TERMOFLUIDIKA

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	Termofluidika
Course title:	Thermofluidics
Članica nosilka/UL Member:	UL FS

Študijski programi in stopnja	Študijska smer	Letnik	Semestri	Izbirnost
Strojništvo - projektno aplikativni program, prva stopnja, visokošolski strokovni	Ni členitve (študijski program)	1. letnik	2. semester	obvezni

Univerzitetna koda predmeta/University course code:	0562665
Koda učne enote na članici/UL Member course code:	3010-V

Predavanja /Lectures	Seminar /Seminar	Vaje /Tutorials	Klinične vaje /Clinical tutorials	Druge oblike študija /Other forms of study	Samostojno delo /Individual student work	ECTS
45		45			35	5

Nosilec predmeta/Lecturer:	Boštjan Mavrič, Božidar Šarler

Izvajalci predavanj:	
Izvajalci seminarjev:	
Izvajalci vaj:	
Izvajalci kliničnih vaj:	
Izvajalci drugih oblik:	
Izvajalci praktičnega usposabljanja:	

Vrsta predmeta/Course type:	Obvezni splošni predmet /Compulsory general course

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

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	**Prerequisites:**
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.

Vsebina:	**Content (Syllabus outline):**
1. Uvod: - cilji in namen predmeta (združena obravnava termodinamskih principov ter principov mehanike tekočin), predstavitev učnega programa, pripomočkov in virov, - predstavitev obveznosti študentov in napotki za uspešen študij. - pomen termofluidike v tehniki. 2. Struktura termodinamike: - termodinamski koncepti, termodinamski zakoni, - spremeljivke termodinamskaga stanja, eksperimentalne spremenljivke, - procesne spremenljivke: delo in toplota. 3. Termodinamske spremenljivke in funkcije: - temperatura, volumen, tlak, notranja energija, entalpija, kemični potencial, - idealni plin, - led, voda in vodna para. 4. Eksperimentalne spremenljivke: - koeficient termičnega volumskega raztezka, koeficient stisljivosti, - specifična toplota pri konstantnem tlaku, specifična toplota pri konstantnem volumnu, - trdnine, kapljevine, plini. 5. Procesne spremenljivke: - analiza zunanjih vplivov na sistem - mehansko in druge vrste dela - toplota in mehanizmi prenosa toplote:	1. Introduction: - objectives and purpose of the course (combined treatment of thermodynamic principles and principles of fluid mechanics), presentation of the curriculum, tools and resources, - presentation of student obligations and directions for successful study. 2. Structue of thermodynamics: - thermodynamic concepts, thermodynamic laws, - thermodynamic state variables, experimental variables, - process varables: work and heat. 3. Thermodynamic variables and functions: - temperature, volume, pressure, internal energy, enthalpy, chemical potential, - ideal gas, - ice, water and water steam. 4. Experimental variables: - thermal expansion coefficient, compressibility coefficient, - specific heat at constant pressure, specific heat at constant volume, - solids, liquids and gasses. 5. Process variables: - analysis of external influences on the system, - mechanical and other types of work, - heat and mechanisms of heat transfer: conduction, convection,

