

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	Ni členitve (študijski program)	3. letnik	1. semester	obvezna

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: Mitjan Kalin

Izvajalci predavanj:

Izvajalci seminarjev:

Izvajalci vaj:

Izvajalci kliničnih vaj:

Izvajalci drugih oblik:

Izvajalci praktičnega usposabljanja:

Vrsta predmeta/Course Obvezni splošni predmet /Compulsory general course

type:

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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.
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Vsebina:

Content (Syllabus outline):

<ul style="list-style-type: none">. Predavanje:- Uvod, pomen, zgodovina2. Predavanje:- Površine kontaktov, razlike z materiali in značilnosti, mehanske lastnosti, hrapavost, merjenje 2D in 3D3. Predavanje:- Hertzov kontakt, Osnove: napetosti in deformacije brez trenja in s trenjem, kontaktna površina, deformacije4. Predavanje:- Vrste maziv, olja: proizvodnja, sestava, baze različnih vrst5. Predavanje:- Aditivi, Vrste, lastnosti, formulacija, vplivi6. Predavanje:- Lastnosti maziv, Fi-Ke lastnosti maziv: viskoznost, p-v odvisnosti, kontaminacija, nečistoče7. Predavanje:- Režimi mazanja, HD, EHD, mešano, mejno8. Predavanje:- Masti, Značilnosti, fizikalno-kemijske lastnosti, mehanske lastnosti, posebnosti, uporaba9. Predavanje:- Mehanizmi trenja, Mehanizmi trenja, izvori trenja, teorije trenja10. Predavanje:- Trenje v inženirskih sistemih, Trenje v praktičnih primerih, napoved trenja, doseganje željenega trenja, modeliranje	<ul style="list-style-type: none">. Lecture:- Introduction, impact, history2. Lecture:- Contact surfaces, material properties, mechanical properties, roughness, measurement 2D and 3D3. Lecture:- Hertz contact, Basics: stresses and strains with and without friction, contact area, deformations4. Lecture:- Types of lubricants, oils: production, composition, base oils types5. Lecture:- Additives, types, properties, formulations, effects6. Lecture:- Lubricant properties, Phys-Chem properties, viscosity, p-v relations, contamination, impurities7. Lecture:- Lubrication regimes, HD, EHD, mixed, boundary8. Lecture- Greases, properties, phys-chem properties, mechanical properties, specifics, use9. Lecture:- Friction mechanisms, source of friction, theories of friction10. Lecture:- Friction in engineering systems, practical cases, friction prediction, modelling
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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.	11. Lecture: - Wear, basics: classification, models, prediction, measurement 12. Lecture: - Wear mechanisms 1: fatigue, adhesion 13. Lecture: - Wear mechanisms 2: abrasion, erosion, cavitation, 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
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Temeljna literatura in viri/Readings:

1. Gwidon W. Stachowiak, Andrew W. Batchelor, Engineering tribology, Elsevier, 4th edition, 2014, ISBN 978-0-12-397047-3.
2. B. Bhushan, Introduction to Tribology, Wiley, 2nd Edition, 2013, ISBN: 978-1-119-94453-9.
3. B. Basu, M. Kalin, Tribology of Ceramics and Composites: A Materials Science Perspective, Wiley, 2011, ISBN:9780470522639.

Cilji in kompetence:

Cilji: <ol style="list-style-type: none"> 1. Spoznati in razumeti pomen tribologije 2. Spoznati in razumeti lastnosti maziv in površin ter njihovih medsebojnih interakcij 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: <ol style="list-style-type: none"> 1. P1-RRP: Obvladovanje temeljnih teoretičnih znanj na področju tribologije. 2. S6-RRP + P3-RRP: Sinteza mazanih kontaktov z izbiro ustreznih površin in maziv.
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Objectives and competences:

Objectives: <ol style="list-style-type: none"> 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. 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: <ol style="list-style-type: none"> 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.
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<p>3. P1-RRP + S1-RRP: Sposobnost razumevanja mehanizmov mazanja in njihove uporabe glede na aplikacijo.</p> <p>4. S7-RRP + P4-RRP: Sposobnost analize, vrednotenja in kritične presoje tornih in obrabnih razmer v različnih aplikacijah.</p>	<p>3. P1-RRP + S1-RRP: The ability to understand lubrication mechanisms and their use in different applications.</p> <p>4. S7-RRP + P4-RRP: The ability to analyse, evaluate and critical judge friction and wear conditions in different applications.</p>
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Predvideni študijski rezultati:

<p>Znanja:</p> <p>Z1: Poglobljeno strokovno teoretično in praktično znanje na področju površin in maziv, podprto s širšo teoretično in metodološko osnovo o tribologiji in mazanju.</p> <p>Spretnosti:</p> <ol style="list-style-type: none"> 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
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Intended learning outcomes:

<p>Knowledge:</p> <p>Z1: In depth theoretical and practical knowledge of surfaces and lubricants, supported by a wider theoretical and methodological knowledge of tribology and lubrication.</p> <p>Abilities:</p> <ol style="list-style-type: none"> 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.
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Metode poučevanja in učenja:

<p>P1 Avditorna predavanja z reševanjem izbranih - za področje značilnih - teoretičnih in praktično uporabnih primerov.</p> <p>P2 Obravnava snovi po urejeni in vnaprej razloženi sistematiki.</p> <p>P3 Avditorne vaje, kjer se teoretično znanje s predavanj podkrepi z računskimi primeri.</p> <p>P4 Laboratorijske vaje.</p> <p>P5 Uporaba študijskega gradiva v obliki (e-verzija predstavitve predavanj).</p> <p>P15 Uporaba video vsebin kot priprava na predavanja in vaje</p>
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Learning and teaching methods:

<p>P1 Auditorial lectures, which include solving theoretical and practical examples relevant to the field.</p> <p>P2 Content teaching in an orderly and systematical fashion.</p> <p>P3 Auditorial tutorials, which upgrade the theoretical knowledge from the lectures with practical cases.</p> <p>P4 Lab tutorials.</p> <p>P5 Use of study materials (e-version of lecture materials).</p> <p>P15 Use of video contents as preparation for lectures and tutorials.</p>

Načini ocenjevanja:	Delež/ Weight	Assessment:
Teoretična snov (predavanja).	50,00 %	Theoretical knowledge (lecture).
Samostojno delo na vajah.	20,00 %	Independent tutorial work.
Laboratorijsko delo na vajah (vključno s poročili).	20,00 %	Lab tutorial work (with reports).
Seminar.	10,00 %	Seminar.

Reference nosilca/Lecturer's references:

Mitjan Kalin:

1. SIMONOVIC, Kosta, **KALIN, Mitjan**. Experimentally derived friction model to evaluate the anti-wear and friction-modifier additives in steel and DLC contacts. *Tribology international*. July 2017, vol. 111, str. 116-137, ISSN 0301-679X.
2. **KALIN, Mitjan**, ZALAZNIK, Maša, NOVAK, Saša. Wear and friction behaviour of poly-ether-ether-ketone (PEEK) filled with graphene, WS2 and CNT nanoparticles. V: *20th International Conference on Wear Materials*. [Amsterdam]: Elsevier, 2015. Vol. 330/331, str. 855-862, Wear (Lausanne. Print), Vol. 330/331. ISSN 0043-1648.
3. **KALIN, Mitjan**, SIMIČ, Rok, HIRAYAMA, Tomoko, GEUE, Thomas M., KORELIS, P. Neutron-reflectometry study of alcohol adsorption on various DLC coatings. *Applied Surface Science*. Jan. 2014, vol. 288, str. 405-410, ISSN 0169-4332.
4. **KALIN, Mitjan**, POLAJNAR, Marko. The wetting of steel, DLC coatings, ceramics and polymers with oils and water : the importance and correlations of surface energy, surfacetension, contact angle and spreading. *Applied Surface Science*. Feb. 2014, vol. 293, str. 97-108, ISSN 0169-4332.
5. **KALIN, Mitjan**, KOGOVŠEK, Janez, KOVAČ, Janez, REMŠKAR, Maja. The formation of tribofilms of MoS2 nanotubes on steel and DLC-coated surfaces. *Tribology letters*. Sep. 2014, vol. 55, iss. 3, str. 381-391, ISSN 1023-8883.