

SISTEMI KOMPRIMIRANIH MEDIJEV IN VAKUUMA

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	Sistemi komprimiranih medijev in vakuuma
Course title:	SYSTEMS FOR COMPRESSED GASES AND VACUUM
Članica nosilka/UL Member:	UL FS

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

Univerzitetna koda predmeta/University course code:	0562728
Koda učne enote na članici/UL Member course code:	3029-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:	Jurij Prezelj
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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:

<p>1. Uvod:</p> <ul style="list-style-type: none"> - Primeri uporabe kapljev in plinov pod visokim tlakom; (toplotne črpalke, stisnjen zrak, hidravlični stroji, biokemični procesi, abrazivni vodni curek, pridobivanje žlahtnih plinov...); - Primerjava turbinskih in volumetričnih strojev - Primeri uporabe vakuum (degazacija kapljev, površinska obdelava orodij, sušenje, sterilizacija...); - Opis univerzalnega sistema za pripravo komprimiranih medijev in univerzalnega sistema za pripravo in vzdrževanje vakuum, z opisom razlik med njima; - Delitev delovnih strojev s poudarkom na razlikah med turbinskimi in volumetričnimi delovnimi stroji; - Opis nevarnosti ob delu z visokim tlakom. <p>2. Batni in dvo-lamelni kompresorji:</p> <ul style="list-style-type: none"> - Krilni oziroma lamelni kompresor - primeri najpogostejše uporabe lamelnih kompresorjev; - Snovanje njegove geometrije ohišja in rotorja; - Izpeljava enačb za izračun pretoka lamelnega kompresorja; - Vpliv nagiba lamel in položaj dovodne in odvodne odprtine; - Opis sil, ki delujejo na lamele in izgube zaradi trenja; - Teoretični indikatorski diagram lamelnega kompresorja; - Izmerjeni indikatorski diagram; - Vpliv delovne točke lamelnega kompresorja na indikatorski diagram; - Notranja in zunanja kompresija ob razliki med dvokrilnim in večkrilnim kompresorjem. <p>3. Kompresorji s kotalnim batom in več-lamelni kompresorji:</p> <ul style="list-style-type: none"> - Kompresor s kotalnim batom: primeri
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Content (Syllabus outline):

<p>1. Introduction:</p> <ul style="list-style-type: none"> - Examples of the use of high pressure liquids and gases; (heat pumps, compressed air, hydraulic machines, biochemical processes, abrasive water jet, extraction of precious gases...); - Comparison of turbo machinery and volumetric machines - Vacuum applications (degassing of liquids, surface treatment of tools, drying, sterilization, etc.); - Description of the universal system for the preparation of compressed gasses and the universal system for the preparation and maintenance of vacuum, and the differences between them; - Division of machinery with a focus on the differences between turbo machinery and positive displacement machinery; - Hazardous work with high pressure systems. <p>2. Reciprocating and two-vanes compressors</p> <ul style="list-style-type: none"> - Vane compressor - examples of the most common use of vane compressors; - Design of its housing and rotor geometry; - Derivation of equations for calculating the flow rate of the vane compressor; - Impact of the vane tilt and the position of the inlet and outlet openings on the compressor functional properties; - Description of forces acting on vanes and friction losses; - Theoretical indicator diagram of the vane compressor and its comparison to typically measured indicator diagram; - Impact of the operating point on the indicator diagram; - Internal and external compression with the difference between a two-vane and a multi-vane compressor.

najpogostejše uporabe kompresorjev s kotalnim batom;

- Snovanje geometrije ohišja in kotalnega bata;
- Izpeljava enačb za izračun dobave kompresorja s kotalnim batom;
- Vpliv položaja in obrabe kotalnega bata na tesnjenje;
- Vpliv položaja in velikosti sesalne in tlačne odprtine;
- Notranja in zunanja kompresija;
- Opis sil, ki delujejo na ekscentrični ležaj in na ventil;
- Indikatorski diagram kompresorja s kotalnim batom.

