

# HIDRAVLIČNE KOMPONENTE IN SISTEMI

## UČNI NAČRT PREDMETA/COURSE SYLLABUS

|                                   |                                   |
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| <b>Predmet:</b>                   | Hidravlične komponente in sistemi |
| <b>Course title:</b>              | Hydraulic Components and Systems  |
| <b>Članica nosilka/UL Member:</b> | UL FS                             |

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

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| <b>Univerzitetna koda predmeta/University course code:</b> | 0566883 |
| <b>Koda učne enote na članici/UL Member course code:</b>   | 6030-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> | izr. prof. dr. Franc Majdič |
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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 Konstruiranje, ki je izbirni strokovni predmet na ostalih smereh./Compulsory specialised course in the study of Design 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):**

1. Prehodni pojavi v hidravličnih sistemih:
  - hidravlični udar,
  - pogoji,
  - preračuni,
  - meritve,
  - vplivni parametri.
2. Hidrostatični pogoni v zaprtem tokokrogu:
  - vrste vezav hidravličnih pogonov,
  - komponente,
  - lastnosti,
  - preračuni,
  - izbor ustreznih hidravličnih component.
3. Hidravlično krmiljenje smeri vožnje mobilnih strojev:
  - vrste hidravličnih volanskih sistemov,
  - značilnosti,
  - preračuni,
  - izbor ustreznih hidravličnih component.
4. Napredno krmiljenje in regulacija črpalk s spremenljivo iztisinno:
  - krmiljenje/regulacija z enojnim in dvojnimi tlačnim kompenzatorjem,
  - električno razbremenjevanje,
  - zvezno krmiljenje,
  - sistem z zaznavanjem obremenitev,
  - krmiljenje po moči.
5. Konstruiranje in razvoj novih hidravličnih komponent:
  - postopek,
  - snovanje,
  - preračuni,
  - konstruiranje,
  - izdelava prototipa,
  - eksperimentalne raziskave,
  - izboljšave.
6. Elektro hidravlično krmiljenje:
  - osnovni pojmi,
  - preračuni,
  - posebni električni tokokrogi za hidravlična krmilja,
  - PWM tehnika,
  - generator rampe,
  - proporcionalni in servo ojačevalnik,
  - digitalno krmiljenje.
7. Diagnostika hidravličnih sistemov:
  - merilna hidravlična zaznava,
  - principi merjenja,
  - fizikalne značilnosti,
  - tlak, pretok, viskoznost, vlaga, temperature,
  - dielektrična konstanta,
  - pomik, zasuk,

1. Transient phenomena in hydraulic systems:
  - hydraulic pressure shock,
  - conditions,
  - calculations,
  - measurements,
  - influence parameters.
2. Hydrostatic actuators in a closed circuit:
  - types of hydraulic drive circuits,
  - components,
  - properties,
  - calculations,
  - selection of suitable hydraulic components.
3. Hydraulic control of the direction of travel of mobile machines:
  - types of hydraulic steering systems,
  - characteristics,
  - calculations,
  - selection of suitable hydraulic components.
4. Advanced control and regulation of variable displacement pumps:
  - control / regulation with single and double pressure compensators,
  - electrical unloading,
  - continuous control,
  - load sensing system,
  - power control.
5. Design and development of new hydraulic components:
  - process,
  - design,
  - calculations,
  - construction,
  - prototype production,
  - experimental studies,
  - improvements.
6. Electro-hydraulic control:
  - basic concepts,
  - calculations,
  - special electrical circuits for hydraulic controls,
  - PWM technique,
  - ramp generator,
  - proportional and servo amplifiers,
  - digital control.
7. Diagnostics of hydraulic systems:
  - measuring hydraulic sensors,
  - measurement principles,
  - physical characteristics,
  - pressure, flow, viscosity, humidity, temperatures,
  - dielectric constant,