prevod, konvekcija, sevanje. 6. Zakoni termodinamike: - ničti in prvi zakon, - drugi in tretji zakon, - relacije, ki izhajajo iz zakonov termodinamike za zaprte in odprte sisteme. 7. Termodinamski procesi: - Izotermni, izentropni, izobarni, izohorni, politropni - procesi z idealnim plinom in vodno paro - idealni in dejanski procesi, analiza in izkoristek procesov. 8. Pomembni termodinamski krožni procesi: - Carnotov, Rankinov, - Hladilni procesi in toplotne črpalke, - Ottov and Dieselov proces. 9. Mešanice: - mešanica nereaktivnih idealni plinov, - plini v stiku s trdninami, kapljevinami in drugimi plini, - procesi z vlažnim zrakom. 10. Hidrostatika - tlak v tekočini med mirovanjem, - vzgon in stabilnost plavajočih teles, - tlak v sistemih s togim gibanjem. 11. Osnove dinamike tekočin - nestisljivi tok: - Bernoullijeva enačba, - tok nestisljive viskozne tekočine v kanalih in ceveh, - turbulentni tok v ceveh. 12. Osnove dinamike tekočin - stisljivi tok: - izotremni, adiabatni in izentropni stisljivi tok, - stisljivi tok v ceveh, - stisljivi tok skozi šobe. 13. Osnove dinamike tekočin - tok okoli teles: - mejna plast, - upor, - vzgon. 14. Osnove dinamike tekočin - tok v kanalih: - valovi, - tok v kanalih s spremenjivo geometrijo, - hidravlični skok.	radiation. 6. Thermodynamic laws: - zero and first law, - second and third law, - relations that stem from thermodynamics laws for open and closed systems. 7. Termodynamic processes: - Isothermal. isentopic, isobaric, isochoric, polytropic, - processes with ideal gas and water steam, - ideal and actual processes, analysis and process efficiency. 8. Important thermodynamic cycles: - Carnot cycle, Rankin cycle, - Cooling processes and heat pumps, - Otto and Diesel cycle. 9. Mixtures: - mixture of non-reactive ideal gasses, - gases in contacts with solids, liquids and other gasses, - humid air processes. 10. Hydrostatics: - pressure in liquid while stationary, - buoyancy and stability of floating bodies, - pressure in systems with rigid motion. 11. Fluid dynamics fundamentals - incompressible flow: - Bernoulli equation, - flow of incompressible viscous fluid in channels and tubes, - turbulent flow in tubes. 12. Fluid dynamics fundamentals - compressible flow: - isothermal, adiabatic and isentropic compressile flow, - compressible flow in tubes, - compressible flow through nozzles. 13. Fluid dynamics fundamentals - flow around bodies: - boundary layer, - drag, - llift. 14. Fluid dynmics fundamentals - channel flow: - waves, - flow in channels with changing geometry,

15. Osnove dvofaznega toka: - značilnosti dvofaznih tokov, - dvofazni tokovi v horizontalnih in vertikalnih ceveh, - fazni prehodi.	- hydraulic jump. 15. Fundamentals of two-phase flow: - characteristics of two-phase flow, - two-phase flow in horizontal and vertical tubes, - phase-change.

Temeljna literatura in viri/Readings:

1. M. Massoud, Engineering Thermofluids: Thermodynamics, Fluid Mechanics, and Heat Transfer, Springer Verlag, Berlin, 2005. ISBN - 3-540-22292-8; 978-3-540-22292-7, [COBISS.SI-ID 28005637]
2. S. R. Turns, Thermal-Fluid Sciences: An Integrated Approach. Cambridge University Press, Cambridge, 2006. ISBN - 0-521-85043-6; 978-0-521-85043-8, [COBISS.SI-ID 28005125]
3. F. W. Schmidt, R.E. Henderson, C. H. Wolgemuth, Introduction to Thermal Sciences: Thermodynamics Fluid Dynamics, Heat Transfer. J.Wiley & Sons, New York, 199 ISBN - 0-471-60008-3, [COBISS.SI-ID 728347]
4. C. Marquand, D. Croft, Thermofluids, An Integrated Approach to Thermodynamics and Fluid Mechanics Principles, J.Wiley & Sons, New York, 1994. ISBN - 0-471-94184-0; 0-471-94357-6, [COBISS.SI-ID 14761989]

Cilji in kompetence:	**Objectives and competences:**
Cilji: Spoznati osnovne pojme in principe termofluidike. Spoznati kritični pristop k razčlenitvi in razumevanju ter zmožnost reševanja inženirskih problemov. Kompetence: S11-PAP, P1-PAP: Prepoznava tehniško relevantnih aplikacij termofluidnih konceptov, (P8-PAP): ki jih povezujejo termodinamske lastnosti, preobrazbe, sistemi in procesi.	Objectives: To learn the basic concepts and principles of thermofluidics. To learn the critical approach to breakdown and understanding as well as the ability to solve enginering problems. Competences: S11-PAP, P1-PAP: Recognizing technically relevant applications of thermofluidic concepts, (P8-PAP) coupled by thermodynamic properties, transformations, systems and processes.

