

# PROCESI V TOPLOTNIH MOTORJIH

## UČNI NAČRT PREDMETA/COURSE SYLLABUS

|                                   |                              |
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| <b>Predmet:</b>                   | Procesi v toplotnih motorjih |
| <b>Course title:</b>              | Processes in Heat Engines    |
| <b>Članica nosilka/UL Member:</b> | UL FS                        |

| Študijski programi in stopnja                                          | Študijska smer                | Letnik    | Semestri    | Izbirnost |
|------------------------------------------------------------------------|-------------------------------|-----------|-------------|-----------|
| Strojništvo - Razvojno raziskovalni program, druga stopnja, magistrski | Energetsko strojništvo (smer) | 1. letnik | 2. semester | obvezni   |

|                                                            |         |
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| <b>Univerzitetna koda predmeta/University course code:</b> | 0566857 |
| <b>Koda učne enote na članici/UL Member course code:</b>   | 6005-M  |

| Predavanja<br>/Lectures | Seminar<br>/Seminar | Vaje<br>/Tutorials | Klinične vaje<br>/Clinical<br>tutorials | Druge oblike<br>študija<br>/Other forms<br>of study | Samostojno<br>delo<br>/Individual<br>student work | ECTS |
|-------------------------|---------------------|--------------------|-----------------------------------------|-----------------------------------------------------|---------------------------------------------------|------|
| 30                      |                     | 30                 |                                         |                                                     | 65                                                | 5    |

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| <b>Nosilec predmeta/Lecturer:</b> | prof. dr. Tomaž Katrašnik |
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| <b>Izvajalci predavanj:</b>                 |  |
| <b>Izvajalci seminarjev:</b>                |  |
| <b>Izvajalci vaj:</b>                       |  |
| <b>Izvajalci kliničnih vaj:</b>             |  |
| <b>Izvajalci drugih oblik:</b>              |  |
| <b>Izvajalci praktičnega usposabljanja:</b> |  |

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| <b>Vrsta predmeta/Course type:</b> | Obvezni strokovni predmet na smeri Energetsko strojništvo, ki je izbirni strokovni predmet na ostalih smereh./Compulsory specialised course in the study of Energy engineering, which is an elective specialised course in other fields of study. |
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| <b>Jeziki/Languages:</b> | Predavanja/Lectures: | Slovenščina |
|                          | Vaje/Tutorial:       | Slovenščina |

**Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:**

**Prerequisites:**

|                                                                                                                       |                                                                                                                                  |
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| Izpolnjevanje pogojev za vpis v Magistrski študijski program II. stopnje Strojništvo - Razvojno raziskovalni program. | Meeting the enrollment conditions for the Master's study programme of Mechanical Engineering - Research and Development program. |
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**Vsebina:**

