sistemov v glavnih koordinatah.</p> <p>Nihanja zveznih sistemov, analitične in približne metode. Osnove nihanj nelinearnih sistemov. Vibracijska testiranja.</p> <p>Eksperimentalni pristop pri obvladovanju vibracij. Analiza dinamskih spremenljivk v časovnem in frekvenčnem prostoru.</p> <p>Kriteriji stabilnosti gibanja.</p> <p>Dinamika rotorjev, izračun kritičnih vrtilnih hitrosti. Masno uravnotežanje rotorjev.</p> <p>Dinamika batnih strojev.</p> <p>Preračun vibroizolacije elastično podprtih motorjev.</p> <p>Torzijska nihanja gredi. Osnove nihanj plošč, nihanje rotirajočih palic.</p> <p>Slučajna nihanja linearnih sistemov. Obdelava in vrednotenje izmerjenih slučajnih nihanj. Interakcija človek – vibracije.</p>	<p>Vibrations of linear systems with several degrees-of-freedom. Modal transformation. The response of the system in modal coordinates.</p> <p>Vibrations of continuous systems, analytical and approximate methods. The basic principles of nonlinear vibrations.</p> <p>Vibration testing.</p> <p>Experimental work in vibrations. Analysis of measured variables in the time and frequency domains.</p> <p>Dynamic stability.</p> <p>Rotor dynamics, determination of critical speed of rigid and flexible rotors. Mass balancing of rotors.</p> <p>Dynamics of reciprocating engines.</p> <p>Vibroisolations of elastically mounted engines.</p> <p>Torsional vibrations of shafts. Basics of vibrations of plates, vibrations of rotating bars.</p> <p>Random vibrations, theoretical and experimental aspects.</p> <p>Human response to vibrations.</p>
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**Temeljna literatura in viri/Readings:**

<p>[1] Rao, S.S.: Mechanical vibrations.- 3rd ed.- Reading etc.: Addison-Wesley Publishing Company, cop. 1995.</p> <p>[2] Rao, J.S.: Dynamics of plates.- New York; Basel; Hong Kong: M. Dekker; New</p>
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Delhi etc.: Narosa, cop. 1999.

[3] Frolov, K.V., Furman, F.A.: Applied theory of vibration isolation systems.- New York etc.: Hemisphere, 1990.

[4] McConnell, K.G.: Vibration testing: theory and practice.- New York etc.: John Wiley & Sons, cop. 1995.

[5] Lee, Chong-Won: Vibration analysis of rotors.- Dordrecht; Boston; London: Kluwer Academic, cop. 1993.- (Solid mechanics and its applications; vol. 21)

[6] Newland, D.E.: An introduction to random vibrations: spectral and wavelet analysis, 3rd ed.- Longman, 1997. - Izbrana poglavja

[7] Griffin, M.J.: Handbook of human vibration – 2nd ed.- London etc.: Academic Press, 1994, cop. 1990. - Izbrana poglavja

### **Cilji in kompetence:**

#### **Cilji:**

Cilji predmeta so nagradnja znanj iz druge stopnje na področju dinamike ter vibracij za doseg sposobnosti samostojnega reševanja specialne problematike, tako v fazi razvoja izdelkov, njihovi izdelavi kot tudi pri transportu ter vzdrževanju.

#### **Kompetence:**

Študent postane sposoben identifikacije, modeliranja ter merjenja tipičnih dinamskih pojavov v strojništvu. To so predvsem nihanja realnih sistemov z več prostostnimi stopnjami, zagotavljanje ustrezne vibroizolacije za zaščito naprav ter okolice, razumevanje problematike vibracijskih testiranj.

### **Objectives and competences:**

#### **Goals:**

The aim of the course is to upgrade the previously learned knowledge in the field of dynamics and vibrations in order to achieve the level of independent researcher in the design phase of the products, manufacturing phase as well as at transport and maintenance.

#### **Competences:**

The student acquires specific knowledge of identification, modelling and experimentation of typical dynamic phenomena in mechanical engineering, connected to mechanical vibrations. This includes specifically vibrations of multi-degree-of-freedom systems, vibroisolation to protect machinery and environment and understanding of vibration testing.

### **Predvideni študijski rezultati:**

Študent postane sposoben identifikacije, modeliranja ter merjenja tipičnih dinamskih pojavov v strojništvu. To so predvsem nihanja realnih sistemov z več prostostnimi stopnjami, zagotavljanje ustrezne vibroizolacije za zaščito naprav ter okolice, razumevanje problematike vibracijskih testiranj.

