

TRANSMISIJE IN POGONI V INDUSTRIJI

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	Transmisije in pogoni v industriji
Course title:	INDUSTRIAL POWER-TRAINS
Članica nosilka/UL Member:	UL FS

Študijski programi in stopnja	Študijska smer	Letnik	Semestri	Izbirnost
Strojništvo - projektno aplikativni program, prva stopnja, visokošolski strokovni	Konstruiranje industrijskih sistemov (smer)	3. letnik	1. semester	obvezno

Univerzitetna koda predmeta/University course code:	0563471
Koda učne enote na članici/UL Member course code:	3054-V

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:	Jernej Klemenc, Simon Oman
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Vrsta predmeta/Course type:	Izbirni strokovni predmet/Elective specialised course
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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 Visokošolski strokovni študijski program I. stopnje Strojništvo - Projektno aplikativni program.	Meeting the enrollment conditions for the MECHANICAL ENGINEERING - Project Oriented Applied Programme.
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Vsebina:

1. Predavalnje: Bilanca sil in moči v industrijskih pogonih:
 - Upori in bremena kot ponori moči;
 - Pogonski stroj kot izvor moči;
 - Transmisija kot sestav komponent od izvora do ponora moči.
2. Predavanje: Vrste prenosa moči in možnosti za rekuperacijo energije:
 - Mehanski prenos moči;
 - Hidravlični prenos moči;
 - Električni prenos moči.
3. Predavanje: Vrste pogonskih strojev in njihove značilnosti:
 - Karakteristika idealnega pogonskega stroja;
 - Elektromotorji;
 - Motorji z notranjim zgorevanjem.
4. Predavanje: Gonila za mehanski prenos moči:
 - Kdaj potrebujemo različna prestavna razmerja v gonilih;
 - Diskretna prestavna razmerja;
 - Zvezno nastavljiva prestavna razmerja.
5. Predavanje: Gonila za mehanski prenos moči:
 - Značilnosti gonil z oblikovnim prenosom moči;
 - Izgube in samozapornost gonila;
 - Značilnosti gonil s tornim prenosom moči.
6. Predavanje: Pogonski sistemi z več izvori ali ponori moči:
 - Princip delitve moči iz enega izvora;
 - Princip sumacije moči iz več virov;
 - Distribuirani pogoni;
 - Problem sinhronizacije tokov moči.
7. Predavanje: Osnove planetnih gonil kot mehanskih sumatorjev ali delilnikov moči:
 - Vrste in oznake planetnih gonil;
 - Grafična določitev notranjih prestav enostavnega planetnega gonila;
 - Navori na gredeh planetnega gonila.

Content (Syllabus outline):

1. Lecture: Force and power balance in industrial power-trains:
 - Resistors and loads as power consumers;
 - Driving engine as power source;
 - Transmission as an assembly of components between power source and power consumption.
2. Lecture: Power-transmission types and possibilities for energy recovery:
 - Mechanical transmissions;
 - Hydraulic transmissions;
 - Electric transmissions.
3. Lecture: Driving engine types and their output characteristics:
 - Characteristics of an ideal power source;
 - Electric motors;
 - Internal combustion engines.
4. Lecture: Mechanical transmission systems:
 - When different transmission ratios are needed in gearboxes;
 - Discrete transmission ratios;
 - Continuously variable transmissions.
5. Lecture: Mechanical transmission systems:
 - Characteristics of transmissions with geometric power transmission;
 - Power losses and self-locking;
 - Characteristics of transmissions with frictional power transmission.
6. Lecture: Transmission systems with multiple power sources and outputs:
 - Principle of power splitting from one source;
 - Principle of power summation from multiple sources;
 - Distributed transmissions;
 - Problem of power-flow synchronisation.
7. Lecture: Introduction to planetary gears as mechanical power summaters or splitters:

<p>8. Predavanje: Osnove planetnih gonil kot mehanskih sumatorjev ali delilnikov moči:</p> <ul style="list-style-type: none"> - Wolfova shema; - Zunanje prestave planetnega gonila; - Kotalna in sklopna moč planetnega gonila. <p>9. Predavanje: Osnove planetnih gonil kot mehanskih sumatorjev ali delilnikov moči:</p> <ul style="list-style-type: none"> - Kombinirana planetna gonila. <p>10. Predavanje: Primeri mehanskih menjalnikov:</p> <ul style="list-style-type: none"> - Ročni sekvenčni menjalnik; - Ročni menjalnik s predležno gredjo; - Avtomatski menjalnik z dvojno sklopko. <p>11. Predavanje: Avtomatski menjalnik s pretvornikom navora:</p> <ul style="list-style-type: none"> - Ravigneaux planetno gonilo; - Hidravlični pretvornik navora; - Izgube pri prenosu moči. <p>12. Predavanje: Usmerjanje navora v transmisiji z razvejišči:</p> <ul style="list-style-type: none"> - Diferencialna gonila v transmisiji z razvejišči; - Uporaba visko-sklopke v transmisiji z razvejišči; - Vektoriranje navora. <p>13. Predavanje: Električni hibridni prenosniki moči:</p> <ul style="list-style-type: none"> - Zaporedni hibridni pogon; - Vzporedni hibridni pogon; - Kombinirani hibridni pogon. <p>14. Predavanje: Hidravlični prenosniki moči:</p> <ul style="list-style-type: none"> - Hidrostatski prenosnik moči; - Hidrodinamični prenosnik moči. <p>15. Predavanje: Kombinirani mehansko-hidravlični prenosnik moči:</p> <ul style="list-style-type: none"> - Razcep in združenje tokov moči; - Zveznost prestavnega razmerja; - Inverzija smeri vrtenja in blokada hidravličnega toka moči; - Izkoristek transmisije. 	<ul style="list-style-type: none"> - Types and designations of planetary gears; - Graphical determination of internal (stable) gear ratios for a simple planetary gear; - Torques in shafts of the planetary gear. <p>8. Lecture: Introduction to planetary gears as mechanical power summators or splitters:</p> <ul style="list-style-type: none"> - Wolf's scheme; - Outer gear ratios of the planetary gear; - Rolling and swirching power in the planetary gear. <p>9. Lecture: Introduction to planetary gears as mechanical power summators or splitters:</p> <ul style="list-style-type: none"> - Combined planetary gears. <p>10. Lecture: Examples of mechanical gearboxes:</p> <ul style="list-style-type: none"> - Manual sequential gearbox; - Manual conventional gearbox; - Automatic dual-clutch gearbox. <p>11. Lecture: Automatic gearbox with torque converter:</p> <ul style="list-style-type: none"> - Ravigneaux planetary gear; - Hydraulic torque converter; - Power losses during power transmission. <p>12. Lecture: Torque vectoring in transmission with multiple branches:</p> <ul style="list-style-type: none"> - Differential gear in transmission with multiple branches; - Application of visco-clutch in transmission with multiple branches; - Torque vectoring. <p>13. Lecture: Electric hybrid power-trains:</p> <ul style="list-style-type: none"> - Serial hybrid drive; - Parallel hybrid drive; - Combined hybrid drive. <p>14. Lecture: Hydraulic power-trains:</p> <ul style="list-style-type: none"> - Hydrostatic hydraulic transmission; - Hydrodynamic hydraulic transmission. <p>15. Lecture: Combined hydro-mechanical transmission systems:</p> <ul style="list-style-type: none"> - Power splitting and summation; - Continuously variable transmission; - Inverter of angular velocity and
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	locking of hydraulic power flow; - Power efficiency.
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Temeljna literatura in viri/Readings:

Klemenc J. Dinamika vozil – učbenik. Ljubljana: UL, Fakulteta za strojništvo, 2019.

Wittel H., Jannasch D., Vossiek J., Spura C. Roloff/Matek Maschinenelemente – 23. Auflage. Springer Vieweg, 2017.

Granzow C. ZF Vector Drive – better driving dynamics and driving safety through Torque Vectoring. Praesentation Praktischer Entwurf mechatronischer Systeme, Karlsruhe 13.12.2013.

Flašker J., Pehan S. Prenosniki moči : učbenik. UM, Fakulteta za strojništvo, 2005.

