

## UČNI NAČRT PREDMETA/COURSE SYLLABUS

<b>Predmet:</b>	Eksperimentalne metode v energetske strojništvu
<b>Course title:</b>	EXPERIMENTAL METHODS IN ENERGY ENGINEERING
<b>Članica nosilka/UL Member:</b>	UL FS

Študijski programi in stopnja	Študijska smer	Letnik	Semestri
Strojništvo - projektno aplikativni program, prva stopnja, visokošolski strokovni	Energetsko strojništvo (smer)	2. letnik	2. semester

**Univerzitetna koda predmeta/University course code:** 0562722

**Koda učne enote na članici/UL Member course code:** 3025-V

Predavanja	Seminar	Vaje	Klinične vaje	Druge oblike študija	Samostojno delo	ECTS
30		30			40	4

**Nosilec predmeta/Lecturer:** Jože Kutin, Marko Hočevar

**Vrsta predmeta/Course type:** Izbirni strokovni predmet/Elective specialised course

<b>Jeziki/Languages:</b>	Predavanja/Lectures:	Slovenščina
	Vaje/Tutorial:	Slovenščina

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

Izpolnjevanje pogojev za vpis v Visokošolski strokovni študijski program I. stopnje Strojništvo - Projektno aplikativni program.

Meeting the enrollment conditions for the MECHANICAL ENGINEERING - Project Oriented Applied Programme.

**Vsebina:**

**Content (Syllabus outline):**

- Uvod
  - Pomen preskušanj in drugih področij eksperimentalnega dela v energetske strojništvu
  - Pregled značilnih preskušanih naprav in sistemov
  - Pregled pomembnejših fizikalnih veličin, ki jih treba meriti oz. nadzorovati
- Tehnične zahteve za obvladovanje eksperimentalnega dela 1
  - Pregled standardnih zahtev za obvladovanje preskušanj in drugih področij eksperimentalnega dela
  - Zahteve glede usposobljenosti osebja

- Introduction
  - Purpose of testing and other fields of experimental work in energy engineering
  - Review of typical devices and systems under test
  - Review of most important physical quantities that should be measured or controlled
- Technical requirements for management of experimental work 1
  - Review of standard requirements for management of testing and other fields of experimental work
  - Requirements for qualification of personnel

