TRIBOLOGIJA

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	TRIBOLOGIJA
Course title:	TRIBOLOGY
Članica nosilka/UL Member:	UL FS

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

Univerzitetna koda predmeta/University course code:	0033445
Koda učne enote na članici/UL Member course code:	7121

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:	Mitjan Kalin

Izvajalci predavanj:	Mitjan Kalin
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):**
1. Uvod: zgodovinski in ekonomski vidiki. 2. Osnove površin: geometrijska, realna, parametri za določanje površin, merilne metode, indeks plastičnosti. 3. Osnove kontaktov: oblike kontaktov, Hertzev kontakt, kontakti z in brez trenja. 4. Maziva in mehanizmi mazanja: bazna olja, aditivi, formulirana olja, masti, trda maziva, fizikalno-kemijske in mehanske lastnosti, hidrodinamično, elastohidrodinamično, hidrostatično, mejno, mešano. 5. Trenje: vzroki, nastanek, oblike, vplivi. 6. Obraba: mehanizmi in oblike obrabe. 7. Površinske analize: topografija, hrapavost, SEM, EDS, XPS, AES, AFM, STM, TEM 8. Tribološki vidiki uporabe: drsni ležaji, kotalni ležaji, zobniki, tesnila, ...	1. Introduction: relevance for industrial environment and economy. 2. Fundamental properties of contacting surfaces: real contact area, Greenwood-Williamson model, roughness parameters and effect on tribological performance, topography, measurements, plasticity index 3. Tribological contacts: types of contacts, Hertzian contact contacts with and without friction 4. Lubrication: base oils, additives, their functionality, lubrication regimes, Reynolds equation, HL and EHL lubrication, pressure distribution in lubricant film, viscosity and deformation effects, mixed lubrication, boundary lubrication, influences of lubrication regime on component life 5. Friction: components of friction, basic models, effects 6. Wear: mechanisms and forms of wear 7. Characterization of surfaces and damages: typical damage forms – examples, solutions, techniques for surface characterization (topography, SEM, EDS; XPS; AES, AFM, STM, TEM..) 8. Tribological aspects of mechanical components: sliding and rolling bearings, gears, seals..

Temeljna literatura in viri/Readings:

[1] Williams, J.A.: Engineering tribology.- Oxford etc.: Oxford University Press, 1994.- (Oxford science publications) COBISS.SI-ID - 16271877
[2] Stachowiak, G.W., Batchelor, A.W.: Engineering tribology.- Amsterdam etc.: Elsevier, 1993.- (Tribology series; 24) COBISS.SI-ID - 736283
[3] Stolarski, T.A.: Tribology in machine design.- Reprinted.- Oxford etc.: Butterworth-Heinemann, BH, 2000 COBISS.SI-ID - 3558427
[4] Hutchings, I.M.: Tribology: friction and wear of engineering materials.- London ... etc.: Edward Arnold, cop. 1992.- (Metallurgy & materials science series) COBISS.SI-ID - 1156635

Cilji in kompetence:	**Objectives and competences:**
Cilji: Temeljni cilji učnega načrta so posredovati študentom teoretično in praktično poglobljena znanja s področja triboloških kontaktov v mehanskih sistemih, ki se medsebojno relativno gibljejo. Opredeliti je treba pomen in vlogo lastnosti kontaktnih površin, materialov in okolice z njihovimi lastnostmi ter kako te komponente tribološkega sistema in kontaktni pogoji vplivajo na same lastnosti trenja in obrabe. Uporabi se teoretične modele, ki so na voljo. Pojasniti je treba vrste in pomen maziv in njihov pomen pri kvaliteti mazanja ter kako se ti vplivi odražajo na trenje, na različne mehanizme trenja in mehanizme obrabe. V povezavi s temi vsebinami je treba predstaviti analitske tehnike, ki so na voljo za analizo lastnosti površin, maziv, tribološkega obnašanja in širših sistemov. **Kompetence**: Študent bo sposoben poglobljene analize in vrednotenja relevantnih triboloških parametrov, kot so primernost materialov in obdelave površin, izbora maziv in obremenitev kontaktov. Samostojno bo predvideval in analiziral tribološke učinke in njihove vplive na trenje in obrabo. Poznal bo temeljna in naprednejša orodja in tehnike na nano/mikro in makro skali za analizo površin in triboloških lastnosti mehanskih sistemov.	**Goals**: Goals of the subject are to introduce students with theoretical and practical details on tribological contacts in mechanical components, which are in relative motion. Influence of contacting surfaces, materials and environment need to be described and discussed how these influence the friction and wear. Existing theoretical models are used. Types and influence of lubricants with their effect on proper lubrication and to friction and wear are further presented. Related to these issues, analytical techniques for analyzing surfaces, oils, tribological contacts and mechanical systems are presented. **Competences**: Students will be able of analyze tribological parameters in great detail, such as effect of materials, surfaces, selection of lubricants, loads and others. Independently will discuss and define the tribological effects and their influences on friction and wear. Students will understand and be aware of basic and advances surface tools on nano/micro and macro scale to analyze surfaces, and tribological properties of mechanical components.

