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 - razvojno raziskovalni program, prva stopnja, univerzitetni (od študijskega leta 2026/2027 dalje)	Ni členitve (študijski program)	3. letnik	1. semester	obvezni

Univerzitetna koda predmeta/University course code:	0562765
Koda učne enote na članici/UL Member course code:	2028-U

Predavanja /Lectures	Seminar /Seminar	Vaje /Tutorials	Klinične vaje /Clinical tutorials	Druge oblike študija /Other forms of study	Samostojno delo /Individual student work	ECTS
30		30			40	4

Nosilec predmeta/Lecturer:	prof. dr. Mitjan Kalin, doc. dr. Marko Polajnar

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 Univerzitetni študijski program I. stopnje Strojništvo - Razvojno raziskovalni program.	Meeting the enrollment conditions for the Academic study programme of Mechanical Engineering - Research and Development program.

Vsebina:	Content (Syllabus outline):
. Predavanje: - Uvod, pomen, zgodovina 2. Predavanje: - Površine kontaktov, razlike z materiali in značilnosti, mehanske lastnosti, hrapavost, merjenje	. Lecture: - Introduction, impact, history 2. Lecture: - Contact surfaces, material properties, mechanical properties, roughness, measurement 2D and 3D

2D in 3D 3. Predavanje: - Hertzov kontakt, Osnove: napetosti in deformacije brez trenja in s trenjem, kontaktna površina, deformacije 4. Predavanje: - Vrste maziv, olja: proizvodnja, sestava, baze različnih vrst 5. Predavanje: - Aditivi, Vrste, lastnosti, formulacija, vplivi 6. Predavanje: - Lastnosti maziv, Fi-Ke lastnosti maziv: viskoznost, p-v odvisnosti, kontaminacija, nečistoče 7. Predavanje: - Režimi mazanja, HD, EHD, mešano, mejno 8. Predavanje: - Masti, Značilnosti, fizikalno-kemijske lastnosti, mehanske lastnosti, posebnosti, uporaba 9. Predavanje: - Mehanizmi trenja, Mehanizmi trenja, izvori trenja, teorije trenja 10. Predavanje: - Trenje v inženirskih sistemih, Trenje v praktičnih primerih, napoved trenja, doseganje željenega trenja, modeliranje 11. Predavanje: - Obraba, Osnove: klasifikacija, modeli, napoved, merjenje 12. Predavanje: - Mehanizmi obrabe 1, Utrujanje, adhezija 13. Predavanje: - Mehanizmi obrabe 2, Abrazija, erozija, kavitacija, freting 14. Predavanje: - Mehanizmi obrabe 3, Oksidacija, korozija, tribokemija 15. Predavanje: - Uporaba tribologije v inženirskih sistemih, Primeri triboloških rešitev v avtomobilskih aplikacijah in industriji: ležaji, zavore, zobniki, odrezavanje in preoblikovanje, polimerni pogoni, visokotemperaturne aplikacije.	3. Lecture: - Hertz contact, Basics: stresses and strains with and without friction, contact area, deformations 4. Lecture: - Types of lubricants, oils: production, composition, base oils types 5. Lecture: - Additives, types, properties, formulations, effects 6. Lecture: - Lubricant properties, Phys-Chem properties, viscosity, p-v relations, contamination, impurities 7. Lecture: - Lubrication regimes, HD, EHD, mixed, boundary 8. Lecture - Greases, properties, phys-chem properties, mechanical properties, specifics, use 9. Lecture: - Friction mechanisms, source of friction, theories of friction 10. Lecture: - Friction in engineering systems, practical cases, friction prediction, modelling 11. Lecture: - Wear, basics: classification, models, prediction, measurement 12. Lecture: - Wear mechanisms 1: fatigue, adhesion 13. Lecture: - Wear mechanisms 2: abrasion, erosion, caviation, fretting 14. Lecture: - Wear mechanisms 3: oxidation, corrosion, tribochemistry 15. Lecture: - Tribology in engineering systems, examples of tribological solutions in automotive industry: bearings, brakes, gears, cutting and shaping, polymer drives, high temperature applications

Temeljna literatura in viri/Readings:

1. Gwidon W. Stachowiak, Andrew W. Batchelor, Engineering tribology, Elsevier, 4th edition, 2014, ISBN 978-0-12-397047-3 [COBISS.SI-ID 10031126].
2. B. Basu, M. Kalin, Tribology of Ceramics and Composites: A Materials Science Perspective, Wiley, 2011, ISBN:9780470522639 [COBISS.SI-ID 11385371].
3. *Pawlak, Zenon,* Tribochemistry of lubricating oils*, 1937*-Amsterdam [etc.] : Elsevier, 2003, ISBN - 0-444-51296-9; 0-444-41677-3, [COBISS.SI-ID 7261723].

