RZESZÓW UNIVERSITY OF TECHNOLOGY

TECHNOLOGY TRANSFER CENTRE
RZESZÓW UNIVERSITY OF TECHNOLOGY

RESEARCH OFFER

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POLITECHNICZNA SIEĆ
VIA CARPATIA

Financed by the Ministry of Science and Higher Education within the framework of the commissioned task entitled
"VIA CARPATIA Universities of Technology Network named after the President of the Republic of Poland Lech Kaczyński"

Minister of Science and Higher Education
Republic of Poland

Ministry of Science and Higher Education
Republic of Poland

Research offer of the Rzeszów University of Technology

Rzeszów, 2025

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Introduction

We would like to present to you the research offer of the Rzeszów University of Technology, which was produced within the framework of the commissioned task entitled "VIA CARPATIA Universities of Technology Network named after the President of the Republic of Poland Lech Kaczyński". The aim of the project is to develop in the following areas: education, science and commercialisation so that, thanks to the merge of their potentials, the universities associated in the Network become competitive on the global market and significantly improve the quality of life of the society, with particular emphasis on Eastern Poland.

The research offer contained in this study presents the research potential including and indicates the possibilities of the Ignacy Łukasiewicz Rzeszów University of Technology in the scope of conducted research.

The University has an extensive group of specialists with high substantive competences and many years of experience, deepened through internships and placements both in Poland and abroad. The University's ultramodern research infrastructure (laboratories, workshops) is constantly being upgraded to best meet scientific challenges and the needs of industry.

We hope that this offer will allow us to develop existing and establish new cooperation with partners from the socio-economic environment, jointly solve construction and operational problems, jointly seek new research challenges, and jointly apply for research projects.

We invite you to enter into cooperation with us.

Poznańska 2, 35-084 Rzeszów
e-mail: rb@prz.edu.pl
wbisia.prz.edu.pl

FACULTY OF
CIVIL AND ENVIRONMENTAL ENGINEERING, AND ARCHITECTURE
RZESZÓW UNIVERSITY OF TECHNOLOGY

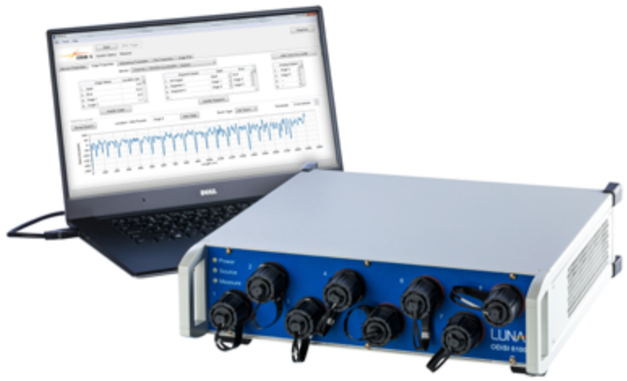
Department of Roads and Bridges

Methods and techniques:

- the instrument uses a wavelength sweep interferometric (SWI) method to measure Rayleigh scattering

Apparatus available:

- Luna OBR 4600
- Luna ODiSi 6100
- S179 Fusion Splicer
- Fitel S326 High Precision Cleaver



Optical reflectometer set

The LUNA OBR is an ultra-high-resolution reflectometer with the capability for continuous fiber-optic sensing. It includes software for strain and temperature measurements, enabling a standard telecommunication fiber to function as a high-resolution sensor for both parameters. The OBR uses Swept Wavelength Interferometry (SWI) to measure Rayleigh scattering. External stimuli, such as strain or temperature changes, cause temporary spectral shifts, which are then evaluated by the OBR system. The SWI method enables reliable and practical measurement of temperature and strain along up to 70 meters of fiber with a resolution of 1 µm or 0.1°C. The LUNA ODiSi is an OFDR-type reflectometer with a spatial resolution of 0.6 mm, allowing for the construction of a continuous sensing system (Optical Distributed Sensor Interrogator) using standard telecom fiber. It is a system designed to measure strain and temperature, with a measurement range of 20 meters, spatial resolution of 1.25 mm, and acquisition rate up to 250 Hz.

ul. Poznańska 2, 35-084 Rzeszów
phone: +48 17 865 15 96, 17 865 10 15
e-mail: bc@prz.edu.pl
kdim.prz.edu.pl

Department Chair:
Tomasz Siwowski, BEng, PhD, DSc, Prof. Tit.
phone: +48 phone: +48 17 865 10 19
e-mail: siwowski@prz.edu.pl

Department of Roads and Bridges
Faculty's Structures Testing Laboratory

Tests of bridge structures under a static and dynamic test load

The laboratory conducts accredited testing of bridges under test loads. The tests cover road bridges, railway bridges and footbridges. Structures are tested under static and dynamic loads. During static load tests, settlement of supports, displacements (deflections) of spans and stresses in structural components are recorded. During dynamic load tests, displacements and vibration accelerations are predominantly registered. The dynamic coefficient and the damping coefficient are determined. During tests on railway bridges, maximum vibration accelerations are checked, and during tests on footbridges, vibration comfort is verified. Only calibrated measuring equipment is used. Testing of bridges under test loads is research covered by a management system in accordance with PN-EN ISO/IEC 17025:2018-02 and accredited by the Polish Centre for Accreditation.

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Methods and techniques:

- static-strength loads
- fatigue loads
- displacement measurements using clock and inductive methods
- displacement measurements using geodetic methods
- strain measurements using strain gauges
- rotation angle measurements using inclinometers
- vibration acceleration measurements using accelerometers

Apparatus available:

- set of analog, digital, and inductive instruments for displacement measurements
- set of precision levels for measurements of support settlements and bridge displacements
- precision automatic theodolite for displacement measurements
- set for strain measurements
- set of accelerometers for acceleration measurements

Standard compliance tests:

- PN-EN ISO/IEC 17025:2018-02
- own procedures
- Individual research projects

ul. Poznańska 2, 35-084 Rzeszów
phone: +48 17 865 12 14
e-mail: wlbk@prz.edu.pl
wlbk.prz.edu.pl

Lab Coordinator:
Lucjan Janas, BEng, PhD
phone: +48 17 865 14 61
e-mail: ljanas@prz.edu.pl

Faculty's Structures Testing Laboratory

Methods and techniques:

- tensile test at room temperature
- bending test

Apparatus available:

- Instron strength testing machine with a load range of 1200 kN
- video extensometer with a measurement range of 300 mm

Standard compliance tests:

- PN-EN ISO/IEC 17025:2018-02
- PN-EN ISO 6892-1:2016-09, Met. B
- PN-EN ISO 6892-1:2020-05, Met. B
- PN-EN ISO 7438:2006
- PN-EN ISO 7438:2021-04
- PN-EN ISO 15630-1:2011 p.5
- PN-EN ISO 15630-1:2019-04 p.5
- PN-EN ISO 15630-1:2011 p.6
- PN-EN ISO 15630-1:2019-04 p.6
- PN-EN ISO 15630-2:2011 p.5
- PN-EN ISO 15630-2:2019-04 p.5
- PN-EN ISO 15630-2:2011 p.6
- PN-EN ISO 15630-2:2019-04 p.6
- PN-EN ISO 15630-3:2011 p.5
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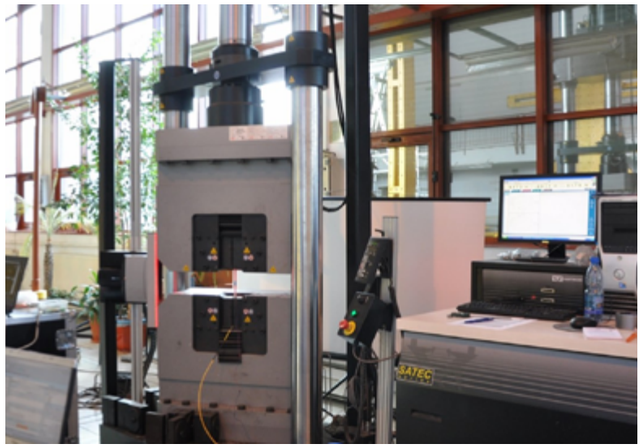

Strength Testing of Materials

The Faculty's Structures Testing Laboratory conducts accredited tests on the mechanical properties of metals and susceptibility to plastic deformation. Determined parameters include, among others:

- real yield strength (Re)
- apparent yield strength (Rp),
- tensile strength (Rm)
- percentage elongation after fracture (A),
- total percentage elongation at maximum force (Agt),
- percentage reduction in area (Z) and maximum force (Fm)

The tests cover metals, bars, rolled products, and wire for concrete reinforcement, welded reinforcement mesh, and prestressing steel. The force range extends up to 600 kN. Metal tests adhere to a management system compliant with the PN-EN ISO/IEC 17025:2018-02 standard and are accredited by the Polish Centre for Accreditation. Beyond accreditation, the laboratory conducts tests on other materials, such as composites and wood.

PCA
Polskie Centrum Akredytacji
BADANIA
AB 1413

ul. Poznańska 2, 35-084 Rzeszów
phone: +48 17 865 12 14
e-mail: wlbk@prz.edu.pl
wlbk.prz.edu.pl

Lab Coordinator:
Lucjan Janas, BEng, PhD
phone: +48 17 865 14 61
e-mail: ljanas@prz.edu.pl

Faculty's Structures Testing Laboratory

Structural Strength Testing

The laboratory conducts structural strength tests on elements, structures, connections, and finished building products under both static and dynamic (fatigue) loading. For static strength tests, a universal Schenck strength testing machine is primarily used, along with a force floor measuring 9.6 m x 21.6 m and an adjustable testing stand. The maximum span of the tested element is 21.6 m, with a maximum load of 2 x 630 kN. The testing station is constructed based on specific requirements, utilizing elements available in the laboratory. During tests, in addition to recording forces, measurements include, for example:

- displacements and deformations of structures using clock or inductive sensors,
- displacements using geodetic methods,
- strain/stress using strain gauge methods,
- rotation angles,
- vibration accelerations.

Fatigue tests may involve elements of structures, finished building products, connections, or vibration isolation. Variable loads are applied in a frequency range from 0.2 to 20 Hz, with a force range up to 630 kN.

Methods and techniques:

- static strength loads
- fatigue loads
- displacement measurements using clock and inductive methods
- displacement measurements using geodetic methods
- strain measurements using strain gauges
- rotation angle measurements using inclinometers
- vibration acceleration measurements using accelerometers

Apparatus available:

- computer-controlled hydraulic actuators with a range of 2 x 630 kN
- set of analog and digital instruments for displacement measurements
- set of precision levels and theodolite
- strain measurement system
- set for measuring rotation angles
- set for acceleration measurements

Standard compliance tests:

- PN-B-06281:1973
- PB-05 (proprietary procedure)
- Individual research projects

ul. Poznańska 2, 35-084 Rzeszów
phone: +48 17 865 12 14
e-mail: wlbk@prz.edu.pl
wlbk.prz.edu.pl

Lab Coordinator:
Lucjan Janas, BEng, PhD
phone: +48 17 865 14 61
e-mail: ljanas@prz.edu.pl

Faculty's Structures Testing Laboratory

Methods and techniques:

- in-situ method
- computational method

Apparatus available:

- dual-channel sound meters and analyzers
- acoustic calibrator
- multidirectional sound source with amplifier
- reference tap
- thermohygrometer

Standard compliance tests:

- PN-EN ISO 140-4:2000
- PN-EN ISO 16283-1:2014-05
- PN-EN ISO 140-5:1999
- PN-EN ISO 16283-3:2016-04
- PN-EN ISO 140-7:2000
- PN-EN ISO 16283-2:2021-09
- PN-EN ISO 717-1:2021-06
- PN-EN ISO 717-2:2021-06
- PN-EN ISO 3382-2:2010
- PN-B-02151-4:2015-06

Acoustic studies – evaluation of sound insulation of building partitions and reverberation time

The laboratory conducts studies on the acoustic insulation of partitions in residential and public buildings. The research may include both internal partitions between rooms and external partitions (façades). The primary focus is on determining the insulation index for airborne sounds and, for ceilings, the acoustic insulation index for airborne and impact sounds. The studies employ dual-channel sound meters and analyzers, a multidirectional sound source with an amplifier, and a specialized reference tap. The laboratory also determines the reverberation time in rooms, which is crucial for assessing speech intelligibility.

ul. Poznańska 2, 35-084 Rzeszów
phone: +48 17 865 12 14
e-mail: wlbk@prz.edu.pl
wlbk.prz.edu.pl

Lab Coordinator:
Lucjan Janas, BEng, PhD
phone: +48 17 865 14 61
e-mail: ljanas@prz.edu.pl

Faculty's Structures Testing Laboratory

Acoustic studies – traffic noise

The laboratory conducts research on noise originating from roads, railways, and tram lines. The equivalent sound level A and the exposure sound level A (direct method) are determined, as well as the equivalent sound level A for the reference time T expressed by the indicators L_{Aeq} D and $L_{Aeq\,N}$ (computational method). Only calibrated measurement equipment is used. The measurement range is 25-129 dB. Studies on traffic noise are covered by a management system compliant with the PN-EN ISO/IEC 17025:2018-02 standard and accredited by the Polish Centre for Accreditation.

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Methods and techniques:

- direct method
- computational method

Apparatus available:

- dual-channel sound meters and analyzers
- acoustic calibrator
- weather station

Standard compliance tests:

- PN-EN ISO/IEC 17025:2018-02
- Attachment No. 3 to the Regulation of the Minister of the Environment dated June 16, 2011 (Official Gazette 2011, No. 140, item 824), excluding point H (Official Gazette 2011, No. 288, item 1697)

ul. Poznańska 2, 35-084 Rzeszów
phone: +48 17 865 12 14
e-mail: wlbk@prz.edu.pl
wlbk.prz.edu.pl

Lab Coordinator:
Lucjan Janas, BEng, PhD
phone: +48 17 865 14 61
e-mail: ljanas@prz.edu.pl

Faculty's Structures Testing Laboratory

Methods and techniques:

- laboratory method
- computational method

Apparatus available:

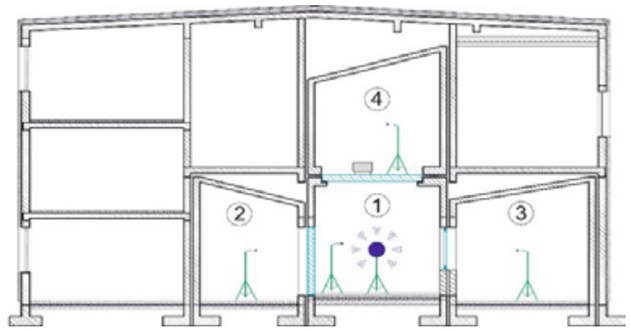
- dual-channel sound meters and analyzers
- acoustic calibrator
- multidirectional sound source with amplifier
- calibrated tapping device
- thermohygrometer

Standard compliance tests:

- PN-EN ISO 10140-1:2021-10
- PN-EN ISO 10140-2:2021-10
- PN-EN ISO 10140-3:2021-10
- PN-EN ISO 10140-4:2021-10
- PN-EN ISO 10140-5:2021-10
- PN-EN ISO 140-6:1999
- PN-EN ISO 717-1:2021-06
- PN-EN ISO 717-2:2021-06
- PN-EN 1793-2:2018-08
- PN-EN 1793-3:2001
- PN-EN ISO 354:2005 excluding point 7.3
- PN-EN ISO 11654:1999
- PN-EN 1793-1:2017-05
- PN-EN 1793-3:2001

Acoustic research – acoustic insulation testing of materials and building products

The laboratory conducts research on the acoustic insulation of materials and building products. This includes determining indicators for the assessment of insulation from airborne sounds and acoustic insulation from impact sounds. The studies take place in a specialized laboratory for building acoustics equipped with 4 anechoic chambers – see the diagram below:



1 – transmitting-receiving chamber, 2, 3 – receiving chambers, 4 – transmitting chamber

In chambers 1-2, the insulation from airborne sounds is determined, e.g., for construction ceramics or screens; in chambers 1-3, the insulation of windows or doors; and in chambers 1-4, the insulation of ceilings. All chambers are air-conditioned, have appropriate acoustic parameters, and meet normative requirements. The laboratory also has an anechoic chamber for determining the sound absorption coefficient. The frequency range of applied mid-band frequencies: 100 – 5000 Hz.

ul. Poznańska 2, 35-084 Rzeszów
phone: +48 17 865 12 14
e-mail: wlbk@prz.edu.pl
wlbk.prz.edu.pl

Lab Coordinator:
Lucjan Janas, BEng, PhD
phone: +48 17 865 14 61
e-mail: ljanas@prz.edu.pl

Faculty's Structures Testing Laboratory

Methods and techniques:

- in-situ method
- computational method

Apparatus available:

- 2-channel sound meters and analyzers
- 6-channel system for measuring acoustic pressure
- acoustic calibrator
- multidirectional sound source with amplifier
- weather station

Standard compliance tests:

- PN-ISO 10847:2002
- PN-EN 1793-1_2017-05
- PN-EN 1793-2_2018-08
- PN-EN 1793-3_2001
- PN-EN 1793-4_2015-05

Acoustic studies – evaluation of acoustic barrier effectiveness

The laboratory conducts studies on the effectiveness of road noise barriers. Acoustic properties are determined during field and laboratory research. During field studies, the level of acoustic pressure is recorded at a minimum of two measurement points simultaneously in 1/3-octave bands. The frequency range of the analyzed frequencies is 50 – 5000 Hz. The effectiveness of the barriers is determined by computational method. The laboratory also conducts measurements of sound diffraction at the installation site using a 6-channel measurement system. In addition to in-situ studies, the laboratory conducts research on the acoustic insulation of barriers under laboratory conditions and studies the sound absorption coefficient.

ul. Poznańska 2, 35-084 Rzeszów
phone: +48 17 865 1214
e-mail: wlbk@prz.edu.pl
wlbk.prz.edu.pl

Lab Coordinator:
Lucjan Janas, BEng, PhD
phone: +48 17 865 14 61
e-mail: ljanas@prz.edu.pl

Faculty's Structures Testing Laboratory

Methods and techniques:

- for bridge objects – direct method
- for buildings – indirect method

Apparatus available:

- measurement amplifiers based on LAN technology
- handheld vibration calibrator (1000 Hz)
- multifrequency vibration calibrator
- set of accelerometers

Standard compliance tests:

- PN-EN ISO/IEC 17025:2018-02
- PB-03 (proprietary procedure)
- PN-B-02170:1985
- PN-B-02170:2016-12
- PN-B-02171:1988

Vibration tests for bridges and buildings

The laboratory performs accredited vibration testing of bridges and buildings. The tests use a set-up consisting of measuring amplifiers and accelerometers that enable vibrations of structures to be measured at up to a dozen points simultaneously. A range of single-axis and triaxial accelerometers is used, from those with high sensitivity (for seismic measurements) to those capable of measuring impulse vibrations, including vibrations from explosions. The range of measured amplitudes is between 0.001 m/s2 and 20000 g, the frequency range between 0.1 Hz and 6 kHz. For tests on bridges, free vibration frequencies and acceleration amplitudes are determined. A safety criterion is checked and vibration comfort is assessed. For buildings, the effect of vibrations on buildings and the effect of vibrations on people in buildings is assessed. The maximum value of vibration acceleration in the 1/3 octave bands in the frequency range of 0.5 - 100 Hz or 0.5 - 80 Hz is determined. The range of measured amplitudes in these studies is ± 4.9 m/s2 pk. Vibration testing of bridges and buildings is covered by a management system in accordance with PN-EN ISO/IEC 17025:2018-02 and accredited by the Polish Centre for Accreditation.

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Polskie Centrum Akredytacji
BADANIA
AB 1413

ul. Poznańska 2, 35-084 Rzeszów
phone: +48 17 865 12 14
e-mail: wlbk@prz.edu.pl
wlbk.prz.edu.pl

Lab Coordinator:
Lucjan Janas, BEng, PhD
phone: +48 17 865 14 61
e-mail: ljanas@prz.edu.pl

Department of Geodesy and Geotechnics

We conduct the following tests:

- examination and assessment of the technical condition of structures,
- periodical measurements of vertical and horizontal displacements and deformations of structures and engineering objects,
- control measurements of the geometry of tracks, cranes, bridges, viaducts and tower structures as well as structural elements of buildings and engineering structures and machinery and equipment,
- testing of bridges under static test loads,
- trial loads on piles and measurements of deformations of structures and the subsoil,
- earth mass and volume measurements
- static and kinematic GNSS measurements in solving various types of engineering problems,
- inventory measurements of cubic objects and 3D modelling for architectural purposes,
- accuracy assessment of measuring instruments according to field test procedures for surveying and measuring instruments as specified in PN-ISO 17123,
- field and laboratory studies of the ground medium and preparation of geotechnical and geological-engineering documentation,
- studies of geotechnical parameters describing physical properties of subsoil as well as advanced studies of strength and deformation properties of soil medium,
- design of foundations of structures and geotechnical constructions, including on weak soils, in complex geological-engineering conditions,
- design studies on stabilisation and elimination of consequences of landslides, including on communication routes and in urbanised areas,
- consultancy, advisory and verification of construction and execution designs for complex industrial and public utility buildings,
- providing scientific and technical opinions and expert opinions and other studies in the field of: geodesy, geotechnics, research and evaluation of stability and durability of engineering structures.

Methods and techniques:

- DJI Phantom 4 RTK drone
- GPS/GNSS receivers
- FARO laser scanners
- total stations
- tachymeters
- GDS ground testing equipment

ul. Poznańska 2, 35-084 Rzeszów
phone: +48 17 865 13 06
e-mail: kg@prz.edu.pl
kgig.prz.edu.pl

Department Chair:
Izabela Skrzypczak, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 10 10
e-mail: izas@prz.edu.pl

Department of Geodesy and Geotechnics

Methods and techniques:

- ability to perform triaxial tests on soils with different load and deformation characteristics
- ability to test samples with a diameter of 38 mm and 50 mm
- ability to test the coefficient of soil filtration

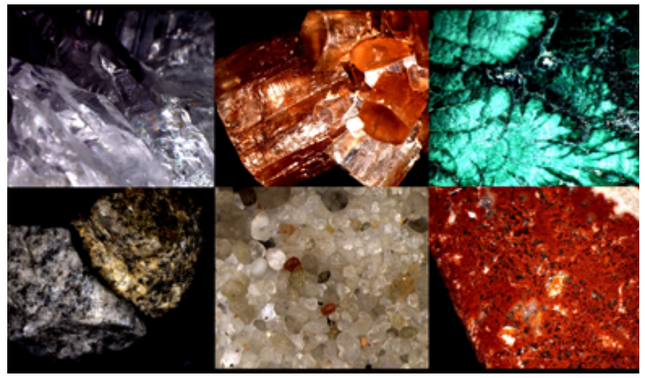
GDS triaxial compression testing system

The permeability testing system allows independent control of the pressure in the chamber, and at both ends of the specimen, to replicate in - situ conditions (or other required stress state) and a constant hydraulic gradient or flow. Triaxial testing is an excellent way to measure the mechanical parameters of soils, rocks and aggregates, and the results are used to address a wide range of geotechnical engineering issues. The testing is controlled by GDSLAB software with the optional Permeability Testing Module.

ul. Poznańska 2, 35-084 Rzeszów
phone: +48 17 865 13 06
e-mail: kg@prz.edu.pl
kgig.prz.edu.pl

Department Chair:
Izabela Skrzypczak, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 10 10
e-mail: izas@prz.edu.pl

Department of Environmental and Chemistry Engineering: Geological Laboratory



Petrographic tests

Mineralogical and petrographic examination of rocks, building materials, mineral raw materials in the basic as well as in the aspect of detailed analysis, e.g:

- mineral composition of rocks, bottom sediments, construction materials,
- properties of rocks used in building and road construction,
- granulation, sorting and dressing of crumb material,
- identification of reactive silica minerals in aggregates, e.g. opal, cristobalite, tridymite, chalcedony and quartz,
- evaluation of secondary and mineralisation processes,
- study of structural and textural characteristics of rocks, construction aggregates,
- analysis of the effects of environmental factors on mineral aggregates, rocks.

Methods and techniques:

- testing the basic properties of aggregates
  Petrographic description
- Recommended test method RILEM: AAR-1.1 Detection of potential alkaline reactivity Part 1: Petrographic test method
- GDDKiA test procedure PB/3/18, appendix 3

Apparatus available:

- Panthera TEC POL polarising microscope
- Olympus SZX7 stereo microscope

Standard compliance tests:

- E.g. PN – EN 932-3: 2022-12
- E.g. ASTM C295

ul. Poznańska 2, 35-959 Rzeszów
phone: +48 17 865 12 51
e-mail: apekala@prz.edu.pl
ziics.prz.edu.pl

Department Chair:
Renata Gruca-Rokosz, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 13 61
e-mail: renatagr@prz.edu.pl

Department of Environmental and Chemistry Engineering: Laboratory for New Technologies in Water Research and Wastewater Treatment

Methods and techniques:

- 8700 LDIR Chemical Imaging System
- proprietary method for chemical sample preparation for microscopic analysis of microplastics

Apparatus available:

- Agilent 8700 LDIR

Microplastic testing

Quantitative and qualitative determination of polymeric microparticles. Extraction of microplastics from diverse environmental samples:

- water
- wastewater
- bottom sediments
- soil

Graphical presentation of results

al. Powstańców Warszawy 6, 35-959 Rzeszów
phone: +48 17 865 19 64
e-mail: w.strojny@prz.edu.pl
ziics.prz.edu.pl

Department Chair:
Renata Gruca-Rokosz, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 13 61
e-mail: renatagr@prz.edu.pl

Department of Environmental and Chemistry Engineering: Laboratory for New Technologies in Water Research and Wastewater Treatment

Chromatographic analysis - ion chromatography

An ion chromatograph with a conductometric detector is used for this type of analysis. This instrument has a stable and sensitive chromatographic system. Analyses of liquid samples such as drinking water, surface water, groundwater, industrial and municipal wastewater, among others, are performed on it. The typical analytical range includes simultaneous measurement of:

- cations: Li^+, Na^+, NH_4^+, K^+, Mg^{2+}, Ca^{2+}
- anions: F^-, Cl^-, NO_2^-, NO_3^-, Br^-, SO_4^{2-}, PO_4^{3-}.

