IZBOLJŠANI PRENOS TOPLOTE

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	IZBOLJŠANI PRENOS TOPLOTE
Course title:	ENHANCED HEAT TRANSFER
Članica nosilka/UL Member:	UL FS

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

Univerzitetna koda predmeta/University course code:	0033448
Koda učne enote na članici/UL Member course code:	7203

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:	Iztok Golobič

Izvajalci predavanj:	Iztok Golobič
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):**
Predavanja, ki se začno z uvodom v izboljšani prenos toplote, zajemajo mnoge tehnike, ki so bile razvite za izboljšanje konvektivnega prenosa toplote. Tehnike so razvrščene, podan je tudi uvod v širšo literaturo. Predstavljena je uporaba različnih oblik prenosa toplote: enofazna prosta konvekcija, enofazna prisilna konvekcija, integralna hrapavost, vrenje, konvektivno vrenje, parno-prostorska kondenzacija in konvektivna kondenzacija ter nesnaga. Zajete so tako pasivne tehnike izboljšanja prenosa toplote (ne potrebujejo zunanje energije) kot aktivne tehnike (potrebujejo zunanjo energijo) ter sestavljene tehnike (istočasno delujoče dve ali več tehnik). Precej pozornosti je posvečeno določitvi karakteristik tako enofaznega kot tudi dvofaznega prenosa toplote, nečistoči, aditivivom za pline in kapljevine, nanofluidom, mikrokanalom ter prenosu toplote pri hlajenju elektronskih komponent. Študentje se učijo kako izbrati ustrezno tehniko izboljšanega prenosa toplote za eno in večfazne tokove in kako določiti cenilne kriterije za izboljšanje prenosa toplote. Napredno izboljšanje predstavlja tretjo in v povezavi s hkratno delujočimi različnimi aktivnimi tehnikami četrto generacijo tehnologije prenosa toplote.	The lectures begin with introduction to enhancements of heat transfer. They give many techniques, which were developed for convective heat transfer enhancements. The techniques are classified and a wider range of literature is introduced. Application of different heat transfer modes is presented: single phase natural convection, single phase forced convection, integral roughness, pool boiling and thin film evaporation, convective vaporization, vapor space condensation and convective condensation. Passive techniques of heat transfer enhancements (no external energy source is needed) as well as active techniques (external energy is required) and combined techniques (simultaneous application of two techniques or more) are included. Determination of characteristics of single phase as well as two-phase heat transfer, fouling, additives for liquids and gases, nanofluids, microchannels and electronic cooling heat transfer are presented. Students learn how to choose an appropriate enhancement technique for single- and multi-phase flow and how to determine performance evaluation criteria for enhancements. Advanced enhancements belong to the third generation of heat transfer technology and to the fourth generation, when combined with different active techniques

Temeljna literatura in viri/Readings:

[1] Webb R.L.: Principles of enhanced heat transfer. Second edition, Taylor& Francis, Boca Raton, 2005. (Cobiss ID: 8602651)
[2] Joshua P. Mayer, Michael De Paepe: The Art of Measuring in the Thermal Sciences, 1st ed., CRC Press, London, 2021 (Cobiss ID: 55605507)
[3] Incropera F.P., DeWitt P.D., Bergman, T.L, Lavine, A.S.: Fundamentals of Heat and Mass Transfer, Sixth Edition, John Wiley and Sons, New York, 2007. (Cobiss ID: 12387634)
[4] Gašperšič B.: Prenos toplote, Univerza v Ljubljani, Fakulteta za strojništvo, Ljubljana, 2001. (Cobiss ID: 111288064)
[5] VDI Gesellschaft, VDI Heat Atlas. 2nd Edition, Springer, Düsseldorf, 1993 (Cobiss ID: 1398555).
[6] Atkins, Peter William, idr. Atkins' physical chemistry. 11th ed., Oxford University Press, 2018. (COBISS.SI-ID 21197846)

Cilji in kompetence:	**Objectives and competences:**
Cilji: Usposobiti študenta za uporabo inženirskih orodij za reševanje problemov iz prenosa toplote in utrjevanje inženirskega raziskovalnega pristopa k njihovemu reševanju. Pri študiju so dani poudarki na spoznavanju mehanizmov izboljšanega prenosa toplote ob poudarku na možnostih nadgradnje za učinkovitejši prenos toplote v konkretni aplikaciji. Vsebina in način izvedbe predmeta s poudarkom na eksperimentalnem pristopu in računalniški podpori v virtualnem okolju omogoča študentu samostojnost in kreativnost pri reševanju sestavljenih kompleksnih problemov iz prenosa toplote ter ga uvaja v samostojno raziskovalno delo. **Kompetence:** Predmet razvija sposobnost samostojnega učenja, osebne ter profesionalne rasti, kreativnost, sposobnost za timsko delo, sposobnost upoštevanja inženirskega kodeksa ter profesionalne in okoljske odgovornosti. Študent osvoji nova znanja in nadgradi že pridobljena znanja iz področja prenosa toplote. Študent je sposoben razumeti območje uporabe razpoložljivih tehnik izboljšanja prenosa toplote in	**Goals:** The course aims to qualify students for application of engineering tools in order to solve the problems occurring at heat transfer and to revise the engineering approach for solving them. Mechanisms of enhanced heat transfer are taught with emphasis on possibilities of upgrading them in order to achieve the heat transfer enhancements in real applications. After completing the course, the students understand the range of available techniques to enhance heat transfer and their application to the various modes of heat transfer. When faced with a heat exchanger or heat dissipator, they are able to specify an appropriate enhanced surface or enhancement device. They can locate information that will allow estimation of the percentage improvement in heat transfer with the chosen scheme, and with performance evaluation criteria for formal estimation of the benefits of enhancement. The course is conducted with an emphasis on experimental approach and computer support in virtual environment which allows the student to gain independence and creativity when solving the complex heat transfer problems and introduces him

