

# 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)		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** Izbirni predmet /Elective course

**type:**

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**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.
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**Vsebina:**

**Content (Syllabus outline):**

<ol style="list-style-type: none"><li>1. Uvod: zgodovinski in ekonomski vidiki.</li><li>2. Osnove površin: geometrijska, realna, parametri za določanje površin, merilne metode, indeks plastičnosti.</li><li>3. Osnove kontaktov: oblike kontaktov, Hertzev kontakt, kontakti z in brez trenja.</li><li>4. Maziva in mehanizmi mazanja: bazna olja, aditivi, formulirana olja, masti, trda maziva, fizikalno-kemijske in mehanske lastnosti, hidrodinamično, elastohidrodinamično, hidrostatično, mejno, mešano.</li><li>5. Trenje: vzroki, nastanek, oblike, vplivi.</li><li>6. Obraba: mehanizmi in oblike obrabe.</li><li>7. Površinske analize: topografija, hrapavost, SEM, EDS, XPS, AES, AFM, STM, TEM</li><li>8. Tribološki vidiki uporabe: drsni ležaji, kotalni ležaji, zobniki, tesnila, ...</li></ol>	<ol style="list-style-type: none"><li>1. Introduction: relevance for industrial environment and economy.</li><li>2. Fundamental properties of contacting surfaces: real contact area, Greenwood-Williamson model, roughness parameters and effect on tribological performance, topography, measurements, plasticity index</li><li>3. Tribological contacts: types of contacts, Hertzian contact contacts with and without friction</li><li>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</li><li>5. Friction: components of friction, basic models, effects</li><li>6. Wear: mechanisms and forms of wear</li><li>7. Characterization of surfaces and damages: typical damage forms – examples, solutions, techniques for surface characterization (topography, SEM, EDS; XPS; AES, AFM, STM, TEM..)</li><li>8. Tribological aspects of mechanical components: sliding and rolling bearings, gears, seals..</li></ol>
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## Temeljna literatura in viri/Readings:

- [1] Williams, J.A.: Engineering tribology.- Oxford etc.: Oxford University Press, 1994.- (Oxford science publications)
- [2] Suh, N.P.: Tribophysics.- Englewood Cliffs: Prentice-Hall, 1986
- [3] Stachowiak, G.W., Batchelor, A.W.: Engineering tribology.- Amsterdam etc.: Elsevier, 1993.- (Tribology series; 24)
- [4] Stolarski, T.A.: Tribology in machine design.- Reprinted.- Oxford etc.: Butterworth-Heinemann, BH, 2000
- [5] Blau, P.J.: Friction science and technology.- Marcel Dekker, inc., 1995
- [6] CRC handbook of lubrication / edited by E. Richard Booser.- 7th ed.- Boca Raton: CRC Press, 1990
- [7] Hutchings, I.M.: Tribology: friction and wear of engineering materials.- London ... etc.: Edward Arnold, cop. 1992.- (Metallurgy & materials science series)

## Cilji in kompetence:

### 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

## Objectives and competences:

### 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.

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.	
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#### **Predvideni študijski rezultati:**

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.

#### **Intended learning outcomes:**

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:**

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 (pisni izpit, ustno izpraševanje, naloge, projekt): • projektni seminar, izvedba, poročilo (50%) • rezultati in aplikacija na obravnavani sistem, poročilo (30%) • ustno izpraševanje (20%) Pogoji 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.
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#### **Reference nosilca/Lecturer's references:**

**prof. dr. Mitjan KALIN**

KALIN, Mitjan, ZALAZNIK, Maša, NOVAK, Saša. Wear and friction behaviour of poly-ether-ether-ketone (PEEK) filled with graphene, WS [sub] 2 and CNT nanoparticles. *Wear*, 2015, vol. 330/331, str. 855-862.

PEJAKOVIĆ, Vladimir, IGARTUA, Amaya, KALIN, Mitjan. Frictional behaviour of imidazolium sulfate ionic liquid additives under mixed slide-to-roll conditions. Part 2, Influence of concentration and chemical composition of ionic liquid additive. *Lubrication science*, ISSN 0954-0075, 2015, str. 1-15,

KOGOVSĚK, Janez, KALIN, Mitjan. Various MoS [sub] 2-, WS [sub] 2- and C-based micro- and nanoparticles in boundary lubrication. *Tribology letters*, Mar. 2014, vol. 53, iss. 3, str. 585-597.

KALIN, Mitjan, SIMIČ, Rok. Atomic force microscopy and tribology study of the adsorption of alcohols on diamond-like carbon coatings and steel. *Applied Surface Science*, 2013, vol. 271, str. 317-328.

KALIN, Mitjan, KOGOVSĚK, Janez, REMŠKAR, Maja. Nanoparticles as novel lubricating additives in a green, physically based lubrication technology for DLC coatings. *Wear*, Jun. 2013, vol. 303, iss. 1/2, str. 480-485.