

TEORIJA TURBINSKIH STROJEV

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	TEORIJA TURBINSKIH STROJEV
Course title:	TURBOMACHINERY THEORY
Članica nosilka/UL Member:	UL FS

Študijski programi in stopnja	Študijska smer	Letnik	Semestri	Izbirnost
Strojništvo, tretja stopnja, doktorski	Ni členitve (študijski program)	1. letnik, 2. letnik	Celoletni	izbirni

Univerzitetna koda predmeta/University course code: 0033424

Koda učne enote na članici/UL Member course code: 7016

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: Marko Hočevar, Mihael Sekavčnik

Izvajalci predavanj: Matevž Dular, Marko Hočevar, Mihael Sekavčnik

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):**

- Razvrstitev turbinskih strojev in osnove dinamike tekočin v turbinskih strojih
- Osnovni principi, analiza in delovne karakteristike turbinskih strojev
- Ne viskozni tok skozi kaskado rotorja turbostroja
- Tridimenzionalni neviskozni in kvaziviskozni tok v pretočnem traktu turbinskih strojev
- Izračun tokovnih lastnosti v pretočnem traktu turbinskih strojev
- Hlajenje in prenos toplote v turbinskih strojih
- Kavitacija v turbinskih strojih
- Nestacionarnosti pri obremenitvah izven optimalnega obratovalnega področja kompresorjev (rotirajoče odlepljanje – rotating stall, goltnost – surge)
- Nadzvočni tok v turbinskih strojih
- Popis in analiza značilnih fizikalnih pojavov in relevantne raziskovalne aktivnosti na področju:
 - o vodnih turbin
 - o črpalk
 - o parnih in plinskih turbin
 - o turbinskih kompresorjev

- Classification of turbomachinery and fundamentals of turbomachinery fluid dynamics;
- Basic principles, analyses and performance characteristics of turbomachinery;
- In-viscid fluid flow through the turbomachinery cascade;
- 3-D in-viscid and quasi-viscid fluid flow within turbomachinery flow channel;
- Calculation of flow dynamics within the turbomachinery flow channels;
- Cooling and heat transfer in turbomachinery;
- Cavitation in turbomachinery;
- Off-design operation of turbo-compressors (rotating stall and surge);
- Supersonic flow in turbomachinery;
- Determination and analysis of typical physical phenomena and relevant research activities in the field of:
 - o water turbines
 - o pumps
 - o steam and gas turbines
 - o turbo-compressors

Temeljna literatura in viri/Readings:

- [1] Pfleiderer, C., Petermann, N.: Strömungsmaschinen.- 4. Aufl.- Berlin etc.: Springer, COBISS.SI-ID - 8907525, 1972
- [2] Raabe, J.: Hydro power: the design, use and function of hydromechanical, hydraulic and electrical equipment.- Düsseldorf: VDI, COBISS.SI-ID - 378907, 1985
- [3] Lakshminarayana, B.: Fluid dynamics and heat transfer of turbomachinery.- New York etc.: J. Wiley & Sons, COBISS.SI-ID - 17136645, 1996
- [4] B.Širok, M.Dular, B.Stoffel. Kavitacija. 1. natis. Ljubljana: i2, 164 str., , COBISS.SI-ID - 227838208, 2006
- [5] Saravanamuttoo H., Rogers G., Cohen H.: Gas turbine theory, 5th Edition, Prentice Hall, COBISS.SI-ID - 42078465, 2001

Cilji in kompetence:

Cilji:

Študenti:

- razumejo vlogo in pomen poznavanja teorije turbinskih strojev;
- razumejo mehanizme energijskih pretvorb v turbinskih strojih v najširšem smislu;
- poznajo teoretične nastavke za popis značilnih tokovnih lastnosti na posameznih področjih turbinskih strojev;
- poznajo metodologijo sodobnega raziskovalnega dela pri snovanju, numeričnem modeliranju dinamike toka v pretočnem traktu turbinskih strojev in eksperimentalnem delu na ravni energijskih karakteristik celotnega turbinskega stroja kakor tudi značilnih pojavov na mikr-ravni;
- znajo določiti osnovne karakteristike turbinskih strojev, ki so vgrajeni v energetske sisteme;
- poznajo potrebne podatke in analize energetskih postrojenj za vgradnjo turbinskih strojev v najširšem smislu.