### **Intended learning outcomes:**

The student acquires specific knowledge of identification, modelling and experimentation of typical dynamic phenomena in mechanical engineering, connected to mechanical vibrations. This includes specifically vibrations of multi-degree-of-freedom systems, vibroisolation to protect machinery and environment and understanding of vibration testing.

**Metode poučevanja in učenja:**

Predavanja, laboratorijske vaje, seminarsko delo, e-izobraževanje, konzultacije. Seminarsko delo v čim večji meri navezuje se na področje doktorskega raziskovanja. Študij z uporabo priporočene literature.

**Learning and teaching methods:**

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 (50%), poročilo o seminarskem delu (50%). Pogoji za opravljanje ustnega izpita je uspešno izdelano in pozitivno ocenjeno seminarsko delo.

Oral exam (50%), report on seminar work (50%). The condition for admission to oral exam is successful completion of seminar work, rewarded with a passing grade.

**Reference nosilca/Lecturer's references:****prof. dr. Miha Boltežar**

RAZPOTNIK, Matej, BISCHOF, T., BOLTEŽAR, Miha. The influence of bearing stiffness on the vibration properties of statically overdetermined gearboxes. *Journal of sound and vibration*, ISSN 0022-460X. [Print ed.], Sep. 2015, vol. 351, str. 221-235, ilustr., doi: 10.1016/j.jsv.2015.04.021.

SLAVIČ, Janko, BOLKA, Špela, BRATUŠ, Vitoslav, BOLTEŽAR, Miha. A novel laboratory blanking apparatus for the experimental identification of blanking parameters. *Journal of materials processing technology*, ISSN 0924-0136. [Print ed.], Feb. 2014, vol. 214, iss. 2, str. 507-513, ilustr., doi: 10.1016/j.jmatprotec.2013.10.006.

JAVORSKI, Matija, ČEPON, Gregor, SLAVIČ, Janko, BOLTEŽAR, Miha. A generalized magnetostrictive-forces approach to the computation of the magnetostriction-induced vibration of laminated steel structures. *IEEE transactions on magnetics*, ISSN 0018-9464, 2013, vol. 49, no. 11, str. 5446-5453, doi: 10.1109/TMAG.2013.2269316.

ŠKOFIC, Jan, BOLTEŽAR, Miha. Numerical modelling of the rotor movement in a permanent-magnet stepper motor. *IET electric power applications*, ISSN 1751-8660, 2014, vol. 8, iss. 4, str. 155-163, ilustr. <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6786889>, doi: 10.1049/iet-epa.2013.0274.

**prof.dr. Janko Slavič**

OGRINEC, Primož, SLAVIČ, Janko, ČESNIK, Martin, BOLTEŽAR, Miha. Vibration fatigue at half-sine impulse excitation in the time and frequency domains. *International journal of fatigue*, ISSN 0142-1123, Jun. 2019, vol. 123, str. 308-317, ilustr. <https://www.sciencedirect.com/science/article/pii/S0142112319300568?via%3Dihub>, doi: [10.1016/j.ijfatigue.2019.02.031](https://doi.org/10.1016/j.ijfatigue.2019.02.031). [COBISS.SI-ID [16539419](#)], [JCR, SNIP, WoS do 15. 12. 2019: št. citatov (TC): 1, čistih citatov (CI): 0, čistih citatov na avtorja (CIAu): 0, Scopus do 29. 2. 2020: št. citatov (TC): 1, čistih citatov (CI): 0,

čistih citatov na avtorja (CIAu): 0]

kategorija: 1A1 (Z, A', A1/2); uvrstitev: SCI, Scopus, MBP; tip dela je verificiral OSICN

SKRINJAR, Luka, SLAVIČ, Janko, BOLTEŽAR, Miha. A Review of continuous contact-force models in multibody dynamics. *International journal of mechanical sciences*, ISSN 0020-7403, Sep. 2018, vol. 145, str. 171-187, ilustr.