<ul style="list-style-type: none"> <li>- Izbira in validacija preskusnih metod in postopkov</li> </ul> <p>3. Tehnične zahteve za obvladovanje eksperimentalnega dela 2</p> <ul style="list-style-type: none"> <li>- Obvladovanje merilne in programske opreme</li> <li>- Obvladovanje okoljskih pogojev</li> <li>- Zapisi in poročanje o rezultatih</li> </ul> <p>4. Eksperimentalni procesi s tlakom kot merjeno veličino 1</p> <ul style="list-style-type: none"> <li>- Opredelitev tlaka kot merjene veličine</li> <li>- Pregled merilnih metod za tlak</li> <li>- Pregled sistemov za nadzor tlaka</li> </ul> <p>5. Eksperimentalni procesi s tlakom kot merjeno veličino 2</p> <ul style="list-style-type: none"> <li>- Vplivni dejavniki pri merjenju tlaka</li> <li>- Izvedba odjema tlaka in tlačnih povezav</li> <li>- Korekcija vpliva višinske razlike</li> </ul> <p>6. Eksperimentalni procesi s temperaturo kot merjeno veličino 1</p> <ul style="list-style-type: none"> <li>- Opredelitev temperature kot merjene veličine</li> <li>- Pregled merilnih metod za merjenje temperature</li> <li>- Pregled sistemov za nadzor temperature</li> </ul> <p>7. Eksperimentalni procesi s temperaturo kot merjeno veličino 2</p> <ul style="list-style-type: none"> <li>- Vplivni dejavniki na dotikalno merjenje temperature v tekočinah, na površinah</li> <li>- Vplivi toplotnih izgub</li> <li>- Vplivi dinamičnih lastnosti merilnega sistema</li> </ul> <p>8. Eksperimentalni procesi s temperaturo kot merjeno veličino 3</p> <ul style="list-style-type: none"> <li>- Vplivni dejavniki na področju sevalne termometrije</li> <li>- Vplivi lastnosti merjene površine</li> <li>- Vplivi prenosa toplotnega sevanja in motilnih izvorov</li> </ul> <p>9. Postopki merjenja energetskih sistemov: terenske in laboratorijske meritve, opis štirih kategorij postaj v skladu s standardom načina strojev, vloga pomožnih strojev, dušilnih loput, usmerjevalnikov in umirjevalnikov toka, določanje statičnega in dinamičnega tlaka ter izgub.</p> <p>10. Merilne postaje: merjenje pretoka, tlaka in izkoristka na merilnih postajah: izbira in vgradnja merilne opreme za pretok, tlak, in izkoristek, izvedba priključitve na merilno postajo, povezovanje v sistem.</p> <p>11. Pomen in način meritve električne in mehanske moči: merjenje navora, moči in električnih spremenljivk, metode za merjenje navora, vrtilne frekvence in mehanske moči, izvedba uležajenja, primeri merjenja na modelu in izvedbi, merjenje električnih spremenljivk (napetost, tok, moč).</p> <p>12. Merjenje lastnosti energetskih strojev na merilnih postajah: merilne postaje za merjenje ventilatorjev, turbin in črpalk, določanje karakteristike, izkoristka, NPSH in kavitacije.</p> <p>13. Merjenje emisij delcev energetskih sistemov: merilna oprema in postopki za merjenje emisij delcev,</p>	<ul style="list-style-type: none"> <li>- Selection and validation of testing methods and procedures</li> </ul> <p>3. Technical requirements for management of experimental work 2</p> <ul style="list-style-type: none"> <li>- Management of measuring and programming equipment</li> <li>- Management of surrounding conditions</li> <li>- Records and reporting of results</li> </ul> <p>4. Experimental processes with pressure as measured quantity 1</p> <ul style="list-style-type: none"> <li>- Defining pressure as measured quantity</li> <li>- Review of pressure measurement methods</li> <li>- Review of systems for control of pressure</li> </ul> <p>5. Experimental processes with pressure as measured quantity 2</p> <ul style="list-style-type: none"> <li>- Influence factors in pressure measurements</li> <li>- Design of a pressure tap and pressure connections</li> <li>- Correction of effects of hydrostatic height</li> </ul> <p>6. Experimental processes with temperature as measured quantity 1</p> <ul style="list-style-type: none"> <li>- Defining temperature as measured quantity</li> <li>- Review of temperature measurement methods</li> <li>- Review of systems for control of temperature</li> </ul> <p>7. Experimental processes with temperature as measured quantity 2</p> <ul style="list-style-type: none"> <li>- Influence factors in contact temperature measurements in fluids, on solid surfaces</li> <li>- Influences related to heat losses</li> <li>- Influences of dynamic characteristics of the measurement system</li> </ul> <p>8. Experimental processes with temperature as measured quantity 3</p> <ul style="list-style-type: none"> <li>- Influence factors in the field of radiation thermometry</li> <li>- Influence properties of measured surface</li> <li>- Influences related to the transmission of thermal radiation and unwanted sources</li> </ul> <p>9. Measurement procedures for energy systems: field and laboratory measurements, description of four categories of measuring stations according to standard, the role of auxiliary machines, dampers, flow straighteners, determination of static and dynamic pressure and losses.</p> <p>10. Measuring stations: measurement of flow, pressure, and efficiency at measuring stations: selection and installation of measuring equipment for flow, pressure and efficiency, connection to the measuring station, connection to the system.</p> <p>11. Importance and method of measurement of electrical and mechanical power: measurement of torque, power and electrical variables, methods for measuring torque, rotational speed and mechanical power, bearing design, examples of measurement on model and prototype, measurement of electrical</p>
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<p>visokovolumski vzorčevalnik, kaskadni impaktor, etalometer, nefelometer, analiza slik, sejalna analiza, difraktometer, izokinetično vzorčenje.</p> <p>14. Merjenje emisij plinov energetskih sistemov: merilna oprema in postopki za merjenje emisij plinov, ultravijolična fluorescenca, kemiluminiscenca, spektroskopija, plamensko ionizacijska metoda, elektrokemične metode, polprevodniško zaznavalo, merjenje količine preostalega kisika z lambda zaznavalom.</p> <p>15. Izvedba merjenja emisij delcev in plinov na energetskih strojih in napravah: primeri uporabe za motorje z notranjim zgorevanjem in v termoelektrarnah.</p>	<p>variables (voltage, current, power).</p> <p>12. Measuring of properties of energy machines at measuring stations: measuring stations for fans, turbines, and pumps, determining of characteristics, efficiency, NPSH and cavitation.</p> <p>13. Measurement of particle emissions of energy systems: measuring equipment and procedures for the measurement of particle emissions, high-volume sampler, cascade impactor, aethalometer, nephelometer, image analysis, seeding analysis, diffractometer, isokinetic sampling.</p> <p>14. Measurement of gas emissions of energy systems: measuring equipment and procedures for measuring gas emissions, ultraviolet fluorescence, chemiluminescence, spectroscopy, flame ionization method, electrochemical methods, semiconductor sensor, measurement of the amount of oxygen remaining with the lambda sensor.</p> <p>15. Performance of measurement of particulate and gas emissions on energy machinery and systems: Examples of use for internal combustion engines and thermal power plants.</p>
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#### Temeljna literatura in viri/Readings:

1. SIST EN ISO/IEC 17025:2017: Splošne zahteve za usposobljenost preskuševalnih in kalibracijskih laboratorijev.
2. Wheeler, A. J., Ganji, A. R.: Introduction to engineering experimentation. Pearson, 2009.
3. NPL Guide to the Measurement of pressure and vacuum. Institute of Measurement and Control, 1998.
4. Michalski, L., Eckersdorf, K., Kucharski, J., McGhee, J.: Temperature measurement. John Wiley & Sons, Chichester, 2001.
5. ISO 5801:2017, Fans - Performance testing using standardized airways, 2017
6. Marko Hočvar, Matevž Dular, Diagnostika v okoljskem strojništvu, učbenik, Fakulteta za strojništvo, 2016

#### Cilji in kompetence:

##### Cilji:

1. Spoznati tehnične zahteve za obvladovanje eksperimentalnega dela v energetskem strojništvu.
2. Spoznati principe merenj v energetskem strojništvu
3. Spoznati osnovne gradnike merilnih postaj za merjenje karakteristik energetskih strojev
4. Spoznati postopke meritev emisij v energetskem strojništvu

##### Kompetence:

1. S1-PAP + S4-PAP: Sposobnost obvladovanja tehničnih zahtev za eksperimentalno delo
2. P4-PAP: Sposobnost razumevanja delovanja gradnikov merilnih postaj.
3. S7-PAP: Sposobnost sprejemanja odločitev v postopku preskušanja energetskih strojev in naprav.
4. P8-PAP: Sposobnost diagnosticiranja posebnosti v postopku preskušanja energetskih strojev in naprav.

#### Objectives and competences:

##### Objectives:

1. To familiarize with technical requirements for management of experimental work in energy engineering
2. To familiarize with principles of measurement in energy engineering
3. To know the basic building blocks of measuring stations for measuring the characteristics of energy machines
4. To know the procedures for measuring emissions in energy engineering

##### Competences:

1. S1-PAP + S4-PAP: The ability to manage technical requirements of experimental work
2. P4-PAP: The ability to understand operation of different components of testing systems.
3. S7-PAP: The ability to make decisions in the testing

	process of energy machines and appliances. 4. P8-PAP: Ability to diagnose specificities in the process of testing power machines and appliances.
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<b>Predvideni študijski rezultati:</b>	<b>Intended learning outcomes:</b>
<p>Znanja:</p> <p>Z1: Poglobljeno strokovno teoretično in praktično znanje na določenem področju, podprto s širšo teoretično in metodološko osnovo.</p> <ul style="list-style-type: none"> <li>Znanje o področju preskušanja energetskega sistemov in drugem eksperimentalnem delu v energetskega strojništva.</li> </ul> <p>Spretnosti:</p> <p>S1.1 Izvajanje kompleksnih operativno-strokovnih opravil, ki vključujejo tudi uporabo metodoloških orodij.</p> <ul style="list-style-type: none"> <li>- Načrtovanje merilnih in preskusnih sistemov na področju energetskega strojništva</li> </ul> <p>S1.2 Obvladovanje zahtevnih, kompleksnih delovnih procesov ob samostojni uporabi znanja v novih delovnih situacijah.</p> <ul style="list-style-type: none"> <li>- Obvladovanje modernih merilnih in preskusnih metod za analizo delovanja energetskega strojev in naprav</li> </ul>	<p>Outcomes:</p> <p>Z1: Thorough professional theoretical and practical knowledge in a selected field of expertise that is supported with a broad theoretical and methodological basis.</p> <ul style="list-style-type: none"> <li>Knowledge about testing of energy systems and other experimental work in energy engineering.</li> </ul> <p>Skills:</p> <p>S1.1 Executing complex operational-professional tasks that incorporate usage of methodological tools.</p> <ul style="list-style-type: none"> <li>- Design of measuring and testing systems in the field of energy engineering</li> </ul> <p>S1.2 Mastering demanding and complex work processes by independent usage of knowledge in new working situations.</p> <ul style="list-style-type: none"> <li>- Management of modern measurement and test methods for analyses of operation of energy machines and devices</li> </ul>