Kompetence:

Študent:

- je usposobljen za samostojno in izvirno znanstveno-raziskovalno delo na področju turbinskih strojev;
- pridobi vpogled v aktualno znanstveno literaturo s področja turbinskih strojev in je seznanjen z

Objectives and competences:

Goals:

The student:

- understands the role and importance of the expertise of the turbomachinery theory;
- understands the principles of energy conversion in turbomachinery in general meaning;
- understands the theoretical approaches to describe characteristic flow phenomena for typical parts of turbomachinery;
- understands the methodology of contemporary research activities for designing, numerical modeling of fluid flow within the flow channel of turbomachinery and experimental activities in the field of determination of energy characteristics of the whole turbomachinery as well as typical micro-scale-phenomena;
- is able to determine basic characteristics of turbomachinery which are part of complex power systems;
- is able to obtain relevant data and perform analysis of energy-conversion systems for the purposes of turbomachinery integration;

Competences:

The student:

- is qualified to perform independent original research activities in the field of turbomachinery;

<p>relevantnimi problemi raziskovalne skupnosti;</p> <ul style="list-style-type: none"> • je sposoben planirati in izvajati raziskovalno delo do končnega cilja raziskav; • je usposobljen za numerično modeliranje značilnih fizikalnih pojavov v turbinskih strojih; • je usposobljen za eksperimentalno raziskovanje pojavov v turbinskih strojih; • pridobi strokovne podlage za oblikovanje pretočnih traktov turbinskih strojev; • je sposoben diagnosticirati vzroke za napake v delovanju turbinskih strojev; • pozna vlogo in delovanje perifernih sklopov turbinskih strojev (tesnjenje, kompenzacija aksialnih sil, hladilni sistemi itd.); • pozna vlogo in delovanje širšega postrojenja, v katerega je turbinski stoj vgrajen; • je usposobljen za opravljanje raziskovalnega dela z modelnimi turbinskimi stroji in uporabljati teorijo podobnosti turbinskih strojev; • je usposobljen za strokovno presojo ustreznosti izbora turbinskih strojev za vgradnje v tehniške sisteme. 	<ul style="list-style-type: none"> • acquires thorough insight of relevant scientific literature in the field of turbomachinery including the contemporary research-community issues; • is able to plan and execute specific research activities that lead towards the research goals; • is qualified for numerical modeling of typical turbomachinery flow phenomena; • is qualified for experimental research activities in the field of turbomachinery; • acquires the expert guidelines for turbomachinery-flow-channel design; • is able to diagnose the malfunctions in turbomachinery operation; • is acquainted with the role and performance of auxiliary turbomachinery components (sealing, compensation of axial forces, cooling systems, etc.); • is acquainted with performance of complex power system in which the turbomachinery is integrated; • is able to perform model tests and use the similarity theory in the field of turbomachinery; • is qualified for expert assessment of turbomachinery-integration suitability
--	--

Predvideni študijski rezultati:

<p>Študent:</p> <ul style="list-style-type: none"> • je usposobljen za samostojno in izvirno znanstveno-raziskovalno delo na področju turbinskih strojev; • pridobi vpogled v aktualno znanstveno literaturo s področja turbinskih strojev in je seznanjen z relevantnimi problemi raziskovalne skupnosti; • je sposoben planirati in izvajati 	<p>The student:</p> <ul style="list-style-type: none"> • is qualified to perform independent original research activities in the field of turbomachinery; • acquires thorough insight of relevant scientific literature in the field of turbomachinery including the contemporary research-community issues; • is able to plan and execute
---	---