<https://reader.elsevier.com/reader/sd/903B8919459DA3FF13D9A5978641A8FD72722BBB5166ED0277F867AC3F587204A839D299CDEEBD3F76FFEFAB7B5B2E53>, doi: [10.1016/j.ijmecsci.2018.07.010](https://doi.org/10.1016/j.ijmecsci.2018.07.010). [COBISS.SI-ID [16175131](#)], [JCR, SNIP, WoS do 9. 2. 2020: št. citatov (TC): 10, čistih citatov (CI): 10, čistih citatov na avtorja (CIAu): 3.33, Scopus do 29. 2. 2020: št. citatov (TC): 17, čistih citatov (CI): 17, čistih citatov na avtorja (CIAu): 5.67]

kategorija: 1A1 (Z, A', A1/2); uvrstitev: SCI, Scopus, MBP; tip dela je verificiral OSICT

JAVH, Jaka, SLAVIČ, Janko, BOLTEŽAR, Miha. Experimental modal analysis on full-field DSLR camera footage using spectral optical flow imaging. *Journal of sound and vibration*, ISSN 0022-460X. [Print ed.], Nov. 2018, vol. 434, str. 213-220, ilustr.

<https://www.sciencedirect.com/science/article/pii/S0022460X18304905>, doi: [10.1016/j.jsv.2018.07.046](https://doi.org/10.1016/j.jsv.2018.07.046). [COBISS.SI-ID [16182299](#)], [JCR, SNIP, WoS do 21. 9. 2018: št. citatov (TC): 0, čistih citatov (CI): 0, čistih citatov na avtorja (CIAu): 0, Scopus do 18. 8. 2018: št. citatov (TC): 0, čistih citatov (CI): 0, čistih citatov na avtorja (CIAu): 0]

kategorija: 1A1 (Z, A', A1/2); uvrstitev: SCI, Scopus, MBP; tip dela je verificiral OSICN

MRŠNIK, Matjaž, SLAVIČ, Janko, BOLTEŽAR, Miha. Vibration fatigue using modal decomposition. *Mechanical systems and signal processing*, ISSN 0888-3270, Jan. 2018, vol. 98, str. 548-556, ilustr. [http://ac.els-cdn.com/S0888327017302728/1-s2.0-S0888327017302728-main.pdf?\\_tid=05277f10-46ab-11e7-8377-00000aab0f26&acdnat=1496308779\\_741233a7c58e44148923265c09da0eaa](http://ac.els-cdn.com/S0888327017302728/1-s2.0-S0888327017302728-main.pdf?_tid=05277f10-46ab-11e7-8377-00000aab0f26&acdnat=1496308779_741233a7c58e44148923265c09da0eaa), doi:

[10.1016/j.ymssp.2017.03.052](https://doi.org/10.1016/j.ymssp.2017.03.052). [COBISS.SI-ID [15513115](#)], [JCR, SNIP, WoS do 15. 12. 2019: št. citatov (TC): 12, čistih citatov (CI): 9, čistih citatov na avtorja (CIAu): 3.00, Scopus do 29. 2. 2020: št. citatov (TC): 16, čistih citatov (CI): 12, čistih citatov na avtorja (CIAu): 4.00]

kategorija: 1A1 (Z, A', A1/2); uvrstitev: SCI, Scopus, MBP; tip dela je verificiral OSICN

### **izr.prof.dr. Gregor Čepon**

BREGAR, Tomaž, HOLEČEK, Nikola, ČEPON, Gregor, RIXEN, Daniel J., BOLTEŽAR, Miha. Including directly measured rotations in the virtual point transformation. *Mechanical systems and signal processing*. 2019, str. 1-21, ilustr. ISSN 0888-3270.

<https://www.sciencedirect.com/science/article/pii/S0888327019306612>, DOI: [10.1016/j.ymssp.2019.106440](https://doi.org/10.1016/j.ymssp.2019.106440). [COBISS.SI-ID [17033755](#)], [JCR, SNIP]

DROZG, Armin, ROGELJ, Jakob, ČEPON, Gregor, BOLTEŽAR, Miha. On the performance of direct piezoelectric rotational accelerometers in experimental structural dynamics. *Measurement : journal of the International Measurement Confederation*. [Print ed.]. Oct. 2018, vol. 127, str. 292-298, ilustr. ISSN 0263-2241. <https://reader.elsevier.com/reader/sd/B28E22E5972D215221D9A597D883BE04B10E907D7451102D498644D812331AD7B71655B9FCC92A69672B0D3ABE553520>, DOI: [10.1016/j.measurement.2018.05.081](https://doi.org/10.1016/j.measurement.2018.05.081). [COBISS.SI-ID [16120091](#)], [JCR, SNIP,

[Scopus](#) do 8. 2. 2020: št. citatov (TC): 2, čistih citatov (CI): 1]

DROZG, Armin, ČEPON, Gregor, BOLTEŽAR, Miha. Full-degrees-of-freedom frequency based substructuring. *Mechanical systems and signal processing*. [Online ed.]. jan. 2018, vol. 98, str. 570-579, ilustr. ISSN 1096-1216.