Methods and techniques:

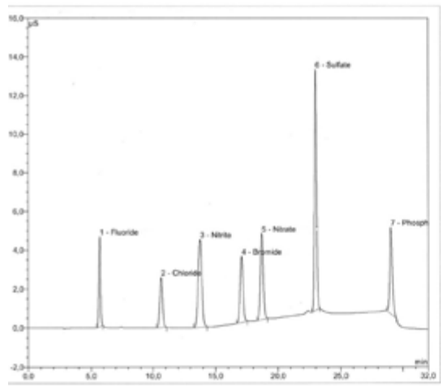
- the ions under test are separated on a separation column by liquid chromatography and then measured with a conductometric detector.

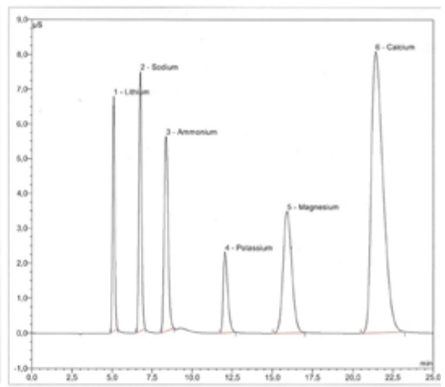
Apparatus available:

- DIONEX ICS5000 ion chromatograph

Standard compliance tests:

- PN-EN ISO 14911
- PN-EN ISO 10304





al. Powstańców Warszawy 6, 35-959 Rzeszów
phone: +48 17 865 19 64
e-mail: mmiasik@prz.edu.pl
ziics.prz.edu.pl

Department Chair:
Renata Gruca-Rokosz, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 13 61
e-mail: renatagr@prz.edu.pl

Department of Environmental and Chemistry Engineering: Laboratory for New Technologies in Water Research and Wastewater Treatment

Methods and techniques:

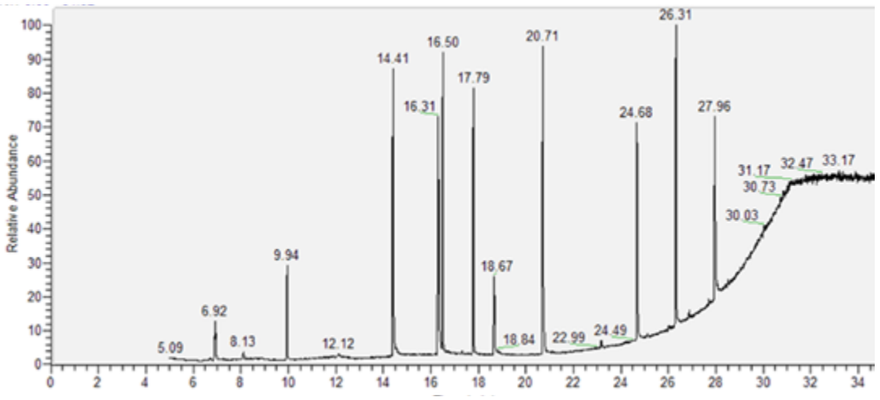
- quantitative analysis of organic compounds by calibration with internal standard,
- gas analysis by external calibration,
- preparation techniques for sample analysis: liquid samples: liquid-liquid extraction, SPE extraction, solid samples: microwave extraction.

Apparatus available:

- dual channel gas chromatograph (GC - 2010 PLUS) with FID and BID detectors
- Gas Chromatograph combined with mass spectrometer (with ion trap Thermo Electron Finnigan)

Chromatographic analysis - gas chromatography

- qualitative and quantitative analysis of organic compounds
- testing the level of contamination of environmental samples (water, soil, air, wastewater, leachate) and other matrices
- determination of gases, e.g. N_2, O_2, CO, CO_2, CH_4 and others
- testing the mechanism of decomposition of organic substances
- testing of emissions of gases and organic substances.



al. Powstańców Warszawy 6, 35-959 Rzeszów
phone: +48 17 743 24 07
e-mail: s.ksiazek@prz.edu.pl, mkida@prz.edu.pl
ziics.prz.edu.pl

Department Chair:
Renata Gruca-Rokosz, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 13 61
e-mail: renatagr@prz.edu.pl

Department of Environmental and Chemistry Engineering: Laboratory for New Technologies in Water Research and Wastewater Treatment

Carbon and nitrogen analysis

Determination in water samples:

- total carbon (TC),
- inorganic carbon (IC),
- total organic carbon (TOC),
- total nitrogen (TN).

The organic carbon content of water and wastewater is an important indicator of environmental pollution. Unlike the results of biochemical oxygen demand (BOD) and chemical oxygen demand (COD) measurements, which provide information on the content of organic substances susceptible to decomposition under specific conditions, the measurement of total organic carbon gives complete information on the content of all organic substances, i.e. all pollutants containing organic carbon.

Methods and techniques:

- determination of TC, IC, TOC: analysis of spectra after oxidation by catalysed combustion at 680°C,
- TN determination: using chemiluminescence after oxidation by combustion.

Apparatus available:

- Shimadzu TOC-VCPN apparatus

Standard compliance tests:

- PN-EN 1484

al. Powstańców Warszawy 6, 35-959 Rzeszów
phone: +48 17 865 1788
e-mail: ewbuj@prz.edu.pl
ziics.prz.edu.pl

Department Chair:
Renata Gruca-Rokosz, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 13 61
e-mail: renatagr@prz.edu.pl

Methods and techniques:

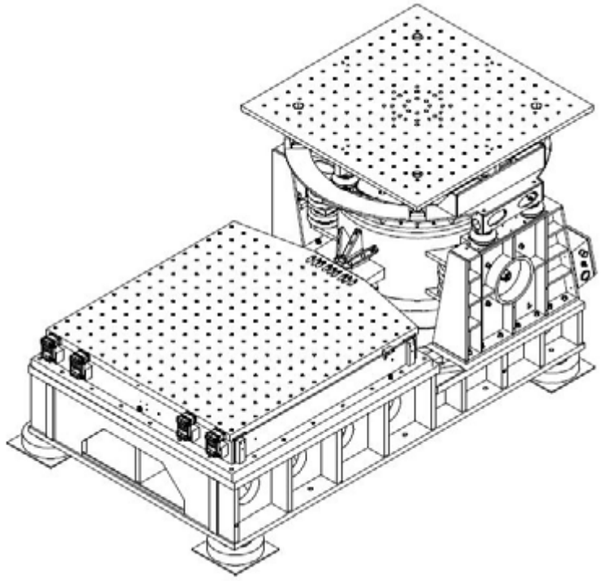
- forcing and measurement of mechanical vibrations

Apparatus available:

- Siemens SCM202V analyser
- accelerometers
- tensometers
- vibrometers

Standard compliance tests:

- ECSS-E-ST-10-03C
- EN 61373
- ICC-ES AC156



Vibration test system

The vibration test system makes it possible to assess the resistance of components (mechanical, electrical, electronic) to dynamic loads (vibrations, shocks). The system consists of an electrodynamic inductor (TIRA TV 59389/AIT-440), a sliding table (TGT MO 60 XXL) and a control system providing tuned sine, noise or shock tests with the following parameters:

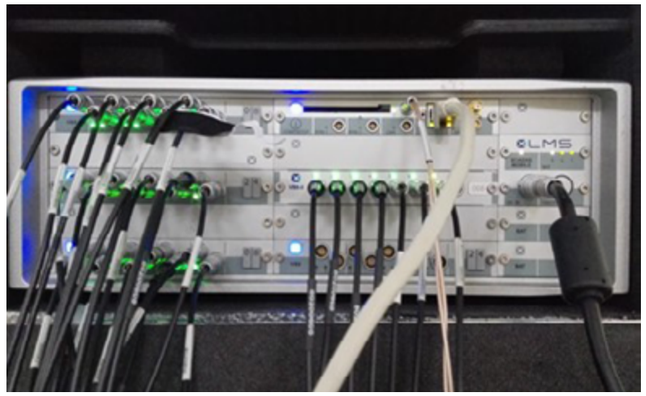
- Maximum force: sinus/noise 89 kN, impact 178 kN;
- Frequency band: 5 Hz- 2000 Hz;
- Maximum displacement: 50.8 mm;
- maximum speed: sine/noise 2.0 m/s, stroke 3.0 m/s;
- maximum acceleration: vertical sinus/noise 100g, impact 200g; horizontal sinus/noise 28g, impact 56g;
- maximum mass of test objects: forced vertically 620 kg. (max. 10 g); forced horizontally 620 kg. (max. 10 g)

Vertically, tests are carried out on objects attached directly to the 440 mm diameter inductor armature or to a head with a work surface measuring 1500 by 1500 mm. Horizontally, tests are carried out using a sliding table with the possibility of attaching objects to a work surface of 1500 by 1500 mm. The hole spacing for fixing with M10x25 screws is 100 mm.

ul. Poznańska 2, 35-084 Rzeszów,
phone: +48 17 865 15 35
e-mail: kmk@prz.edu.pl
kmk.prz.edu.pl

Department Chair:
Bartosz Miller, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 16 23
e-mail: bartosz.miller@prz.edu.pl

Department of Structural Mechanics



Assessment of the harmfulness of vibrations transmitted from the ground to buildings

The assessment of the harmfulness of vibrations transmitted by the ground to buildings is carried out in accordance with the provisions of PN-B--02170_2016-12P. The basis for the assessment are the maximum values of accelerations describing vibrations transmitted to buildings, regardless of their propagation in the ground from the vibration source to the building. The requirements of this standard apply:

- in diagnostics for assessing the impact of vibrations from either operating or planned vibration sources on existing buildings and equipment located in buildings,
- in the design of buildings that will be in the area affected by vibrations from either operational or projected sources of vibration.

Assessment of the impact of vibrations on people in buildings

The assessment of the harmfulness of vibrations transmitted by the ground to buildings is carried out in accordance with the provisions of PN-B--02170_2016-12P. The basis for the assessment are the maximum values of accelerations describing vibrations transmitted to buildings, regardless of their propagation in the ground from the vibration source to the building. The requirements of this standard apply:

- in diagnostics for assessing the vibration comfort of people living in existing buildings and passively receiving vibrations from either operating or designed vibration sources,
- during the design of buildings that will be affected by vibrations from either operating or designed vibration sources and where occupants will be exposed to these vibrations.

Methods and techniques:

- recording of vibration acceleration signals
- analysis of recorded signals in 1/3-octave bands

Apparatus available:

- recorder with signal analysis software
- set of uniaxial accelerometers, including seismic accelerometers and triaxial accelerometers

Standard compliance tests:

- PN-B-02170_2016-12
- PN-B-02171_2017-06

ul. Poznańska 2, 35-084 Rzeszów
phone: +48 17 865 15 35
e-mail: kmk@prz.edu.pl
kmk.prz.edu.pl

Department Chair:
Bartosz Miller, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 16 23
e-mail: bartosz.miller@prz.edu.pl

Department of Structural Mechanics

Methods and techniques:

- Digital Image Correlation (DIC)

Apparatus available:

- PHANTOM V341 cameras 2 pcs. CMOS 35mm
- 4MPx resolution, 2560x1600
- frame rate of 800 fps at full resolution /s or 130,000 fps at reduced resolution
- Phantom v640 2 cameras, CMOS
- 4MPx resolution, 2560x1600
- frame rate of 1,500 frames at full resolution /s or 300,000 frames /s at reduced resolution

Non-contact displacement measurement
Non-contact strain measurement

Dantec Dynamics GmbH's Q450 system enables non-contact measurement of displacements and deformations at all points in the observed area, both in the plane and in three-dimensional space. On the basis of the observation of changes in the distribution of the strain field occurring in time as a result of a given load, it is possible to determine stress concentration zones in the component or structure under investigation. Data obtained from measurements by digital image correlation can be used to verify and validate numerical models. Due to the use of high-speed cameras, it is possible to film, play back in slow motion and analyse fast-moving processes (so-called slow motion) and vibrations. By recording phenomena with high resolution, the system can be used in ballistic research, impact testing, fracture mechanics, etc. The Q450 system can also be used to control the position of the specimen during measurements by other methods (e.g. to control the clamping of the specimen in the jaws of a testing machine). Carrying out DIC measurements involves, in many cases, applying a random pattern to the object/sample in the form of black spots on a white background. The accuracy of the measurement depends on a number of factors, including the size of the observed area, the applied pattern and the data calculated in the calibration process, and is determined for each individual task. With the equipment at hand, it is possible to perform displacement measurements with an accuracy of a few µm.

ul. Poznańska 2, 35-084 Rzeszów,
phone: +48 17 865 15 35
e-mail: kmk@prz.edu.pl
kmk.prz.edu.pl

Department Chair:
Bartosz Miller, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 16 23
e-mail: bartosz.miller@prz.edu.pl

Department of Structural Mechanics

Laser scanning of geometries
Laser scanning of engineering objects

We perform laser scanning of 3D geometry of machine and equipment components for reverse engineering purposes. Based on the obtained point cloud, models can be created for reverse engineering purposes. We also perform laser scanning of existing civil engineering objects. The resulting point cloud can be used to inventory these objects and create their digital models. The Surphaser line of scanners is known for its unparalleled scanning accuracy and quality. They enable the creation of both short- and medium-range models, making them suitable for use in reverse engineering tasks, dimensional control, BIM technology, historic preservation, architecture and forensics.

- Sub-millimetre accuracy with a scanning speed of up to 1.2 million points per second and an operating range of up to 70 m.
- Designed for industrial environments and outdoor applications.
- The software allows the export of datasets in PolyWorks®, RapidForm®, Geomagic®, Cyclone®, RealWorks® and other point cloud processing applications.
- Portable and easy to transport - the kit fits in a dedicated case for safe transportation.

The result of measurements with the Surphaser 25HSX scanner is a point cloud without RGB colours. It requires assembly in separate software. As part of the service, we provide individual scans as well as scans combined into one set. Based on the point cloud, we can also develop a surface model using polygonal meshes. We use Geomagic Studio to assemble the scans.

Methods and techniques:

- assembling individual scans into a single point cloud
- creation of 3D surface models consisting of polygonal meshes

Apparatus available:

- laser scanner
- 25HSX Surphaser

software:

- SurphaserExpress,
- Geomagic Studio

ul. Poznańska 2, 35-084 Rzeszów
phone: +48 17 865 15 35
e-mail: kmk@prz.edu.pl
kmk.prz.edu.pl

Department Chair:
Bartosz Miller, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 16 23
e-mail: bartosz.miller@prz.edu.pl

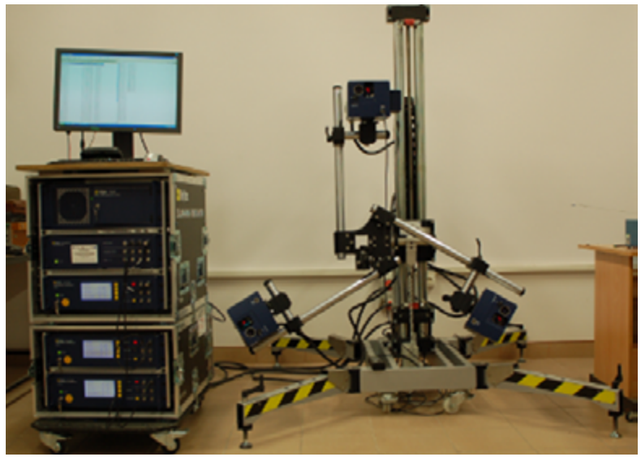
Department of Structural Mechanics

Methods and techniques:

- measurement of vibration velocity/displacement at single points (recording of time signals and vibration spectrum)
- scanning of 2D surfaces and 3D objects for vibration analysis and determination of vibration forms (animation of vibration forms for selected frequencies)
- scanning of 2D surfaces and 3D objects for visualization and analysis of temporal signals of elastic wave propagation

Apparatus available:

- RSV-150 single-point vibrometer
- scanning vibrometer PSV-400-1D
- PSV-400-3D-M scanning vibrometer with distance measuring unit



Non-contact measurement of vibrations (velocity/ displacement). Recording and visualisation of vibration time signals associated with elastic wave propagation

Non-contact vibration measurements are carried out using laser vibrometers from Polytec. The type of apparatus used depends on the specific measurement requirements: The RSV-150 single-point vibrometer enables the recording of temporal velocity or vibration displacement signals at a single measuring point. With it, information on the frequency spectrum of the measured quantity can be obtained. The advantage of the vibrometer is the speed of set-up and the possibility of measuring from a long distance (from 0.6 to 50 m). The PSV-400-1D scanning vibrometer allows non-contact measurement of vibration velocity both at single points and at set points of the measurement grid (1D and 2D). This makes it possible to scan a preset area and visualise changes in the measured parameters. The scanning process requires the measurement to be repeated with the same forcing for each measurement point. In order to reduce measurement noise, the measurement at each point can be averaged. The instrument is equipped with a dedicated signal generator, but can also work with an external signal source. The vibrometer allows the determination and visualisation of vibration waveforms and recorded time signals. Available measurement modes are: time waveform, FFT, FastScan. PSV-400-3D-M. The vibrometer is equipped with three laser heads. This allows vibrations of the test object to be scanned and recorded in three dimensions. The results obtained in this way can be analysed in a similar way to the 1D and 2D model measurements.

ul. Poznańska 2, 35-084 Rzeszów,
phone: +48 17 865 15 35
e-mail: kmk@prz.edu.pl
kmk.prz.edu.pl

Department Chair:
Bartosz Miller, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 16 23
e-mail: bartosz.miller@prz.edu.pl

Department of Structural Mechanics

Methods and techniques:

- measurement of the infrared radiation intensity of objects subjected to thermal excitation

Apparatus available:

- FLIR X6540SC thermal imaging camera
- resolution 640x512; bandwidth 1.5-5 µm, detector sensitivity < 25mK, operating frequency 125 Hz for full frame, max. 4011 Hz for 64x8 frame, temperature measurement range: 5 (-20) to 1500ºC
- flash generator with 3.0 kJ flash energy
- laser excitation modules
- 15-25 kHz ultrasonic excitation module with 2 kW output
- Mobile C-CheckIR kit with thermal imaging camera

Damage detection using active thermography

The use of active thermography enables non-contact and rapid analysis of the condition of a structure and its components for the detection of damage and manufacturing defects. The test involves supplying, in a controlled manner, an appropriate amount of thermal energy to the material structure in order to disrupt its thermal equilibrium. The energy can be introduced by means of a heat wave generated by halogen lamps, flash lamps, laser beams, eddy currents or ultrasonic excitation. The response of the material with the thermal equilibrium disturbed in a controlled manner is then recorded using a high-resolution thermal imaging camera. It is assumed that the presence of defects in the form of cracks, delaminations, inclusions or delamination results in disturbances in the propagation of the thermal wave, which makes it possible, following the application of appropriate signal processing algorithms, to effectively detect and localise the disturbances. The stationary system, which consists of an advanced thermal imaging camera with a set of devices allowing for the excitation of thermal waves and a powerful computer with specialised software, makes it possible to perform analyses for the detection of defects in materials and composite structures. This applies both to objects in use (periodic inspections, failures) and materials in production (quality control). The system can also be used for testing and analysis of in-service machinery and equipment. It can prove effective in detecting defects in electrical, heating, plumbing and other industrial installations. The mobile set is particularly useful for the analysis of large-scale structures, where extensive surfaces are being examined (tank walls, aircraft skin, etc.). The advanced scientific camera also proves its worth in classic thermal imaging diagnostic applications, without the need for external excitation.

ul. Poznańska 2, 35-084 Rzeszów
phone: +48 17 865 15 35
e-mail: kmk@prz.edu.pl
kmk.prz.edu.pl

Department Chair:
Bartosz Miller, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 16 23
e-mail: bartosz.miller@prz.edu.pl

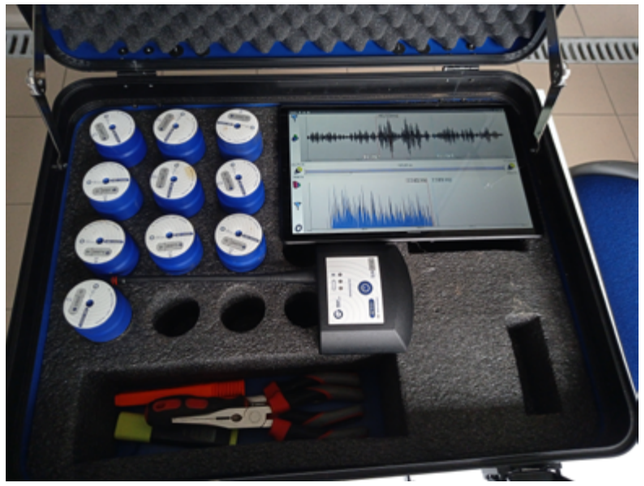
Department of Water Supply and Sawage Systems

Methods and techniques:

- detection of noise indicating a potential leakage in the network
- correlation of collected results from loggers

Apparatus available:

- 15 BIDI LOGGER loggers F.A.S.T. GmbH
- AZBIDI F.A.S.T. GmbH radio recorder
- Lenovo tablet with AZA-OAD application



Apparatus - Logger Set BIDI LOGGER F.A.S.T. GmbH

The kit allows for the detection of leaks (based on noise recorded through loggers set up at designated points) from the water supply network and their transmission to a tablet with the AZA-OAD software installed, which reads out potential leaks with the possibility of locating the exact leak from the pipe and correlating the data received from the loggers. The kit allows for the simultaneous search for leaks on a water supply network from 3 to 5 km.

al. Powstańców Warszawy 6, 35-959 Rzeszów
phone: +48 17 865 14 08
e-mail: cbarbara@prz.edu.pl
kzwwios.prz.edu.pl

Department Chair:
Barbara Tchórzewska-Cieślak, BEng, PhD, DSc, Prof.Tit.
phone: +48 17 865 1449
e-mail: cbarbara@prz.edu.pl

Department of Heating and Air-conditioning
Laboratory of Energy Conversion Systems and Environmental Technologies

Measurement of volatile organic compounds

The OVF 3000 Volatile Organic Compound Analyser is a compact, portable instrument characterised by high reliability, accuracy, sensitivity and stability. The instrument uses the continuous flame ionisation detection (FID) method, which allows the reliable determination of both high molecular weight hydrocarbons and trace contaminants in higher purity gases. All components in contact with the sample are heated to 180°C. This prevents loss of hydrocarbons and ensures reliable results especially for low ranges.

Resolution: 8 or 4 cm-1
T90 response time: < 120 s,
Sample flow rate, sample pressure: 40 l/h, atmospheric pressure
Required sample filtration: 2 µm
Temperature in measuring cell: up to 180 °C

EXAMPLE: Exhaust gas, air.

Methods and techniques:

- Number of gaseous compounds measured: max. 50, simultaneous measurement
- Measured compounds and measuring ranges: user selectable
- Wave number range: 900 - 4 200 cm-1

Apparatus available:

- GASMET DX4000 gas analyser

Standard compliance tests:

- EN 15267-3

al. Powstańców Warszawy 6, 35-959 Rzeszów
phone: +48 17 865 1263
e-mail: rabczak@prz.edu.pl

Department Chair:
Sławomir Rabczak, BEng, PhD
phone: +48 17 865 1263
e-mail: rabczak@prz.edu.pl

Methods and techniques:

- Piezoresistive measurement

Apparatus available:

- Testo Balometer 420

Standard compliance tests:

- EN 15267-3

Measurement of the ventilation airflow

The testo 420 balometer for measurements on larger ventilation grilles, including vortex anemostats, allows the guidelines and standards for air quality in rooms with large volume volumes to be met quickly and easily. High accuracy of measurements on vortex anemostats thanks to the integrated air flow straightener. The air flow rate is the basic parameter measured on vortex anemostats. The Testo 420 balometer allows measurement errors to be significantly reduced. The integrated air stream straightener calms turbulence by turning the actual air flow into a practically uniform flow. This makes it possible to accurately determine the flow rate between 80 and 3,500 m3/h.