4. Spiralni kompresorji:

- Uvod v delovanje spiralnega kompresorja;
- Oblika spiralnih krivulj za popis teoretičnih neskončno tankih lamel;
- Korekcija geometrije za končno debele lamele, utekanje lamelnega para;
- Analitična izpeljava teoretične dobave spiralnega kompresorja;
- Matematični opis zvezne notranje kompresije;
- Vpliv aksialne in radialne lekaže na dobavo;
- Indikatorski diagram kot funkcija delovne točke kompresorja in točke opazovanja med spiralnimi lamelami.

5. Radialna in Rootsova puhala:

- Opis delovanja Rootsovega puhala in primeri uporabe,
- Snovanje geometrije rotorjev in ohišja, vpliv stopnje zajedanja rotorskih lamel na pretok in oscilacije tlaka,
- aktualne metode zniževanja oscilacij tlaka rootsovega puhala, indikatorski diagram rootsovega puhala, zunanja skoraj izohorna kompresija;
- Vijačni kompresor kot izpeljava rootsovega puhala na osnovi zvijanja rotorja, poti notranjega puščanje, relativne hitrosti fluida pri obtekanju rotorjev, vpliv notranje kompresije na izkoristek sistema v primeru delovanja izven optimalne delovne točke;
- Primerjava karakteristik vijačnega kompresorja z radialnim kompresorjem enake moči.

3. Rolling piston and multi-vane compressors

- Rolling piston compressor: examples of the most common use of rolling piston compressors;
- Design of the housing geometry and the rolling piston;
- Derivation of equations for calculating the delivery of a rolling piston compressor;
- Impact of the rolling piston position and its wear on the sealing;
- Impact of the position and size of the suction and discharge ports;
- Internal and external compression;
- Description of forces acting on the eccentric bearing and on the valve / blade using vibration and noise reduction methods;
- Rolling piston compressor indicator diagram.

4. Spiral compressors

- Description of spiral compressor working principle and its applications;
- Shape of spiral curves for the description of theoretically infinitely thin lamellae;
- Geometry correction for finely thick lamellae, run-in lamellar pair;
- Analytical derivation of the theoretical delivery of the spiral compressor;
- Mathematical description of continuous internal compression;
- Impact of axial and radial lenses on delivery;
- Indicator diagram as a function of compressor operating point and observation point between spiral blades.

5. Radial and Roots Blowers

- Description of Roots blower working principle and its applications;
- Design of the rotor geometry and the housing geometry, the influence of the under-teeth rate in the rotor design on the flow and pressure oscillations,
- State of the art methods of reducing the pressure oscillations of the root blower, indicator diagram of the root blower, external almost isochoric compression;