**Content (Syllabus outline):**

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| <ol style="list-style-type: none"> <li>1. Predavanje: <ul style="list-style-type: none"> <li>• sistematizacija toplotnih motorjev z ozirom na različne kriterije in značilnosti toplotnih motorjev;</li> <li>• raba energije in izpusti onesnažil toplotnih motorjev;</li> <li>• energijske pretvorbe v toplotnih motorjih;</li> <li>• tehnološke smernice in zahteve razvoja toplotnih motorjev.</li> </ul> </li> <li>2. Predavanje: <ul style="list-style-type: none"> <li>• definicija in analiza procesov v realnih toplotnih motorjih;</li> <li>• lastnosti realnega delovnega medija.</li> </ul> </li> <li>3. Predavanje: <ul style="list-style-type: none"> <li>• teoretični procesi v toplotnih motorjih (določitev izkoristka, delovne sposobnosti) in njihova primerjava s procesi v realnih toplotnih motorjih;</li> <li>• metode za izboljšanje izkoristka motorjev.</li> </ul> </li> <li>4. Predavanje: <ul style="list-style-type: none"> <li>• zasnove batnih MNZ in njihove značilnosti;</li> <li>• kinematika bata in uravnoteženje prostih sil in navorov.</li> </ul> </li> <li>5. Predavanje: Motorji s prisilnim vžigom (Ottovi motorji): <ul style="list-style-type: none"> <li>• zasnova in komponente;</li> <li>• značilnosti in delovanje sistemov za dobavo in vbrizgavanje goriva;</li> <li>• potek sproščanja toplote v valju;</li> <li>• samovžig zmesi;</li> <li>• pristopi modeliranja procesov.</li> </ul> </li> <li>6. Predavanje: Motorji s samovžigom (dizelski motorji): <ul style="list-style-type: none"> <li>• zasnova in komponente;</li> <li>• značilnosti in delovanje sistemov za dobavo in vbrizgavanje goriva;</li> <li>• potek sproščanja toplote v valju;</li> <li>• pristopi modeliranja procesov.</li> </ul> </li> <li>7. Predavanje: Motorji z naprednimi procesi zgorevanja (LTC, CAI...): <ul style="list-style-type: none"> <li>• zasnova in komponente;</li> <li>• značilnosti in delovanje sistemov za dobavo in vbrizgavanje goriva;</li> <li>• potek sproščanja toplote v valju;</li> <li>• pristopi modeliranja procesov</li> </ul> </li> <li>8. Predavanje: Pristopi za zmanjševanje izpustov onesnažil v batnih MNZ (dušikovi oksidi, ogljikov monoksid, nezgoreli ogljikovodiki, delci).</li> <li>9. Predavanje: Sistemi in naprave za naknadno obdelavo izpušnih plinov batnih MNZ (TWC, DOC, SCR, LNT, DPF, GPF).</li> <li>10. Predavanje: <ul style="list-style-type: none"> <li>• izmenjava delovnega medija;</li> <li>• mehanske izgube in sistemi mazanja v batnih MNZ;</li> <li>• termoregulacija batnih MNZ.</li> </ul> </li> <li>11. Predavanje <ul style="list-style-type: none"> <li>• zmogljivosti batnih MNZ;</li> <li>• prisilno polnjenje batnih MNZ (valovna dinamika,</li> </ul> </li> </ol> | <ol style="list-style-type: none"> <li>1. Lecture: <ul style="list-style-type: none"> <li>• Classification of heat engines with respect to their type and characteristics,</li> <li>• Use of energy and emissions of heat engines,</li> <li>• Energy conversion paths in heat engines,</li> <li>• Technology guidelines and R&amp;D requirements of heat engines.</li> </ul> </li> <li>2. Lecture: <ul style="list-style-type: none"> <li>• Definition and analysis of processes in real engines,</li> <li>• Properties of real working media.</li> </ul> </li> <li>3. Lecture: <ul style="list-style-type: none"> <li>• Theoretical processes in heat engines (evaluation of efficiency and indicated mean effective pressure) and their interrelation to processes in real heat engines,</li> <li>• Methods for increasing efficiency of heat engines.</li> </ul> </li> <li>4. Lecture: <ul style="list-style-type: none"> <li>• Types and designs of piston ICEs and their characteristics,</li> <li>• Kinematics of the piston motion in piston engines and balancing free forces and moments.