<p>raziskovalno delo do končnega cilja raziskav;</p> <ul style="list-style-type: none"> • je usposobljen za numerično modeliranje značilnih fizikalnih pojavov v turbinskih strojih; • je usposobljen za eksperimentalno raziskovanje pojavov v turbinskih strojih; • pridobi strokovne podlage za oblikovanje pretočnih traktov turbinskih strojev; • je sposoben diagnosticirati vzroke za napake v delovanju turbinskih strojev; • pozna vlogo in delovanje perifernih sklopov turbinskih strojev (tesnjenje, kompenzacija aksialnih sil, hladilni sistemi itd.); • pozna vlogo in delovanje širšega postrojenja, v katerega je turbinski stoj vgrajen; • je usposobljen za opravljanje raziskovalnega dela z modelnimi turbinskimi stroji in uporabljati teorijo podobnosti turbinskih strojev; • je usposobljen za strokovno presojo ustreznosti izbora turbinskih strojev za vgradnje v tehniške sisteme. 	<p>specific research activities that lead towards the research goals;</p> <ul style="list-style-type: none"> • is qualified for numerical modeling of typical turbomachinery flow phenomena; • is qualified for experimental research activities in the field of turbomachinery; • acquires the expert guidelines for turbomachinery-flow-channel design; • is able to diagnose the malfunctions in turbomachinery operation; • is acquainted with the role and performance of auxiliary turbomachinery components (sealing, compensation of axial forces, cooling systems, etc.); • is acquainted with performance of complex power system in which the turbomachinery is integrated; • is able to perform model tests and use the similarity theory in the field of turbomachinery; • is qualified for expert assessment of turbomachinery-integration suitability
---	--

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:

Način(ustni izpit, seminarsko delo, projekt) - naloge (30%) -projektni seminar (50%) -ustno izpraševanje (20%)		Method (written exam, oral examination, assignments, project) • assignments (30%) • project seminar (50%) • oral
--	--	--

		examination (20%)
--	--	-------------------

Ocenjevalna lestvica:

Grading system:

--	--

Reference nosilca/Lecturer's references:

prof. dr. Mihael SEKAVČNIK

MORI, Mitja, NOVAK, Lovrenc, SEKAVČNIK, Mihael. Measurements on rotating blades using IR thermography. *Experimental thermal and fluid science*. [Print ed.]. 2007, letn. 32, št. 2, str. 387-396. ISSN 0894-1777.

<http://dx.doi.org/10.1016/j.expthermflusci.2007.05.002>. [COBISS.SI-ID [10121755](#)], [JCR, SNIP, WoS do 17. 5. 2023: št. citatov (TC): 27, čistih citatov (CI): 26, čistih citatov na avtorja (CIAu): 8,67, Scopus do 16. 4. 2023: št. citatov (TC): 40, čistih citatov (CI): 39, čistih citatov na avtorja (CIAu): 13,00]

DROBNIČ, Boštjan, SEKAVČNIK, Mihael, OMAN, Janez. Use of the kriging method in determining the properties of gases in large channels. *International journal of thermal sciences*. Oct. 2009, vol. 48, iss. 10, str. 1901-1907. ISSN 1290-0729.

<http://dx.doi.org/10.1016/j.ijthermalsci.2009.02.019>, DOI: [10.1016/j.ijthermalsci.2009.02.019](https://doi.org/10.1016/j.ijthermalsci.2009.02.019). [COBISS.SI-ID [11008795](#)], [JCR, SNIP, WoS, Scopus]

SEKAVČNIK, Mihael, GANTAR, Tine, MORI, Mitja. A single-stage centripetal pump - design features and an investigation of the operating characteristics. *Journal of fluids engineering : Transactions of the ASME*. Feb. 2010, vol. 132, iss. 2, str. 021106-1-021106-10. ISSN 0098-2202. DOI: [10.1115/1.4000846](https://doi.org/10.1115/1.4000846). [COBISS.SI-ID [11296027](#)], [JCR, SNIP, WoS, Scopus do 22. 8. 2017: št. citatov (TC): 1, čistih citatov (CI): 1, čistih citatov na avtorja (CIAu): 0,33]

DROBNIČ, Boštjan, PIRC, Andrej, MORI, Mitja, SEKAVČNIK, Mihael. A novel approach to the regulation of a self-sufficient energy system using a system-state matrix. *International journal of electrical power & energy systems*. [Print ed.]. Dec. 2013, vol. 53, str. 893-899, ilustr. ISSN 0142-0615.