Temperature measurement - NTC
Measuring range: -20 to +60 °C Accuracy: ±0.5 °C (0 to +60 °C) ±0.8 °C (-20 to +0 °C) Resolution: 0.1 °C
Humidity - capacitive sensor
Measuring range: 0 to 100 %RH Accuracy: ±1.8 %RH +3 % meas. (at 25 °C, 5 % to 80 %RH) ±1.0 %rF Hysterese ±0.03 % RH (at 0 to 60 °C) ±1.0 %rF/year Drift Resolution: 0.1 %RH
Differential pressure - piezoresistive
Measuring range: -120 to +120 Pa Accuracy: ±2 % of measured value. + 0.5 pa at +22 °C, 1013 hPa Resolution: 0.001 Pa

EXAMPLE: Air.

al. Powstańców Warszawy 6, 35-959 Rzeszów
phone: +48 17 865 1263
e-mail: rabczak@prz.edu.pl

Department Chair:
Sławomir Rabczak, BEng, PhD
phone: +48 17 865 1263
e-mail: rabczak@prz.edu.pl

Department of Heating and Air-conditioning
Laboratory of Energy Conversion Systems
and Environmental Technologies

Methods and techniques:

- Measurement technique: oscillation method, mechanical with viscosity correction and built-in reference oscillator
- Materials in contact with the sample: borosilicate glass, Teflon

Apparatus available:

- **Density meter DDM 2911**

Standard compliance tests:

ASTM D1250, ASTM D4052, ASTM D5002, DIN 51757, ISO 12185, ASTM D4806, IP 365, ASTM D5931 USP 29<841> (US Pharmacopoeia), JP (Japanese Pharmacopoeia), BP (British Pharmacopoeia), EP (European pharmacopoeia), 21CFR11 part 11 ASTM D1250, ASTM D4052, ASTM D5002, DIN 51757, ISO 12185, ASTM D4806, IP 365, ASTM D5931 USP 29<841> (US pharmacopoeia), JP (Japanese pharmacopoeia), BP (British pharmacopoeia), EP (European pharmacopoeia), 21CFR11 part 11 ASTM D1250, ASTM D4052, ASTM D5002, DIN 51757, ISO 12185, ASTM D4806, IP 365, ASTM D5931 USP 29<841> (US Pharmacopoeia), JP (Japanese Pharmacopoeia), BP (British Pharmacopoeia), EP (European Pharmacopoeia), 21CFR11 part 11

Density measurement

c The Rudolph DDM 2911 PLUS, a high accuracy density meter, is our most powerful instrument offering the widest measuring range, highest accuracy and the on-board methods and electronic data tracking required in the world's most demanding laboratories. The DDM 2911 PLUS is highly recommended for high-level work in the alcohol, pharmaceutical, chemical and petroleum industries.

Technical specifications:
Density measurement range 0 - 3 g/cm3
Sample temperature stabilisation range 0 - 100°C via Peltier system
Pressure range 0 - 10 bar
Viscosity correction over the entire measuring range
Types of operation: continuous measurement, single measurement, multiple measurement in a temperature gradient

EXAMPLE: Liquid fuels, liquid substances.

al. Powstańców Warszawy 6, 35-959 Rzeszów
phone: +48 17 865 1263
e-mail: rabczak@prz.edu.pl

Department Chair:
Sławomir Rabczak, BEng, PhD
phone: +48 17 865 1263
e-mail: rabczak@prz.edu.pl

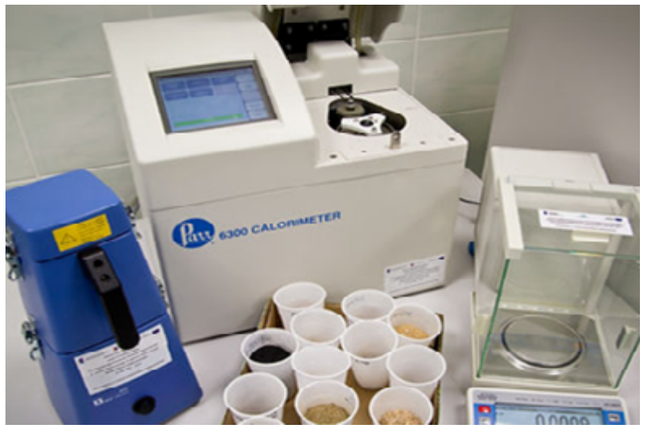
Department of Heating and Air-conditioning
Laboratory of Energy Conversion Systems and Environmental Technologies

Methods and techniques:

- Muffle furnace
- moisture analyser
- furnace for roasting
- crusher

Standard compliance tests:

- PN-ISO 1928, ASTM D240-02, ASTM D5865-07a, ASTM D1989-92a, ASTM D3286-91, ASTM D4809-06, ASTM D5468-02, ASTM E711-87, ISO 1928:1995, BS 1016-105:1992, DIN 51900 PN-ISO 1928, ASTM D240-02, ASTM D5865-07a, ASTM D1989-92a, ASTM D3286-91, ASTM D4809-06, ASTM D5468-02, ASTM E711-87, ISO 1928:1995, BS 1016-105:1992, DIN 51900



Measurement of combustion heat and calorific value

This apparatus belongs to the group of automatic calorimeters and contains an integrated cooling system with a closed circuit. This model is characterised by a permanently fixed bomb and vessel, designed in such a way as to automatically fill the vessel and jacket with water and the bomb with oxygen until the initial parameters are reached. Thanks to the use of an automatic system for cleaning the bomb after combustion products, the length of the preparation process and test implementation is reduced to an absolute minimum.

al. Powstańców Warszawy 6, 35-959 Rzeszów
phone: +48 17 865 1263
e-mail: rabczak@prz.edu.pl

Department Chair:
Sławomir Rabczak, BEng, PhD
phone: +48 17 865 1263
e-mail: rabczak@prz.edu.pl

Department of Heating and Air-conditioning
Laboratory of Energy Conversion Systems and Environmental Technologies

Viscosity measurement

The set includes a complete, ready-to-use control unit, a pump for introducing the measuring substance into the capillary using the vacuum principle, and WinVisco 370 software. The complete viscosity measurement system consists of: a viscosity measuring bath, a measuring stand, an AVS 370 control and executive unit and a PC. The device enables fast, automatic and reproducible series of flow time measurements, determination of viscosity and evaluation of results including documentation.

Measuring range for time: up to 9999.99 s with a resolution of 0.01 s
Measuring range for viscosity: for vacuum: 0.35 - 5,000 mm2/s (cSt)
Measured parameter: flow time [s]
Accuracy of flow time measurement: ± 0.01%
Programming of the thermostating time before measurements: 0 - 20 minutes

EXAMPLE: Liquid fuels, liquid substances.

Methods and techniques:

- Time measuring range: up to 9999.99 s with a resolution of 0.01 s
- Viscosity measuring range: for vacuum: 0.35 - 5,000 mm2/s (cSt)
- Measured parameter: flow time [s]
- Accuracy of flow time measurement: ± 0.01%
- Capillary method

Apparatus available:

- Lepkościomierz AVS 370

Standard compliance tests:

- EN ISO 3104
- DIN 51562 part 1,
- ISO DIS 3105,
- ISO 3105, ASTM D2515,
- ASTM D446,
- DIN 562 part 2
- EN ISO 3104
- DIN 51562 part 1,
- ISO DIS 3105,
- ISO 3105, ASTM D2515,
- ASTM D446,
- DIN 562 part 2
- EN ISO 3104
- DIN 51562 part 1,
- ISO DIS 3105,
- ISO 3105, ASTM D2515,
- ASTM D446,
- DIN 562 part 2

al. Powstańców Warszawy 6, 35-959 Rzeszów
phone: +48 17 865 1263
e-mail: rabczak@prz.edu.pl

Department Chair:
Sławomir Rabczak, BEng, PhD
phone: +48 17 865 1263
e-mail: rabczak@prz.edu.pl

Department of Heating and Air-conditioning
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Methods and techniques:

- Measuring method: Continuous flame ionisation detection (FID)

Apparatus available:

- OFV-3000 VOC analyser J.U.M.

Standard compliance tests:

- PN-EN 12619:2013

Measurement of volatile organic compounds

The OVF 3000 Volatile Organic Compound Analyser is a compact, portable instrument characterised by high reliability, accuracy, sensitivity and stability. The instrument uses the continuous flame ionisation detection (FID) method, which allows the reliable determination of both high molecular weight hydrocarbons and trace contaminants in higher purity gases. All components in contact with the sample are heated to 180°C. This prevents loss of hydrocarbons and ensures reliable results especially for low ranges.

Measuring method: Continuous flame ionisation detection (FID)
Measuring ranges: 0-10, 100, 1 000, 10 000, 100 000 ppm
Sensitivity: Max. 1 ppm CH4 for full scale
Response time: T90 :1.2 s (< 8 s when using an 8 m heated line)
Linearity: 1%
Fuel consumption (100% H2 /): approx. 20 ml/min
Sample filtration required: 2 mm
Air preparation: Built-in air preparation system

EXAMPLE: Exhaust gas, air.

al. Powstańców Warszawy 6, 35-959 Rzeszów
phone: +48 17 865 1263
e-mail: rabczak@prz.edu.pl

Department Chair:
Sławomir Rabczak, BEng, PhD
phone: +48 17 865 1263
e-mail: rabczak@prz.edu.pl

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Flash point temperature measurement

The PAC FP92 5G2 Automated Flash and Fire PointISL Analyser has the following main advantages: automatic ignition of the test flame, analysis of statistical results (AVE, MIN, MAX, SD), alarm messages for out-of-specification results, many safety functions, self-contained operation, possibility to work with PAC IRIS Software instruments

Analytical principle: Cleveland Open Cup, ignition system: gas, flash and fire detection: ionisation, heating rate: 2 programmable speeds: 14 to 17 °C / min; 5.5 °C / min and one preheating mode, calibration: automatic and recorded over time, programmable calibration frequency with lockout control, application range: 1 to 400°C in 0.1°C (38 to 760°F), sample temperature: Pt 100 glass probe , offset capability with correction table: 21 points from 0°C to 400°C., barometric pressure correction: automatic correction with integrated manometer

Technical parameters:
Density measurement range 0 - 3 g/cm3, sample temperature stabilisation range 0 - 100°C realised via a Peltier system, pressure range 0 - 10 bar, viscosity correction over the entire measurement range, types of operation: continuous measurement, single measurement, multiple measurement in a temperature gradient

EXAMPLE: Liquid fuels, liquid substances.

Methods and techniques:

- Flashpoint FP92 5G2

Standard compliance tests:

- ASTM D92, ISO 2592,
- EN 22592, IP 36,
- NF EN 22592

al. Powstańców Warszawy 6, 35-959 Rzeszów
phone: +48 17 865 1263
e-mail: rabczak@prz.edu.pl

Department Chair:
Sławomir Rabczak, BEng, PhD
phone: +48 17 865 1263
e-mail: rabczak@prz.edu.pl

Department of Heating and Air-conditioning
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Methods and techniques:

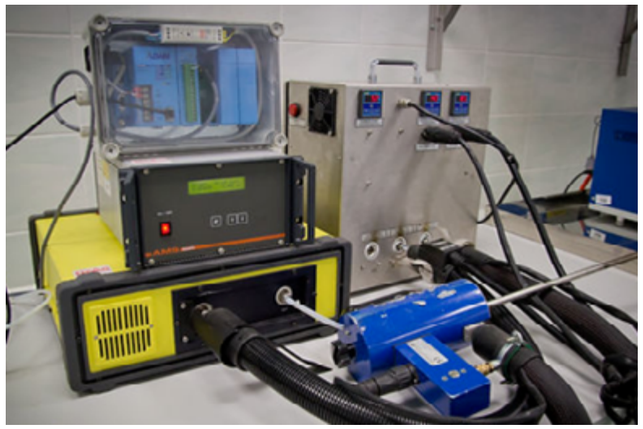
- Number of measured gas compounds: max. 50
- Measured compounds and measurement ranges: user-selectable
- Wavenumber range: 900–4200 cm^{-1}

Apparatus available:

- **GASMET DX4000 gas analyzer**

Standard compliance tests:

- EN 15267-3



Gas analysis during combustion

The GASMET DX-4000 is a portable gas analyzer that operates based on Fourier Transform Infrared (FTIR) absorption spectroscopy. It allows simultaneous measurement of up to 50 chemical compounds found in exhaust gases, flue gases, process gases, and air. Thanks to its special design and the use of a measurement cell made of precious metals, the entire measurement path is maintained at a temperature of 180°C, enabling the measurement of concentrations of water-soluble substances such as NH3, HF, or HCl, as well as H2O and hydrocarbons selectively.

T90 response time: < 120 s, depending on sample flow rate and measurement path length
Sample flow rate, sample pressure: 40 l/h, atmospheric pressure
Required sample filtration: 2 µm
Measurement cell temperature: up to 180 °C
Optical path length: 2.5 or 9.8 m, depending on the application
Calibration: zero calibration with nitrogen (minimum 4.0) every 24 hours
Zero point drift: <2% of the lowest range / time between calibrations

al. Powstańców Warszawy 6, 35-959 Rzeszów
phone: +48 17 865 1263
e-mail: rabczak@prz.edu.pl

Department Chair:
Sławomir Rabczak, BEng, PhD
phone: +48 17 865 1263
e-mail: rabczak@prz.edu.pl

Department of Water Purification and Protection

ZAKŁAD
OCZYSZCZANIA
I OCHRONY WÓD
POLITECHNIKI RZESZOWSKIEJ

Scientific and research offer

- Physicochemical and bacteriological analysis of water.
- Elemental analysis of solids and liquids.
- Microbiological - quantitative studies of environmental samples: water, soil, air.
- Technologies for treatment of rainwater.
- Technological testing of water treatment for drinking and special (industrial) purposes.
- Testing the suitability of sorption and ion exchange materials
- for operation.
- Evaluation of water quality and its suitability for drinking and other purposes.
- Evaluation of corrosive aggressiveness of ground and surface water.
- Assessment of physicochemical and biological stability of tap water.
- Assessment of the impact of investments on the environment.
- Assessment of the sanitary risk of sediments and substances deposited in the environment.
- Natural inventories: floristic and mycological, conducted by the marsh method; faunistic performed on the basis of direct and voice observations, as well as on the basis of animal tracks.

Apparatus available:

- orbital shaker-incubator ES-20/60 Biosan
- Linea Blue Air Bio Activa VE Aquaria laminar airflow chamber
- Q-Cell 60/60 std Pol-Lab and 140/60 std Pol-Lab laboratory thermometer
- aCOLyte Super Count Synbiosis colony counter
- GloMax 20/20 Promega luminometer
- ultrasonic processor Sonikator VCX 130 Sonics Vibra-cell with equipment
- sound-absorbing chamber
- total internal reflection (TXRF) S2 PICOFOX Bruker X-ray spectrometer
- UV-VIS spectrophotometer DR5000 HACH Lange
- DR3900 HACH Lange spectrophotometer
- laboratory total organic carbon (TOC) analyzer Sievers 5310 C GE Analytical Instruments
- HQ40d multi HACH portable multimeter
- Intellical PHC705 RedRod laboratory glass pH electrode
- Intellical LDO101 Luminescent/ Optical Dissolved Oxygen (DO) laboratory sensor
- field, graphite, 4-pole conductivity cell CDC401, 5m cable
- CDC401 laboratory, graphite, 4-pole conductivity cell
- laboratory ORP/RedOx gel probe Intellical MTC101

al. Powstańców Warszawy 6, 35-959 Rzeszów
phone: +48 17 865 13 01, 17 865 16 69
email: dpapciak@prz.edu.pl
zoiow.prz.edu.pl

Department Chair:
Professor Dorota Papciak, BEng, PhD, DSc, Prof.Tit.
phone: +48 17 865 13 01
e-mail: dpapciak@prz.edu.pl

Department of Water Purification and Protection

Methods and techniques:

- plate method
- luminescence

Apparatus available:

- aCOLyte Super Count Synbiosis colony counter
- GloMax 20/20 Promega luminometer

Qualitative and quantitative analysis in microbiological research

The automatic bacterial colony counter allows rapid counting of bacterial colonies grown on petri dishes as small as 0.1mm. It is possible to work not only with light, but also with dark agar, on the most commonly used petri dishes up to 90mm in size.

The luminometer is an ultra-sensitive, compact laboratory instrument for measuring luminescent materials. It collects luciferase measurements for reporter gene studies and ATP-based biomass analysis. Allows rapid measurement of ATP concentration in water (tests for surface water, groundwater, rainwater, tap water). The value of this parameter allows the concentration of living cells of organisms to be determined.

al. Powstańców Warszawy 6, 35-959 Rzeszów
phone: +48 17 865 13 01, 17 865 16 69
email: dpapciak@prz.edu.pl
zoiow.prz.edu.pl

Department Chair:
Professor Dorota Papciak, BEng, PhD, DSc, Prof.Tit.
phone: +48 17 865 13 01
e-mail: dpapciak@prz.edu.pl

Department of Water Purification and Protection

Methods and techniques:

- sonication

Apparatus available:

- VCX 130 Sonics Vibra-cell ultrasound processor with accessories
- soundproofing chamber

Sample preparation Sonication, homogenisation, ultrasonic disintegration

Ultrasonic processor - sonicator for small-volume samples from 0.15 to 150 ml with a 130 W processor is primarily designed for tripod operation using the possibilities offered by automatic pulse operation. Equipped with a sound chamber with tripod rod and converter holder attached to the base. Titanium tip (sonotrode) with a diameter of 6 mm (for samples with a recommended volume of 5 to 50 ml). Programmable pulse operation (pulser) with independently adjustable pulse and interval times (both from 1 to 59 sec). Automatic compensation to ensure that the set amplitude is maintained under changing load conditions (e.g. change in sample density).

al. Powstańców Warszawy 6, 35-959 Rzeszów
phone: +48 17 865 13 01, 17 865 16 69
email: dpapciak@prz.edu.pl
zoiow.prz.edu.pl

Department Chair:
Professor Dorota Papciak, BEng, PhD, DSc, Prof.Tit.
phone: +48 17 865 13 01
e-mail: dpapciak@prz.edu.pl

Department of Water Purification and Protection

Methods and techniques:

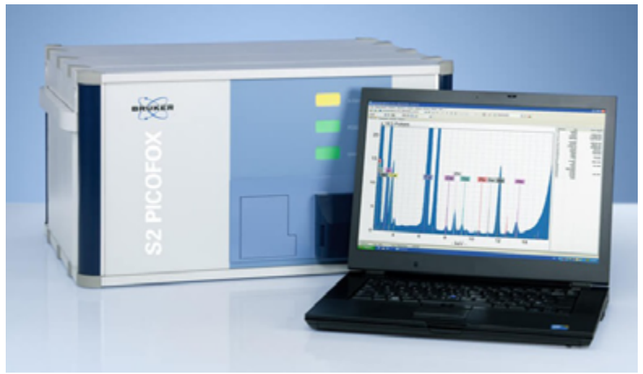
- Total reflection X-ray fluorescence spectrometry (TXRF)

Apparatus available:

- Total Internal Reflectance X-ray Spectrometer (TXRF) S2 PICOFOX Bruker

Standard compliance tests:

- NIST 1640
- PN-EN 15309:201P



Quantitative analysis of the composition of trace elements from Na to U

Simultaneous quantification of trace elements from sodium (Na) to uranium (U) in liquid samples and suspensions without mineralisation. Simultaneous analysis of multiple components significantly reduces cost and analysis time. Standard measurement time of ~15 min. Energy resolution below 159 eV for Mn-K. Sample volume of 1-10 ml required.
Low detection threshold, below ppb in the nanogram or microgram range. Detection limit for nickel (Ni) less than 10 pg.

al. Powstańców Warszawy 6, 35-959 Rzeszów
phone: +48 17 865 13 01, 17 865 16 69
email: dpapciak@prz.edu.pl
zoiow.prz.edu.pl

Department Chair:
Professor Dorota Papciak, BEng, PhD, DSc, Prof.Tit.
phone: +48 17 865 13 01
e-mail: dpapciak@prz.edu.pl

Department of Water Purification and Protection

Preparation of material for microbial culture, microbial cultures, culture of microorganisms

An orbital shaker-incubator is used for the culture of microorganisms and eukaryotic cells and the intensive mixing of various suspensions and materials contained in tubes or flasks. The shaking speed control range is 50 to 250 rpm in a temperature range of 25-80°C. The maximum duration of continuous operation is 30 days. The quantitative and qualitative determination of micro-organisms in environmental samples (water, soil, air) and laboratory cultures is performed using a laminar airflow chamber. It is a professional device used for microbiological cultures with protection against external contamination of the sample. For the storage and incubation of microbial cultures at a well-defined temperature from 3 to 60°C with an accuracy of 0.1°C, 60l and 142l hothouses are used.

Methods and techniques:

- breeding method

Apparatus available:

- orbital shaker-incubator ES-20/60 Biosan
- Linea Blue Air Bio Activa VE Aquaria laminar airflow chamber
- laboratory thermometer Q-Cell 60/60 std Pol-Lab
- laboratory thermometer Q-Cell 140/60 std Pol-Lab

Standard compliance tests:

- PN-EN ISO 6222:2004
- PN-EN ISO 8199:2019-01

al. Powstańców Warszawy 6, 35-959 Rzeszów
phone: +48 17 865 13 01, 17 865 16 69
email: dpapciak@prz.edu.pl
zoiow.prz.edu.pl

Department Chair:
Professor Dorota Papciak, BEng, PhD, DSc, Prof.Tit.
phone: +48 17 865 13 01
e-mail: dpapciak@prz.edu.pl

Department of Water Purification and Protection

Methods and techniques:

- VIS spectrophotometry
- UV-VIS spectrophotometry

Apparatus available:

- sApparatus available:
- UV-VIS DR5000 spectrophotometer by HACH Lange
- DR3900 spectrophotometer by HACH Lange

Standard compliance tests:

- working procedures for research
- HACH-LANGE

Determination of single elements by spectrophotometric method in water and wastewater

The laboratory spectrophotometer DR3900 HACH Lange of the visible spectrum (320 - 1100 nm) as well as the UV-VIS spectrophotometer DR5000 HACH Lange (190-1100 nm) are high-precision spectrophotometers with more than 200 programmed methods optimised for laboratory water analysis.
Accurate analysis of drinking, raw and industrial water. Available tests for various parameters such as absorbance, colour, turbidity, nitrates, nitrites, ammonia, phosphates, sulphates, total chlorine, free chlorine, iron, manganese and others. Operating conditions: 10 - 40 °C.

Note:
The kit includes a high-temperature thermostat for 12 cuvette tests or reaction vessels for rapid sample mineralisation in a housing with integrated locking device.

al. Powstańców Warszawy 6, 35-959 Rzeszów
phone: +48 17 865 13 01, 17 865 16 69
email: dpapciak@prz.edu.pl
zoiow.prz.edu.pl

Department Chair:
Professor Dorota Papciak, BEng, PhD, DSc, Prof.Tit.
phone: +48 17 865 13 01
e-mail: dpapciak@prz.edu.pl

Department of Water Purification and Protection

Determination of total organic carbon in waters with low pollution

The laboratory total organic carbon (TOC) analyser is used for the analysis of natural and tap water.
The analytical range is from 4 ppb to 50 ppm.
The analyser can be used with an autosampler for 120 samples. The analyser uses the UV/sulphate oxidation method and Sievers patented membrane conductivity detection technology, which provides unparalleled accuracy and precision over the analyser's wide operating range.
Instrument sample flow rate: 0.5 ml/min.