Cilji in kompetence:

Cilji:

Spoznati osnovne principe uravnoveženja moči pri industrijskih pogonih.

Spoznati različne variante transmisij in pogonov v industriji.

Spoznati kriterije za izbiro posameznih tipov industrijskih pogonov.

Spoznati delovne principe, koncipiranje in oblikovanje osnovnih mehanskih industrijskih pogonov.

Spoznati delovne principe naprednih industrijskih pogonov v smislu njihove uporabe.

Kompetence:

S1-PAP: Sposobnost uporabe pridobljenega znanja s področja industrijskih pogonov v praksi.

S10-PAP: Sposobnost strokovnega sporazumevanja in pisnega izražanja z obravnavanega področja.

S13-PAP: Sposobnost iskanja virov znanja, selekcija najdenih virov in uporaba tako pridobljenega znanja pri svojem delu.

P1-PAP: Razume fizikalne zakone in pojave, na katerih temelji funkcija mehanskih, hidravličnih in električnih pogonov.

P8-PAP: Obvlada osnovna in potrebna specifična znanja v izbrani študijski

Objectives and competences:

Objectives:

To learn basic principles of power balancing in industrial power-trains.

To learn different types of transmission systems in the industry.

To train usage of the relevant criteria for selecting different types of industrial power-trains.

To learn work principles, conceptualisation and design of basic mechanical industrial power-trains.

To learn working principles of complex industrial power-trains from the viewpoint of their application.

Competences:

S1-PAP: The ability to use the attained knowledge of industrial power-trains in the practice.

S10-PAP: The ability to communicate professionally and express oneself in writing.

S13-PAP: The ability to find sources of knowledge, select among the available resources and use the knowledge acquired for one's work.

P1-PAP: Understanding the laws of physics and the phenomena behind the operating principles of mechanical, hydraulic and electric power-trains.

smeri (analiza in sinteza industrijskih pogonov).	P8-PAP: Mastering the basic and required specific knowledge from the selected study (analysis and synthesis of industrial power-trains).
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Predvideni študijski rezultati:	Intended learning outcomes:
<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"> - Razumevanje zveze med potrebami in viri moči v industrijskih pogonih. - Razumevanje teoretičnih in praktičnih osnov za izbiro, koncipiranje in oblikovanje nezahtevnih industrijskih pogonov. - Razumevanje delovanja naprednih industrijskih pogonov na nivoju njihove aplikacije. <p>Spretnosti:</p> <p>S1.1 Izvajanje kompleksnih operativno-strokovnih opravil, ki vključujejo tudi uporabo metodoloških orodij:</p> <ul style="list-style-type: none"> - Preračun zunanjih karakteristik mehanskih gonil. - Izdelava projektne ali nabavne dokumentacije za sestavne elemente industrijskih gonil. <p>S1.2 Obvladovanje zahtevnih, kompleksnih delovnih procesov ob samostojni uporabi znanja v novih delovnih situacijah:</p> <ul style="list-style-type: none"> - Vodenje vzdrževalnih posegov različne pogonske sisteme v industriji. 	<p>Knowledge:</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"> - Understanding relationship power sources and needs in industrial power-trains. - Understanding theoretical and practical basis for selection, conceptualisation and design of simple industrial power-trains. - Functional understanding of complex industrial power-trains at usage level. <p>Skills:</p> <p>S1.1 Executing complex operationa-professional tasks that incorporate usage of methodological tools:</p> <ul style="list-style-type: none"> - Calculating output characteristics of mechanical power-trains. - Preparation of project or procurement documentation for components of industrial power-trains. <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"> - Managing maintenance activities for different industrial power-trains.

Metode poučevanja in učenja:	Learning and teaching methods:
<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 namenskim didaktičnim pripomočki (prirejeni zobniški menjalniki in diferencialna gonila).</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 (modified gearboxes and differential gears).</p> <p>P8: Making and presenting applied</p>

P8: Izdelava in predstavitev aplikativnih seminarskih nalog.	seminar exercises.
P15: Uporaba video vsebin kot priprava na predavanja in vaje.	P15: Application of videos for preparations to the lectures and exercises.