Predvideni študijski rezultati:	**Intended learning outcomes:**
Znanja: Z1: Študent bo po uspešno končanih študijskih obveznostih znal določiti osnovne lastnosti in zakonitosti s področja termodinamike in dinamike tekočin, določit kontrolni sistem in bilanco prehajajočih energij in gibelne količine.	Knowledge: Z1: After successfully completing the study obligations, the student will be able to determine the basic properties and laws in the field of thermodynamics and fluid dynamics, determine the control system and the balance of

Spretnosti: S1.1 Diagnosticiranje in reševanje problemov v različnih specifičnih delovnih okoljih, povezanih s področjem izobraževanja in usposabljanja. S1.2 Obvladovanje zahtevnih, kompleksnih delovnih procesov ob samostojni uporabi znanja v novih delovnih situacijah. S1.3 Osnova za izvirna dognanja/ stvaritve in kritično refleksijo.	transferred energies and momentum. Skills: S1.1 Diagnosing and solving problems in various specific work environments related to education and training. S1.2 Mastery of demanding, complex work processes with the independent use of knowledge in new work situations. S1.3 Basis for original findings / creations and critical reflection.

Metode poučevanja in učenja:	**Learning and teaching methods:**
P1: Avditorni način predavanja. P3: Avditorialne vaje - teroetično znanje podkrepljeno z računskimi primeri. P4: Laboratorijske vaje: laminaren/turbulenten tok, viskoznost tekočine, toplotna kapaciteta, konvektivni prenos toplote. P5: Uporaba študijskega gradiva v obliki učbenika za predavanja. P5: Uporaba študijskega gradiva v obliki učbenika za vaje. P14: Virtualni eksperimenti. P14: Občasna uporaba računalniške animacije.	P1: Auditory lectures. P3: Auditory exercises - Theoretic knowledge backed by computational examples. P4: Lab work: laminar/turbulent flow, fluid viscosity, heat capacity, convective heat transfer. P5: Use of study materials such as a textbook. P5: Use of study materials such as exercise textbook. P14: Virtual experiments. P14: Occasional use of computer animation.

Načini ocenjevanja:	**Delež/ Weight**	**Assessment:**
Kolokviji in izpiti. Oceno izpita sestavljata teorija (predavanja)	50,00 %	Colloquia and exams. Exam grade consists of theory (lectures)
in vaje (skupaj z laboratorijskimi).	50,00 %	and exercises (including labs).

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:

Božidar Šarler:

1. WANG, Kai, WEN, Shiting, ZAHOOR, Rizwan, LI, Ming, **ŠARLER, Božidar**.

Method of regularized sources for axisymmetric Stokes flow problems. International journal of numerical methods for heat & fluid flow. 2016, vol. 26, iss. 3/4, str. 1226-1239, ilustr. ISSN 0961-5539. http://dx.doi.org/10.1108/HFF-09-2015-0397, DOI: 10.1108/HFF-09-2015-0397. [COBISS.SI-ID 1206954] Ref 1

2. HATIĆ, Vanja, MAVRIČ, Boštjan, **ŠARLER, Božidar**. Simulation of a macrosegregation benchmark with a meshless diffuse approximate method. International journal of numerical methods for heat & fluid flow. 2018, vol. 28, iss. 2, str. 361-380, ilustr. ISSN 0961-5539. http://www.emeraldinsight.com/doi/full/10.1108/HFF-04-2017-0143, DOI: 10.1108/HFF-04-2017-0143. [COBISS.SI-ID 1386922]
3. REK, Zlatko, CHAPMAN, Henry N., **ŠARLER, Božidar**, BAJT, Saša. Numerical simulation of heat load for multilayer laue lens under exposure to XFEL pulse trains. *Photonics*. May 2022, vol. 9, iss. 5, str. 1-18, ilustr. ISSN 2304-6732. https://www.mdpi.com/2304-6732/9/5/362, https://repozitorij.uni-lj.si/IzpisGradiva.php?id=136950, DOI: 10.3390/photonics9050362. [COBISS.SI-ID 109202947]
4. HATIĆ, Vanja, MAVRIČ, Boštjan, **ŠARLER, Božidar**. Simulation of macrosegregation in direct-chill casting : a model based on meshless diffuse approximate method. *Engineering analysis with boundary elements*. Apr. 2020, vol. 113, str. 191-203, ilustr. ISSN 0955-7997. https://www.sciencedirect.com/science/article/pii/S0955799719306678, https://repozitorij.uni-lj.si/IzpisGradiva.php?id=137769, DOI: 10.1016/j.enganabound.2019.12.006. [COBISS.SI-ID 17024283]
5. VERTNIK, Robert, MRAMOR, Katarina, **ŠARLER, Božidar**. Solution of three-dimensional temperature and turbulent velocity field in continuously cast steel billets with electromagnetic stirring by a meshless method. *Engineering analysis with boundary elements*. Jul. 2019, vol. 104, str. 347-363, ilustr. ISSN 0955-7997. https://www.sciencedirect.com/science/article/pii/S0955799718305010?via%3Dihub, DOI: 10.1016/j.enganabound.2019.03.026. [COBISS.SI-ID 1474474]