Methods and techniques:

- UV/sulphate oxidation method and patented Sievers membrane conductivity detection technology

Apparatus available:

- Sievers 5310 C GE laboratory total organic carbon (TOC) analyser
- Analytical Instruments

Standard compliance tests:

- US EPA 415.3

al. Powstańców Warszawy 6, 35-959 Rzeszów
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email: dpapciak@prz.edu.pl
zoiow.prz.edu.pl

Department Chair:
Professor Dorota Papciak, BEng, PhD, DSc, Prof.Tit.
phone: +48 17 865 13 01
e-mail: dpapciak@prz.edu.pl

Department of Water Purification and Protection

Methods and techniques:

- RED ROD technology
- conductivity
- luminescence

Apparatus available:

- HQ40d multi HACH portable multimeter
- Intellical PHC705 RedRod laboratory glass pH electrode
- Intellical LDO101 Luminescent/Optical Dissolved Oxygen (DO) laboratory sensor
- field, graphite, 4-pole conductivity cell CDC401, 5m cable
- CDC401 laboratory, graphite, 4-pole conductivity cell
- laboratory ORP/RedOx gel probe Intellical MTC101

Standard compliance tests:

- Certified performance measurement according to MCERT regulation
- PN-90/C-04540.01
- PN-EN 27888:1999

Measurement of pH, conductivity and oxygen

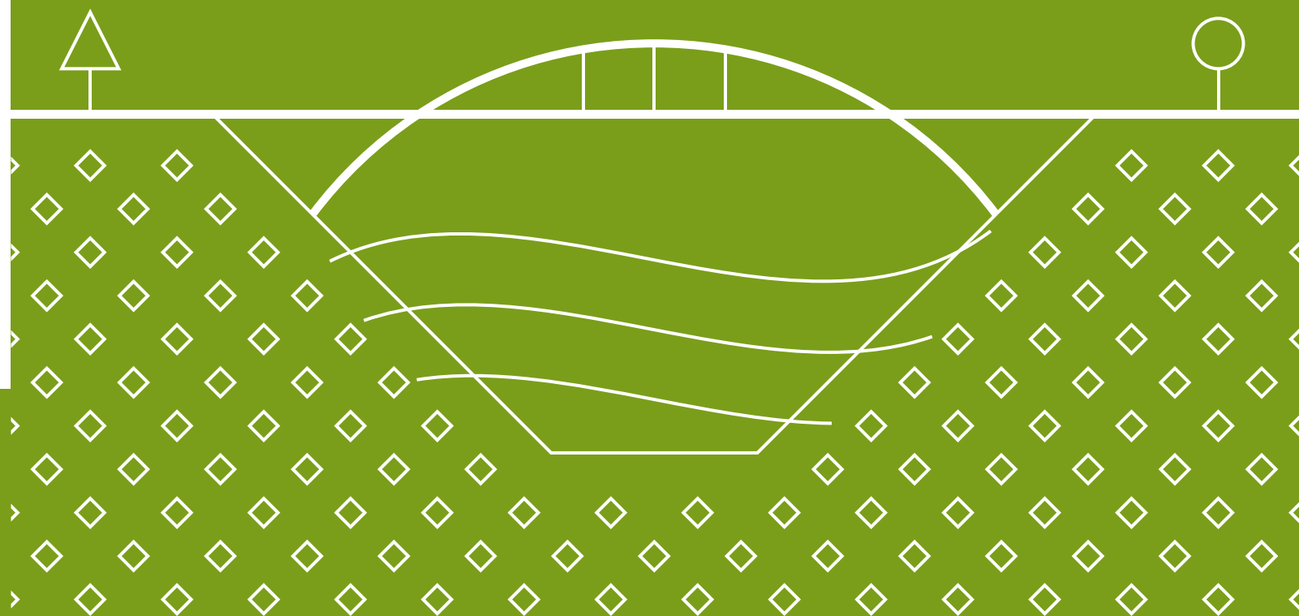
Portable dual-channel multimeter for pH, conductivity, luminescent dissolved oxygen (LDO) and oxidation-reduction potential (ORP/RedOx) measurement both in the laboratory and in the field. The universal electrodes are suitable for measurement in wastewater, drinking water, process water or general water quality assessment applications. The pH electrode is not suitable for use with organic solvents, emulsions and samples with high particulate content.

conductivity
Measuring range: 0.01 µS/cm - 200 mS/cm
Accuracy: ±0.5 % of reading
Temperature range: -10 - 110 °C

pH
Measuring range: 0 - 14 pH
Accuracy: ±0.01 pH
Temperature range: -10 - 100 °C

Dissolved oxygen
Measuring range: 0.05 - 20.0 mg/L
Accuracy: ±0.1 mg/L from 0 to 8 mg/L, ±0.2 mg/L above 8 mg/L
Temperature range: 0 - 50 °C

ORP
Measuring range: ±1200 mV
Accuracy: ±0.02 mV or 0.05 %, the higher of these values
Temperature range: 0 - 80 °C

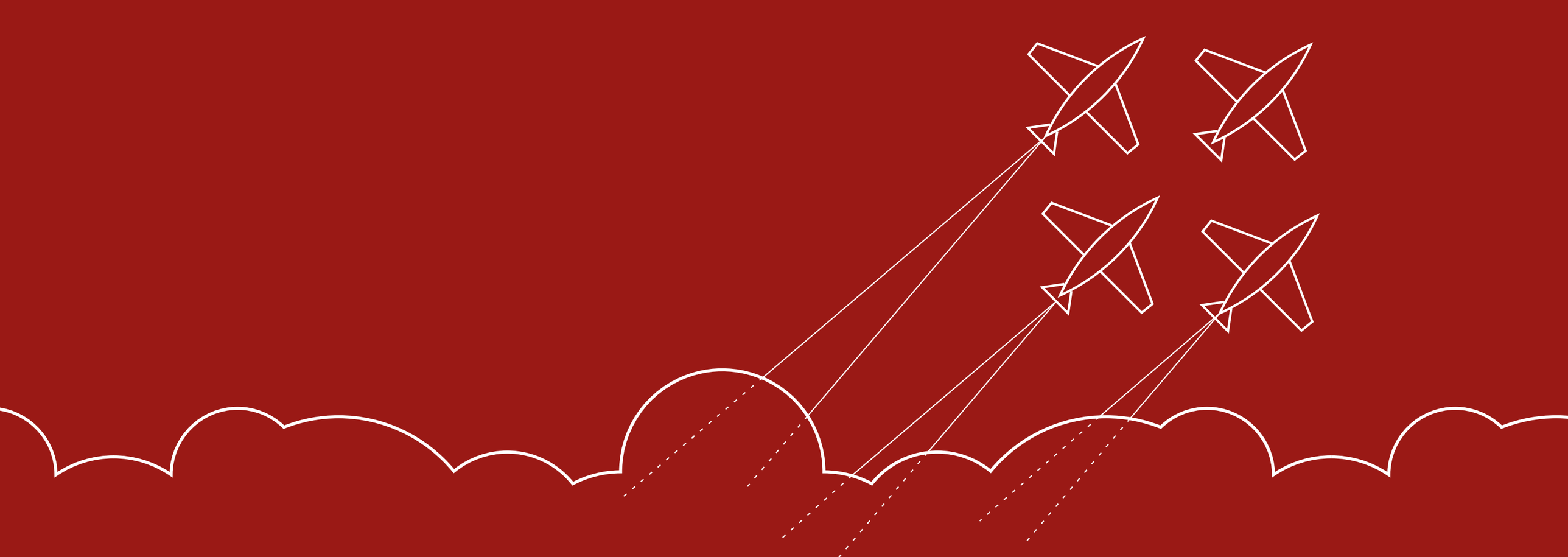


al. Powstańców Warszawy 6, 35-959 Rzeszów
phone: +48 17 865 13 01, 17 865 16 69
email: dpapciak@prz.edu.pl
zoiow.prz.edu.pl

Department Chair:
Professor Dorota Papciak, BEng, PhD, DSc, Prof.Tit.
phone: +48 17 865 13 01
e-mail: dpapciak@prz.edu.pl

Powstańców Warszawy 8, 35-959 Rzeszów
e-mail: rm@prz.edu.pl
wbmil.prz.edu.pl

FACULTY OF
MECHANICAL ENGINEERING AND AERONAUTICS
RZESZÓW UNIVERSITY OF TECHNOLOGY



Methods and techniques:

- measurement of aerodynamic loads by means of the weighting method - forces and moments
- measurements of pressure distribution on solid surfaces and velocity and pressure fields
- visualisation tests
- turbulence measurements
- Measurement of the velocity distribution in the boundary layer
- 2D and 3D thermoanemometric measurements

Apparatus available:

- external strain gauge scales
- internal strain gauge scales
- 3D thermoanalytical systems
- pressure scanners
- smoke visualisation system
- DaqBook 2001 measuring systems
- Fluke pressure calibrators
- vibration and noise analysers

Standard compliance tests:

- PN-EN: 61400-2

Wind tunnel TA2.5
Wind tunnel TA1000 with Eiffel chamber
Water tunnel

Wind tunnel TA2.5
A closed-circuit tunnel with two test spaces enables research in fields such as aviation, automotive, structural engineering, energy, sports, medicine and others where airflows are analysed. The tunnel has two test spaces:

- high-velocity space - dimensions: 1 m x 0.6 m x 2 m, maximum flow velocity: 120 m/s.
- high velocity measurement space - dimensions: 3 m x 2 m x 6 m, maximum flow velocity: 13 m/s.

Wind tunnel TA1000 with Eiffel chamber

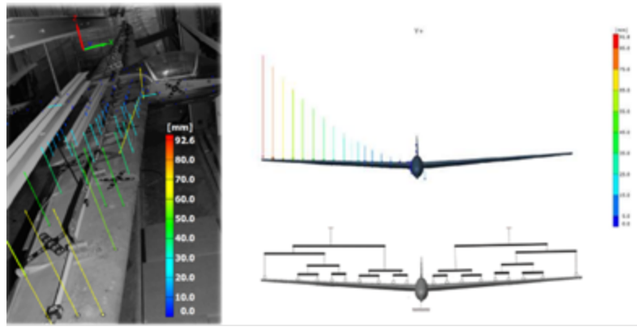
A tunnel with a jet diameter of 1 m, with a maximum air flow velocity of 60 m/s, used in aviation, automotive, structural engineering, energy, sports, medicine and other fields where there is a need to study air flows.

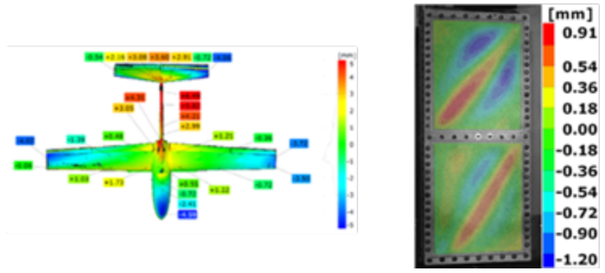
Water tunnel
The water tunnel, measuring 920 mm x 60 mm x 2000 mm, with a maximum water flow velocity of 2 m/s, allows the study of two-dimensional transonic flows. It is also used for the visualisation of flows using the displacement line method and the simulation of isentropic flows using hydraulic analogy.

al. Powstańców Warszawy 8, 35-959 Rzeszów
phone: +48 17 865 1444
e-mail: andrzej.majka@prz.edu.pl
kilik.prz.edu.pl

Department Chair:
Andrzej Majka, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1604
e-mail: andrzej.majka@prz.edu.pl

Department of Aerospace Engineering





Structural strength tests

Conducting tests on the strength and deformation of building surfaces under load:

- Measurements using a digital image correlation system (3D DIC) allowing for the analysis of displacement fields in advanced deformation states, regardless of the material of the test object.
- measurements using a spatial photogrammetry system enabling the determination of the position and displacement of points of large-size objects,
- reproduction of the geometry of elements in digital form using a white light scanner,
- tests using electro-porous and fibre-optic strain gauges.

The available equipment enables strength tests to be carried out on samples, test models and complete structures or their fragments in the field of static and slowly changing loads.

Methods and techniques:

- DIC deformation measurements
- 3D scanner geometry measurements
- deformation measurements using spatial photogrammetrystrain gauge measurements determination of critical and limit loads

Apparatus available:

- 3D DIC scanner (GOM ARAMIS)
- photogrammetric system (GOM Tritop)
- 3D scanner (GOM ATOS) testing machine (Zwick/ Roell Z050)
- electromechanical testing machine (Zwick/Roell E020) hydraulic testing machine 20 kN
- strain gauge bridge (HBM QuantumX)
- optical interrogator (HBM SI405)
- transmission and reflected light polariscopes test cage with force floor

al. Powstańców Warszawy 8, 35-959 Rzeszów
phone: +48 17 865 1444
e-mail: andrzej.majka@prz.edu.pl
kilik.prz.edu.pl

Department Chair:
Andrzej Majka, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1604
e-mail: andrzej.majka@prz.edu.pl

Methods and techniques:

- static force
- alternating cycle loads
- resonance and high-cycle tests
- contact and non-contact measurements

Apparatus available:

- cage dimensions of 14770 x 4506 x 4320 mm (single window min. 1766 x 4320 mm)
- generated force up to 80 kN
- photogrammetric measurements possible
- laser displacement sensors
- pneumatic and hydraulic load generation system
- can be combined with a universal testing machine

High-cycle fatigue and resonance tests

Strength testing facility with a force floor for static, fatigue and resonance strength tests:

- Use of various measuring systems,
- Force generation in the range of a few to 80 kN,
- Generation of loads as concentrated or distributed force,
- Execution of tests for certification by the Civil Aviation Authority, the Office of Technical Inspection and the Transport Technical Inspection.

al. Powstańców Warszawy 8, 35-959 Rzeszów
phone: +48 17 865 1444
e-mail: andrzej.majka@prz.edu.pl
kilik.prz.edu.pl

Department Chair:
Andrzej Majka, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1604
e-mail: andrzej.majka@prz.edu.pl

Department of Aerospace Engineering

Methods and techniques:

- Production of prototype plastic parts using 3D printing on a dual-head printer.
- Production of prototype plastic parts using 3D printing on a large-format printer.
- Production of prototype resin parts using 3D printing.

Apparatus available:

- Ultimaker S5 dual-head 3D printer with a workspace of 330 x 240 x 300 mm.
- Creality CR-M4 3D printer with a workspace of 450 x 450 x 470 mm.
- Anycubic M3 MAX resin 3D printer, with a working space of 290 x 160 x 300 mm, including equipment for cleaning and curing models

Rapid prototyping by 3D printing

Production of prototype parts using 3D printing:

- Production of precise prototype parts made of ABS, PLA, PET, polycarbonate using a dual-head printer with the option of printing supports using PVA, a water-soluble polyvinyl alcohol-based material.
- production of large-scale prototype parts made of ABS, PLA, PET and polycarbonate,
- production of precise prototype parts by UV-curing synthetic resins,
- production of precise parts for polarisation-optical research optical polarisation method using UV light to harden transparent synthetic resins.

al. Powstańców Warszawy 8, 35-959 Rzeszów
phone: +48 17 865 1444
e-mail: andrzej.majka@prz.edu.pl
kilik.prz.edu.pl

Department Chair:
Andrzej Majka, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1604
e-mail: andrzej.majka@prz.edu.pl

Methods and techniques:

- measurements of isochromes in white light
- quantitative and qualitative analysis of the distribution of isochromes under white and sodium monochromatic light
- determination of principal stress trajectories from isocline images

Apparatus available:

- Zeiss polariscope type OS-300 with a white and monochromatic sodium light source
- Polariscope for transmitted light - department's own construction
- microscope polariscope

Model polarisation-optical tests using the transmitted light method

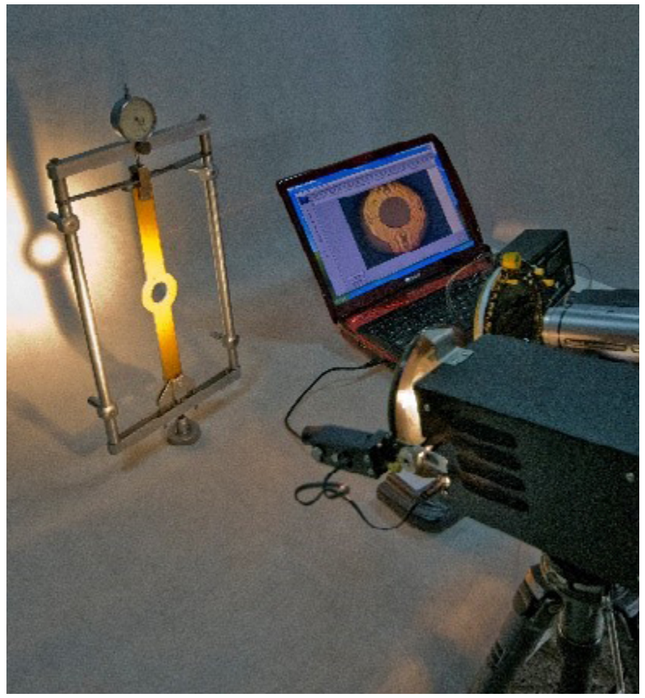
Performing model verification tests using the polarisation-optical method:

- precise measurement of the isochromatic order, mapping the distribution of stresses reduced according to the τmax hypothesis in circularly polarised light,
- quantitative and qualitative analysis of stress concentration in the structure based on an isochromatic image - the ability to observe high orders of isochromes in sodium light,
- determination of the trajectory of principal stresses based on isoclinic images obtained in linearly polarised light,
- the possibility of analysing high orders of isochromes using a polarised light microscope.

al. Powstańców Warszawy 8, 35-959 Rzeszów
phone: +48 17 865 1444
e-mail: andrzej.majka@prz.edu.pl
kilik.prz.edu.pl

Department Chair:
Andrzej Majka, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1604
e-mail: andrzej.majka@prz.edu.pl

Department of Aerospace Engineering



Methods and techniques:

- model making using the Model-Tech method.
- fabrication of optically active thin films.
- isochromic order measurements in white light and sodium monochromic light.
- determination of principal stress trajectories from isocline images

Apparatus available:

- VISHAY reflecting polariscope , model FL/Z-2, incl. compensator and PSCalc software.
- VISHAY reflecting polariscopes, model 030, including compensators, oblique scanning attachments and telemicroscope.
- set of equipment for producing optically active thin films

Model polarisation-optical testing using reflected light

Performing model verification tests using the polarisation-optical method:

- producing elasto-optical models using the Model-Tech method,
- producing thin coatings from optically active materials and conducting tests on real objects using them,
- precise measurement of the isochrome order, mapping the distribution of stresses reduced according to the τmax hypothesis, in circularly polarised light,
- quantitative and qualitative analysis of stress concentration in the structure based on the isochromatic image - the possibility of observing high isochrome orders in monochromatic light using a sodium filter,
- determination of the trajectory of the principal stresses on the basis of isoclinic images obtained in linearly polarised light,
- possibility of detailed observation of an isochromatic image using a telemicrocope.

al. Powstańców Warszawy 8, 35-959 Rzeszów
phone: +48 17 865 1444
e-mail: andrzej.majka@prz.edu.pl
kilik.prz.edu.pl

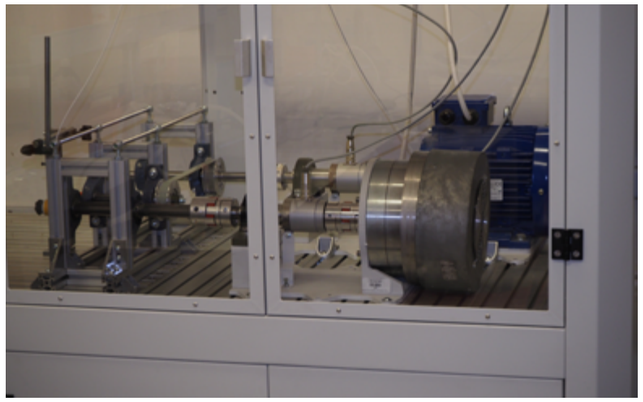
Department Chair:
Andrzej Majka, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1604
e-mail: andrzej.majka@prz.edu.pl

Methods and techniques:

- a method of testing the durability of a gear that involves loading the gear under test with a torque at a specified rotational speed over a specified time

Apparatus available:

- Promotor 2,2kW induction motor
- Goodrive 10 inverter
- two MT 50 Nm torque meters
- RMC recorder
- Elfa P80 powder brake
- Micro-Epsilon pyrometer
- CEM DT-95 hand-held sonometer



Test stand for endurance testing of gears

The test bench is used to carry out durability tests on gears, particularly those made from polymers, e.g. gears obtained using injection moulding or additive technologies (e.g. FFF (Fused Filament Fabrication)) made from thermoplastic materials (e.g. ABS (poly(acrylonitrile-co-butadiene-co-styrene), acrylonitrile-butadiene-styrene terpolymer)). The speed range on the bench is 200÷955 rpm, while the maximum torque is 22 Nm. During the test, the following parameters are recorded in the RMC software: test time and duration, input and output torque, temperature, and input and output speed. The recorded data can be visualised by means of default graphs generated in the RMC recorder immediately after the test, depending on the recording time or duration. The results of the recorded parameters can be saved to a .csv file, which can then be exported to a program such as Excel. The test stand allows a maximum of four cycles to be set up for a single test with different set torque, speed and duration. In addition, during the test, it is possible to continuously monitor and save the results to a .csv file of the sound pressure recorded with the CEM DT-95 handheld sonometer using a mobile app recommended by the device manufacturer. The data is recorded according to the time of recording, and also, as with the RMC recorder, the data can then be exported to a program such as Excel.
Speed range: 200÷955 rpm
Maximum torque: 22 Nm.

al. Powstańców Warszawy 8, 35-959 Rzeszów
phone: 17 743 2574
e-mail: m.gontarz@prz.edu.pl
kkm.prz.edu.pl

Department Chair:
Professor Grzegorz Budzik, BEng, PhD, DSc, Prof.Tit.
phone: +48 17 865 1986
e-mail: gbudzik@prz.edu.pl

Department of Mechanical Engineering

Numerical and experimental analyses of the manufacture of new varieties of plastically shaped joints

The stand, i.e. the press of Tox Pressotechnik company, is equipped with sets of tools for the manufacture of joints, as well as their certain modifications. For the purposes of the laboratory's activities, in-house tools have been designed and manufactured, which are used for optimization studies of the joint manufacturing process, taking into account the strength of joints and reduction of energy consumption of the joint forming process. The obtained connectors are analyzed from the point of view of increasing their shear and tensile strength, as well as in a complex loading condition. The most common loading case for these joints is at least a biaxial loading condition. Hence, testing of the load capacity of the joints is carried out using a proprietary instrument design that allows the angle of load action to be changed so that a state is generated with shear and rupture forces acting on the joint. The team dealing with this subject conducted within the framework of the statutory activities of the Department has to its credit several patent applications on modern methods of joining sheet metal. New ones are being developed for application to the Polish Patent Office. The laboratory's activities have also allowed students to complete theses, postdoctoral theses, and doctoral dissertations. In addition, one implementation of the technology of holeless riveted connections in industry has been carried out.

Methods and techniques:

- clinching
- clinchriveting
- self piercing-riveting
- solid self piercing-riveting

Apparatus available:

- A press from Tox Pressotechnik with a maximum pressing force of 100 KN, equipped with a measuring system for the displacement of the working punch and the pressing force. The whole thing is controlled by a dedicated program for press operation.
- an instrument for testing the strength in the biaxial load condition of the joints,
- a set of a dozen - dies for forming holeless riveted joints,
- a set of punches and dies for forming direct-punched joints,
- tool head and die for forming an overstamped joint with an additional rivet (clinchriveting),
- tool head for forming riveted joints without a hole,
- micrometer digital measuring sensor for checking the thickness of the bottom of the embossing,
- an instrument for testing the strength of joints under biaxial load condition.

al. Powstańców Warszawy 8, 35-959 Rzeszów
phone: 17 865 1636
e-mail: j_mucha@prz.edu.pl
kkm.prz.edu.pl

Department Chair:
Professor Grzegorz Budzik, BEng, PhD, DSc, Prof.Tit.
phone: +48 17 865 1986
e-mail: gbudzik@prz.edu.pl

Department of Mechanical Engineering

Methods and techniques:

- PolyJet method involves applying a layer of polymer from the print head , which is cured by UV light emitted from a lamp integrated with the print head.During the construction of the model, two materials are applied to the working platform, i.e. the model and the structure supporting the model.

Apparatus available:

- 3D printer OBJECT-350 Connex

Standard compliance tests:

- PN-EN ISO 527-2:2012
- PN-EN ISO 178:2019-06
- PN/EN ISO 17296-3:2016-10

Research related to 3D printing

Research characteristics:

- study of manufacturing parameters
- material testing
- strength testing of polymeric materials
- fatigue testing of plastic gears
- testing the accuracy of mapping the geometry of made models
- testing the possibility of combining polymeric materials with different properties

Static tensile test is carried out in accordance with the current standard PN/EN ISO 527-2:2012 entitled. "Plastics. Determination of mechanical properties in static tension". Determination of strength properties in 3-point bending test is performed in accordance with PN/EN ISO 178:2019-06 "Plastics. "Plastics. Determination of bending properties". Testing of parts produced using incremental manufacturing technology is performed in accordance with PN/EN ISO 17296-3:2016-10 titled "Incremental manufacturing - Principles for the determination of bending properties". "Incremental manufacturing - General principles - Part 3. Main features and corresponding test methods".

al. Powstańców Warszawy 8, 35-959 Rzeszów
phone: +48 17 865 1260
e-mail: lprzeszl@prz.edu.pl
kkm.prz.edu.pl

Department Chair:
Professor Grzegorz Budzik, BEng, PhD, DSc, Prof.Tit.
phone: +48 17 865 1986
e-mail: gbudzik@prz.edu.pl

Department of Mechanical Engineering

Methods and techniques:

- Direct Metal Laser Sintering (DMLS) method
- A process in which a laser beam selectively melts layers of metal powder.

Apparatus available:

- EOSINT M270 3D printer

Standard compliance tests:

- ISO/ASTM 52911-1:2019
- PN/EN ISO/ASTM 52909:2021

Research related to 3D printing

Research characteristics:

- testing of manufacturing parameters
- material testing
- strength testing of metal powder materials
- fatigue testing of gears made of metal powders
- testing the accuracy of mapping the geometry of made models

Determination of the characteristics of laser melting of metals in a powder bed is performed in accordance with the current ISO/ASTM 52911-1:2019 "Incremental manufacturing-Design-Part 1. Melting of metal powders by laser". Tensile and bend tests, as well as quantitative and qualitative tests that determine the quality and accuracy of incremental manufacturing systems, are performed in accordance with the current standard PN/EN ISO/ASTM 52909:2021, entitled "Tensile and bend tests. "Incremental manufacturing-Guidance for assessing the geometric accuracy of incremental manufacturing systems".

al. Powstańców Warszawy 8, 35-959 Rzeszów
phone: +48 17 865 1260
e-mail: lprzeszl@prz.edu.pl
kkm.prz.edu.pl

Department Chair:
Professor Grzegorz Budzik, BEng, PhD, DSc, Prof.Tit.
phone: +48 17 865 1986
e-mail: gbudzik@prz.edu.pl

Methods and techniques:

- Fused Deposition Modeling (FDM) method
- A process involving extrusion of a thermoplastic material into a fiber (thread) , layered according to a numerically determined path.