Načini ocenjevanja:	Delež/ Weight	Assessment:
Teoretična znanja (pisni kolokviji in izpit z opsijskim ustnim zagovorom).	50,00 %	Theoretical knowledge (written colloquia and exam with an optional oral examination).
Aplikativne seminarske naloge (poročila s predstavitvami).	10,00 %	Applied seminar exercises (reports with presentations).
Laboratorijske vaje (poročila).	10,00 %	Laboratory exercises (reports).
Avditorne vaje (poročila).	10,00 %	Auditorial exercises (reports).
Pisni preskus praktičnega znanja, osvojenega na vajah.	20,00 %	Written examination of practical knowledge that was acquired in exercises.

Reference nosilca/Lecturer's references:

Jernej Klemenc:

MIKLAVEC, Matej, **KLEMENC, Jernej**, KOSTANJEVEC, Andrej, FAJDIGA, Matija. Fatigue strength of a hybrid joint formed between a PA6-GF60 polymer matrix and a S420MC steel insert. Materials & design, Oct. 2013, vol. 51, str. 493-500, ilustr., doi: 10.1016/j.matdes.2013.04.058.

KLEMENC, Jernej, FAJDIGA, Matija. Simulating a Gaussian random process by conditional PDF. Engineering computations, 2011, vol. 28, no. 5, str. 540-556, doi: 10.1108/02644401111141000.

KLEMENC, Jernej, FAJDIGA, Matija. Improved modelling of the loading spectra using a mixture model approach. International journal of fatigue, 2008, letn. 30, št. 7, str. 1298-1313. <http://dx.doi.org/10.1016/j.ijfatigue.2007.08.024>.

KLEMENC, Jernej, FAJDIGA, Matija. Determining the material parameters of a polyurethane foam with a differential ant-stigmergy algorithm. V: The automobile in the second decade : sharing all energy solutions : final programme and exhibition catalogue. València: Universitat Politècnica. 2011, str. E21-1-E21-9.

ŠKRLEC, Andrej, FRANKO, Mitja, OMAN, Simon, ZOBEC, Peter, NAGODE, Marko, **KLEMENC, Jernej**. Numerical fatigue-life prediction for a trailing arm BMW-UKL : final report. Ljubljana: Faculty of Mechanical Engineering, 2016. 133 f.

Simon Oman:

OMAN, Simon, FAJDIGA, Matija, NAGODE, Marko. Estimation of air-spring life based on accelerated experiments. Materials & design, ISSN 0264-1275, 2010, vol. 31, iss. 8, str. 3859-3868, doi: 10.1016/j.matdes.2010.03.044.

OMAN, Simon, NAGODE, Marko. The influence of piston shape on air-spring fatigue life. Fatigue & fracture of engineering materials & structures, ISSN 8756-

758X, 2018, vol. 41, iss. 5, str. 1019-1031, ilustr.

<http://onlinelibrary.wiley.com/doi/10.1111/ffe.12748/epdf>, doi: 10.1111/ffe.12748.

GOSAR, Aleš, NAGODE, Marko, **OMAN, Simon**. Continuous fatigue damage prediction of a rubber fibre composite structure using multiaxial energy-based approach. *Fatigue & fracture of engineering materials & structures*, ISSN 8756-758X, Jan. 2019, vol. 42, iss. 1, str. 307-320, ilustr.

<https://onlinelibrary.wiley.com/doi/epdf/10.1111/ffe.12908>, doi: 10.1111/ffe.12908.

OMAN, Simon, NAGODE, Marko. Določitev dobe trajanja zračnih vzmeti = Air springs service life determination. *Svet strojništva*, ISSN 1855-6493, nov. 2016, letn. 5, št. 4/5, str. 14-20, ilustr.

ŠKRLEC, Andrej, FRANKO, Mitja, **OMAN, Simon**, ZOBEC, Peter, NAGODE, Marko, KLEMENC, Jernej. Numerical fatigue-life prediction for a trailing arm BMW-UKL : final report. Ljubljana: Faculty of Mechanical Engineering, 2016. 133 f., graf. prikazi.