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| <ul style="list-style-type: none"> <li>- moment,</li> <li>- vibracije, hrup.</li> </ul> <p>8. Proporcionalni in digitalni ventili ter krmiljenje:</p> <ul style="list-style-type: none"> <li>- vrste proporcionalnih ventilov,</li> <li>- posebnosti proporcionalnih magnetov,</li> <li>- preračuni,</li> <li>- dinamična karakteristika,</li> <li>- Diether nihanje,</li> <li>- primerjava z digitalnimi ventili,</li> <li>- izvedba sistemov z digitalnimi ventili,</li> <li>- integracija v hidravlični sistem,</li> <li>- primeri uporabe.</li> </ul> <p>9. Servo ventili in integracija v hidravlični sistem:</p> <ul style="list-style-type: none"> <li>- značilnosti in zgradba servo ventilov,</li> <li>- neposredno in posredno krmiljenje,</li> <li>- primerjava s proporcionalnimi in digitalnimi,</li> <li>- momentni motor,</li> <li>- povratna zanka,</li> <li>- preračuni,</li> <li>- integracija v hidravlični sistem,</li> <li>- primeri uporabe.</li> </ul> <p>10. Eno- in večosna regulacija hidravličnega sistema:</p> <ul style="list-style-type: none"> <li>- regulacija vrtilne hitrosti hidravličnih motorjev,</li> <li>- natančno pozicioniranje s hidravličnimi valji,</li> <li>- hitrost vožnje mobilnega hidravličnega stroja,</li> <li>- regulacija tlaka in položaja,</li> <li>- napake v krmiljenju.</li> </ul> <p>11. Numerični preračuni - simulacije hidravličnih komponent v tridimenzionalnem sistemu:</p> <ul style="list-style-type: none"> <li>- zasnova nove hidravlične komponente,</li> <li>- posebne hidravlične geometrijske značilnosti,</li> <li>- postavitve numeričnega modela za MKE in CFD analizo, mreženje, postavitve robnih pogojev in vrednotenje rezultatov.</li> </ul> <p>12. Simulacije hidravličnih komponent v enodimenzionalnem sistemu:</p> <ul style="list-style-type: none"> <li>- predstavitev simulacijskih orodij,</li> <li>- osnovni fizikalni gradniki hidravličnih komponent,</li> <li>- princip izdelave nove hidravlične komponente,</li> <li>- primeri.</li> </ul> <p>13. Simulacije hidravličnih sistemov – 1. del:</p> <ul style="list-style-type: none"> <li>- ozadje delovanja 1D numeričnega programa,</li> <li>- osnovni sistemski gradniki,</li> <li>- princip gradnje 1D numeričnega modela hidravličnega sistema,</li> <li>- primer hidravlične naprave.</li> </ul> <p>14. Simulacije hidravličnih sistemov – 2. del:</p> <ul style="list-style-type: none"> <li>- napredna simulacijska orodja,</li> </ul> | <ul style="list-style-type: none"> <li>- displacement, rotation,</li> <li>- torque,</li> <li>- vibrations, noise.</li> </ul> <p>8. Proportional and digital valves and controls:</p> <ul style="list-style-type: none"> <li>- types of proportional valves,</li> <li>- the particularities of proportional solenoids,</li> <li>- calculations,</li> <li>- dynamic characteristic,</li> <li>- Diether oscillation,</li> <li>- comparison with digital valves,</li> <li>- implementation of systems with digital valves,</li> <li>- integration into the hydraulic system,</li> <li>- application examples.</li> </ul> <p>9. Servo valves and integration into the hydraulic system:</p> <ul style="list-style-type: none"> <li>- characteristics and structure of servo valves,</li> <li>- direct and indirect control,</li> <li>- comparison with proportional and digital,</li> <li>- torque motor,</li> <li>- feedback loop,</li> <li>- calculations,</li> <li>- integration into the hydraulic system,</li> <li>- application examples.</li> </ul> <p>10. Single and multi-axis control of the hydraulic system:</p> <ul style="list-style-type: none"> <li>- speed control of hydraulic motors,</li> <li>- precise positioning with hydraulic cylinders,</li> <li>- travel speed of the mobile hydraulic machine,</li> <li>- regulation of pressure and position,</li> <li>- control errors.</li> </ul> <p>11. Numerical calculations - simulations of hydraulic components in a three-dimensional system:</p> <ul style="list-style-type: none"> <li>- design of a new hydraulic component,</li> <li>- specific hydraulic geometric characteristics,</li> <li>- setting up a numerical model for FEM and CFD analysis, networking, boundary conditions setting and results evaluation.</li> </ul> <p>12. Simulations of hydraulic components in a one-dimensional system:</p> <ul style="list-style-type: none"> <li>- presentation of simulation tools,</li> <li>- basic physical building blocks of hydraulic components,</li> <li>- the principle of construction of a new hydraulic component,</li> <li>- examples.</li> </ul> <p>13. Hydraulic system simulations - Part 1:</p> <ul style="list-style-type: none"> <li>- the background of the operation of the 1D numerical program,</li> <li>- basic system components,</li> </ul> |
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| <p>- simulacije delovanja proporcionalnih, servo in digitalno-krmiljenih hidravličnih sistemov ter analiza rezultatov.</p> <p>15. Sodobni trendi in smernice razvoja hidravličnih komponent in sistemov:</p> <p>- pregled stanja tehnike z mednarodnih konferenc, revij, sejmov in patentov.</p> | <p>- the principle of construction of a 1D numerical model of a hydraulic system,</p> <p>- an example of a hydraulic device.</p> <p>14. Hydraulic system simulations - Part 2:</p> <p>- advanced simulation tools,</p> <p>- simulations of the operation of proportional, servo and digital-controlled hydraulic systems and analysis of the results.</p> <p>15. Current trends and guidance in the development of hydraulic components and systems:</p> <p>- an overview of the state of the art from international conferences, magazines, fairs and patents.</p> |
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### Temeljna literatura in viri/Readings:

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| <ol style="list-style-type: none"> <li>1. Matthies, H.J.: Renius, K.T.: Einführung in die Ölhydraulik, Teubner Verlag, 2003. [COBISS.SI-ID <a href="#">8701211</a>]</li> <li>2. D. Findeisen, F. Findeisen, Ölhydraulik: Handbuch für die hydrostatische Leistungsübertragung in der Fluidtechnik, 4. Auflage, Springer Verlag, 1994 [COBISS.SI-ID <a href="#">1020187</a>]</li> <li>3. Pezdirnik J., Majdič F. Krmiljene črpalke in hidravlični motorji ter hidrostatični pogoni : seminarsko gradivo. Ljubljana: Fakulteta za strojništvo, 2006. [COBISS.SI-ID <a href="#">9562651</a>]</li> <li>4. J. L. Johnson: Basic electronics for hydraulic motion control, Penton Publishing Inc., 1992 [COBISS.SI-ID <a href="#">4845851</a>]</li> </ol> |
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### Cilji in kompetence:

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| <p>Cilji:</p> <ol style="list-style-type: none"> <li>1. Spoznati napredna znanja na področju razvoja in raziskav novih hidravličnih component.</li> <li>2. Spoznati napredna znanja za preračun prehodnih pojavov znotraj hidravličnih sistemov.</li> <li>3. Spoznati znanje za dimenzioniranje hidrostatičnih pogonov v zaprtih tokokrogih.</li> <li>4. Nadgraditi znanje na področju sodobnih krmiljenih hidravličnih črpalk in motorjev</li> <li>5. Spoznati znanje uporabe proporcionalnih, digitalnih in servo ventilov.</li> <li>6. Spoznati znanje na področju numeričnih preračunov hidravličnih komponent in celotnih sistemov.</li> </ol> <p>Kompetence:</p> <ol style="list-style-type: none"> <li>1. Sposobnost za opredelitev in razumevanje temeljnih znanstvenih problemov z vidika prehodnih hidravličnih pojavov in ustvarjalno reševanje – preprečitev poškodb hidravlične opreme, stroja in človeka (S1-MAG)</li> </ol> | <p>Objectives:</p> <ol style="list-style-type: none"> <li>1. To acquire advanced knowledge in the field of development and research of new hydraulic components.</li> <li>2. To acquire advanced knowledge for the calculation of transient phenomena within hydraulic systems.</li> <li>3. To acquire knowledge of sizing hydrostatic actuators in closed circuits.</li> <li>4. Upgrade knowledge in the field of modern controlled hydraulic pumps and motors.</li> <li>5. Know how to use proportional, digital and servo valves.</li> <li>6. To know how to do numerical calculations of hydraulic components and systems.</li> </ol> <p>Competences:</p> <ol style="list-style-type: none"> <li>1. Ability to identify and understand basic scientific problems in terms of transient hydraulic phenomena and creative resolution - prevention of damage to hydraulic equipment, machine and human (S1-MAG).</li> </ol> |