Apparatus available:

- STRATASYS F170 3D printer

Standard compliance tests:

- PN-EN ISO 527-2:2012
- PN-EN ISO 178:2019-06
- PN/EN ISO 17296-3:2016-10

Research related to 3D printing

Research characteristics:

- study of manufacturing parameters
- material testing
- strength testing of polymeric materials
- fatigue testing of plastic gears
- testing the accuracy of mapping the geometry of made models

Static tensile test is carried out in accordance with the current standard PN/EN ISO 527-2:2012 entitled. "Plastics. Determination of mechanical properties in static tension". Testing of strength properties in 3-point bending test is performed in accordance with PN/EN ISO 178:2019-06 entitled. "Plastics. Determination of bending properties". Testing of parts produced using incremental manufacturing technology is performed in accordance with PN/EN ISO 17296-3:2016-10 titled "Incremental manufacturing - Principles for the determination of bending properties". "Incremental manufacturing - General principles - Part 3. Main features and corresponding test methods".

al. Powstańców Warszawy 8, 35-959 Rzeszów
phone: +48 17 865 1635
e-mail: lkochman@prz.edu.pl
kkm.prz.edu.pl

Department Chair:
Professor Grzegorz Budzik, BEng, PhD, DSc, Prof.Tit.
phone: +48 17 865 1986
e-mail: gbudzik@prz.edu.pl

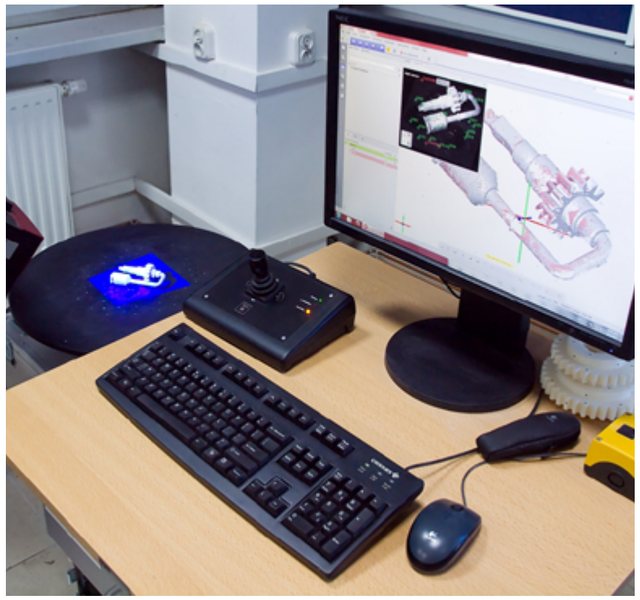
Department of Mechanical Engineering

Methods and techniques:

- optical scanning conducted using structured light

Apparatus available:

- Atos II Triple Scan optical scanner



Shape-dimensional analyses based on measurement data obtained using a 3D optical scanner

Research characteristics:
The equipment on the laboratory's equipment is mainly used in research and development work in the field of coordinate measurement, aimed at determining the accuracy of machine components, including measurements of gears and aircraft engine blades. The Atos II Triple Scan optical measurement system, along with Gom Inspect software, makes it possible to verify the accuracy of workpiece geometry and conduct reverse engineering processes based on the measurement data obtained. The GOM system with GOM Inspect software handles tasks such as 3D printing, 3D part models and reverse engineering. The Atos II Triple Scan projection unit is based on Blue Light technology. Since the sensor uses narrow-band blue light, interfering ambient light can be filtered out during image acquisition. With a powerful light source, short measurement times can be achieved. Based on the high-quality data obtained in a short time and advanced grid editing functions, it makes it easier to exchange data, create precise 3D models or develop new products.

al. Powstańców Warszawy 8, 35-959 Rzeszów
phone: +48 17 865 1662
e-mail: tdziubek@prz.edu.pl
kkm.prz.edu.pl

Department Chair:
Professor Grzegorz Budzik, BEng, PhD, DSc, Prof.Tit.
phone: +48 17 865 1986
e-mail: gbudzik@prz.edu.pl

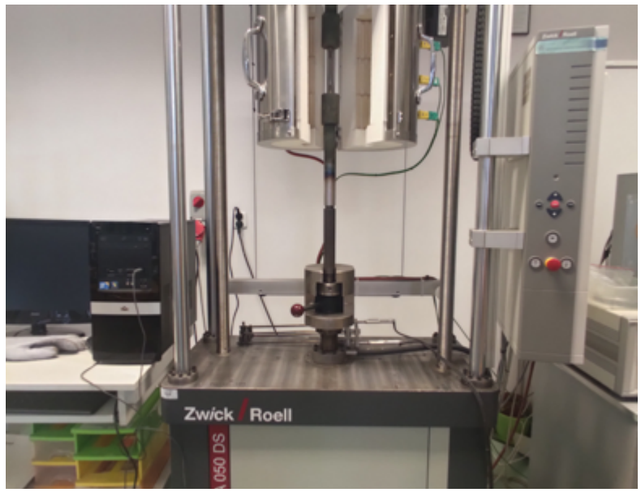
Department of Materials Science
Laboratory of Materials Testing for Aerospace Industry

Apparatus available:

- Instron 5982 testing machine (2 pcs.);
- Zwick Kappa 050 DS testing machine;
- Zwick Kappa 050 LA gravity (weight) testing machine;
- Walter+Bai AG LFMZ-30kN testing machine (2 pcs.);

Standard compliance tests:

- PN-EN ISO 204
- ASTM E139



Creep test of metal alloys

Creep test under uniaxial tension of specimens with circular cross-section with continuous strain measurement with an extensometer, at temperatures up to 760°C;

Determinable quantities:
- time to failure (A),
- Time to achieve the specified relative creep strain (A),
- percent elongation after rupture (A),
- percent creep elongation (A),
- percent sectional constriction (A).

Stress rupture time incandescence test under uniaxial tension of specimens with circular cross-section at temperatures up to 1200°C;

Determined quantities:

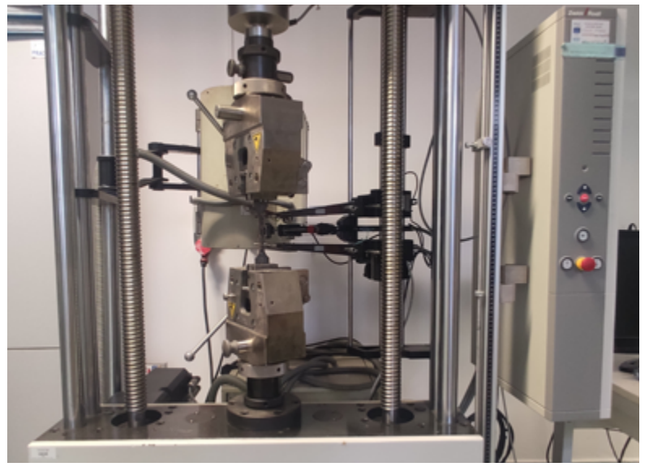
- time to failure (A),
- percent elongation after rupture (A),
- percent constriction of cross section (A).

(A) - measurement covered by PCA accreditation (AB 1283).

ul. Żwirki i Wigury 4
phone: +48 17 743 2414
e-mail: labmat@prz.edu.pl
labmat.w.prz.edu.pl

Department Chair:
Marcin Drajewicz, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 743 24 14
e-mail: labmat@prz.edu.pl

Department of Materials Science
Laboratory of Materials Testing for Aerospace Industry



Static tensile testing of metal alloys

Static uniaxial tensile test of flat or circular cross-section specimens at room or elevated temperature (up to 1200°C);

Determinable quantities:
- clear or conventional yield strength (A),
- tensile strength (A),
- percent elongation after rupture (A),
- percent constriction of section (A),
- the consolidation exponent,
- plastic anisotropy coefficients of flat products (at room temperature).

(A) - measurement covered by PCA accreditation (AB 1283).

Apparatus available:

- Instron 8801 testing machine;
- Zwick UTS 100 testing machine;
- Instron 5982 testing machine (2 pcs.);
- Zwick Kappa 050 DS testing machine;
- Galdabini Quasar 600 testing machine;

Standard compliance tests:

- PN-EN ISO 6892-1
- PN-EN ISO 6892-2
- ASTM E8/E8M
- ASTM E21

ul. Żwirki i Wigury 4
phone: +48 17 743 2414
e-mail: labmat@prz.edu.pl
labmat.w.prz.edu.pl

Department Chair:
Marcin Drajewicz, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 743 24 14
e-mail: labmat@prz.edu.pl

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Laboratory of Materials Testing for Aerospace Industry

Methods and techniques:

- Brinell method
- Rockwell method
- Vickers method

Apparatus available:

- Zwick Universal hardness tester BTC-ZHU250.001

Standard compliance tests:

- PN-EN ISO 6506-1
- ASTM E10
- PN-EN ISO 6507-1
- PN-EN ISO 6508-1
- ASTM E18

Hardness measurement of metal alloys

Brinell method
- HBW 2,5/62,5 (A)
- HBW 2,5/187,5
- HBW 5/250 (A)

Vickers method:
- HV10 (A)
- HV30
- HV50

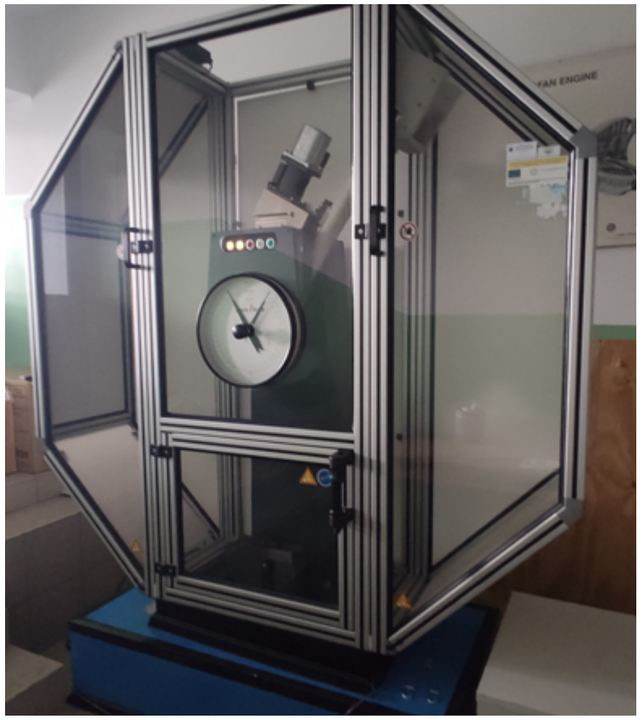
Rockwell method:
- HRA
- HRBW (A)
- HRC (A)
- HREW
- HR15N
- HR15TW

(A) - PCA-accredited measurement (AB 1283)

ul. Żwirki i Wigury 4, 35-959 Rzeszów
phone: +48 17 743 2414
e-mail: labmat@prz.edu.pl
labmat.w.prz.edu.pl

Department Chair:
Marcin Drajewicz, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 743 24 14
e-mail: labmat@prz.edu.pl

Department of Materials Science
Laboratory of Materials Testing for Aerospace Industry



Methods and techniques:

- Charpy method

Apparatus available:

- Impact hammer Zwick/ Roell RA 342038205

Standard compliance tests:

- PN-EN ISO 148-1
- PN-EN 10045-1:1994

Impact testing of metal alloys

Measurement of fracture energy of standardized U- or V-notched specimens made of metal alloys at room temperature (A) and reduced temperature (down to -25°C);

Standard specimens of 10 x 10 x 55 mm or reduced width (7.5; 5.0 or 2.5 mm) with U or V notch

Nominal initial energy of the hammer: 300 J

Ability to make test specimens from entrusted material.

(A) - measurement covered by PCA accreditation (AB 1283)

ul. Żwirki i Wigury 4
phone: +48 17 743 2414
e-mail: labmat@prz.edu.pl
labmat.w.prz.edu.pl

Department Chair:
Marcin Drajewicz, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 743 24 14
e-mail: labmat@prz.edu.pl

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Apparatus available:

- Instron 8801 testing machine (hydraulic);
- Rumul CRACKTRONIC resonance fatigue machine

Standard compliance tests:

- ASTM E606/E606M
- ASTM E466
- ASTM E647

Fatigue testing of metal alloys

Low-cycle and high-cycle fatigue tests in uniaxial tension-compression of cylindrical or flat specimens at room temperature:

- load variation frequency: 0.1-100 Hz,
- maximum tensile load: 100 kN.

High-cycle fatigue test at room temperature under unilateral tension, torsion or bending conditions

- Frequency of load changes: 40-300 Hz;
- maximum tensile load: 8 kN
- maximum bending or torsional moment: 160 Nm;
- rectangular specimens with maximum dimensions: 12 x 24 x 120 mm (bending test)
- cylindrical specimens with a perpendicular section of maximum cross-section: 12 x 12 mm

Fatigue crack propagation test in unilateral tension at room temperature (mini-compact specimen);

- maximum tensile load: 8 kN
- maximum bending or torsional moment: 160 Nm;
- rectangular specimens with maximum dimensions: 12 x 24 x 120 mm (bending test)
- cylindrical specimens with a perpendicular section of maximum cross-section: 12 x 12 mm

ul. Żwirki i Wigury 4
phone: +48 17 743 2414
e-mail: labmat@prz.edu.pl
labmat.w.prz.edu.pl

Department Chair:
Marcin Drajewicz, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 743 24 14
e-mail: labmat@prz.edu.pl

Department of Materials Science
Laboratory of Materials Testing for Aerospace Industry

Climate testing

The device allows for climate testing.

Technical specifications of the unit:

- chamber dimensions: 1200x1000x1000 mm,
- temperature range: -75 to +180ºC,
- humidity range: 10 to 98%,
- temperature change rate: 10ºC/min

Apparatus available:

- climate chamber Angelantoni ANYVIB 1200-5

ul. Żwirki i Wigury 4
phone: +48 17 743 2414
e-mail: labmat@prz.edu.pl
labmat.w.prz.edu.pl

Department Chair:
Marcin Drajewicz, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 743 24 14
e-mail: labmat@prz.edu.pl

Apparatus available:

- Spin tester B13U

Testing the centrifugal force of gas turbine discs

The device allows for conducting spinning tests on rotating components/ gas turbine disks.

Technical parameters of the device:

- max. disk diameter: 350 mm,
- max. mass of the tested object: 50 kg,
- max. rotational speed: 125,000 rpm,
- max. temperature: 600 ºC

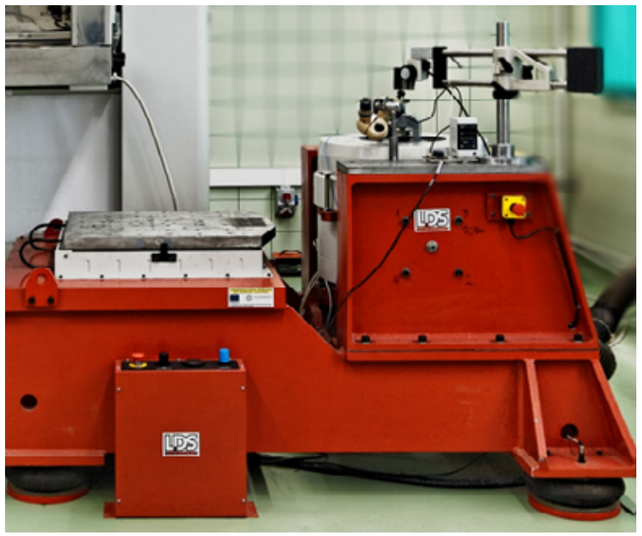
ul. Żwirki i Wigury 4
phone: +48 17 743 2414
e-mail: labmat@prz.edu.pl
labmat.w.prz.edu.pl

Department Chair:
Marcin Drajewicz, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 743 24 14
e-mail: labmat@prz.edu.pl

Department of Materials Science
Laboratory of Materials Testing
for Aerospace Industry

Apparatus available:

- Electrodynamic shaker LDS V-830 with sliding table



High-cycle fatigue tests

The device allows high-cycle fatigue tests to be carried out.

Technical specifications of the device:

- max. sinusoidal cycle force 6.78 kN,
- max. random cycle force 5.77 kN,
- max. frequency 3500 Hz,
- max. head displacement ±25.4 mm,
- maximum test object mass: 160 kg,

ul. Żwirki i Wigury 4
phone: +48 17 743 2414
e-mail: labmat@prz.edu.pl
labmat.w.prz.edu.pl

Department Chair:
Marcin Drajewicz, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 743 24 14
e-mail: labmat@prz.edu.pl

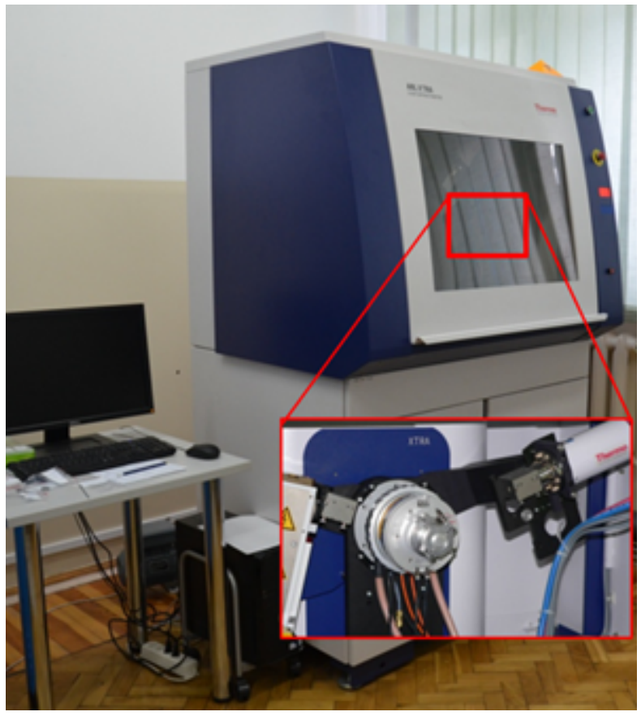
Department of Materials Science
Laboratory of Materials Testing for Aerospace Industry

Methods and techniques:

- phase composition analysis (qualitative and quantitative) of crystalline materials
- qualitative and quantitative analysis of the phase composition of solid materials at room temperature

Apparatus available:

- X-ray diffractometer XTRa ARL
- Rigaku MiniFlexII X-ray diffractometer



Phase composition analysis of crystalline materials

XTRa ARL X-ray diffractometer: this device allows for phase composition analysis (qualitative and quantitative) of crystalline materials. The diffractometer is equipped with a copper anode X-ray tube. Phase composition analysis is performed using a database issued by The International Centre for Diffraction Data (ICDD).

Rigaku MiniFlexII X-ray diffractometer: qualitative and quantitative analysis of the phase composition of solid materials at room temperature. The radiation source is a copper anode with a measuring range θ = 0 - 140° in Bragg-Brentano θ/2θ geometry.

ul. Żwirki i Wigury 4
phone: +48 17 743 2414
e-mail: labmat@prz.edu.pl
labmat.w.prz.edu.pl

Department Chair:
Marcin Drajewicz, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 743 24 14
e-mail: labmat@prz.edu.pl

Department of Materials Science
Laboratory of Materials Testing for Aerospace Industry

Methods and techniques:

- analysis of the oxygen, nitrogen and hydrogen content of solid materials according to the scheme

Apparatus available:

- LECO TCH 600

Analysis of oxygen, nitrogen, and hydrogen content in solid materials according to the provided procedure

The device enables analysis of oxygen, nitrogen, and hydrogen content in solid materials according to the provided procedure, using certified calibration standards for steel, nickel-, cobalt-, and iron-based superalloys, as well as titanium, aluminum, and copper alloys.

ul. Żwirki i Wigury 4
phone: +48 17 743 2414
e-mail: labmat@prz.edu.pl
labmat.w.prz.edu.pl

Department Chair:
Marcin Drajewicz, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 743 24 14
e-mail: labmat@prz.edu.pl

Department of Materials Science
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Methods and techniques:

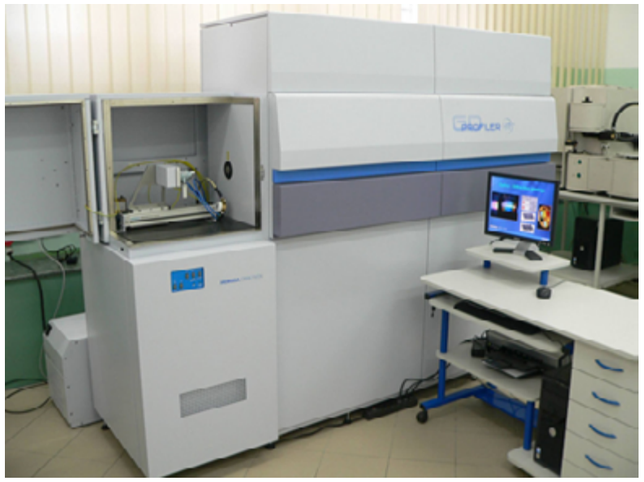
- Determination of the chemical composition of the tested samples using a standard method
- Determination of changes in the concentration of elements as a function of distance from the surface of the tested material
- Identification of elements present in the tested material (full optical spectrum)

Apparatus available:

- GDS GD PROFILER HR

Standard compliance tests:

- PB_P2_01
- PB_P2_02



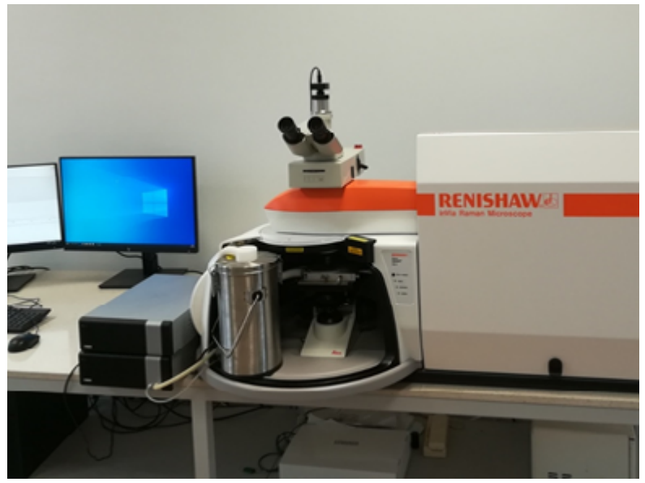
Analysis of the chemical composition, type and elemental content of conductive and non-conductive materials

The device enables analysis of the chemical composition, type and elemental content of conductive and non-conductive materials; enabling a full analysis of the chemical composition of the diffusive surface layer to a depth of 150 µm.

ul. Żwirki i Wigury 4, 35-959 Rzeszów
phone: +48 17 743 2414
e-mail: labmat@prz.edu.pl
labmat.w.prz.edu.pl

Department Chair:
Marcin Drajewicz, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 743 24 14
e-mail: labmat@prz.edu.pl

Department of Materials Science
Laboratory of Materials Testing for Aerospace Industry



Methods and techniques:

- identification of chemical compounds
- determination of chemical composition of the compound and phase transition temperatures

Apparatus available:

- Renishaw inVia Reflex Raman micro-spectrometer
- Leica DM2700 microscope

Analysis of solids, liquids, solutions, suspensions and powder samples

The device is suitable for analysing solids, liquids, solutions, suspensions and powder samples. The spectrometer is equipped with a Linkam Scientific temperature table that allows measurements in a temperature range from -190 to 600 °C. Raman spectroscopy provides information about the interrelationship of atoms in a molecule, which enables the identification of chemical compounds. The temperature chamber allows temperature-dependent measurements to be carried out, both during heating and cooling of the sample with different rates of temperature change (from 0.1 to 150 K/min) in the range from -190 to 600 °C.

ul. Żwirki i Wigury 4, 35-959 Rzeszów
phone: +48 17 743 2414
e-mail: labmat@prz.edu.pl
labmat.w.prz.edu.pl

Department Chair:
Marcin Drajewicz, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 743 24 14
e-mail: labmat@prz.edu.pl

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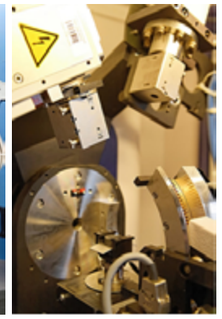
Methods and techniques:

- Evaluation of the structural perfection of nickel superalloy monocrystals using the Ω-scan method
- determination of the full characterisation of the perfection of the crystalline structure in the microcrystalline areas of nickel superalloys

Apparatus available:

- Diffractometer OD-EFG 1
- Diffractometer OD-EFG 2



Evaluation of the perfection of the monocrystal structure and nickel superalloys

The OD-EFG 1 diffractometer allows the evaluation of the perfection of the structure of nickel superalloy single crystals using the Ω-scan method. The OD-EFG 1 diffractometer is additionally equipped with a rotating goniometer and a movable table enabling automatic scanning of the surface of complex-shaped samples. A built-in laser sensor ensures that the distance between the lamp and the detector and the sample surface is constant, with each measuring point at the same distance. The OD-EFG 1 diffractometer is used for the rapid ongoing assessment of the structural perfection of single crystals of nickel superalloys (approx. 7 seconds per measuring point). The in-house X-ray diffractometer OD-EFG 2 is used to evaluate the structural perfection of single crystals of various metals and nickel superalloys in their micro-areas – phase components; γ and γ' crystals. The OD-EFG 2 diffractometer uses a double monochromator to shape the primary beam of radiation and a 2600 W copper anode tube. A smaller X-ray beam diameter of approx. 0.5 mm was achieved than in typical diffractometers, while maintaining a high intensity of this radiation. The basic parameter determining the perfection of the crystal structure is the measurement of the angle α – between the direction of drawing and the direction [001]. The OD-EFG 2 diffractometer can be used to determine the full characteristics of the perfection of the crystalline structure in micro-areas of nickel superalloy single crystals. It can also be used to assess the perfection of the crystalline structure of single crystals of other metals, e.g. gold, silver, silicon and others. The OD-EFG 2 diffractometer is additionally equipped with a rotating goniometer and a movable table enabling automatic scanning of the surface of complex-shaped samples.

ul. Żwirki i Wigury 4, 35-959 Rzeszów
phone: +48 17 743 2414
e-mail: labmat@prz.edu.pl
labmat.w.prz.edu.pl

Department Chair:
Marcin Drajewicz, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 743 24 14
e-mail: labmat@prz.edu.pl

Department of Materials Science
Laboratory of Materials Testing for Aerospace Industry

Methods and techniques:

- quantitative analysis of the chemical composition of test samples by the calibration method

Apparatus available:

- sequential plasma-emission spectrometer ICP ULTIMA 2 HORIBA JOBIN YVON

Qualitative and quantitative analysis of metal alloys

The device enables qualitative and quantitative analysis of metal alloys, including specific trace element and admixture contents in multi-component nickel-cobalt-iron superalloys and standard analysis of industrial water and wastewater.

ul. Żwirki i Wigury 4, 35-959 Rzeszów
phone: +48 17 743 2414
e-mail: labmat@prz.edu.pl
labmat.w.prz.edu.pl

Department Chair:
Marcin Drajewicz, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 743 24 14
e-mail: labmat@prz.edu.pl

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Methods and techniques:

- determination of the chemical composition of tested alloys

Apparatus available:

- ARL 3460

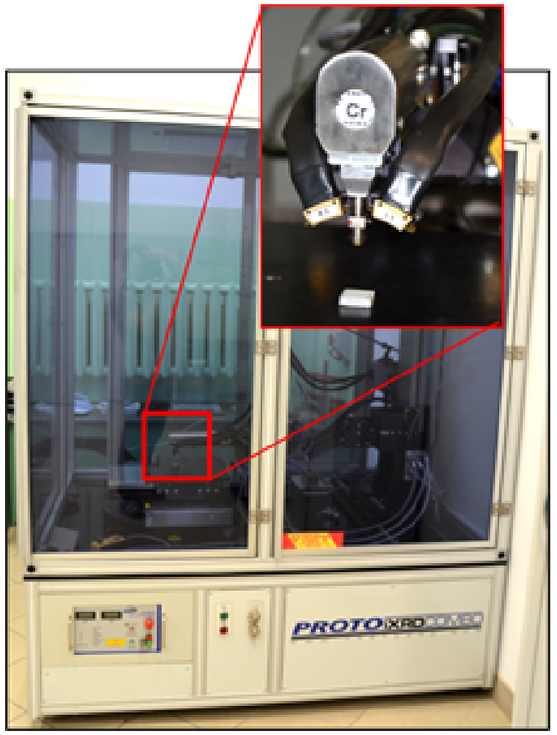
Determination of the chemical composition of iron, aluminium and titanium alloys

The device is equipped with spectrometric lines and standards for determining the chemical composition of iron, aluminium and titanium alloys.

ul. Żwirki i Wigury 4, 35-959 Rzeszów
phone: +48 17 743 2414
e-mail: labmat@prz.edu.pl
labmat.w.prz.edu.pl

Department Chair:
Marcin Drajewicz, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 743 24 14
e-mail: labmat@prz.edu.pl

Department of Materials Science
Laboratory of Materials Testing for Aerospace Industry



Measurement of residual stresses and retained austenite

PROTO iXRD COMBO X-ray diffractometer - determination of residual stresses in the surface layer of metal alloys. It is also possible to determine the relative volume of retained austenite. The sin2Ψ X-ray diffraction method is used to calculate the residual stresses. It is possible to take measurements deep into the material using the electrolytic polishing method.
Basic technical parameters:
types of lamps: Cr, Cu, Mn, Co,
lamp power: 250 W,
Ψ angle range: -45° to +45°.