Cilji in kompetence:	**Objectives and competences:**
Cilji: 1. Spoznati in razumeti pomen tribologije 2. Spoznati in razumeti lastnosti maziv in površin ter njihovih medsebojnih interakcij	Objectives: 1. To get to know and understand the impact of tribology. 2. To get to know and understand the properties of surfaces, lubricants and their interactions.

3. Razumeti mehanizme mazanja in aplikacije v katerih se pojavljajo 4. Znati izmeriti, analizirati in vrednotiti določiti torne in obrabne razmere v različnih aplikacijah Kompetence: 1. P1-RRP: Obvladovanje temeljnih teoretičnih znanj na področju tribologije. 2. S6-RRP + P3-RRP: Sinteza mazanih kontaktov z izbiro ustreznih površin in maziv. 3. P1-RRP + S1-RRP: Sposobnost razumevanja mehanizmov mazanja in njihove uporabe glede na aplikacijo. 4. S7-RRP + P4-RRP: Sposobnost analize, vrednotenja in kritične presoje tornih in obrabnih razmer v različnih aplikacijah.	3. To understand the mechanisms of lubrication and their applications. 4. To know how to measure, analyse and evaluate friction and wear conditions in different applications Competences: 1. P1-RRP: The basic theoretical knowledge from the field of tribology. 2. S6-RRP+P3-RRP: The ability to design lubricated contacts through appropriate selection of surfaces and lubricants. 3. P1-RRP + S1-RRP: The ability to understand lubrication mechanisms and their use in different applications. 4. S7-RRP + P4-RRP: The ability to analyse, evaluate and critical judge friction and wear conditions in different applications.

Predvideni študijski rezultati:	**Intended learning outcomes:**
Znanja: Z1: Poglobljeno strokovno teoretično in praktično znanje na področju površin in maziv, podprto s širšo teoretično in metodološko osnovo o tribologiji in mazanju. Spretnosti: 1. S1 Sposobnost načrtovanja mazanih kontaktov z ustrezno izbiro površin in maziv. 2. S1.2 Samostojna uporaba pridobljenega znanja pri analizi in snovanju mazanih kontaktov. 3. S1.3 Sposobnost snovanja kontaktov z okolju prijaznejšimi mazivi in mehanizmi mazanja. 4. S1.4 Sposobnost nadaljnjega, samostojnega študija	Knowledge: Z1: In depth theoretical and practical knowledge of surfaces and lubricants, supported by a wider theoretical and methodological knowledge of tribology and lubrication. Abilities: 1. S1 The ability to design lubricated contacts with the appropriate selection of surfaces and lubricants. 2. S1.2 Independent use of gained knowledge for analysis and synthesis of lubricated contacts. 3. S1.3 The ability to design contacts with green (environmentally friendly) lubricants and lubrication mechanisms. 4. S1.4 The ability to independently study further.

Metode poučevanja in učenja:	**Learning and teaching methods:**
P1 Avditorna predavanja z reševanjem izbranih - za področje značilnih - teoretičnih in praktično uporabnih primerov. P2 Obravnava snovi po urejeni in vnaprej razloženi sistematiki. P3 Avditorne vaje, kjer se teoretično znanje s predavanj podkrepi z računskimi primeri. P4 Laboratorijske vaje. P5 Uporaba študijskega gradiva v obliki (e-verzija predstavitve predavanj). P15 Uporaba video vsebin kot priprava na predavanja in vaje	P1 Auditorial lectures, which include solving theoretical and practical examples relevant to the field. P2 Content teaching in an orderly and systematical fashion. P3 Auditorial tutorials, which upgrade the theoretical knowledge from the lectures with practical cases. P4 Lab tutorials. P5 Use of study materials (e-version of lecture materials). P15 Use of video contents as preparation for lectures and tutorials.