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| 2. Sposobnost razvoja, raziskav in izboljšav novih hidravličnih sestavin s sinergijo znanja z različnih področij (S2-MAG in S7-MAG)<br>3. Sposobnost razvoja, raziskav in izboljšav novih hidravličnih krmilnih sistemov (P1-MAG in P2-MAG)<br>4. Sposobnost dimenzioniranja in uporabe zvezno-delujočih hidravličnih ventilov v kompleksnejših sistemih (P6-MAG in P7-MAG)<br>5. Sposobnost zaznavanja svetovnih trendov razvoja hidravličnih komponent in sistemov, kritična presoja in nadgradnja v nove, nadgrajene komponente in sisteme (S8-MAG) | 2. Ability to develop, research and improve new hydraulic components with synergy of knowledge in various fields (S2-MAG and S7-MAG)<br>3. Ability to develop, research and improve new hydraulic control systems (P1-MAG and P2-MAG)<br>4. Ability to dimension and use continuous-acting hydraulic valves in more complex systems (P6-MAG and P7-MAG)<br>5. Ability to detect global trends in the development of hydraulic components and systems, critical assessment and upgrading to new, upgraded components and systems (S8-MAG) |
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#### **Predvideni študijski rezultati:**

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| <p>Znanja</p> <p>Z2: Poglobljeno teoretično, metodološko in analitično poznavanje hidravličnih komponent, njihovega delovanja in sinteza znanja pri razvoju in raziskavi novih hidravličnih komponent in pri gradnji kompleksnih hidravličnih sistemov.</p> <p>Spretnosti:</p> <p>S2.1 Obvladovanje zelo zahtevnih, kompleksnih delovnih procesov in metodoloških orodij pri snovanju novih hidravličnih komponent in sistemov</p> <p>S2.2 Načrtovanje in vodenje konstruiranja, preračunov, meritev, montaže in poskusnega zagona nove hidravlične komponente in/ali celotnega sistema na podlagi ustvarjalnega reševanja problemov</p> <p>S2.3 Sposobnost kritične refleksije in izvirnih dognanj na področju hidravličnih komponent in sistemov – novi patenti, izdelki, naprave in/ali znanstveni članki</p> | <p>Knowledge:</p> <p>Z2: In-depth theoretical, methodological and analytical knowledge of hydraulic components, their operation and synthesis of knowledge in the development and research of new hydraulic components and in the construction of complex hydraulic systems.</p> <p>Skills:</p> <p>S2.1 Mastering highly complex, complex work processes and methodological tools in the design of new hydraulic components and systems</p> <p>S2.2 Design and control of the design, calculation, measurement, installation and test run of a new hydraulic component and / or the entire system based on creative problem solving</p> <p>S2.3 Ability to reflect critically and original knowledge of hydraulic components and systems - new patents, products, devices and / or scientific articles</p> |
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#### **Metode poučevanja in učenja:**

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| <p>P1, P2 Avditorna predavanja podprta z interaktivnim prikazom praktičnih primerov.</p> <p>P3 Avditorne vaje z reševanjem praktičnih primerov.</p> <p>P4 Laboratorijske vaje s timskim reševanjem aplikativnih problemov in uporabo progr. opreme ter njihova predstavitev z razpravo.</p> | <p>P1 and P2 Auditorial lectures, presenting the content according to the explained system.</p> <p>P3 Auditorial exercises, in which theoretical content from the lectures is supplemented with practical examples.</p> |
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#### **Learning and teaching methods:**