Methods and techniques:

- X-ray diffraction method sin2Ψ

Apparatus available:

- X-ray diffractometer PROTO iXRD COMBO

Standard compliance tests:

- ASTM E915
- PN-EN 15305:2008
- ASTM E 975-03

ul. Żwirki i Wigury 4, 35-959 Rzeszów
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labmat.w.prz.edu.pl

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Methods and techniques:

- system EDS
- system WDS
- system EBSD

Apparatus available:

- HITACHI S-3400

Observation of the surface of metallic materials

HITACHI S-3400N electron scanning microscope (SEM) – magnification 5x to 100kx – for observation of the surface of metallic materials, with the possibility of observing non-conductive materials (low vacuum) with the EDS and WDS system for chemical composition analysis and EBSD enabling the determination of material texture, crystallographic directions of individual crystals, preparation of crystal orientation maps, identification of phases and determination of phase morphology - microstructure components.

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Analysis of the microstructure of metals, metal alloys, ceramics and composites

Nikon EPIPHOT 300 metallographic microscope – 50x to 1000x magnification – for analysis of the microstructure of metals, metal alloys, ceramics and composites. An automatic stage, a Nikon DS-5 digital camera and software enable measurement, analysis of stereological parameters of the microstructure and their archiving (Lucia programme).

Methods and techniques:

- analysis of microstructures, metal alloys, ceramics and composites

Apparatus available:

- Nikon EPIPHOT 300
- Nikon DS-5 Digital Camera
- Lucia software

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Apparatus available:

- Discotom–6
- Accutom-50
- LaboPress-3
- LaboPol-25
- Tegra Pol–25

Preparation of metallographic samples

The metallographic preparation laboratory is responsible for the preparation of metallographic samples. The equipment used for the preparation of metallographic samples consists of:

- Discotom-6 universal cut-off machine
- Accutom-50 automatic precision cut-off machine
- Struers Epovac vacuum embedding device
- LaboPress-3 automatic hot mounting press
- LaboPol-25 manual grinder/polisher
- Tegra Pol-25 automatic grinder/polisher

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Methods and techniques:

- FE-SEM
- EDS system

Apparatus available:

- Zeiss CrossBeam 350

EDS chemical composition analysis

Zeiss CrossBeam 350 field emission scanning electron microscope (FE--SEM) with detector for EDS chemical composition analysis.

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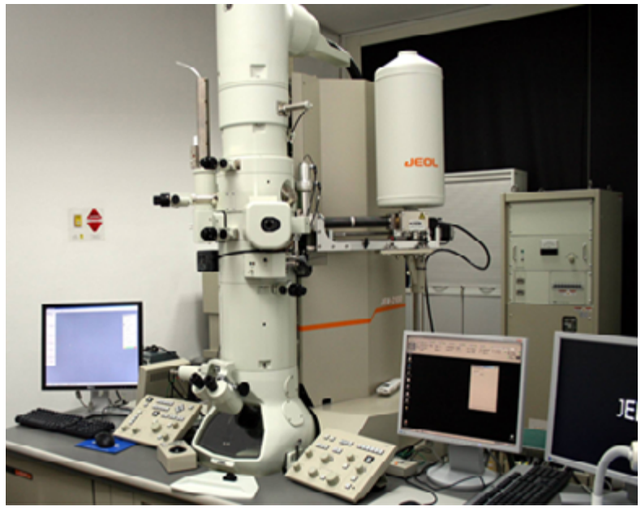
Methods and techniques:

- EDS system

Apparatus available:

- JEOL JEM–2100



JEOL JEM–2100 transmission electron microscope (TEM) – high resolution with 200kV voltage, with EDS system and digital image recording system.

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Methods and techniques:

- Bridgman method
- directional structure

Apparatus available:

- laboratory furnace for the directional crystallization of alloys

Directionally solidified metals and alloys in inert gas

Furnace for directionally solidifying metals and alloys using the Bridgman method in an inert gas atmosphere. Possibility of using a cooling agent (Ga-In-Sn alloy) to increase the temperature gradient or freeze the crystallisation front. Maximum temperature of radiators: 1700°C. Maximum diameter and height of the casting is 10 mm and 100 mm respectively.

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Methods and techniques:

- heat treatment
- annealing of foundry moulds

Apparatus available:

- LINN furnace

Heat treatment, annealing of ceramic moulds

Heat treatment in a protective atmosphere, annealing of ceramic moulds and components made of metal alloys or ceramics in Ar or He atmospheres up to 1300°C.

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Methods and techniques:

- protective atmosphere arc remelting method

Apparatus available:

- arc furnace AM 200

Melting of samples weighing up to approx. 200g at temperatures up to 3500°C

Furnace for melting samples weighing up to approx. 200g at temperatures up to 3500°C. Water-cooled copper crucible plate with universal moulds. Water-cooled, double-walled high-vacuum chamber. Electric drive for easy lifting of the chamber. Motor-driven, water-cooled tungsten electrode, freely movable over the crucibles.

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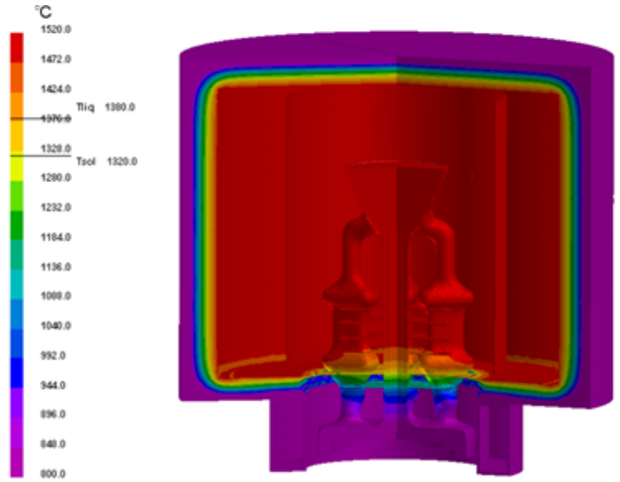
Methods and techniques:

- numerical simulation of casting processes

Apparatus available:

- ProCAST software



Simulation of casting processes

Numerical simulation of casting processes using the commercial ProCAST software. This programme provides numerical simulation of the following processes: filling the mould cavity with liquid metal, directional and volumetric crystallisation of castings. It has the ability to predict the size and shape of grains, their crystallographic orientation and casting defects.

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Methods and techniques:

- method for casting wax models

Apparatus available:

- Autoclave FCR CALDAIE
- IZO electric chamber oven

Melting wax from ceramic moulds

FCR CALDAIE autoclave: Melting wax from ceramic moulds: max. pressure 10 bar, chamber with a volume of 0.84m3 and a diameter of 900 mm.

IZO electric chamber furnace: Firing wax from ceramic moulds at temperatures up to 800°C.

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Methods and techniques:

- method of melting wax models

Apparatus available:

- Ceramic mold mixers
- Fluidized bed powder coaters

Production of ceramic casting moulds

Multilayer ceramic moulds used for the production of castings with polycrystalline or monocrystalline macrostructure made of nickel superalloys and other high-melting alloys. Moulds produced using the fused wax model method - coating wax model kits covered with ceramic mass with ceramic powders - using a ceramic mass mixer and fluidised coating machine. Maximum mould size: diameter 250 mm, height: 450 mm.

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Methods and techniques:

- Bridgman method
- directional, equiaxed and monocrystalline structures

Apparatus available:

- ALD VIMIC 2 E - DS/SC furnace

Production of directional, equiaxed and monocrystalline nickel superalloy castings

Furnace for the production of directional, equiaxed and monocrystalline nickel superalloy castings using the Bridgman process. The melting and production of castings with the required structure can take place in a vacuum or inert gas shield. The temperature of the molten alloy is measured using a type B thermocouple or pyrometer. Temperature measurement with thermocouples (at a maximum of ten points on the castings) is possible during mould filling and alloy crystallisation. Maximum diameter and height of the ceramic mould used during directional crystallisation are 200 mm and 450 mm, respectively. Maximum melting temperature: 1700 °C. Maximum charge quantity: 15 kg.

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Methods and techniques:

- anodising/hard anodising
- fluorescent oxidation

Apparatus available:

- Workstation for the production of protective coatings in anodising and glow discharge oxidation processes

Anodising and fluorescent oxidation

The station includes two 1 m³ tanks (maximum workpiece size 800 mm) for anodising/hard anodising and fluorescent oxidation, equipped with electrolyte cooling systems, a programmable power supply with effective voltage and current values of 550 V and 212 A, and 5 smaller tanks for preparatory and finishing operations. The dimensions of these tanks allow for degreasing, etching, rinsing and possible sealing of elements with a maximum dimension of < 600 mm. The high power of the power supply and the dimensions of the tanks allow for the production of coatings on the basis of real industrial products. The station also includes small tanks with a capacity of 50 and 100 dm3 for the production of protective coatings on a laboratory scale, equipped with 2 programmable power supplies with effective voltage and current values of 500 V and 24 A and 300 V and 10 A.

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labmat.w.prz.edu.pl

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Methods and techniques:

- Glow nitriding

Apparatus available:

- workstation for fluorescent nitriding

Fluorescent nitration

The device allows for the implementation of the process of glow nitriding of steel and other metallic materials, including full control over the structure of the obtained coating (presence of compound and diffusion zones). The size of the chamber is approx. 500x500 mm, which allows for small-batch production.

uul. Żwirki i Wigury 4, 35-959 Rzeszów
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labmat.w.prz.edu.pl

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Methods and techniques:

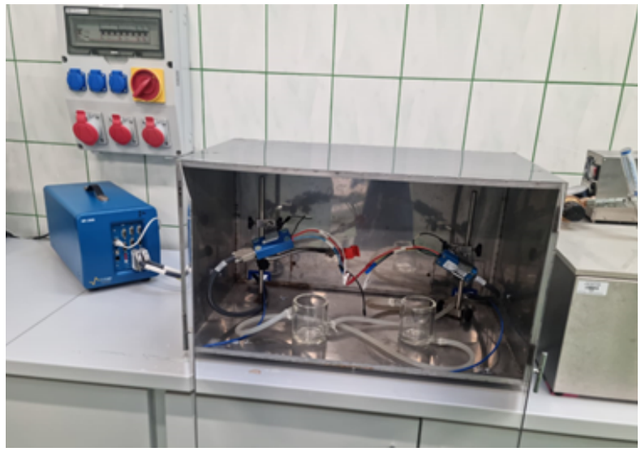
- corrosion testing of metal alloys

Apparatus available:

- workstation for corrosion testing of metal alloys

Standard compliance tests:

- ASTM G28-02
- ASTM G48-03
- ASTM G110-92
- ASTM G59-97
- ASTM G61-86
- ASTM G69-97



Corrosion testing of metal alloys

The station includes a two-channel potentiostat with the necessary equipment (electrochemical cells, auxiliary and reference electrodes, a system for controlling the temperature during tests, a Faraday cage) for determining the corrosion potential of polarisation curves, impedance spectra and conducting other electrochemical tests enabling, among other things, the assessment of the susceptibility of metal alloys to uniform and pitting corrosion. assessing the susceptibility of metal alloys to uniform and pitting corrosion. The available laboratory equipment also allows for assessing the susceptibility of steel to intercrystalline corrosion and aluminium alloys to intercrystalline and laminar corrosion.

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Testing wear resistance under friction conditions

The device is used to assess the abrasion resistance of metallic, ceramic and polymeric materials, including protective coatings produced on a metal substrate, among others. For testing, square samples with dimensions of 100x100 mm or round samples with a diameter of 100 mm and a central hole are used. Abrasive wheels move across the surface of the samples, which are selected depending on the material being tested.

Methods and techniques:

- Taber method

Apparatus available:

- TABER 5135 ABRASER

Standard compliance tests:

- ASTM D4060

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Methods and techniques:

- salt spray corrosion testing

Apparatus available:

- salt/climate chamber SC/KKWT 1000

Standard compliance tests:

- ASTM B117-07a

Salt spray corrosion testing

Device designed for salt spray corrosion testing with neutral pH at temperatures up to 50°C and in an air atmosphere with temperatures up to 60°C and absolute humidity from 20 to 98%. The dimensions of the test chamber are 740/1190 mm in height, 1650 mm in width and 570 mm in depth. The maximum weight of the components to be tested is 150 kg.

ul. Żwirki i Wigury 4, 35-959 Rzeszów
phone: +48 17 743 2414
e-mail: labmat@prz.edu.pl
labmat.w.prz.edu.pl

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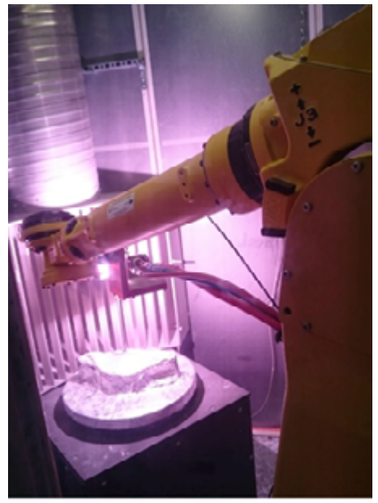

Production of ceramic coatings

The system is equipped with a small spray chamber (approx. 2x2m), a rotary table and an industrial robot. The basic process carried out at the station is atmospheric pressure plasma spraying (APS) using a single-electrode (A60, F4MB) and a three-electrode (Axial III) torch. The control unit and powder feeders are from Thermico. Additionally, there is the possibility of spray plasma suspension (SPS) - GTV feeder. Furthermore, it is possible to use high-pressure supersonic spraying (HP/HVOF) with a JP-5000 burner and conventional HVOF supersonic spraying with a Hipojet 2700 gas burner and flame spraying (6P-II burner).

Methods and techniques:

- atmospheric pressure plasma spraying
- suspension plasma spraying
- high-pressure supersonic spraying (HP/HVOF
- conventional HVOF and flame supersonic spraying

Apparatus available:

- A60 single-electrode burner
- F4MB single-electrode burner
- Axial III three-electrode burner
- Termico powder feeder
- JP-5000 burner
- HipoJet 2700 burner
- 6P-II burner

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Methods and techniques:

- Eddy current method
- magnetic induction method

Apparatus available:

- Fisher DualScope FMP100

Standard compliance tests:

- ASTM B224-07

Determination of coating thickness using the non-destructive testing

The device is used to determine the thickness of protective coatings using the non-destructive eddy current method (paint and conversion coatings on aluminium and magnesium alloy substrates, among others) and magnetic induction (non-magnetic coatings on steel substrates, including paint, zinc, tin, chrome and copper coatings).

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Methods and techniques:

- Production of ceramic coatings
- Plasma-assisted vapour deposition (PS-PVD
- Liquid-phase coating (LLPS-Thin Film)

Apparatus available:

- ALD EB-PVD Smart Coater
- Oerlikon-Metco's LLPS-Hybrid

Production of ceramic coatings

The device enables the production of ceramic coatings with a columnar structure used on the most advanced turbine blades of aircraft engines. The device was developed in cooperation with ALD, among others, to work on new ceramic materials with better performance properties. Small-scale production of blades (3-6 pcs.) is possible. The device enables the production of ceramic coatings with a compact or columnar structure on gas turbine and aircraft engine blades in the process of vapour deposition from the gas phase with evaporation using a plasma torch (PS-PVD) and thin film spraying (LLPS-Thin Film). It also allows for the spraying of metallic coatings, e.g. MCrAlY interlayers, in a conventional low-pressure plasma spraying (LPPS) process. The maximum dimensions of the component are approx. 400x400 mm. Due to the loading chamber, it is possible to carry out processes on a semi-production scale.

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Methods and techniques:

- heat treatment of metals

Apparatus available:

- Vacuum Heat Treatment furnace Mono Therm HK.446.N.20.gr

Heat treatment of nickel superalloys

Single-chamber vacuum furnace used in the heat treatment of nickel superalloys. The furnace is equipped with a heating system with a total power of 80kW. The chamber with a capacity of 3m³ and a working space of 600x400x400 mm is equipped with a set of 9 sheathed thermocouples with the possibility of measuring the temperature with an accuracy of 3°C. The heating process can be carried out by convection up to 950°C (in an atmosphere of argon or helium) or by radiation up to 1350°C (in a vacuum).

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Methods and techniques:

- erosion resistance tests
- corrosion resistance tests

Apparatus available:

- Koehler K93790/HT8 Air Jet Erosion Tester TR-471-800
- Koehler K93700 Air Jet
- Erosion Tester TR-470 GUNT ET 794 gas turbine

Erosion and corrosion resistance tests

Test stand for determining resistance to erosion by particles at ambient temperature. Test bench for determining resistance to erosion (corrosion-erosion) by solid particles at elevated temperatures (up to 800). Heat resistance testing of materials directly in a combustion chamber for gases: propane-butane, methane, etc., possibility of controlling the temperature in the combustion chamber by mounting a thermocouple.

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Methods and techniques:

- Cyclic oxidation
- Heat resistance testing

Apparatus available:

- Nabertherm LHT SN 285910 chamber furnace
- MagmaTherm tube furnace
- Xerion X-Tube thermogravimetric furnace
- Xerion XTube automatic cyclic oxidation furnace

Heat resistance testing of metallic materials and their alloys

Tube and chamber furnaces enabling the heat resistance testing of metallic materials and their alloys: Chamber furnaces: operating temperature range: 500 - 1500 °C in air atmosphere. Tube furnaces: operating temperature range: 500 - 1050 °C in atmospheres: air, air with 20% water vapor content, Ar-XO$_2$, Ar-XO$_2$-20%H$_2$O.

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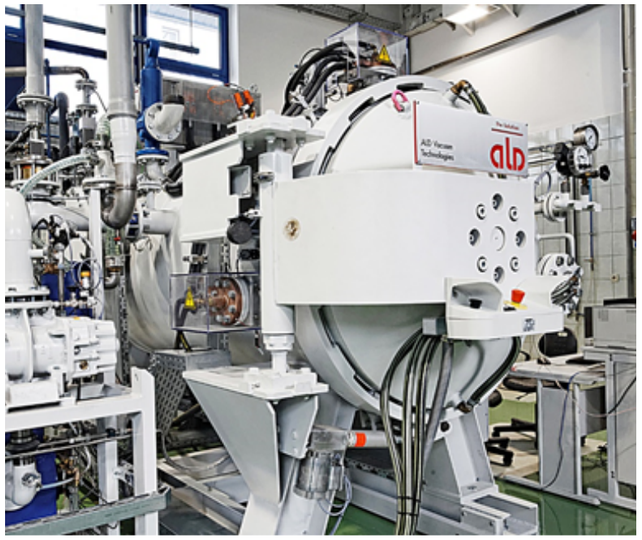

Methods and techniques:

- vacuum carburizing
- vacuum nitriding

Apparatus available:

- Vacuum Heat Treatment Mono Therm HK.446.VC.10.gr furnace

Carburizing, nitriding, and nitrocarburizing processes

Single-chamber vacuum furnace for carburizing, nitriding, and nitrocarburizing using acetylene and ammonia in a nitrogen atmosphere or in vacuum. The furnace is equipped with a heating system with a total power of 80kW. The batch chamber with a capacity of 3m^3 1 and a working space of 600x400x400 mm is equipped with a set of 9 sheathed thermocouples with the possibility of temperature measurement with an accuracy of 2 ±2°C. The heating process can be carried out convectively up to 950°C (in a nitrogen atmosphere) or radiatively up to 1150°C (in vacuum).

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Methods and techniques:

- heat and thermochemical treatment
- CVD coating deposition
- nitriding and boriding processes
- TiN coating deposition

Apparatus available:

- Bernex BPX Pro 325 S CVD system

CVD protective coating deposition

The system enables heat treatment processes in protective atmospheres (argon, nitrogen, etc.) as well as reactive gases (hydrogen). It also allows surface layer modification of iron, nickel, and titanium alloys through thermochemical treatments such as nitriding, carburizing, carbonitriding, boriding, etc. The system is also designed to produce protective coatings on iron and nickel alloy surfaces. Additionally, it facilitates the deposition of abrasion-resistant and heat-resistant coatings based on NiAl phase, through low- and high-activity processes, including those modified with hafnium and zirconium, on nickel-based superalloy substrates.

ul. Żwirki i Wigury 4, 35-959 Rzeszów
phone: +48 17 743 2414
e-mail: labmat@prz.edu.pl
labmat.w.prz.edu.pl

Department Chair:
Marcin Drajewicz, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 743 24 14
e-mail: labmat@prz.edu.pl

Department of Materials Science
Laboratory of Materials Testing
for Aerospace Industry

Methods and techniques:

- thermogravimetric analysis (TGA)
- differential thermal analysis (DTA)
- differential scanning calorimetry (DSC)

Apparatus available:

- STA 449 F1 Jupiter firmy Netzsch

Standard compliance tests:

- ASTM E 1269
- DIN 51 007

Thermal analysis

The equipment enables comprehensive thermal analysis spanning from studies of minerals, inorganic substances, metals and alloys, ceramics, and polymers to pharmaceuticals, food products, and biological materials. It provides detailed assessments of thermal stability, material composition, phase transformations, and decomposition processes. Additionally, the system is equipped with an evolved gas analyzer (EGA), one of the most precise and comprehensive methods for determining thermal properties of organic and inorganic substances, liquids, and solids. This technique facilitates detailed characterization of chemical mechanisms occurring within samples during heating.

ul. Żwirki i Wigury 4, 35-959 Rzeszów
phone: +48 17 743 2414
e-mail: labmat@prz.edu.pl
labmat.w.prz.edu.pl

Department Chair:
Marcin Drajewicz, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 743 24 14
e-mail: labmat@prz.edu.pl

Methods and techniques:

- measurement of physical properties of powder substances

Apparatus available:

- BT-1001 tester

Measurement of angle of repose, flow angle, and flowability indices

Measurements performed using the intelligent BT-1001 tester include the following powder properties: angle of repose, internal friction angle (flow angle), flowability index, fluidity index, etc. The instrument features advanced automation, multifunctionality, user-friendly operation, good repeatability of results, flexible measurement conditions, and compliance with numerous standards. Owing to its well-developed design, the instrument provides precise scientific tools for measuring the physical properties of powder materials.

ul. Żwirki i Wigury 4, 35-959 Rzeszów
phone: +48 17 743 2414
e-mail: labmat@prz.edu.pl
labmat.w.prz.edu.pl

Department Chair:
Marcin Drajewicz, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 743 24 14
e-mail: labmat@prz.edu.pl

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Solid density measurement

The Micromeritics AccuPyc 1330 gas pycnometer enables the measurement of true (absolute) density of solid materials. Measurements are carried out in a helium atmosphere. The use of helium allows for the analysis of porous materials and those with a highly developed surface area. The instrument allows for the analysis of solid, porous, and powdered materials. This is a non-destructive testing method.

The Micromeritics GeoPyc 1360 quasi-liquid pycnometer enables the measurement of bulk (apparent) density of solid materials. The instrument performs precise volume measurements of the sample in a quasi-liquid DryFlo® medium. The GeoPyc 1360 allows for the analysis of solid bodies of various shapes and sizes, including multi-part samples (with dimensions starting from 2 mm). This method is also non-destructive.

Measurements performed using the quasi-liquid pycnometer provide the following sample parameters: bulk (apparent) density, volume, porosity (when the true density value is provided), and bulk density of powders.