</li> </ul> </li> <li>5. Lecture: Spark ignition (SI) engines (Otto engines) <ul style="list-style-type: none"> <li>• Design and components,</li> <li>• Characteristics and working principles of fuel supply and injection systems,</li> <li>• Rate of heat release,</li> <li>• Self-ignition and knocking,</li> <li>• Modelling approaches.</li> </ul> </li> <li>6. Lecture: Compression ignition (CI) engines (Diesel engines) <ul style="list-style-type: none"> <li>• Design and components,</li> <li>• Characteristics and working principles of fuel supply and injection systems,</li> <li>• Rate of heat release,</li> <li>• Modelling approaches.</li> </ul> </li> <li>7. Lecture: Engines with advanced combustion concepts (LTC, CAI...) <ul style="list-style-type: none"> <li>• Design and components,</li> <li>• Characteristics and working principles of fuel supply and injection systems,</li> <li>• Rate of heat release,</li> <li>• Modelling approaches.</li> </ul> </li> <li>8. Lecture: Methods and approaches for reducing pollutant emissions in piston ICEs (nitrogen oxides, carbon monoxide, unburned hydrocarbons, particles).</li> <li>9. Lecture: Exhaust after-treatment systems and devices in piston ICEs (TWC, DOC, SCR, LNT, DPF, GPF).</li> <li>10. Lecture: <ul style="list-style-type: none"> <li>• Exchange of the working media,</li> <li>• Mechanical losses and lubrication systems in piston ICEs,</li> <li>• Thermoregulation of piston ICEs.</li> </ul> </li> <li>11. Lecture: <ul style="list-style-type: none"> <li>• Performance characteristics of piston ICEs,</li> </ul> </li> </ol> |
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| <p>mehansko prisilno polnjenje).</p> <p>12. Predavanje:</p> <ul style="list-style-type: none"> <li>• prisilno polnjenje batnih MNZ (prisilno polnjenje s turbopolnilnikom, kombinacije metod za prisilno polnjenje);</li> <li>• sistemsko modeliranje batnih MNZ.</li> </ul> <p>Turbinski motorji:</p> <p>13. Predavanje:</p> <ul style="list-style-type: none"> <li>• procesi v turbinskih motorjih;</li> <li>• - deli turbinskih motorjev in njihove značilnosti (dovodnik, kompresor).</li> </ul> <p>14. Predavanje:</p> <ul style="list-style-type: none"> <li>• deli turbinskih motorjev in njihove značilnosti (zgorevalna komora, turbina, izpušna šoba);</li> <li>• delovanje turbinskih motorjev in njihove zmogljivosti;</li> <li>• izpusti onesnažil turbinskih motorjev.</li> </ul> <p>Refleksija in sinteza:</p> <p>15. Predavanje: Toplotni motorji prihodnosti:</p> <ul style="list-style-type: none"> <li>• refleksija in povezovanje vsebin;</li> <li>• analiza najustrežnejših izvedenk toplotnih motorjev;</li> <li>• viharjenje na temo učinkovitejših okolju prijaznejših toplotnih motorjev prihodnosti</li> </ul> | <ul style="list-style-type: none"> <li>• Supercharging of piston ICEs (wave dynamics, mechanical supercharging).</li> </ul> <p>12. Lecture:</p> <ul style="list-style-type: none"> <li>• Supercharging of piston ICEs (turbocharging, combined charging),</li> <li>• System level modelling of ICEs.</li> </ul> <p>Turbine engines:</p> <p>13. Lecture:</p> <ul style="list-style-type: none"> <li>• Processes in turbine engines,</li> <li>• Components of turbine engines and their characteristics (engine inlet and diffuser, compressor).</li> </ul> <p>14. Lecture:</p> <ul style="list-style-type: none"> <li>• Components of turbine engines and their characteristics (combustion chamber, turbine, nozzle),</li> <li>• Operating principles of turbine engines and their performance characteristics,</li> <li>• Pollutant emissions of turbine engines.</li> </ul> <p>Reflection and synthesis:</p> <p>15. Lecture: Heat engines of the future</p> <ul style="list-style-type: none"> <li>• Reflection and integration of content,</li> <li>• Analysis of most suitable designs of heat engines,</li> <li>• Brainstorming on the subject of highly efficient and environmentally friendly heat engines.</li> </ul> |
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#### Temeljna literatura in viri/Readings:

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| <ol style="list-style-type: none"> <li>1. Heywood, J.B.: Internal combustion engine fundamentals, McGraw-Hill, N.York,1988,ISBN 0-07-028637-X, [COBISS.SI-ID <a href="#">14910720</a>]</li> <li>2. Pavletič, R.: Motorji z notranjim zgorevanjem, UL, Fakulteta za strojništvo, Ljubljana, 2000, ISBN 961-6238-41-8, [COBISS.SI-ID <a href="#">107660544</a>]</li> <li>3. Taylor, C.F.: The Internal combustion engine in theory and practice, Vol.1 – thermodynamics, fluid flow, performance, The MIT Pres, Massachusetts, 1986, ISBN 0-262-20051-1, [COBISS.SI-ID <a href="#">646171</a>]</li> </ol> |
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#### Cilji in kompetence:

| Cilji in kompetence:                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Objectives and competences:                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
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| <p>Cilji:</p> <ol style="list-style-type: none"> <li>1. Razumeti teoretične osnove in metode vrednotenja procesov v toplotnih motorjih</li> <li>2. Spoznati interakcije in soodvisnosti procesov v toplotnih motorjih</li> <li>3. Spoznati različne zasnove batnih motorjev z notranjim zgorevanjem in razumeti njihove značilnosti in prednosti</li> <li>4. Spoznati pristope za zmanjševanje izpustov onesnažil in sisteme in naprave za naknadno obdelavo izpušnih plinov v batnih motorjev z notranjim zgorevanjem</li> <li>5. Spoznati in razumeti delovanje različnih različne metod za prisilno batnih motorjev z notranjim zgorevanjem</li> <li>6. Spoznati komponente in procese v turbinskih motorjih z notranjim zgorevanjem</li> </ol> | <p>Objectives:</p> <ol style="list-style-type: none"> <li>1. Understand the theoretical foundations and characterisation methods of processes in heat engines</li> <li>2. To know and to understand interactions in interdependencies of processes in heat engines</li> <li>3. To know different designs of heat engines and to understand their characteristics and advantages</li> <li>4. Understand approaches for reduction of pollutant emissions and exhaust gas after-treatment devices in piston internal combustion engines</li> <li>5. To know and to understand working principles of different supercharging methods of internal combustion engines</li> <li>6. To know components and processes in turbine engines</li> </ol> |

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| <p>7. Razumeti pristope za modeliranje procesov v toplotnih motorjih in znati uporabljati ustrezna napredna simulacijska orodj</p> <p>8. Razumeti in znati aplicirati metode za zvišanje izkoristka in povišanje delovne sposobnosti toplotnih motorjev</p> <p>9. Razumeti pristope za razvoj naprednih-okolju prijaznejših toplotnih motorjev</p> <p>Kompetence:</p> <p>1. S2-MAG, P2-MAG: Obvladovanje temeljnih teoretičnih in aplikativnih znanj na področju procesov v toplotnih motorjih.</p> <p>2. S8-MAG: Sposobnost kritične presoje in snovanja toplotnih motorjev z ozirom na namen uporabe, zmogljivosti in mejne vrednosti izpustov onesnažil.</p> <p>3. P2-MAG: Sposobnost razumevanja interakcije in soodvisnosti procesov v toplotnih motorjih.</p> <p>4. P4-MAG: Sposobnost fizikalnega, matematičnega in numeričnega modeliranja procesov v toplotnih motorjih.</p> | <p>7. Understand modelling approaches for simulating processes in heat engines and to know selecting adequate modelling tools</p> <p>8. To understand and to be skilled to apply methods for increasing power and efficiency of heat engines</p> <p>9. Understand approaches for development of advanced-environmentally friendly heat engines</p> <p>Competencies:</p> <p>1. S2-MAG, P2-MAG: Using the fundamental theoretical and applied knowledge in the field of processes in heat engines</p> <p>2. S8-MAG: The ability to critically evaluate and design heat engines with respect to the intended use, performances and limiting values of pollutant emissions</p> <p>3. P2-MAG: Mastering understanding of interactions in interdependencies of processes in heat engines</p> <p>4. P4-MAG: The ability for physical, mathematical and numerical modelling of processes in heat engines</p> |
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#### **Predvideni študijski rezultati:**

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| <p>Znanja:</p> <p>Z1: Poglobljeno teoretično, metodološko in analitično znanje z elementi raziskovanja, ki je osnova za zalo zahtevno znanstveno in strokovno delo na področju razvoja, snovanja in diagnostike toplotnih motorjev.</p> <p>Spretnosti:</p> <p>S1.1: Sposobnost vrednotenja in optimiranja procesov v toplotnih motorjih z ozirom na zvišanje izkoristka in znižanje izpustov onesnažil.</p> <p>S1.2: Samostojna uporaba pridobljenega znanja pri analizi, snovanju in diagnostiki toplotnih motorjev.</p> <p>S1.3: Sposobnost snovanja okolju prijaznejših toplotnih motorjev na osnovi inovativnih geometrijskih in procesnih pristopov.</p> <p>S1.4: Sposobnost nadaljnega, samostojnega študija.</p> | <p>Z1: In-depth theoretical, methodological and analytical knowledge with elements of research, which is the basis for scientific and professional work in the development, design and diagnostics of heat engines.</p> <p>Skills:</p> <p>S1.1: Ability to evaluate and optimize processes in heat engines in terms of maximizing the efficiency and reducing pollutant emissions.</p> <p>S1.2: Independent use of acquired knowledge in the analysis, design and diagnostics of processes in heat engines.</p> <p>S1.3: Ability to design environmentally friendly heat engines based on innovative geometrical and process driven methods.</p> <p>S1.4: Ability of independent self-driven education and research.</p> |
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#### **Metode poučevanja in učenja:**