Načini ocenjevanja:	**Delež/Weight**	**Assessment:**
Teoretična snov (predavanja).	70,00 %	Theoretical knowledge (lecture).
Samostojno delo na vajah.	30,00 %	Independent tutorial work

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:

Mitjan Kalin:

1. Muhammad Shahid Arshad, Lucija Čoga, Janez Kovač, Thomas Geue, Sandra M. A. Cruz, **Mitjan Kalin**. Understanding the Role of Tungsten species in Diamond-like Carbon Coatings for Enhanced Interaction with Ionic Liquids, *Tribology international*, 2025, https://doi.org/10.1016/j.tribonit.2024.110220 [COBISS.SI-ID 218359043]
2. GANGWANI, Prashant, EMAMI, Nazanin, **KALIN, Mitjan**. Tribological behaviour of nano-titanium dioxide filled UHMWPE composites with a variety of micro fillers based on carbon, boron nitride and silicon dioxide under water-lubricated condition. *Tribology international*. 2025, vol. 204, 110479, 1-22. [COBISS.SI-ID 220683779]
3. KNEISSL, Lucas M., JOFFE, Roberts, **KALIN, Mitjan**, EMAMI, Nazanin. Improving the tribological performance of POM through the incorporation of bio-based materials. *Polymers*. 2024, vol. 16, iss. 16, [art. no.] 2310, str. 1-22, ilustr. ISSN 2073-4360. https://www.mdpi.com/2073-4360/16/16/2310, Repozitorij Univerze v Ljubljani – RUL, DOI: 10.3390/polym16162310. [COBISS.SI-ID 236391427]
4. SHU, Ju, ESPEJO, Cayetano, **KALIN, Mitjan**, MORINA, Ardian. Tribological performance of fatty acid, acid/amine additive mixture and ionic liquid. *Proceedings of the Institution of Mechanical Engineers. Part J, Journal of engineering tribology*. 2024, vol. 238, iss. 10, str. 1320-1334, ilustr. ISSN 2041-305X. https://journals.sagepub.com/doi/full/10.1177/13506501241251524, Repozitorij Univerze v Ljubljani – RUL, DOI: 10.1177/13506501241251524. [COBISS.SI-ID 196287235]
5. AJEEB, Rayan, POŽAR, Tomaž, **KALIN, Mitjan**. Elastohydrodynamic lubrication under slip conditions : Navier-Stokes, Fsi and Spikes equation approach. V: SLOTRIB 2024 : Posvetovanje o tribologiji, mazivih in zelenih tehnologijah : 10. junij 2024, Portorož. [Ljubljana]: Slovensko društvo za tribologijo, [2024]. Str. 1-10, ilustr. [COBISS.SI-ID 201825283]

Marko Polajnar:

1. **POLAJNAR, Marko**, POŽAR, Tomaž, KALIN, Mitjan. Perfluorotetradecanoic acid as an additive for friction reduction in full-film EHD contacts : the role of functional group, base oil polarity, additive concentration and contact pressure. *Lubricants*. 2025, vol. 13, issue 6 , [article no.] 263, 12 str., ilustr. ISSN 2075-4442. https://www.mdpi.com/2075-4442/13/6/263, DOI: 10.3390/lubricants13060263. [COBISS.SI-ID 240516611]
2. SADLIK, Julia, **POLAJNAR, Marko**, KUMAR, Rahul, KALIN, Mitjan, KRAVANJA, Gaia, HRIBAR, Luka, et al. Effect of laser surface texturing and fabrication methods on tribological properties of ti6al4v/hap biocomposites. *Materials*. 2025, vol. 18, issue 11, 27 str., ilustr. ISSN 1996-1944. https://www.mdpi.com/1996-1944/18/11/2468, Repozitorij Univerze v Ljubljani – RUL, DOI: 10.3390/ma18112468. [COBISS.SI-ID 237657859]
3. **POLAJNAR, Marko**, POŽAR, Tomaž, KALIN, Mitjan. Perfluorocarboxylic acids as additives for friction reduction in full-film EHD contacts : influence of additive chain length. *Tribology international*. 2025, vol. 211, [article no.] 110892, 12 str., ilustr. ISSN 1879-2464. https://www.sciencedirect.com/science/article/pii/S0301679X25003871?via%3Dihub, DOI: 10.1016/j.triboint.2025.110892. [COBISS.SI-ID 240528387]
4. JING, Zhaogang, GUO, Feng, JIN, Wei, KALIN, Mitjan, **POLAJNAR, Marko**. Study on the influence of interfacial slip on the lubrication performance of a step slider bearing. *Tribology international*. Dec. 2022, vol. 176, str. 1-9, ilustr. ISSN 0301-679X. https://www.sciencedirect.com/science/article/pii/S0301679X22003942, Repozitorij Univerze v Ljubljani – RUL, DOI: 10.1016/j.triboint.2022.107822. [COBISS.SI-ID 120203523]
5. **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, Repozitorij Univerze v Ljubljani – RUL, DOI: 10.1016/j.triboint.2021.107203. [COBISS.SI-ID 73795843]