Methods and techniques:

- Solid density measurement

Apparatus available:

- Micromeritics AccuPyc 1330 gas pycnometer
- Micromeritics GeoPyc 1360 quasi-liquid pycnometer

ul. Żwirki i Wigury 4, 35-959 Rzeszów
phone: +48 17 743 2414
e-mail: labmat@prz.edu.pl
labmat.w.prz.edu.pl

Department Chair:
Marcin Drajewicz, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 743 24 14
e-mail: labmat@prz.edu.pl

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Methods and techniques:

- measurement of thermal diffusivity, specific heat capacity, and density as a function of temperature

Apparatus available:

- Netzsch LFA 427

Thermal conductivity and thermal diffusivity

This instrument allows for the study of key thermophysical parameters of materials, such as thermal conductivity and thermal diffusivity, which are essential for describing heat transfer phenomena in the analyzed materials. The LFA 427 determines thermal conductivity based on the measurement of thermal diffusivity, specific heat capacity, and density as a function of temperature, followed by the calculation of thermal conductivity from these values. The laser flash method enables contactless measurement of thermal diffusivity using an IR detector. Thermal diffusivity is measured in the range of 0.01–1000 mm²/s, thermal conductivity in the range of 0.1–2000 W/m·K, with a temperature range from 20 to 2000°C. Measurements are carried out in an argon atmosphere. Sample dimensions: cylindrical – diameter 12.6 mm, height from 0.1 to 6 mm; rectangular – cross-section 10 × 10 mm, height from 0.1 to 6 mm. The instrument also allows for the measurement of specific heat capacity.

ul. Żwirki i Wigury 4, 35-959 Rzeszów
phone: +48 17 743 2414
e-mail: labmat@prz.edu.pl
labmat.w.prz.edu.pl

Department Chair:
Marcin Drajewicz, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 743 24 14
e-mail: labmat@prz.edu.pl

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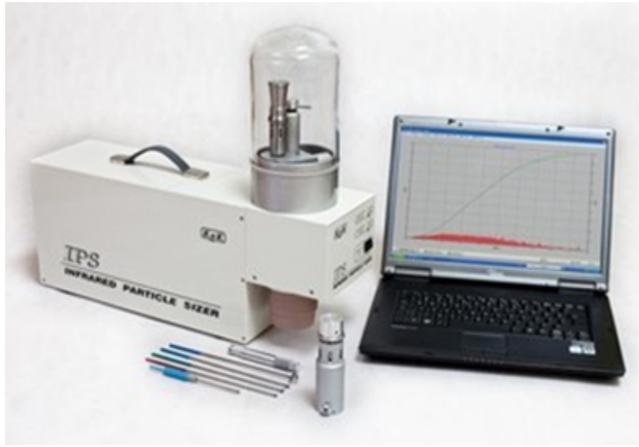

Particle size distribution of solid materials

The IPS U system by KAMIKA is a laboratory device for measuring the particle size distribution of solid materials in air, regardless of their physical and chemical properties. It is used to measure the size of moist and agglomerating particles in the range of 0.5 µm to 600 µm, to determine the second mean particle dimension and shape factor, and to assess the specific surface area of the tested substances.

Methods and techniques:

- determination of shape factor
- determination of specific surface area of tested substances

Apparatus available:

- KAMIKA IPS U system

ul. Żwirki i Wigury 4, 35-959 Rzeszów
phone: +48 17 743 2414
e-mail: labmat@prz.edu.pl
labmat.w.prz.edu.pl

Department Chair:
Marcin Drajewicz, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 743 24 14
e-mail: labmat@prz.edu.pl

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Methods and techniques:

- recording changes in sample length during controlled thermal treatments, identification of the onset and end of phase transformations
- determination of linear thermal expansion coefficients

Apparatus available:

- Netzsch Dil 402C dilatometer

Linear thermal expansion

The Netzsch Dil 402C dilatometer is an instrument used to conduct tests aimed at determining, in metals or their alloys as well as in ceramic and polymer materials, the onset and end of phase transformations based on recorded changes in sample length during controlled thermal treatments, the calculation of linear thermal expansion coefficients, or the identification of processes occurring during various heat treatment procedures by simulating those treatments in the DIL 402C dilatometer under both static and dynamic atmospheres, as well as in vacuum.

ul. Żwirki i Wigury 4, 35-959 Rzeszów
phone: +48 17 743 2414
e-mail: labmat@prz.edu.pl
labmat.w.prz.edu.pl

Department Chair:
Marcin Drajewicz, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 743 24 14
e-mail: labmat@prz.edu.pl

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Deckel Maho DMU 80P machining center

5-axis high-speed machining (HSM) center with a working space of 800/800/800 mm, rotary axes: B (head) and C (table), spindle: n = 18,000 rpm, P = 28 kW, M = 121 Nm, tool magazine: 40 tools, HSK-A63, control system: Sinumerik 840D Powerline, workspace measurement: workpiece and tool, cooling through the spindle, two pressure levels: 4/8 MPa, MQL system, and oil mist extraction system.

Apparatus available:

- Deckel Maho DMU 80P laser

ul. Żwirki i Wigury 4, 35-959 Rzeszów
phone: +48 17 743 2414
e-mail: labmat@prz.edu.pl
labmat.w.prz.edu.pl

Department Chair:
Marcin Drajewicz, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 743 24 14
e-mail: labmat@prz.edu.pl

Department of Materials Science
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Methods and techniques:

- cutting force measurement

Apparatus available:

- Kistler 9123CXX11

Cutting force measurement

Measurement of the components of cutting force in three axes; operation at a maximum spindle speed of 10,000 rpm; maximum tool diameter: 18 mm.

ul. Żwirki i Wigury 4, 35-959 Rzeszów
phone: +48 17 743 2414
e-mail: labmat@prz.edu.pl
labmat.w.prz.edu.pl

Department Chair:
Marcin Drajewicz, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 743 24 14
e-mail: labmat@prz.edu.pl

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Measurement of cutting force components

Measurement of cutting force components in three axes, maximum force: 5 kN, using CutPRO software for force measurement, visualization, analysis, and data archiving, including machine tool stiffness analysis and cutting process simulation.

Methods and techniques:

- cutting force measurement

Apparatus available:

- Kistler 9257BA

ul. Żwirki i Wigury 4, 35-959 Rzeszów
phone: +48 17 743 2414
e-mail: labmat@prz.edu.pl
labmat.w.prz.edu.pl

Department Chair:
Marcin Drajewicz, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 743 24 14
e-mail: labmat@prz.edu.pl

Methods and techniques:

- surface roughness measurement

Apparatus available:

- Mahr S2

Measurement of machined surface roughness

Mahr S2 profilometer.

Department of Materials Science
Laboratory of Materials Testing
for Aerospace Industry

Presetting and measurement of tools

Tool presetting and measurement outside the machine workspace; the manual spindle ensures high measurement accuracy. Haimer Td1002 balancing unit for rotating tools – automatic tool clamping, spindle speed range: 300–1100 rpm, power: 0.4 kW, maximum tool length: 360 mm, maximum tool diameter: 340 mm, maximum tool weight: 30 kg.

Apparatus available:

- Microset ECO210

ul. Żwirki i Wigury 4, 35-959 Rzeszów
phone: +48 17 743 2414
e-mail: labmat@prz.edu.pl
labmat.w.prz.edu.pl

Department Chair:
Marcin Drajewicz, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 743 24 14
e-mail: labmat@prz.edu.pl

Department of Materials Science
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Apparatus available:

- MAG VDF 220 CD machining center
- TruDiode 3006

MAG VDF 220 CD machine tool

The TruDiode 3006 laser unit by Trumpf features an output power of 3 kW and a wavelength range of 900–1030 nm. The use of variable wavelengths in the laser beam enhances the heating efficiency of materials with low radiation absorption and high thermal conductivity. The laser head, equipped with an optical system and nozzle, is mounted on the milling head of the machine tool, allowing it to move along the X, Y, and Z axes independently of the tool support movement. Additionally, the machine tool is equipped with a cryogenic cooling system. The simultaneous application of laser-based surface heating and cryogenic cooling of the cutting insert with liquid nitrogen or carbon dioxide contributes to extended tool life and increased process efficiency.

ul. Żwirki i Wigury 4, 35-959 Rzeszów
phone: +48 17 743 2414
e-mail: labmat@prz.edu.pl
labmat.w.prz.edu.pl

Department Chair:
Marcin Drajewicz, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 743 24 14
e-mail: labmat@prz.edu.pl

Department of Materials Science
Laboratory of Materials Testing for Aerospace Industry

Methods and techniques:

- laser beam cladding and welding

Apparatus available:

- TRUMPF TruLaser Cell 3008
- TruDisk 1000 laser
- TruPulse 203
- GTV PF2/1 powder feeder

Laser processing

The workstation is equipped with:

- TRUMPF TruLaser Cell 3008 system,
- TruDisk 1000 laser
- TruPulse 203,
- GTV PF2/1 powder feeder

It is intended for powder-based laser cladding as well as welding and cutting of thin sheet metal.

ul. Żwirki i Wigury 4, 35-959 Rzeszów
phone: +48 17 743 2414
e-mail: labmat@prz.edu.pl
labmat.w.prz.edu.pl

Department Chair:
Marcin Drajewicz, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 743 24 14
e-mail: labmat@prz.edu.pl

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Laboratory of Materials Testing for Aerospace Industry

Apparatus available:

- NEF 600 CNC lathe

NEF 600 CNC lathe

Working area: maximum turning diameter 600 mm, longitudinal travel 1250 mm, main drive: P = 18 kW, n = 3000 rpm, M = 615 Nm, number of tool stations: 8, control system: GE Fanuc 210i, tool holder: VDI 40, complete set of Sandvik tools.

ul. Żwirki i Wigury 4, 35-959 Rzeszów
phone: +48 17 743 2414
e-mail: labmat@prz.edu.pl
labmat.w.prz.edu.pl

Department Chair:
Marcin Drajewicz, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 743 24 14
e-mail: labmat@prz.edu.pl

Department of Casting and Welding

Robotised APS coating station

The scientific and research infrastructure is located in five thematically divided laboratories. The Casting Laboratory is equipped with induction furnaces for melting metals, equipment for controlling the temperature of liquid metal, equipment for testing molding masses, a precision casting set, which allow to develop and analyze the technology of casting production. An important element of this laboratory is a casting process simulation program, which allows to check the correctness of the designed technological concept of the casting manufacturing process. The equipment of the Welding Laboratory allows the development of welding technology and quality control of welded joints (non-destructive testing). It is equipped with equipment for welding by MMA, MIG/MAG methods along with a welding robot and TIG method. A highlight of this laboratory is a robotic station for applying metallic and non-metallic coatings using the APS (Air Plasma Spraying) method, as well as two stations for thermal spraying (powder and wire). The Metallographic Research Laboratory is a fully equipped unit that allows the preparation of metallographic specimens for observation of the microstructure of metals and alloys, using optical microscopy and scanning electron microscopy. It is possible to observe the specimens in the un-etched state and after chemical or electrolytic etching. The Materials Testing Laboratory has an apparatus for measuring macro- and micro-hardness, an apparatus for nanoindentation testing, an apparatus for scratch test (scratch resistance) and a profilometer for assessing surface roughness. The Heat Treatment Laboratory is equipped with electric, resistance furnaces, enabling the development and execution of heat treatment of castings and other machine parts even at temperatures up to 1800oC. It is possible to analyze the kinetics of solid state transformations (phase transformations) using dilatometric tests.

Methods and techniques:

- metallographic studies (analysis of microstructure and chemical composition of metals and alloys)
- testing of material properties.
- testing of functional properties of metals and alloys (abrasion resistance and fatigue strength)
- research on welding technology
- investigations of the technological concept of the casting process
- application of coatings by the APS method
- tests of heat treatment processes.
- studies of phase transformations in the solid state of metals and alloys.

Apparatus available:

- optical microscope
- scanning microscope
- optical emission spectrometer
- Vickers hardness tester
- Vickers micro hardness tester
- nanoindentation tester
- Scratch tester
- high-temperature tribometer
- T8000 stationary profilometer
- plasma spraying device

Standard compliance tests:

- PN-EN ISO 6507-1:2018-05
- ISO 20502
- ISO 4287
- PN-EN ISO 14577-1:2005

ul. Żwirki i Wigury 2, 35-036 Rzeszów
phone: +48 17 743-24-55
e-mail: zois@prz.edu.pl
labmat.w.prz.edu.pl

Department Chair:
Marek Mróz, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1683
e-mail: mfmroz@prz.edu.pl

Department of Casting and Welding
Casting Laboratory

Methods and techniques:

- melting of Fe-C alloys
- melting of non-ferrous metal alloys (Al, Cu alloys)
- cast iron modification treatment
- cast iron spheroidization processmodification of Al-S alloys

Apparatus available:

- induction crucible furnace
- set of crucibles for melting Fe-C and non-ferrous metal alloys
- molten metal temperature measurement system
- chemical composition analyzer (optical emission spectrometer)

Metal and alloy melting unit

Induction crucible furnaces are a modern and cost-effective alternative to electric resistance, gas, and oil-fired furnaces. Their high efficiency enables rapid heating and melting of the charge. The Termetal induction crucible furnace, with a power rating of 30 kW, allows for heating and melting of ferrous and non-ferrous alloys, with a charge capacity of 2 dm^3.

ul. Żwirki i Wigury 2, 35-036 Rzeszów
phone: +48 17 743 2455
e-mail: kois@prz.edu.pl
kois.prz.edu.pl

Lab Coordinator:
Marek Mróz, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1683
e-mail: mfmroz@prz.edu.pl

Department of Casting and Welding
Casting Laboratory

Investment casting system

Investment casting system using the lost wax method by PAT. Castings made with this technique are characterized by precise surface reproduction. It allows for the production of thin-walled castings with various cross-sections. The REDO CAST casting unit is used in the process to pour gypsum molds in a vacuum chamber.

Methods and techniques:

- investment casting (lost wax method)

Apparatus available:

- vulcanizing press
- wax injector
- REDO CAST casting unit
- TG1 melting furnace
- APE800A burnout furnace

ul. Żwirki i Wigury 2, 35-036 Rzeszów
phone: +48 17 743 2455
e-mail: kois@prz.edu.pl
kois.prz.edu.pl

Lab Coordinator:
Marek Mróz, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1683
e-mail: mfmroz@prz.edu.pl

Department of Casting and Welding
Heat Treatment Laboratory

Methods and techniques:

- heat treatment up to 1280°C
- thermochemical treatment: nitriding, carburizing

Apparatus available:

- Nabertherm N 61H resistance furnace

Heat treatment furnace

The Nabertherm N 61H furnace is designed for heat treatment processes at temperatures up to 1280°C. The PID controller allows programming of 9 treatment schemes, each with 20 steps and time delay settings. The heating chamber has a capacity of 61 dm^3 (internal dimensions: 84 × 141 × 132 cm). The N 61H furnace also supports thermochemical treatments such as carburizing and nitriding.

ul. Żwirki i Wigury 2, 35-036 Rzeszów
phone: +48 17 743 2455
e-mail: kois@prz.edu.pl
kois.prz.edu.pl

Lab Coordinator:
Marek Mróz, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1683
e-mail: mfmroz@prz.edu.pl

Department of Casting and Welding
Heat Treatment Laboratory

Dilatometry testing station

The LS 4 dilatometry testing station with computer-based data acquisition enables the analysis of phase transformation kinetics in the solid state for both metallic and non-metallic materials. It also allows for the determination of the linear thermal expansion coefficient. Tests can be conducted under controlled heating and cooling rates within a temperature range of -180 to 1100°C. It is also possible to perform tests under protective atmospheres such as helium or argon. The cooling process can be carried out in various media, including air, water, hartenol, liquid nitrogen, etc.

Methods and techniques:

- phase transformation analysis
- determination of linear thermal expansion coefficient

Apparatus available:

- LS4 dilatometer

ul. Żwirki i Wigury 2, 35-036 Rzeszów
phone: +48 17 743 2455
e-mail: kois@prz.edu.pl
kois.prz.edu.pl

Lab Coordinator:
Marek Mróz, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1683
e-mail: mfmroz@prz.edu.pl

Department of Casting and Welding
Welding Laboratory

Methods and techniques:

- application of metallic and non-metallic coatings using the APS method
- acetylene-oxygen flame spraying using wire
- acetylene-oxygen flame spraying using powder

Apparatus available:

- robotic APS coating system by Sulzer Metco with ABB robot
- CastoDyn DS 8000 torch
- flame spraying torch for wire-based thermal spraying

APS coating workstation

The robotic workstation for thermal spraying using the APS (Air Plasma Spray) method with metallic and non-metallic powders is equipped with a plasma generator from Sulzer Metco. The system includes a powder feeder and a spray gun (model IRB 2400) mounted on a robotic arm by ABB. APS spraying enables the application of dense coatings with a wide range of thicknesses. The METATHERM MDP-115 torch for acetylene--oxygen flame thermal spraying with wire feed features a high-torque motor and electronic control system, ensuring precise wire feeding. It can be used in automated applications for small series as well as in manual spraying. The CastoDyn DS 8000 is a modular acetylene-oxygen torch for thermal spraying, designed for applying a wide range of materials using either cold or hot spraying techniques.

ul. Żwirki i Wigury 2, 35-036 Rzeszów
phone: +48 17 743 2455
e-mail: kois@prz.edu.pl
kois.prz.edu.pl

Lab Coordinator:
Marek Mróz, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1683
e-mail: mfmroz@prz.edu.pl

Department of Casting and Welding
Welding Laboratory

Methods and techniques:

- abrasive blasting surface cleaning

Apparatus available:

- KCW-1200-1150+FCPd2 abrasive blasting system

Abrasive blasting

The abrasive blasting unit is intended for cleaning component surfaces prior to welding processes (resistance welding, arc welding, brazing). It is also used in surface preparation for plasma spray coating (APS). The process involves directing a high-velocity stream of abrasive material onto the surface to be treated. The blasting cabinet is suitable for use with abrasives ranging from 0.1 to 0.8 mm in grain size.

ul. Żwirki i Wigury 2, 35-036 Rzeszów
phone: +48 17 743 2455
e-mail: kois@prz.edu.pl
kois.prz.edu.pl

Lab Coordinator:
Marek Mróz, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1683
e-mail: mfmroz@prz.edu.pl

Department of Casting and Welding
Welding Laboratory

Methods and techniques:

- MIG welding
- MAG welding

Apparatus available:

- MIG/MAG welding unit
- wire feeder
- COMAU robot

Standard compliance tests:

- PN-EN ISO 13916
- PN-EN ISO 1011
- PN-EN ISO 15614

Robotic MIG/MAG welding station

The station is equipped with a MIG/MAG welding unit and a wire feeder from Fronius. The torch is mounted on a Comau SMART NS 16-1.65 ARC robot. The robot can be programmed manually or using the Smartcimstation 5.1 software.

ul. Żwirki i Wigury 2, 35-036 Rzeszów
phone: +48 17 743 2455
e-mail: kois@prz.edu.pl
kois.prz.edu.pl

Lab Coordinator:
Marek Mróz, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1683
e-mail: mfmroz@prz.edu.pl

Department of Casting and Welding
Welding Laboratory

Methods and techniques:

- TIG welding
- TIP-TIG welding

Apparatus available:

- Tetrix 351 ARC DC/AC welding machine
- wire feeder

Standard compliance tests:

- PN-EN ISO 13916
- PN-EN ISO 1011
- PN-EN ISO 15614

Welding equipment

The TIG/TIP-TIG welding station is equipped with a Tetrix 351 ARC DC/AC welder and a wire feeder. The TIP/TIG feeder enables resistive preheating of the wire and allows for adjustment of the wire feed rate. It eliminates the need for manual wire feeding, significantly facilitating weld formation.

ul. Żwirki i Wigury 2, 35-036 Rzeszów
phone: +48 17 743 2455
e-mail: kois@prz.edu.pl
kois.prz.edu.pl

Lab Coordinator:
Marek Mróz, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1683
e-mail: mfmroz@prz.edu.pl

Department of Casting and Welding
Metallographic Research Laboratory

Methods and techniques:

- electro-discharge machining (EDM) of components

Apparatus available:

- BP-95d wire EDM machine

Wire EDM machine

The BP95d wire EDM machine (2-axis) is used for cutting components made of electrically conductive materials (copper, aluminum, steel, sintered alloys, etc.). The cutting process is performed using the electro-erosion method with a wire moving vertically through guides relative to the table. Electrical discharge machining is particularly well suited for cutting precise samples, e.g., specimens for metallographic analysis.

ul. Żwirki i Wigury 2, 35-036 Rzeszów
phone: +48 17 743 2455
e-mail: kois@prz.edu.pl
kois.prz.edu.pl

Lab Coordinator:
Marek Mróz, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1683
e-mail: mfmroz@prz.edu.pl

Department of Casting and Welding
Metallographic Research Laboratory

Metallographic sample preparation laboratory

The metallographic sample preparation laboratory conducts work related to the preparation of specimens for macro- and microstructure observation. The preparation process includes cutting a sample from the tested component, rough polishing, cold mounting in non-conductive epoxy resin or hot mounting in conductive thermosetting resin, grinding with abrasive papers, final polishing, and chemical or electrochemical etching.

Methods and techniques:

- metallographic sample preparation

Apparatus available:

- Struers Labotom-3 cutting machine
- BP-95d wire EDM machine
- D28700 universal cutter
- MLG 11 manual grinder
- ATM Opal 410 mounting press
- ATM Saphir 320E polisher with
- ATM Rubin 500 head
- Metasinex manual polisher
- Monodest 3000E water distillation unit
- ElektroMat ET1 electrolytic etching device

ul. Żwirki i Wigury 2, 35-036 Rzeszów
phone: +48 17 743 2455
e-mail: kois@prz.edu.pl
kois.prz.edu.pl

Lab Coordinator:
Marek Mróz, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1683
e-mail: mfmroz@prz.edu.pl

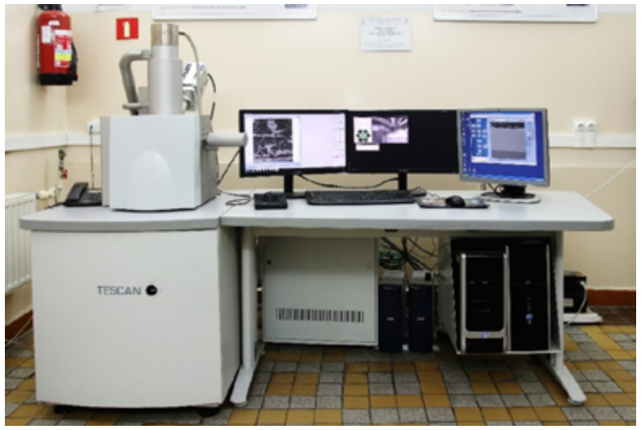
Department of Casting and Welding
Metallographic Research Laboratory

Methods and techniques:

- microstructure analysis using scanning electron microscopy (SEM)
- chemical composition analysis (point, line, surface, mapping, cameo)

Apparatus available:

- VEGA 3 scanning electron microscope
- INCA X-ACT chemical microanalysis system



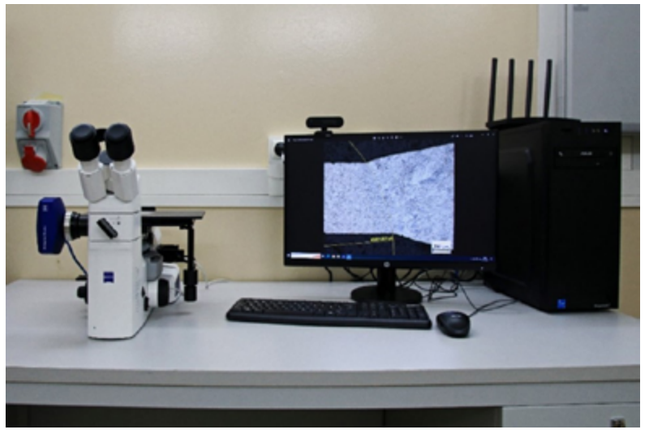
Macro- and microstructure analysis using scanning electron microscopy

The TESCAN VEGA 3 scanning electron microscope (SEM) equipped with SE and BSE detectors, along with the INCA OXFORD X-ACT chemical microanalysis system, enables macro- and microstructural observation of dry materials at magnifications ranging from 5× to 100,000× under high vacuum conditions. The microscope allows the observation of metallic and non-metallic materials using silver or gold sputter coating. The sample stage offers movement along five axes. The X-ray microanalysis attachment provides both qualitative and quantitative assessment of elemental composition at a selected point or within a defined area. Elemental mapping makes it possible to generate spatial distribution maps of elements.

ul. Żwirki i Wigury 2, 35-036 Rzeszów
phone: +48 17 743 2455
e-mail: kois@prz.edu.pl
kois.prz.edu.pl

Lab Coordinator:
Marek Mróz, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1683
e-mail: mfmroz@prz.edu.pl

Department of Casting and Welding
Metallographic Research Laboratory



Macro- and microstructure observation using optical microscopy

The inverted metallographic microscope for materials engineering research is equipped with a digital camera and image analysis software. The microscope enables microstructure observation in bright field, dark field, or polarized light, along with digital image capture and analysis. The observation magnification range spans from 10× to 2000×

Methods and techniques:

- optical microscopy

Apparatus available:

- Carl Zeiss optical microscope
- Makrolite 4 inspection microscope
- Neophot 2 optical microscope

ul. Żwirki i Wigury 2, 35-036 Rzeszów
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kois.prz.edu.pl

Lab Coordinator:
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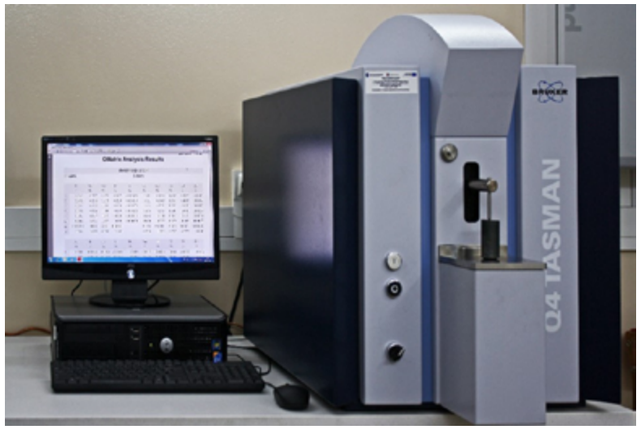
Methods and techniques:

- spectral analysis of the chemical composition of metals and alloys

Apparatus available:

- Bruker Q4 Tasman spectrometer



Chemical composition analysis of metals and alloys

The Bruker Q4 Tasman spectrometer enables chemical composition analysis of samples made from Fe-C alloys, aluminum, copper, nickel, chromium, cobalt, and other alloys, regardless of their form—such as foils, sheets, or wires. The Bruker Q4 Tasman spectrometer is characterized by high repeatability and precision in elemental content measurements, with detection limits for each element at trace levels.

ul. Żwirki i Wigury 2, 35-036 Rzeszów
phone: +48 17 743 2455
e-mail: kois@prz.edu.pl
kois.prz.edu.pl

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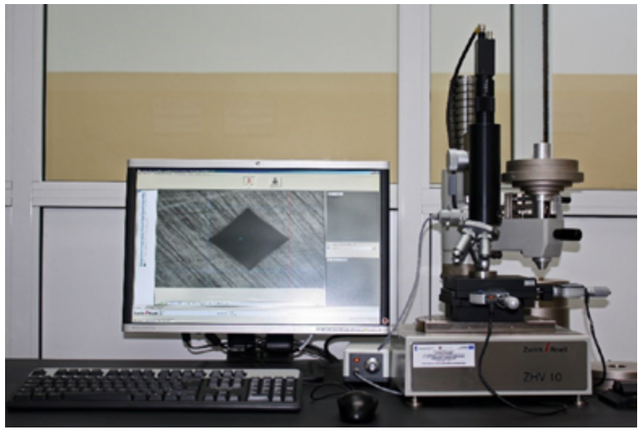

Hardness testing using the Vickers method (HV)

Hardness testing using the Vickers method (HV) is performed in accordance with the PN-EN ISO 6507-1 standard. The test involves assessing the plastic deformation of a material resulting from pressing a diamond indenter into the test surface. Hardness is determined by measuring the diagonals of the resulting square-shaped impression. The Vickers hardness scale is the most widely used method for evaluating material hardness and, combined with the ease of execution, offers high versatility. This method is frequently applied in the hardness testing of welded joints. During testing, a load ranging from 200 to 30,000 g can be applied. Vickers microhardness testing can be performed with loads ranging from 10 to 1000 g.