<http://dx.doi.org/10.1016/j.ijepes.2013.06.010>, DOI: [10.1016/j.ijepes.2013.06.010](https://doi.org/10.1016/j.ijepes.2013.06.010). [COBISS.SI-ID [12988187](#)], [SNIP, WoS, Scopus]

prof. dr. Marko HOČEVAR

KOZMUS, Gregor, ZEVIK, Jure, HOČEVAR, Marko, DULAR, Matevž, PETKOVŠEK, Martin. Characterization of cavitation under ultrasonic horn tip : proposition of an acoustic cavitation parameter. *Ultrasonics Sonochemistry*. 2022, vol. 89, str. 1-10, ilustr. ISSN 1350-4177.

<https://www.sciencedirect.com/science/article/pii/S1350417722002553>,

<https://repozitorij.uni-lj.si/IzpisGradiva.php?id=140393>, DOI:

[10.1016/j.ultsonch.2022.106159](https://doi.org/10.1016/j.ultsonch.2022.106159). [COBISS.SI-ID [121319171](#)], [JCR, SNIP, WoS do 14. 4. 2023: št. citatov (TC): 3, čistih citatov (CI): 3, čistih citatov na avtorja (CIAu): 0,60, Scopus do 6. 5. 2023: št. citatov (TC): 4, čistih citatov (CI): 4, čistih citatov na avtorja (CIAu): 0,80]

PIPP, Peter, HOČEVAR, Marko, DULAR, Matevž. Challenges of numerical simulations of cavitation reactors for water treatment - an example of flow simulation inside a cavitating microchannel. *Ultrasonics Sonochemistry*. Sep. 2021, vol. 77, str. 1-10, ilustr. ISSN 1350-4177.

<https://www.sciencedirect.com/science/article/pii/S1350417721002054>,

<https://repozitorij.uni-lj.si/IzpisGradiva.php?id=128620>, DOI:

10.1016/j.ultsonch.2021.105663. [COBISS.SI-ID 70757891], [JCR, SNIP, WoS do 28. 12. 2022: št. citatov (TC): 4, čistih citatov (CI): 4, čistih citatov na avtorja (CIAu): 1,33, Scopus do 4. 12. 2022: št. citatov (TC): 4, čistih citatov (CI): 4, čistih citatov na avtorja (CIAu): 1,33]

MUNIHI, Jernej, HOČEVAR, Marko, PETRIČ, Klemen, DULAR, Matevž. Development of CFD-based procedure for 3d gear pump analysis. *Engineering applications of computational fluid mechanics*. 2020, vol. 14, iss. 1, str. 1023-1034, ilustr. ISSN 1994-2060. <https://www.tandfonline.com/doi/full/10.1080/19942060.2020.1789506>, <https://repozitorij.uni-lj.si/IzpisGradiva.php?id=125684>, DOI:

10.1080/19942060.2020.1789506. [COBISS.SI-ID 27653635], [JCR, SNIP, WoS do 16. 2. 2023: št. citatov (TC): 8, čistih citatov (CI): 8, čistih citatov na avtorja (CIAu): 2,00, Scopus do 8. 2. 2023: št. citatov (TC): 8, čistih citatov (CI): 8, čistih citatov na avtorja (CIAu): 2,00]

PETKOVŠEK, Martin, HOČEVAR, Marko, DULAR, Matevž. Visualization and measurements of shock waves in cavitating flow. *Experimental thermal and fluid science*. [Print ed.]. Nov. 2020, vol. 119, str. 1-10, ilustr. ISSN 0894-1777.