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| <p>P5 Uporaba študijskega gradiva v e-obliki, skripta in e-verzija predavanj.</p> <p>P6 Interaktivna predavanja.</p> <p>P7 Študij literature in razprava</p> <p>P8, P9 Izdelava in predstavitev aplikativno-raziskovalnih seminarskih nalog (po 2 študenta) ter razprava pred celotno skupino.</p> | <p>P4 Application of study material: hydraulic testing and diagnostic equipment for measuring hydraulic parameters.</p> <p>P5 Use of study materials in e-format, script and e-version of lectures</p> <p>P6 Interactive lectures.</p> <p>P7 Literature study and discussion.</p> <p>P8, P9 Preparation and presentation of applied seminar tasks: two students solve a specific individual task and discussion in front of the whole group.</p> |
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| Načini ocenjevanja:                                                            | Delež/Weight | Assessment:                                                                                                 |
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| Teoretične vsebine (predavanja).                                               | 40,00 %      | A theoretical contents (lectures).                                                                          |
| Avditorne in laboratorijske vaje (pisni preizkus znanja, osvojenega na vajah). | 30,00 %      | Auditorial and Laboratory exercises (written examination of the practical knowledge, aquired on exercises). |
| Aplikativni seminar s predstavitvijo in ustnim zagovorom.                      | 30,00 %      | Written applicative seminar with an oral presentation.                                                      |

| 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:

##### **Franc Majdič:**

1. TRAJKOVSKI, Ana, MATKOVIČ, Sebastjan, NOVAK, Nejc, NADEEM, Irfan, KALIN, Mitjan, **MAJDIČ, Franc**. Glycerol aqueous solutions for the enhanced tribological behaviour of polymer composites sliding against steel. *Tribology international*. Apr. 2024, vol. 192, [article no.] 109173, str. 1-11, ilustr. ISSN 1879-2464. <https://www.sciencedirect.com/science/article/pii/S0301679X23009647>, [Repozitorij Univerze v Ljubljani – RUL](#), DOI: [10.1016/j.triboint.2023.109173](https://doi.org/10.1016/j.triboint.2023.109173). [COBISS.SI-ID [180530947](#)]
2. NOVAK, Nejc, TRAJKOVSKI, Ana, POLAJNAR, Marko, KALIN, Mitjan, **MAJDIČ, Franc**. Wear of hydraulic pump with real particles and medium test dust. *Wear*. [Print ed.]. Nov. 2023, vol. 532/533, str. 1-13, ilustr. ISSN 0043-1648. <https://www.sciencedirect.com/science/article/pii/S0043164823004842>, [Repozitorij Univerze v Ljubljani – RUL](#), DOI: [10.1016/j.wear.2023.205101](https://doi.org/10.1016/j.wear.2023.205101). [COBISS.SI-ID [162606851](#)]
3. **MAJDIČ, Franc**. Fluid power technology and development trends. V: LOVREC, Darko (ur.), TIČ, Vito (ur.). *International conference Fluid Power 2023 : conference proceedings : [Maribor, Slovenia, 20th - 21st September 2023]*. 1st ed. Maribor: University of Maribor, University Press, 2023. Str. [1]-12, ilustr. ISBN 978-961-286-782-9. <https://press.um.si/index.php/ump/catalog/book/811>, [Repozitorij Univerze v Ljubljani – RUL](#). [COBISS.SI-ID [165510915](#)]
4. **MAJDIČ, Franc**. Matematični model za hidravlične akumulacije. *Ventil : revija za fluidno tehniko in avtomatizacijo*. avg. 2021, letn. 27, št. 4, str. 246-253, ilustr. ISSN 1318-7279. [Digitalna knjižnica Slovenije - dLib.si](#). [COBISS.SI-ID [74262531](#)]
5. BARTOLJ, Jan, TRAJKOVSKI, Ana, **MAJDIČ, Franc**, ČELIK, Anže. Razvoj, izdelava in testiranje proporcionalnega potnega ventila, izdelanega s 3D-tiskanjem kovin in z uporabo topološke optimizacije. *Ventil : revija za fluidno tehniko in avtomatizacijo*. jun. 2022, letn. 28, št. 3, str. 190-196, ilustr. ISSN 1318-7279. [Digitalna knjižnica Slovenije - dLib.si](#). [COBISS.SI-ID [114646019](#)]