<p>6. Komprimiran zrak kot oblika energenta:</p> <ul style="list-style-type: none"> - Primeri uporabe stisnjenega zraka kot energenta; - Priprava stisnjenega zraka in njegovi razredi kakovosti; - Analiza in načrtovanje potreb po stisnjenem zraku; - Sistemi za nadzor porabe in stanja sistemov za dobavo komprimiranega zraka; - Ekonomska upravičenost uporabe stisnjenega zraka kot energenta; - Elementi priprave komprimiranega zraka. <p>7. Elementi za pripravo komprimiranega zraka:</p> <ul style="list-style-type: none"> - Sušilniki; (hladilniški adsorpcijski, absorpcijski, membranski); - Hladilniki (odprt, polodprt in zaprt sistem); - Razoljevalniki (avtomatski ročni, ločevalniki olja in vode); - Filtri (na vstopu na izstopu, mehanizmi filtriranja, energijske izgube zaradi filtriranja); - Spremljanje stanja filtrov; - Reducirni ventili in sistemi za ohranjanje tlaka; - Ekonomska uporabičenost zahtev po visokih razredih kvalitete komprimiranega zraka. <p>8. Sistemi za dobavo komprimiranega zraka:</p> <ul style="list-style-type: none"> - Vodila pri načrtovanju sistemov dobave komprimiranega zraka; (izračun efektivne dolžina cevovoda, izbira preseka cevi, kolena, vrsta cevi, ...); - Večtlačni razvodi in vezave cevovodov za znižanje stroškov; - Metode detekcije in lokalizacije puščanja komprimiranega zraka iz sistema; - Analiza stroškov puščanja komprimiranega zraka; - Tlačne posode; izbira velikosti, postavitev, zakonsko predpisano preverjanje sten in zvarov, varnostni ventili. <p>9. Sistemi krmiljenja kompresorjev:</p> <ul style="list-style-type: none"> - Predstavitev težav krmiljenja dobave 	<ul style="list-style-type: none"> - Screw compressor as a derivative of a root blower based on the rotor twisting; - Internal leakage path, relative fluid velocity during rotation of the rotors, influence of internal compression on system efficiency in case of operation outside the optimum operating point; - Comparison of the characteristics of a screw compressor with a radial compressor of equal power. <p>6. Compressed air as a form of energy</p> <ul style="list-style-type: none"> - Examples of compressed air as an energy source; - Compressed air treatment for different quality classes; - Analysis, planning and optimization of needs for compressed air; - Systems for monitoring the consumption and condition of a compressed air supply systems; - The economic justification of compressed air as an energy source; - Influence of elements for compressed air treatment on operational costs. <p>7. Elements for treatment of compressed air</p> <ul style="list-style-type: none"> - Dryers; (refrigerant adsorption, absorption, membrane); - Refrigerators (open, semi-open and closed); - Oil separators (automatic manual, oil and water separators); - Filters (at the inlet at the outlet, filtering mechanisms, energy losses due to filtration); - Monitoring of the filter status; - Pressure reducing valves and systems for pressure stabilization; - Economic viability of the demand for high quality compressed air. <p>8. Systems for the supply of compressed air:</p> <ul style="list-style-type: none"> - Guidelines for the design of compressed air supply systems; (calculation of the effective length of the pipeline, selection of pipe cross section, elbows, type of pipes, etc...); - Pressure reliefs and different types of pipeline connections to reduce costs; - Methods for detecting and localizing compressed air leakage from the system;
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<p>kompresorjev z elektromotorji velikih moči;</p> <ul style="list-style-type: none"> - Vrste krmiljenja dobave; (vklop/izklop, obremenitev/razbremenitev, povratni vod, pripiranj ventilov, sprememba delovnega volumna, krmiljenje vrtljajev, uporaba več majhnih kompresorjev; - Krmiljenje kompresorskih postaj; - Vodila pri načrtovanju kompresorskih postaj. <p>10. Črpalke:</p> <ul style="list-style-type: none"> - Raznolikost lastnosti medijev črpanja (eksplozivni mediji, agresivni mediji, živila, biološke tekočine...); - Stisljivost kapljev; - Opis različnih tipov črpalk glede na razmerje med tlačnim in pretočnim številom; - Raznolikost velikostnih razredov črpalk (mikrofluidika in naftna industrija); - Primerjava radialnih črpalk in volumetričnih črpalk; - Opis batnih črpalk, opis oscilacij tlaka, metode zniževanja oscilacij, kavitacija; - Ventili, ventilske ploščice, tesnila, obraba. <p>11. Vakuumska tehnika:</p> <ul style="list-style-type: none"> - Pregled območij podtlaka oziroma delitev na grobi, srednji, visoki, in ultravisoki vakuum; - Različne oblike pretoka kot funkcija podtlaka (Viskozni, Knudsenov in Molekularni tok); - Konduktanca viskoznega in molekularnega toka; - Lastnosti materialov v vakuumu - izhlapevanje; - Lekaža vakumskih sistemov; Permeacija, difuzija, povratni tok iz črpalke, razplinjevanje, desorpcija); - Načrtovanje in izbira materialov za vakuumske sisteme; - Metodologija ocenjevanja potrebnega pretoka vakuumske črpalke za vzdrževanje vakuumu. <p>12. Vakuumske črpalke:</p> <ul style="list-style-type: none"> - Opis različnih vrst vakumskih črpalk in principov delovanja za doseganje 	<ul style="list-style-type: none"> - Compressed air leakage cost analysis; - Pressure vessels; size selection, location in the system, legislation on vessels walls and welds inspection, safety valves; <p>9. Control strategies for compressors:</p> <ul style="list-style-type: none"> - Presentation of the problems involved in controlling the supply of compressors with high-performance electric motors; - Types of supply control; (on/off, loading/unloading, return line, valve closures, volume change, speed control, use of several small compressors; - Control of compressor stations; - Guidelines for the design of compressor stations. <p>10. Pumps:</p> <ul style="list-style-type: none"> - Variety of characteristics of multitude of different pumped media (explosive media, aggressive media, food, biological fluids, etc...); - Compressibility of liquids; - Description of the different pump types, according to the ratio of pressure to flow rate; - Diversity of pump sizes (from microfluidics to oil industry); - Comparison of radial pumps and volumetric pumps; - insight into different piston pumps, description of pressure oscillations, oscillation reduction methods, cavitation; - Valves, valve plates, gaskets, wear. <p>11. Vacuum technology:</p> <ul style="list-style-type: none"> - Overview of wide range of pressure and division into rough, medium, high and ultra-high vacuum; - Different flow patterns in vacuum as a function of pressure (Viscous, Knudsen and Molecular flow); - Conductance of viscous and molecular flow; - Properties of materials in vacuum - evaporation; - Vacuum systems leakage; Permeation, diffusion, backflow from the pump, degassing, desorption); - Design and selection of materials for use in vacuum systems;
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<p>grobega vakuuma (radialno puhalo, membranske črpalke, krilne vakuumske črpalke, spiralni kompresor kot vakuumska črpalka;</p> <ul style="list-style-type: none"> - Radialno puhalo kot vakuumska črpalka; - Opis delovanja črpalk za doseganje visokega vakuuma (Rootsovo puhalo, oljno difuzna črpalka, turbomolekularna črpalka; - Ocena potrebnega časa praznjenja vakuumske posode. <p>13. Sistemi za pripravo in analizo plinskih zmesi:</p> <ul style="list-style-type: none"> - Uporaba plinskih mešanic (medicina, analizna kemija, biokemija, živilska industrija); - Sistemi za pripravo plinskih mešanic; - Separacijske tehnike za plinske mešanice (tlačna, vakuumska in temperaturna adsorpcija); - Pridobivanje kisika in dušika iz zraka - Plinska kromatografija. <p>14. Sistemi utekočinjanja plinov:</p> <ul style="list-style-type: none"> - Sistemi za proizvodnjo; utekočinjenega vodika, kisika, dušika, zraka; - Pridobivanje žlahtnih plinov; - Shranjevanje utekočinjenih plinov; - Varnost pri uporabi utekočinjenih plinov. <p>15. Nadzor in monitoring delovanja sistemov komprimiranih medijev in vakuuma:</p> <ul style="list-style-type: none"> - Spremljanje dobave in porabe komprimiranega zraka za identifikacijo izrednih dogodkov; - Kontrolne karte kompresorjev (Pretok, tlak in električna moč, kvaliteta olja, raven vibracij); - Spremljanje signalov vibracij delovnih strojev in metode njihove analize za načrtovanje preventivnega vzdrževanja; - Uporaba spektrov za analizo rotirajočih se delov in uporaba signalov kot časovnih vrst za linearno premikajoče se dele; - Izdelava načrtov preventivnega vzdrževanja na osnovi kontrolnih kart; - Spremljanje padca tlaka na filterih, 	<ul style="list-style-type: none"> - Methodology for estimating the required vacuum pump flow rate for maintenance of vacuum in vessels. <p>12. Vacuum pumps:</p> <ul style="list-style-type: none"> - Description of various working principles of rough vacuum pumps (radial blower, diaphragm pumps, vane vacuum pumps, helical compressor as a vacuum pump; - Radial blower as a vacuum pump; - Description of the various principles of operation of high vacuum pumps (Roots blower, oil diffusion pump, turbomolecular pump; - Derivation of equations for calculation of estimated time, needed to achieve desired vacuum in a multistage system. <p>13. Systems for the preparation and analysis of gas mixtures:</p> <ul style="list-style-type: none"> - Applications of gas mixtures (medicine, analytical chemistry, biochemistry, food industry); - Gas mixture preparation systems; - Separation techniques for gas mixtures (pressure, vacuum and temperature adsorption); - Extraction of oxygen and nitrogen from the air - Gas chromatography. <p>14. Gas liquefaction systems:</p> <ul style="list-style-type: none"> - Production systems; liquefied hydrogen, oxygen, nitrogen and air; - Precious gas production; - Storage of liquefied gases; - Hazards in working with Liquid gases and safety precautions for handling liquefied air. <p>15. Monitoring of compressed gas and vacuum systems:</p> <ul style="list-style-type: none"> - Monitoring the supply and use of compressed air for the identification of emergencies; - Control charts for compressors and vacuum pumps (pressure difference, flow and electric power, oil quality, vibration level); - Monitoring of vibroacoustic signals on machines and methods of their analysis for preventive maintenance planning; - Use of vibroacoustic signal spectrum to
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plan njihove menjave; - Merilni sistemi za vakuum.	analyze rotating parts and use of signals as time series for linearly moving parts; - Preparation of preventive maintenance plans - Monitoring of pressure drop on filters, plan of their replacement; - Vacuum measuring systems.
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Temeljna literatura in viri/Readings:

Heinz P. Bloch, A practical guide to compressor technology, A John Wiley & sons, inc. Publications, 2006, New Jersey

Johann Friedrich Gülich, Centrifugal Pumps, Springer, 2010, New York

James B. Rishel, HVAC Pump Handbook, McGraw Hill handbooks, 2006 New York

Paul C. Hanlon, Compressor Handbook, McGraw-Hill, 2001, New York

Walter Umrath, Fundamentals of vacuum technology, Oerlikon Leybold vacuum, 2007, Cologne

Handbook of vacuum science, D.M.Hoffman, B.Singh, J.H Thomas, Academic press, 1998, London

Cilji in kompetence:

Cilji:

Študente seznaniti s širino področja komprimiranih medijev, ki se razširja od majhnih radialnih puhal z nekaj 10 W preko ogromnih vijačnih kompresorjev z nekaj 100 kW, za različne pline v različnih aplikacijah, do proizvodnje utekočinjenih plinov.

Študentom podati znanje, ki je potrebno za samostojno načrtovanje sistemov za proizvodnjo pripravo in dobavo komprimiranega zraka.

Študente usposobiti z znanji in sposobnostmi ki omogočajo izdelavo fizikalno-matematičnih modelov za opis delovanja radialnih puhal in volumetričnih kompresorjev.

Študentom podati občutek za razumevanje fizikalnih procesov ki potekajo v vakuumu in razširiti znanje termodinamike na področje vakuuma.

Seznaniti študente s številnimi najsodobnejšimi metodami za spremljanje procesov v sistemih za

Objectives and competences:

Objectives:

To give students a comprehensive insight into the wide range of compressed media and vacuum systems, for various applications, extending from a small radial blowers of about 10 W, used in laboratories, to huge screw compressors of about 100 kW, used in heavy industry

To provide students with the necessary knowledge and skills to independently design systems for the production of compressed air, its treatment and supply.

Provide students with the necessary knowledge to develop physical and mathematical models to describe the operation of centrifugal blowers and volumetric compressors

To provide students with an understanding of the physical processes taking place in vacuum and to extend their knowledge of thermodynamics to the field of vacuum

<p>pripravo stisnjenih medijev in vakuumu ter z metodami spremljanja delovanja strojev in naprav, ki sestavljajo te sisteme.</p> <p>Študentom podati specifična znanja, ki so potrebna za izvajanje merilnih metod v industrijskem okolju.</p> <p>Kompetence:</p> <p>S1-PAP: Sposobnost uporabe pridobljenega znanja v praksi.</p> <p>S11-PAP: Sposobnost predstavitve strokovnih problemov in njihovih rešitev v svojem okolju in širše.</p> <p>S14-PAP: Poznavanje važnejših strokovnih izrazov v angleškem jeziku</p> <p>P10-PAP: Sposobnost povezovanja znanj iz več različnih področij (termodinamika, turbinski stroji, elektrotehnika, numerične metode) v novo zaključeno celoto</p>	<p>To familiarize students with a range of state of the art methods for monitoring the processes in the systems for preparation of compressed media and vacuum, and methods for monitoring the operation of machinery and devices that make up this systems</p> <p>To provide the students with the specific knowledge required to implement measurement methods in an industrial environment.</p> <p>Competences:</p> <p>S1-PAP: The ability to use the attained knowledge in the practice.</p> <p>S11-PAP: The ability to present professional problems and the solutions thereof in own environment and wider.</p> <p>S14-PAP: Learning the indispensable technical vocabulary in English language.</p> <p>P10-PAP: Ability to integrate knowledge from several different fields (thermodynamics, turbo machinery, electrical engineering, numerical methods) into a newly completed entity.</p>
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Predvideni študijski rezultati:

<p>Znanja:</p> <p>Poglobljeno strokovno teoretično in praktično znanje s področja komprimiranih medijev in vakuumu, podprto s širšo teoretično in metodološko osnovo, ki posamezniku omogoča samostojni razvoj fizikalno-matematičnih modelov praktičnih termodinamskih pojavov do katerih prihaja ob dovajanja energije tekočinam in modeliranju toka fluidov. Specifična znanja pri tem so:</p> <p>Znanje in razgledanost na področju proizvodnje, priprave in dobave komprimiranega zraka kot energenta s pogledom preko različnih velikostnih razredov.</p> <p>Znanja in veščine, ki posamezniku omogočajo samostojno načrtovanje</p>	<p>Intended learning outcomes:</p> <p>Knowledge:</p> <p>In-depth theoretical and practical expertise in the field of compressed gases and vacuum, backed up with a wide theoretical and methodological basis, enabling individuals to independently develop physical-mathematical models of practical thermodynamic phenomena, which occur during the energy supply to liquids, and the modeling of flows. Specific skills in this area are:</p> <p>Knowledge and insight into the generation, processing and supply of compressed air as an energy source with an overview across different size classes.</p> <p>Knowledge and skills that enable an individual to independently design systems for monitoring processes,</p>
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<p>sistemov za spremljanje procesov, strojev in naprav za manipulacijo komprimiranih medijev</p> <p>Znanja, ki omogočajo poglobljeno razumevanje delovanja širokega nabora različnih kompresorjev in vakumskih črpalk, in s katerimi bo posameznik lahko samostojno pristopil k njihovem načrtovanju, istočasno pa lahko z njimi načrtoval energijsko učinkovite sisteme.</p> <p>Znanja ki omogočajo spremljanja procesov ki potekajo v vakuumu.</p> <p>Praktična znanja na osnovi katerih se bo posameznik z lahkoto vključil v delovno okolje.</p> <p>Spretnosti:</p> <p>S1.1: Izvajanje kompleksnih operativno-strokovnih opravil, ki vključujejo uporabo metodoloških orodij, ki temeljijo na iskanju povezave med eksperimentalnimi rezultati meritev termodinamskih veličin in teoretičnimi osnovami.</p> <p>S1.2: Obvladovanje zahtevnih, kompleksnih delovnih procesov ob samostojni uporabi znanja v novih delovnih situacijah.</p> <p>S1.3: Diagnosticiranje in reševanje problemov v različnih specifičnih delovnih okoljih, povezanih.</p>	<p>machinery and equipment for handling compressed gasses.</p> <p>Knowledge that enables an in-depth understanding of the operation of a wide range of different compressors and vacuum pumps and enables a person to work independently during their designing an energy-efficient system.</p> <p>Knowledge that enables the monitoring of processes that take place in a vacuum.</p> <p>Practical knowledge that allows a person to easily integrate into the working environment.</p> <p>Skills:</p> <p>S1.1: Performing complex operational and professional tasks involving the use of methodological tools based on the search for a correlation between the experimental results of measurements of thermodynamic quantities and theoretical principles.</p> <p>S1.2: Mastering complex, multilayered work processes with the independent application of knowledge in new work situations.</p> <p>S1.3: Diagnosis and problem solving in various specific working environments.</p>
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Metode poučevanja in učenja:

P1: Avditorna predavanja z reševanjem izbranih teoretičnih in praktično uporabnih primerov.

P2: Obravnava snovi po urejeni in vnaprej razloženi sistematiki.

P4: Laboratorijske vaje z namenskimi didaktičnimi pripomočki:

Batni kompresor s senzorjem za tlak za merjenje indikatorskih diagramov v različnih delovnih točkah in meritve dobave v odvisnosti od tlačne razlike

Kompresor s kotalnim batom v merilnem sistemu za merjenje njegovih

Learning and teaching methods:

P1: Auditorial lectures with solving selected field-specific theoretical and applied use cases.