<b>Metode poučevanja in učenja:</b>	<b>Learning and teaching methods:</b>
<p>P1 Avditorna predavanja z reševanjem izbranih - za področje značilnih - teoretičnih in praktično uporabnih primerov.</p> <p>P3 Avditorne vaje, kjer se teoretično znanje s predavanj podkrepi z računskimi primeri.</p> <p>P4 Laboratorijske vaje z namenski didaktični pripomočki (postaje za preskušanje različnih energetskega strojev in naprav, merilni sistemi za tlak, temperature in druge merjene veličine, drugi gradniki merilnih in preskusnih postaj).</p> <p>P7 Študij literature in razprava</p> <p>P9 Skupinsko delo</p> <p>P14 Virtualni eksperimenti</p> <p>P15 Uporaba video vsebin kot priprava na predavanja in vaje</p>	<p>P1 Auditorial lectures with solving selected field-specific theoretical and applied use cases.</p> <p>P3 Auditorial exercises, in which theoretical content from the lectures is supplemented with practical examples.</p> <p>P4 Laboratory exercises with special-purpose didactic devices (rigs for testing of different energy machines and devices, measuring systems for pressure, temperature and other measured quantities, other components of measurement and test rigs).</p> <p>P7 Literature study and discussion.</p> <p>P9 Team work</p> <p>P14 Virtual experiments.</p> <p>P15 Application of videos for preparations to the lectures and exercises</p>

<b>Načini ocenjevanja:</b>	<b>Delež/Weight</b>	<b>Assessment:</b>
Pisno ocenjevanje teorije	45,00 %	Written examination of theory

Praktično delo na vajah	45,00 %	Practical work on exercises
Ustni zagovor	10,00 %	Oral examination

#### Reference nosilca/Lecturer's references:

Marko Hočevar

1. RAK, Gašper, HOČEVAR, Marko, STEINMAN, Franci. Non-intrusive measurements of free-water-surface profiles and fluctuations of turbulent, two-phase flow using 2-D laser scanner. Measurement science & technology. 2020, letn. , št. , str. 1-14, [COBISS.SI-ID 9074529]
2. RAK, Gašper, STEINMAN, Franci, HOČEVAR, Marko, DULAR, Matevž, JEZERŠEK, Matija, PAVLOVČIČ, Urban. Laser ranging measurements of turbulent water surfaces. European journal of mechanics.B, Fluids. feb. 2020, letn. xx, št. xx, str. 1-12, ilustr. [COBISS.SI-ID 9085793]
3. NOVAK, Lovrenc, ŠIROK, Brane, HOČEVAR, Marko, GATARIĆ, Pero. Influence of load mass and drum speed on fabric motion and performance of a heat pump tumble dryer. Drying technology. [Print ed.]. 2020, str. 1-15, ilustr., [COBISS.SI-ID 17092379]
4. GATARIĆ, Pero, ŠIROK, Brane, HOČEVAR, Marko, NOVAK, Lovrenc. Modeling of heat pump tumble dryer energy consumption and drying time. Drying technology. [Print ed.]. 2019, vol. 37, no. 11, str. 1396-1404, [COBISS.SI-ID 16268571]
5. KHLIFA, Ilyass, VABRE, Alexandre, HOČEVAR, Marko, FEZZAA, Kamel, FUZIER, Sylvie, ROUSSETTE, Olivier, COUTIER-DELGOSHA, Olivier. Fast X-ray imaging of cavitating flows. Experiments in fluids. Nov. 2017, vol. 58, str. 1-22, ilustr., [COBISS.SI-ID 15738139]

Jože Kutin

1. KUTIN, Jože, SVETE, Andrej. On the theory of the frequency response of gas and liquid pressure measurement systems with connecting tubes. Measurement science & technology, 2018, vol. 29, no. 12, str. 1-11 [tipologija 01, SCI]
2. SVETE, Andrej, KUTIN, Jože, BOBOVNIK, Gregor, BAJSIČ, Ivan. Theoretical and experimental investigations of flow pulsation effects in Coriolis mass flowmeters. Journal of sound and vibration, 2015, vol. 352, str. 30-45 [tipologija 1.01, SCI]
3. RUPNIK, Klemen, KUTIN, Jože, BAJSIČ, Ivan. Identification and prediction of the dynamic properties of resistance temperature sensors. Sensors and actuators. A, Physical, 2013, vol. 197, str. 69-75 [tipologija 1.01, SCI]
4. BAJSIČ, Ivan, KUTIN, Jože, ŽAGAR, Tomaž. Response time of a pressure measurement system with a connecting tube. Instrumentation science & technology, ISSN 1073-9149, 2007, letn. 35, št. 4, str. 399-409 [tipologija 1.01, SCI]
5. KUTIN, Jože, BOBOVNIK, Gregor, BAJSIČ, Ivan. Razvoj temperaturnega merilnega zaznavala za izpušne sisteme. Ljubljana: Fakulteta za strojništvo, Laboratorij za meritve v procesnem strojništvu, 2007 [tipologija 2.12]