njihovo aplikativnost pri različnih oblikah prenosa toplote. Je sposoben specificiranja in izbire ustrezne izboljšane napredne površine ali naprave pri različnih aplikacijah prenosnikov toplote. Na konkretnih eksperimentalnih primerih študent pridobi praktične izkušnje in osvoji osnove eksperimentalnega pristopa v raziskovalnem delu.	into independent research work. **Competences:** The course develops an ability of independent learning and personal as well as professional advancement, creativity, ability of team work, ability of consideration of engineering codes with professional and environmental responsibility. The know-how of previous heat transfer courses is upgraded and additional knowledge is obtained. After completing the course, the students have an understanding of basic heat transfer, particularly convective heat transfer. The practical experience is given with presentation of real experimental examples and basics of experimental approach are taught.

Predvideni študijski rezultati:	**Intended learning outcomes:**
Predmet razvija sposobnost samostojnega učenja, osebne ter profesionalne rasti, kreativnost, sposobnost za timsko delo, sposobnost upoštevanja inženirskega kodeksa ter profesionalne in okoljske odgovornosti. Študent osvoji nova znanja in nadgradi že pridobljena znanja iz področja prenosa toplote. Študent je sposoben razumeti območje uporabe razpoložljivih tehnik izboljšanja prenosa toplote in njihovo aplikativnost pri različnih oblikah prenosa toplote. Je sposoben specificiranja in izbire ustrezne izboljšane napredne površine ali naprave pri različnih aplikacijah prenosnikov toplote. Na konkretnih eksperimentalnih primerih študent pridobi praktične izkušnje in osvoji osnove eksperimentalnega pristopa v raziskovalnem delu.	Knowledge and understanding: The course develops an ability of independent learning and personal as well as professional advancement, creativity, ability of team work, ability of consideration of engineering codes with professional and environmental responsibility. The know-how of previous heat transfer courses is upgraded and additional knowledge is obtained. After completing the course, the students have an understanding of basic heat transfer, particularly convective heat transfer. The practical experience is given with presentation of real experimental examples and basics of experimental approach are taught.

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	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

uporabo priporočene literature.	literature basis.

Načini ocenjevanja:	**Delež/Weight**	**Assessment:**
Način (pisni izpit, ustno izpraševanje, naloge, projekt) - naloge (20%) - projektni seminar (60%) - ustno izpraševanje (20%)		Method (written exam, oral examination, assignments, project): • assignments (20%) • project seminar (60%) • oral examination (20%)

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. Iztok GOLOBIČ

BUCCI, Mattia, ZUPANČIČ, Matevž, GARIVALIS, Alekos Ioannis, SIELAFF, Axel, DI MARCO, Paolo, GOLOBIČ, Iztok. The role of the electric field in the departure of vapor bubbles in microgravity. *Physics of fluids*. 2023, vol. 35, iss. 1, str. 1-13, ilustr. ISSN 1070-6631. https://aip.scitation.org/doi/10.1063/5.0127123, https://repozitorij.uni-lj.si/IzpisGradiva.php?id=143668, DOI: 10.1063/5.0127123. [COBISS.SI-ID 136576515

RAZA, Md. Qaisar, KÖCKRITZ, Moritz von, SEBILLEAU, Julien, COLIN, Catherine, ZUPANČIČ, Matevž, BUCCI, Mattia, TROHA, Tadej, GOLOBIČ, Iztok. Coalescence-induced jumping of bubbles in shear flow in microgravity. *Physics of fluids*. 2023, vol. 35, iss. 2, str. 1-12, ilustr. ISSN 1070-6631. https://aip.scitation.org/doi/full/10.1063/5.0138200, https://repozitorij.uni-lj.si/IzpisGradiva.php?id=144581, DOI: 10.1063/5.0138200. [COBISS.SI-ID 143706627]

MOŽE, Matic, ZUPANČIČ, Matevž, GOLOBIČ, Iztok. Pattern geometry optimization on superbiphilic aluminum surfaces for enhanced pool boiling heat transfer. *International journal of heat and mass transfer*. 2020, vol. 161, f. 1-13, ilustr. ISSN 0017- 9310. https://www.sciencedirect.com/science/article/pii/S0017931020332014?via%3Dihub, https://repozitorij.uni-lj.si/IzpisGradiva.php?id=118090, DOI: 10.1016/j.ijheatmasstransfer.2020.120265. [COBISS.SI-ID 25544963]

MOŽE, Matic, SENEGAČNIK, Matej, GREGORČIČ, Peter, HOČEVAR, Matej, ZUPANČIČ, Matevž, GOLOBIČ, Iztok. Laser-engineered microcavity surfaces with a nanoscale superhydrophobic coating for extreme boiling performance. *ACS applied materials & interfaces*. 2020, vol. 12, iss. 21, str. 24419-24431, ilustr. ISSN 1944-8244. https://pubs.acs.org/doi/10.1021/acsami.0c01594, https://repozitorij.uni-lj.si/IzpisGradiva.php?id=116531, DOI: 10.1021/acsami.0c01594. [COBISS.SI-ID 14158851]