Predvideni študijski rezultati:	Intended learning outcomes:
Študent bo sposoben poglobljene analize in vrednotenja relevantnih triboloških parametrov, kot so primernost materialov in obdelave površin, izbora maziv in obremenitev kontaktov. Samostojno bo predvideval in analiziral tribološke učinke in njihove vplive na trenje in obrabo. Poznal bo temeljna in naprednejša orodja in tehnike na nano/mikro in makro skali za analizo površin in triboloških lastnosti mehanskih sistemov.	Students will be able of analyze tribological parameters in great detail, such as effect of materials, surfaces, selection of lubricants, loads and others. Independently will discuss and define the tribological effects and their influences on friction and wear. Students will understand and be aware of basic and advances surface tools on nano/micro and macro scale to analyze surfaces, and tribological properties of mechanical components.

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 uporabo priporočene literature.	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 (pisni izpit, ustno izpraševanje, naloge, projekt): • projektni seminar, izvedba, poročilo (50%) • rezultati in aplikacija na obravnavani sistem, poročilo (30%) • ustno izpraševanje (20%) Pogoj za opravljanje ustnega izpita je uspešno izdelano in pozitivno ocenjeno seminarsko delo.		Method (written exam, oral examination, assignments, project): • project seminar, execution, report (50%) • results and application in scope of the discussed system, report (30%) • oral examination (20%) The condition for admission to oral exam is successful completion of seminar work, rewarded with a passing grade.

Ocenjevalna lestvica:	Grading system:

Reference nosilca/Lecturer's references:

prof. dr. Mitjan KALIN

KOGOVŠEK, Janez, KALIN, Mitjan. Comparison of graphene as an oil additive with conventional automotive additives for the lubrication of steel and DLC-coated surfaces. *Tribology international*. Feb. 2023, vol. 180, str. 1-11, ilustr. ISSN 0301-679X. https://www.sciencedirect.com/science/article/pii/S0301679X23000075, DOI: 10.1016/j.triboint.2023.108220. [COBISS.SI-ID 136743939], [JCR, SNIP]

NADEEM, Irfan, MALOK, Matjaž, KOVAČ, Janez, YAQUB, Talha Bin, CAVALEIRO, A., KALIN, Mitjan. Superior macro-scale tribological performance of steel contacts based on graphene quantum dots in aqueous glycerol. *Tribology international*. Mar. 2023, vol. 181, str. 1-15, ilustr. ISSN 1879-2464. https://www.sciencedirect.com/science/article/pii/S0301679X23001159, DOI: 10.1016/j.triboint.2023.108328. [COBISS.SI-ID 144799747], [JCR, SNIP, Scopus]

ČOGA, Lucija, AKBARI, Somayeh, KOVAČ, Janez, KALIN, Mitjan. Differences in nano-topography and tribochemistry of ZDDP tribofilms from variations in contact configuration with steel and DLC surfaces. *Friction*. Feb. 2022, vol. 10, iss. 2, str. 296–315, ilustr. ISSN 2223-7690. https://link.springer.com/article/10.1007%2Fs40544-021-0491-7, DOI: 10.1007/s40544-021-0491-7. [COBISS.SI-ID 88250627], [JCR, SNIP, WoS do 9. 1. 2023: št. citatov (TC): 2, čistih citatov (CI): 2, čistih citatov na avtorja (CIAu): 0,50, Scopus do 5. 9. 2022: št. citatov (TC): 2, čistih citatov (CI): 2, čistih citatov na avtorja (CIAu): 0,50]

SHANKAR VADIVEL, Hari, AL-MAQDASI, Zainab, PUPURE, Liva, JOFFE, Roberts, KALIN, Mitjan, EMAMI, Nazanin. Time-dependent properties of newly developed multiscale UHMWPE composites. *Polymer testing*. [Print ed.]. Jan. 2022, vol. 105, str. 1-10, ilustr. ISSN 0142-9418. https://www.sciencedirect.com/science/article/pii/S0142941821003445?via%3Dihub, DOI: 10.1016/j.polymertesting.2021.107400. [COBISS.SI-ID 85192195], [JCR, SNIP, WoS do 29. 11. 2022: št. citatov (TC): 2, čistih citatov (CI): 1, čistih citatov na avtorja (CIAu): 0,17, Scopus do 30. 11. 2022: št. citatov (TC): 2, čistih citatov (CI): 1, čistih citatov na avtorja (CIAu): 0,17]

POLAJNAR, Marko, THIÉBAUT, Benoît, JARNIAS, Frederic, KALIN, Mitjan. Elasto-hydrodynamic friction changes on steel surfaces arising from the modified surface energy of the steel due to additive boundary films. *Tribology international*. Dec. 2021, vol. 164, str. 1-10, ilustr. ISSN 0301-679X. https://www.sciencedirect.com/science/article/pii/S0301679X21003510, DOI: 10.1016/j.triboint.2021.107203. [COBISS.SI-ID 73795843], [JCR, SNIP, WoS do 3. 1. 2022: št. citatov (TC): 1, čistih citatov (CI): 1, čistih citatov na avtorja (CIAu): 0,25, Scopus do 5. 12. 2021: št. citatov (TC): 1, čistih citatov (CI): 1, čistih citatov na avtorja (CIAu): 0,25]