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)		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.

[2] Bergles A.E., Jensen M.K., Shome B.: Bibliography on enhancement of convective

heat and mass transfer: Heat transfer laboratory report, HTL-23, Rensselaer

Polytechnic Institute, Troy, 1995.

[3] Thome J.R.: Enhanced boiling heat transfer. Hemisphere, New York,1990.

[4] Sobhan C.B., Peterson G.P.: Microscale and nanoscale heat transfer. Fundamentals

and engineering applications. CRC Press, Boca Raton, 2008.

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	**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

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.	creativity when solving the complex heat transfer problems and introduces him 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	Lectures, laboratory practice & seminar work, e-education, consulting. The seminar work is related, as much as

meri navezujoče se na področje doktorskega raziskovanja. Študij z uporabo priporočene literature.	possible, to the student's doctoral research field. Study on a recommended 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%)

Reference nosilca/Lecturer's references:

prof. dr. Iztok GOLOBIČ

SITAR A., GOLOBIČ I.: Heat transfer enhancement of self-rewetting aqueous n-butanol solutions boiling in microchannels. International journal of heat and mass transfer, 2015,

MELE J., GOLOBIČ I., SENEGAČNIK A.. A method to detect and control fully fluidized conical beds with a wide size distribution of particles in the vicinity of the minimum fluidization velocity. Thermal science, 2015.

ZUPANČIČ M., NOVAK D., DIACI J., GOLOBIČ I.: An evaluation of industrial ultrafiltration systems for surface water using fouling indices as a performance indicator. Desalination, 2014.

SITAR A., SEDMAK I., GOLOBIČ I.: Boiling of water and FC-72 in microchannels enhanced with novel features. International journal of heat and mass transfer, 2012.

SANNA A., KARAYIANNIS T.G., KENNING D.B.R., HUTTER C., SEFIANE K., WALTON A.J., GOLOBIČ I., PAVLOVIČ E., NELSON R.A.: Steps towards the development of an experimentally verified simulation of pool nucleate boiling on a silicon wafer with artificial sites. Applied Thermal Engineering, 2009.