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| <p>P1: Avditorna predavanja z reševanjem izbranih - za področje značilnih - teoretičnih in praktično uporabnih primerov.</p> | <p>P1: Classroom lectures with inclusion of solving selected typical and practical examples.</p> |
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#### **Learning and teaching methods:**

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| P2: Obravnava snovi po urejeni in vnaprej razloženi sistematiki.                         | P2: Presenting of the learning content in an orderly and pre-interpreted systematics          |
| P3: Avditorne vaje, kjer se teoretično znanje s predavanj podkrepi z računskimi primeri. | P3: Tutorials where theoretical knowledge of lectures is supported by computational examples. |
| P4: Laboratorijske vaje.                                                                 | P4: Laboratory work.                                                                          |
| P5: Uporaba študijskega gradiva v obliki (e-verzija predstavitve predavanj).             | P5: Use of study materials in format (e-version of lecture presentation).                     |
| P8: Izdelava in predstavitev aplikativnih seminarских nalog.                             | P8: Design and presentation of applied seminar work                                           |
| P10: Uporaba anket v realnem času.                                                       | P10: Use of real-time surveys                                                                 |
| P14: Virtualni eksperimenti.                                                             | P14: Virtual Experiments                                                                      |
| P15: Uporaba video vsebin kot priprava na predavanja in vaje.                            | P15: Using video content to prepare for lectures and exercises                                |

| Načini ocenjevanja:             | Delež/Weight | Assessment:          |
|---------------------------------|--------------|----------------------|
| Teoretične vsebine (predavanja) | 50,00 %      | Theory (lectures)    |
| Samostojno delo na vajah        | 50,00 %      | Practical coursework |

| 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:

##### Tomaž Katrašnik:

- KATRAŠNIK, Tomaž.** Innovative 0D transient momentum based spray model for real-time simulations of CI engines. *Energy*, ISSN 0360-5442. [Print ed.], Oct. 2016, vol. 112, str. 494-508, [COBISS.SI-ID [14780955](#)].
- KRAVOS, Andraž, SELJAK, Tine, RODMAN OPREŠNIK, Samuel, **KATRAŠNIK, Tomaž.** Operational stability of a spark ignition engine fuelled by low H2 content synthesis gas: Thermodynamic analysis of combustion and pollutants formation. *Fuel*, Feb 2020, vol. 261, <https://doi.org/10.1016/j.fuel.2019.116457> [COBISS.SI-ID [16879643](#)].
- VIHAR, Rok, ŽVAR BAŠKOVIČ, Urban, **KATRAŠNIK, Tomaž.** Real time capable virtual NOx sensor for diesel engines based on a two-zone thermodynamic model. *Oil & gas science and technology*, ISSN 1953-8189, Apr. 2018, vol. 73, f. 1-17. [COBISS.SI-ID [16019995](#)].
- ŽVAR BAŠKOVIČ, Urban, **KATRAŠNIK, Tomaž**, FAUSSONE, Gian Claudio, GRILC, Miha, SELJAK, Tine. Ultra-low emission power generation utilizing chemically stabilized waste plastics pyrolysis oil in RCCI combustion concept. *Journal of environmental management*. Oct. 2023, vol. 344, str. 1-13, ilustr. ISSN 1095-8630. <https://www.sciencedirect.com/science/article/pii/S0301479723014998>, DOI: 10.1016/j.jenvman.2023.118711. [COBISS.SI-ID [161635843](#)].
- FAUSSONE, Gian Claudio, SELJAK, Tine, JASIUKAITYTE, Edita, ŽVAR BAŠKOVIČ, Urban, **KATRAŠNIK, Tomaž**, GRILC, Miha, FAUSSONE, Gian Claudio. Pyrolysis oil from post-consumer packaging and its ageing : physical and chemical properties and drop-in performance in a power generating unit. *Energy reports*. Nov. 2023, vol. 10, str. 613-627, ilustr. ISSN 2352-4847. <https://www.sciencedirect.com/science/article/pii/S2352484723010946>, DOI: [10.1016/j.egy.2023.07.018](https://doi.org/10.1016/j.egy.2023.07.018). [COBISS.SI-ID [161718531](#)].