[https://www.sciencedirect.com/science/article/pii/S0894177720307196?via](https://www.sciencedirect.com/science/article/pii/S0894177720307196?via%3Dihub)

[%3Dihub](https://www.sciencedirect.com/science/article/pii/S0894177720307196?via%3Dihub), <https://repozitorij.uni-lj.si/IzpisGradiva.php?id=117685>, DOI:

10.1016/j.expthermflusci.2020.110215. [COBISS.SI-ID 23172099], [JCR, SNIP, WoS do 3. 4. 2023: št. citatov (TC): 26, čistih citatov (CI): 17, čistih citatov na avtorja (CIAu): 5,67, Scopus do 15. 5. 2023: št. citatov (TC): 29, čistih citatov (CI): 19, čistih citatov na avtorja (CIAu): 6,33]

prof. dr. Matevž DULAR

GOSTIŠA, Jurij, ŠIROK, Brane, BIZJAN, Benjamin, ORTAR, Jernej, DULAR, Matevž, ZUPANC, Mojca. Multiparametric experimental analysis of the pin disc rotational cavitation generator. *Engineering science and technology : an international journal*. Feb. 2023, vol. 38, str. 1-13, ilustr. ISSN 2215-0986.

<https://www.sciencedirect.com/science/article/pii/S2215098622002324>, DOI:

[10.1016/j.jestch.2022.101323](https://www.sciencedirect.com/science/article/pii/S2215098622002324). [COBISS.SI-ID [137051651](https://www.sciencedirect.com/science/article/pii/S2215098622002324)], [JCR, SNIP, Scopus]

PIPP, Peter, HOČEVAR, Marko, DULAR, Matevž. Challenges of numerical simulations of cavitation reactors for water treatment - an example of flow simulation inside a cavitating microchannel. *Ultrasonics Sonochemistry*. Sep. 2021, vol. 77, str. 1-10, ilustr. ISSN 1350-4177.

<https://www.sciencedirect.com/science/article/pii/S1350417721002054>, DOI:

[10.1016/j.ultsonch.2021.105663](https://www.sciencedirect.com/science/article/pii/S1350417721002054). [COBISS.SI-ID [70757891](https://www.sciencedirect.com/science/article/pii/S1350417721002054)], [JCR, SNIP, WoS do 28. 12. 2022: št. citatov (TC): 4, čistih citatov (CI): 4, čistih citatov na avtorja (CIAu): 1,33, Scopus do 4. 12. 2022: št. citatov (TC): 4, čistih citatov (CI): 4, čistih citatov na avtorja (CIAu): 1,33]

GOSTIŠA, Jurij, ZUPANC, Mojca, DULAR, Matevž, ŠIROK, Brane, LEVSTEK, Meta, BIZJAN, Benjamin. Investigation into cavitation intensity and COD reduction

performance of the pinned disc reactor with various rotor-stator arrangements. *Ultrasonics Sonochemistry*. Sept. 2021, vol. 77, str. 1-11, ilustr. ISSN 1350-4177. <https://www.sciencedirect.com/science/article/pii/S135041772100211X#!>, DOI: [10.1016/j.ultsonch.2021.105669](https://doi.org/10.1016/j.ultsonch.2021.105669). [COBISS.SI-ID [70807811](#)], [JCR, SNIP, WoS do 11. 9. 2022: št. citatov (TC): 3, čistih citatov (CI): 1, čistih citatov na avtorja (CIAu): 0,17, Scopus do 31. 3. 2023: št. citatov (TC): 6, čistih citatov (CI): 2, čistih citatov na avtorja (CIAu): 0,33]

MUNIH, Jernej, HOČEVAR, Marko, PETRIČ, Klemen, DULAR, Matevž. Development of CFD-based procedure for 3d gear pump analysis. *Engineering applications of computational fluid mechanics*. 2020, vol. 14, iss. 1, str. 1023-1034, ilustr. ISSN 1994-2060. <https://www.tandfonline.com/doi/full/10.1080/19942060.2020.1789506>, DOI: [10.1080/19942060.2020.1789506](https://doi.org/10.1080/19942060.2020.1789506). [COBISS.SI-ID [27653635](#)], [JCR, SNIP, WoS do 16. 2. 2023: št. citatov (TC): 8, čistih citatov (CI): 8, čistih citatov na avtorja (CIAu): 2,00, Scopus do 8. 2. 2023: št. citatov (TC): 8, čistih citatov (CI): 8, čistih citatov na avtorja (CIAu): 2,00]