P2: Presenting the content according to the explained system.

P4: Laboratory exercises with special-purpose didactic devices

Piston compressor with integrated pressure sensor for measuring indicator diagrams at different operating points and measuring delivery as a function of pressure difference

Compressor with a rolling piston in a

karakteristik in indikatorskih diagramov v odvisnosti od tlačne razlike

Tlačna posoda s sistemom za menjavo zaslonk, za prikaz časovnega poteka praznjenja posode v odvisnosti od velikosti in oblike zaslonke, in za določanje koeficienta zaslonk

Umirjevalna komora radialnega puhala za demonstracijo delovanja puhala kot vakuumske črpalke

Črpalni sistem za vodo pod vakuumom za prikaz vpliva absolutnega tlaka na delovanje radialnih črpal

Membranska črpalka v merilnem sistemu za prikaz vpliva mrtvega volumna na delovanje membranske črpalke za kapljevine kot vakuumske črpalke.

Lamelna vakuumska črpalka z vakuumsko posodo za prikaz merjenja karakteristik vakuumske črpalke in izračun deoseganja minimalnega tlaka v posodi.

Vakuumski sistem z več vakuumskimi puhali, za prikaz razlike med vzporedno in zaporedno vezavo vakuumskih črpal

Vakuumski top za prikaz več termodinamskih in mehanskih zakonov; (ekspanzija plinov, delovanje šobe, merjenje hitrosti izstrelka)

Vakuumski sistem za sesanju polimernih filamentov z zvočno hitrostjo

P5: Uporaba študijskega gradiva v obliki:

Skripta s predavanj v obliki interaktivnih prosojnic.

Predloge za pripravo na vsako vajo posebej

Navajanje aktualnih povezav na javno dostopna predavanja iz tematik komprimiranih medijev in vakuum, ki so objavljena in javno dostopna na internetu.

measuring system for measuring its characteristics and indicator diagrams depending on the pressure difference

Pressure vessel with interchangeable aperture, to show the timeline of pressure drop, depending on the aperture size and shape, and to determine the aperture coefficient

Radial blower with plenum chamber for demonstrating the operation of the blower as a vacuum pump

Water pumping system under vacuum to show the effect of absolute pressure on the operation of radial pumps

A diaphragm pump in a measuring system to show the effect of dead volume on the operation of a diaphragm pump as a vacuum pump.

Vane type vacuum pump and vacuum chamber for measuring the characteristics of the vacuum pumps and for comparing theoretical predictions for discharge time of vacuum tank with measurements.

Vacuum system with multiple vacuum blowers, to show the difference between parallel and sequential connection of vacuum pumps

Vacuum gun for displaying several thermodynamic and mechanical laws; (gas expansion, nozzle operation, projectile velocity measurement)

Vacuum system for suction of polymer filaments with the speed of sound.

P5: Application of study material

Script with lectures in the form of interactive slides.

Templates for preparation for each laboratory exercise individually

Providing links to publicly available lectures on topics of compressed media and vacuum, which are published and publicly available on the Internet.

P7: Literature study and discussion.

P7: Študij literature in razprava. P8: Izdelava in predstavitev aplikativnih seminarskih nalog. P10: Uporaba anket v realnem času. P14: Virtualni eksperimenti. P15: Uporaba video vsebin kot priprava na predavanja in vaje.	P8: Making and presenting applied seminar exercises. P10: Application of questionnaires in real time. P14: Virtual experiments. P15: Application of videos for preparations to the lectures and exercises.
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Načini ocenjevanja:	Delež/ Weight	Assessment:
- Teoretične vsebine	40,00 %	- Theoretical content
- Samostojno delo na vajah	20,00 %	- Independent work at laboratory exercises
- Poročanje rezultatov meritev iz vaj	20,00 %	- Reporting on experiments
- Seminar z vsebinami iz vaj	20,00 %	- Seminar with content from laboratory exercises

Reference nosilca/Lecturer's references:

Jurij Prezelj:

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