<http://www.sciencedirect.com/science/article/pii/S088832701730273X>, DOI: [10.1016/j.ymssp.2017.04.051](https://doi.org/10.1016/j.ymssp.2017.04.051). [COBISS.SI-ID [15565339](#)], [JCR, SNIP, WoS do 3. 12. 2019: št. citatov (TC): 10, čistih citatov (CI): 9, [Scopus](#) do 29. 2. 2020: št. citatov (TC): 18, čistih citatov (CI): 15]

STARC, Blaž, ČEPON, Gregor, BOLTEŽAR, Miha. The influence of washing machine-leg hardness on its dynamics response within component-mode synthesis techniques. *International journal of mechanical sciences*. 2017, vol. 127, str. 23-30, ilustr. ISSN 0020-7403.

<http://www.sciencedirect.com/science/article/pii/S0020740316304027>. [COBISS.SI-ID [15686939](#)], [JCR, SNIP, WoS do 3. 12. 2019: št. citatov (TC): 1, čistih citatov (CI): 1, [Scopus](#) do 3. 12. 2019: št. citatov (TC): 3, čistih citatov (CI): 3]

STARC, Blaž, ČEPON, Gregor, BOLTEŽAR, Miha. A mixed-contact formulation for a dynamics simulation of flexible systems : an integration with model-reduction techniques. *Journal of sound and vibration*. [Print ed.]. Apr. 2017, vol. 393, str. 145-156, ilustr. ISSN 0022-460X.

<http://www.sciencedirect.com/science/article/pii/S0022460X17300494>, DOI: [10.1016/j.jsv.2017.01.026](https://doi.org/10.1016/j.jsv.2017.01.026). [COBISS.SI-ID [15398939](#)], [JCR, SNIP, WoS do 3. 12. 2019: št. citatov (TC): 1, čistih citatov (CI): 1, [Scopus](#) do 3. 12. 2019: št. citatov (TC): 2, čistih citatov (CI): 2]

PIRNAT, Miha, ČEPON, Gregor, BOLTEŽAR, Miha. Structural-acoustic model of a rectangular plate-cavity system with an attached distributed mass and internal sound source : theory and experiment. *Journal of sound and vibration*. [Print ed.]. 2014, vol. 333, str. 2003-2018, ilustr. ISSN 0022-460X. DOI:

[10.1016/j.jsv.2013.11.044](https://doi.org/10.1016/j.jsv.2013.11.044). [COBISS.SI-ID [13289499](#)], [JCR, SNIP, WoS do 3. 12. 2019: št. citatov (TC): 8, čistih citatov (CI): 8, [Scopus](#) do 3. 12. 2019: št. citatov (TC): 12, čistih citatov (CI): 12]

JAVORSKI, Matija, ČEPON, Gregor, SLAVIČ, Janko, BOLTEŽAR, Miha. A generalized magnetostrictive-forces approach to the computation of the magnetostriction-induced vibration of laminated steel structures. *IEEE transactions on magnetics*. 2013, vol. 49, no. 11, str. 5446-5453, ilustr. ISSN 0018-9464.

<https://ieeexplore.ieee.org/document/6542757>, DOI: [10.1109/TMAG.2013.2269316](https://doi.org/10.1109/TMAG.2013.2269316). [COBISS.SI-ID [13091611](#)], [JCR, SNIP, WoS do 3. 12. 2019: št. citatov (TC): 9, čistih citatov (CI): 7, [Scopus](#) do 26. 1. 2020: št. citatov (TC): 12, čistih citatov (CI): 10]

PIRNAT, Miha, ČEPON, Gregor, BOLTEŽAR, Miha. Introduction of the linear contact model in the dynamic model of laminated structure dynamics : an experimental and numerical identification. *Mechanism and machine theory*. 2013, vol. 64, str. 144-154, ilustr. ISSN 0094-114X. DOI:

[10.1016/j.mechmachtheory.2013.02.003](https://doi.org/10.1016/j.mechmachtheory.2013.02.003). [COBISS.SI-ID [12732443](#)], [JCR, SNIP, WoS do 3. 12. 2019: št. citatov (TC): 12, čistih citatov (CI): 8, [Scopus](#) do 26. 2. 2020: št. citatov (TC): 19, čistih citatov (CI): 15]