Boštjan Mavrič:

1. RANA, Khush Bakhat, **MAVRIČ, Boštjan**, ZAHOOR, Rizwan, ŠARLER, Božidar. A meshless solution of the compressible viscous flow in axisymmetric tubes with varying cross-sections. *Engineering analysis with boundary elements*. Oct. 2022, vol. 143, str. 340-352, ilustr. ISSN 0955-7997. https://www.sciencedirect.com/science/article/pii/S0955799722002260, Repozitorij Univerze v Ljubljani – RUL, DOI: 10.1016/j.enganabound.2022.06.029. [COBISS.SI-ID 114950915], [JCR, SNIP, WoS do 3. 1. 2024: št. citatov (TC): 1, čistih citatov (CI): 0, čistih citatov na avtorja (CIAu): 0.00, Scopus do 17. 2. 2024: št. citatov (TC): 1, čistih citatov (CI): 0, čistih citatov na avtorja (CIAu): 0.00]
2. NAJAFI, Mahboubeh, DEHGHAN, Mehdi, ŠARLER, Božidar, KOSEC, Gregor, **MAVRIČ, Boštjan**. Divergence-free meshless local Petrov–Galerkin method for Stokes flow. *Engineering with computers*. [Online ed.]. [in press] 2022, 19 str. ISSN 1435-5663. DOI: 10.1007/s00366-022-01621-w. [COBISS.SI-ID 99503875], [JCR, SNIP, WoS do 2. 12. 2023: št. citatov (TC): 4, čistih citatov (CI): 3, čistih citatov na avtorja (CIAu): 0.60, Scopus do 21. 11. 2023: št. citatov (TC): 6, čistih citatov (CI): 5, čistih citatov na avtorja (CIAu): 1.00]
3. TALAT, Nazia, **MAVRIČ, Boštjan**, HATIĆ, Vanja, BAJT, Saša, ŠARLER, Božidar.

Phase field simulation of Rayleigh-Taylor instability with a meshless method. *Engineering analysis with boundary elements*. Feb. 2018, vol. 87, str. 78-89, ilustr. ISSN 0955-7997. https://www.sciencedirect.com/science/article/pii/S0955799717304009, DOI: 10.1016/j.enganabound.2017.11.015. [COBISS.SI-ID 1376682], [JCR, SNIP, WoS do 6. 10. 2023: št. citatov (TC): 25, čistih citatov (CI): 17, čistih citatov na avtorja (CIAu): 3.40, Scopus do 8. 10. 2023: št. citatov (TC): 28, čistih citatov (CI): 19, čistih citatov na avtorja (CIAu): 3.80]

4. HATIĆ, Vanja, **MAVRIČ, Boštjan**, ŠARLER, Božidar. Simulation of casting geometry effect in low-frequency electromagnetic casting. V: OKADA, Hiroshi (ur.), ATLURI, Satya N. (ur.). *Computational and experimental simulations in engineering : proceedings of ICCES 2019*. [s.l.]: Springer, [2020]. F. 815-825, ilustr. Mechanisms and machine science, 75. ISBN 3-030-27053-X. ISSN 2211-0984. https://www.springer.com/cn/book/9783030270520. [COBISS.SI-ID 1527978]
5. ŠARLER, Božidar, DOBRAVEC, Tadej, **MAVRIČ, Boštjan**, GOŠNIK, Tin. *Vertical semi-continuous casting online model : description of models and user manual : confidential technical report*. Version 1. Ljubljana: Faculty of Mechanical Engineering, 2023. 12 f., graf. prikazi. [COBISS.SI-ID 169294083]