Methods and techniques:

- hardness testing
- microhardness testing

Apparatus available:

- ZHV10 hardness tester, Zwick/Roell
- ZHVμ Indentec microhardness tester, Zwick/Roell

Standard compliance tests:

- PN-EN ISO 6507-1

ul. Żwirki i Wigury 2, 35-036 Rzeszów
phone: +48 17 743 2455
e-mail: kois@prz.edu.pl
kois.prz.edu.pl

Lab Coordinator:
Marek Mróz, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1683
e-mail: mfmroz@prz.edu.pl

Department of Casting and Welding
Materials Testing Laboratory

Methods and techniques:

- nanoindentation
- nanoscratch

Apparatus available:

- nanoindentation Tester NHT (CSM Instruments)
- nanoscratch tester

Standard compliance tests:

- PN-EN ISO 14577

Material parameter testing (Nanoindentation Test)

The nanoindentation test of microstructural constituents is carried out in accordance with the PN-EN ISO 14577 standard. This method enables the determination of instrumental hardness (HIT), elastic modulus under indenter (EIT), Vickers hardness (HV) during indentation, Young's modulus E [GPa], plastic and elastic work, and permanent deformation. The test uses a Berkovich diamond indenter B-L 32 with a tip angle of 65.3° and a tip radius of 50 nm. It is also possible to assess the scratch resistance of individual phases in the material using the nanoscratch test. For each constituent, parameters such as friction coefficient, acoustic emission, and penetration depth of the indenter can be evaluated.

ul. Żwirki i Wigury 2, 35-036 Rzeszów
phone: +48 17 743 2455
e-mail: kois@prz.edu.pl
kois.prz.edu.pl

Lab Coordinator:
Marek Mróz, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1683
e-mail: mfmroz@prz.edu.pl

Department of Casting and Welding
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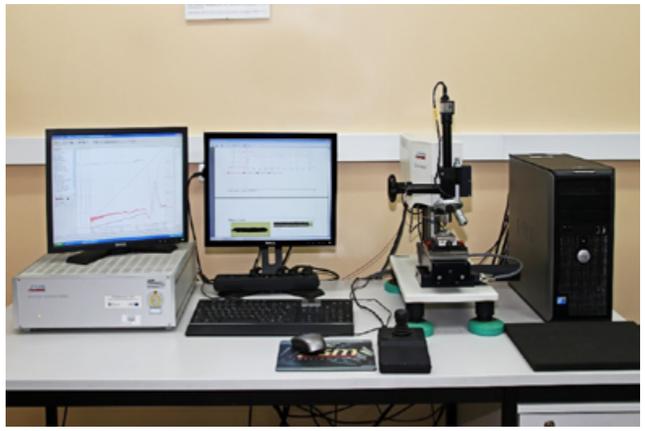

Scratch resistance testing (scratch test)

The Revetest RST Scratch Tester is a system designed for evaluating adhesion, bonding strength, and scratch resistance of materials or coatings. It also allows for Vickers hardness testing and can operate in tribological mode (wear resistance testing) under linear, reciprocating motion. The measurement is performed by dragging a diamond indenter across the sample surface under a specified constant or progressive load, leading to material scratching, delamination, or coating failure. The applied force is continuously monitored via a closed-loop feedback system, enabling testing of curved, inclined, or rough surfaces. The resulting data, combined with scratch trace analysis via an integrated optical microscope, provides insight into the wear behavior of the tested layer. The Revetest allows scratch testing under loads ranging from 1 to 200 N. It supports the assessment of friction force, friction coefficient, penetration depth, and acoustic emission.

Methods and techniques:

- scratch resistance testing (scratch test)
- analysis of material adhesion and cohesion

Apparatus available:

- Scratch Tester Revetest RST (CSM Instruments)

Standard compliance tests:

- ASTM C1624
- ISO 20502
- PN-EN ISO 1071

ul. Żwirki i Wigury 2, 35-036 Rzeszów
phone: +48 17 743 2455
e-mail: kois@prz.edu.pl
kois.prz.edu.pl

Lab Coordinator:
Marek Mróz, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1683
e-mail: mfmroz@prz.edu.pl

Department of Casting and Welding
Materials Testing Laboratory

Methods and techniques:

- roughness profile evaluation surface geometric
- structure analysis

Apparatus available:

- T8000 stationary profilometer
- T1000 portable profilometer

Standard compliance tests:

- IS 21920

Surface geometric structure (SGP) analysis

The Hommel Etamic T8000 profilometer enables the evaluation of roughness profile, surface geometric structure, waviness, and contour. Measurements can be performed in both 2D and 3D modes. Surface topography measurements are supported by a system equipped with a CNC stage, allowing for controlled movement of the tested element along the Y axis. The acquired data is analyzed using advanced Hommel-MapExpert 6.2 software. A portable profilometer allows for roughness and waviness assessment in mobile conditions.

ul. Żwirki i Wigury 2, 35-036 Rzeszów
phone: +48 17 743 2455
e-mail: kois@prz.edu.pl
kois.prz.edu.pl

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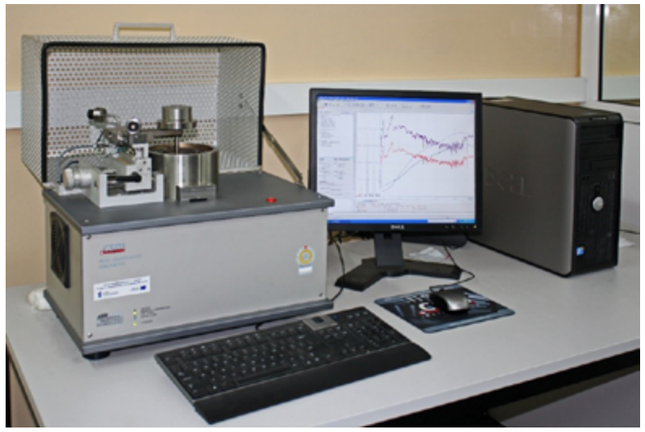

THT high-temperature tribometer

The device enables wear resistance testing under dry and lubricated friction conditions at ambient temperature and up to 800°C. It also allows for the determination of the coefficient of friction.

Methods and techniques:

- determination of the coefficient of friction and abrasive wear of contact surfaces using the Pin-on-Disk and Ball-on-Disk methods

Apparatus available:

- THT high-temperature tribometer (CSM Instruments)

ul. Żwirki i Wigury 2, 35-036 Rzeszów
phone: +48 17 743 2455
e-mail: kois@prz.edu.pl
kois.prz.edu.pl

Lab Coordinator:
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e-mail: mfmroz@prz.edu.pl

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Methods and techniques:

- abrasive wear intensity testing
- coefficient of friction determination

Apparatus available:

- T8000 stationary profilometer
- T1000 portable profilometer

Abrasive wear testing device

A dual-station device for testing abrasive wear intensity and determining the coefficient of friction. Tests can be performed under various linear speed and load conditions.

ul. Żwirki i Wigury 2, 35-036 Rzeszów
phone: +48 17 743 2455
e-mail: kois@prz.edu.pl
kois.prz.edu.pl

Lab Coordinator:
Marek Mróz, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1683
e-mail: mfmroz@prz.edu.pl

Department of Automotive Vehicles and Transport Engineering

Testing and diagnostics of injection systems in internal combustion engines

The scope of injection system testing includes:

- testing and diagnostics of high-pressure pumps lubricated with diesel fuel (CP1, CP1H, CP3) and their components;
- testing and diagnostics of electromagnetic and piezoelectric injectors used in common rail systems;
- testing and diagnostics of rotary and in-line injection pumps and injectors;
- testing and diagnostics of gasoline injectors in both port and direct injection systems, including piezoelectric types

Diagnostics of diesel injection components are performed in accordance with manufacturers' procedures—mainly those of Bosch—with the possibility of testing components from other manufacturers. With the addition of a hydraulic system, testing of compression ignition engine injection components can also be performed using diesel fuel as well as alternative fuels, such as blends of diesel with ethanol, rapeseed oil, or other additives. Gasoline injector testing is conducted through dosage measurement, while for direct injection systems, the delay in needle lift (reaction time) can be measured, and in the case of piezoelectric injectors, stack revitalization can be performed.

Methods and techniques:

- manufacturer diagnostic procedures

Measurement of injection quantity and return flow under various operating conditions of the injection system:

- injection duration: 130–3000 µs,
- injection pressure: 0–180 MPa,
- rotational speed: 50–4000 rpm

Apparatus available:

Bosch EPS-815 test bench equipped with:

- KMA-822 electronic dosage measurement,
- CRS-845 high-pressure pump testing module,
- CRI-846 injector testing module

Gasoline injector testing station equipped with:

- Carbon Zapp GS4.20 low-pressure injector tester,
- Carbon Zapp GDR1 high-pressure injector tester,
- UB-15 ultrasonic cleaner.

al. Powstańców Warszawy 8, 35-959 Rzeszów
phone: +48 17 865 1531
e-mail: austrzyc@prz.edu.pl;
pojazdy.prz.edu.pl

Department Chair:
Paweł Woś, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1355
e-mail: pwos@prz.edu.pl

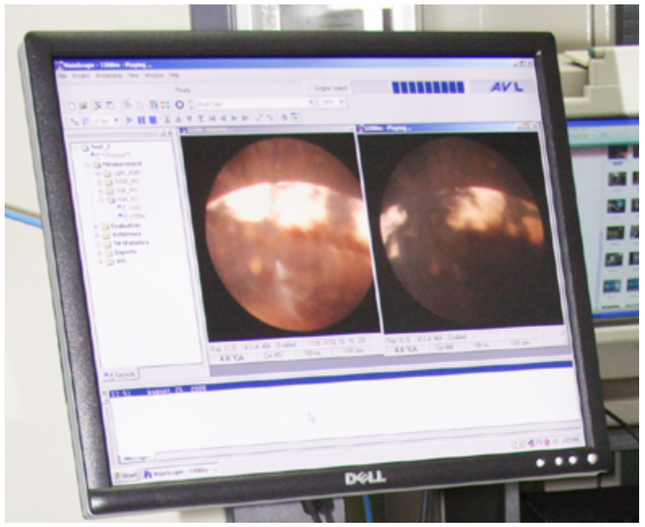
Department of Automotive Vehicles and Transport Engineering

Methods and techniques:

- time-lapse photography of the phenomenon in successive cycles of the tested process
- recording and analysis of rapidly changing signals: injector current, injector voltage, pressure in the injection line, pressure in the accumulator, pressure in the intake manifold

Apparatus available:

- AVL Visioscope
- AVL Indimodul 621
- measurement station for fuel spray development analysis
- AVL MICROIFEM 3 pressure sensor amplifier
- Kistler pressure measurement systems
- AVL 3076 A01 current amplifiers for lift sensors
- Wolff electromagnetic injector needle lift measurement system



Visual analysis of rapidly changing processes in internal combustion engines

The service includes testing of rapidly changing processes occurring in the combustion chamber of the engine, fuel injection processes, valve operation, etc. These processes, if they do not emit light themselves, can be recorded using a light module that illuminates them via a fiber optic source. The recording is performed using time-lapse photography, which allows for high-resolution imaging and process averaging (multiple events are recorded with a defined angular offset in each cycle). For combustion process imaging, a thermal imaging module enables temperature analysis of phenomena occurring in compression ignition engines. Additionally, with the use of supplementary modules, it is possible to record up to 16 parameters such as:

- in-cylinder pressure,
- pressures at various points in the injection system,
- injector needle lift (for selected models),
- valve lifts
- control signals of the injection system.

al. Powstańców Warszawy 8, 35-959 Rzeszów
phone: +48 17 865 1531
e-mail: austrzyc@prz.edu.pl;
pojazdy.prz.edu.pl

Department Chair:
Paweł Woś, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1355
e-mail: pwos@prz.edu.pl

Department of Automotive Vehicles and Transport Engineering

Testing of operational and environmental parameters of internal combustion engines

The service includes testing of operational and environmental parameters of internal combustion engines with power output up to 220 kW and engine speed up to 9500 rpm. Basic measurements cover engine parameters such as:

- rotational speed, torque,
- hourly fuel consumption,
- exhaust gas temperature,
- intake air parameters (temperature, pressure, and humidity).

n terms of environmental performance, the tests include measurement of exhaust gas concentrations of:

- nitrogen oxides (NOx),
- carbon monoxide (CO),
- hydrocarbons (HC),
- carbon dioxide (CO_2),
- oxygen (O_2),
- soot.

Methods and techniques:

Measurement of parameters and development of:

- external characteristics,
- load characteristics,
- smoke limit characteristic,
- general performance characteristic

Apparatus available:

- Dynas2 220 kW dynamometer
- AVL 735S fuel consumption meter
- fuel mass flow rate measurement system: ABB Sensyflow P-Tube,
- exhaust gas analysis system with particulate separator and HC/NOx analyzers Pierburg PTP-2000
- three-channel exhaust gas analyzer Signal Group Multi Gas Analyser,
- soot concentration measurement system for diluted exhaust gases AVL Micro Soot Sensor 483

al. Powstańców Warszawy 8, 35-959 Rzeszów
phone: +48 17 865 1531
e-mail: austrzyc@prz.edu.pl;
pojazdy.prz.edu.pl

Department Chair:
Paweł Woś, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1355
e-mail: pwos@prz.edu.pl

Department of Automotive Vehicles and Transport Engineering

Methods and techniques:

- Testin under various environmental conditions.
- Testing the driver's reaction to damage to vehicle assemblies.
- Testing on different types of vehicles.
- Testing the effects of intoxicants (alcohol, drugs) on driving ability (using alcogoggles).

Apparatus available:

- Truck driving simulator AS 1600
- Alcogoggles: day model A (range 0.4-06 per mille); day model B (range 0.8-1.5 per mille; night model (range 0.6-0.8 per mille); night model (range 1-1.7 per mille); and NARKOgoggles.

Testing of lorry drivers

The AS 1600 truck driving simulator with a 6-degree-of-freedom motion platform allows simulation of driving at different times of the day, in different road conditions (with different traffic volumes, city roads on highways and mountainous terrain) and weather conditions (rain, snow, fog, wind). The study of the driver's reaction to damage to vehicle assemblies (damage to the braking system, tire puncture), the sudden intrusion of a pedestrian, the behavior of other road users. The tests can be carried out on different types of vehicles (passenger car, van, truck tractor with semi-trailer, truck tractor with tanker, truck with trailer). It is possible to test the effect of intoxicants (alcohol, drugs) on driving ability (using alcogoggles). The cab of a SCANIA CP 14 vehicle is mounted on a platform with 6 actuators allowing 6 degrees of freedom of the vehicle. The simulator is equipped with:

- An audio system to provide surround sound in the vehicle cabin,
- a system to ensure that the cabin vibrates in accordance with engine speed,
- intercom for communication between driver and attendant,
- a system of three projectors with screens for displaying the vehicle's surroundings,
- screens emitting the vehicle's mirrors (4 units).

al. Powstańców Warszawy 8, 35-959 Rzeszów
phone: +48 17 865 1531
e-mail: austrzyc@prz.edu.pl
pojazdy.prz.edu.pl

Department Chair:
Paweł Woś, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1355
e-mail: pwos@prz.edu.pl

Department of Automotive Vehicles and Transport Engineering

Testing of fuel and lubricant parameters

The research offer includes work related to the determination of physicochemical and quality parameters of liquid fuels and lubricants used in the internal combustion propulsion of means of transport. Most of the work carried out focuses on alternative fuels and mixtures of alternative and conventional fuels. In addition to conventional fuels, such as motor gasoline and diesel fuel, research uses fuels of vegetable origin, especially vegetable oils and FAME. A number of works also deal with the possibility of using organic oxygenated compounds as additives to conventional fuels, especially diesel fuel. The results obtained in the laboratory are used in research work on the functioning of fuel injection systems and the working processes of reciprocating internal combustion engines. Measurements carried out as part of research work, are performed in accordance with normative procedures or based on non-standard programs. Modifications of measurement procedures are carried out, in particular, during tests aimed at alternative fuels and include:

- measurements of derived cetane number (DCN), ignition delay period and combustion in a constant volume combustion chamber,
- lubricity measurements of fuels at elevated temperatures with digital recording of the trace of test ball wear (HFRR method),
- viscosity measurements at low temperatures,
- fuel vapor pressure measurements,
- analyses of the fractional composition of fuels,
- fuel lubricity tests using the four-ball method.

Methods and techniques:

- fixed-volume combustion chamber
- atmospheric distillation
- Ubbelohde capillary
- oscillatory method
- HFRR method
- four-ball method
- Fourier transform infrared spectroscopy
- Pensky Martens closed crucible
- Reid's method
- Karl Fischer coulometric method

Apparatus available:

- OPTIDIST
- HVU 482
- DMA 4500
- HVP 972
- HFP 339
- FPP 5Gs
- IKA C 5000
- TD PPA
- HFRR (PCS)
- T-02U
- MultiTek
- AquaMAX KF
- CID 510

al. Powstańców Warszawy 8, 35-959 Rzeszów
phone: +48 17 865 1531
e-mail: austrzyc@prz.edu.pl
pojazdy.prz.edu.pl

Department Chair:
Paweł Woś, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1355
e-mail: pwos@prz.edu.pl

Department of Automotive Vehicles and Transport Engineering

Methods and techniques:

- Tests performed under road conditions or NEDC, WLTC and other user-defined driving cycles.
- Temperature range in the climate chamber: from -20°C to +30°C,
- Nominal brake power: 150 kW;
- Roller diameter: 1219 mm,
- Maximum axle load: 2000 kg,
- Maximum speed: 200 km/h,
- Range of simulated test weight: from 454 kg to 2722 kg,
- Nominal driving force: 5870 N.

Apparatus available:

- AVL-Zöllner 150 kW roller dynamometer stand equipped with:
- AVL CVS i60 exhaust gas intake and dilution system,
- AVL AMA i60 exhaust gas analysis system,
- AVL iGEM test and measurement automation system.
- HORIBA OBS-2200 mobile flue gas analyzer equipped with:
- CO analyzer - NDIR, range 0-10%,
- CO2 analyzer - NDIR, range 0-10%,
- THC analyzer - FID, range 0-10000 ppm,
- NOX analyzer - CLD, range 0-3000 ppm, Sampling frequency - 0.1-1 Hz.
- Hioki 3390 power analyzer with CT6843A 200A/700kHz AC/DC and CT6844A 500A/500kHz AC/DC clamp probes.

Testing of cars for engine exhaust emissions and energy consumption

The scope of emissions and energy consumption studies includes:

- bench measurements of gaseous emissions in driving cycles, at various ambient temperatures ranging from -20°C to +30°C,
- measurements of gaseous pollutant emissions of a car's internal combustion engine under road conditions (RDE),
- wheel power and engine power according to static and dynamic methods,
- measurements of fuel consumption (energy) in driving cycles,
- measurements of energy consumption and range of electric cars according to the WLTP procedure.

The offer includes tests of gaseous pollutant emissions (CO2, CO, NOx, THC, CH4) in the exhaust of internal combustion engines of cars in laboratory conditions on a chassis dynamometer, measurements of gaseous pollutant emissions (CO2, CO, NOx, THC) in road conditions, and measurements of energy consumption and range of electric cars. Bench tests are carried out on a 150 kW AVL-Zöllner roller dynamometer. It is possible to perform driving tests according to WLTP, NEDC, FTP, Japan procedures, including starting tests at low ambient temperatures down to -20°C.

al. Powstańców Warszawy 8, 35-959 Rzeszów
phone: +48 17 865 1531
e-mail: austrzyc@prz.edu.pl
pojazdy.prz.edu.pl

Department Chair:
Paweł Woś, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1355
e-mail: pwos@prz.edu.pl

Department of Materials Forming and Processing

Analysis of the possibilities of recycling polymeric materials

Determine the feasibility and analyze the recycling of thermoplastic polymeric materials starting from the generation of the material in the extrusion process, its granulation, drying, followed by injection molding, grinding of the resulting products and reprocessing in the extrusion or injection molding process.

The above procedure can make it possible to utilitarianly determine the feasibility of manufacturing, primary molding of products and recycling of thermoplastic polymer materials.

Methods and techniques:

- extrusion
- pelletizing
- drying
- injection moulding
- grinding

Apparatus available:

- Injection molding machine Boy 55E
- ZAMAK EHP-25E single-screw extruder
- ZAMAK RES-2P12A Explorer twin-screw extruder
- Granulator G 13/32
- Plastic mill WANNER C17.26sv
- Vacuum dryer DZ-2BC

Al. Powstańców Warszawy 8, 35-959 Rzeszów
phone: +48 17 865 1505
e-mail: jus@prz.edu.pl
kpp.prz.edu.pl

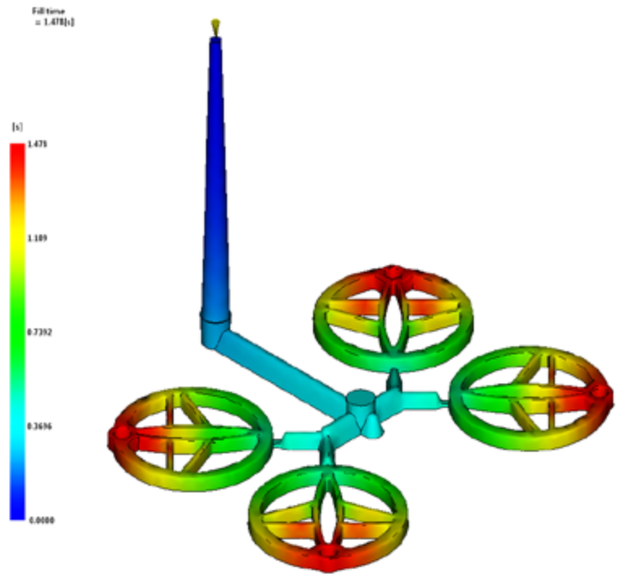
Department Chair:
Maciej Motyka, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1538
e-mail: motyka@prz.edu.pl

Methods and techniques:

- numerical analyses in the field of computational techniques: Midplane, Dual Domain, 3D

Apparatus available:

- MES software: Ansys, Abaqus, Autodesk Moldflow Insight, Moldex 3D



Numerical analyses of technological processes for polymer processing

Ability to perform technological numerical analysis of polymer molding processes in closed molds (including gas injection molding, injection molding with foaming, multi-component injection, RIM technology, overmolding of electronic circuits, molding technology of composites with fiber reinforcement) in CAE programs.

Ability to perform complex strength analyses of products made of polymeric materials and composites with fiber fillers (short and long).

Al. Powstańców Warszawy 8, 35-959 Rzeszów
phone: +48 17 865 1505
e-mail: jus@prz.edu.pl
kpp.prz.edu.pl

Department Chair:
Maciej Motyka, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1538
e-mail: motyka@prz.edu.pl

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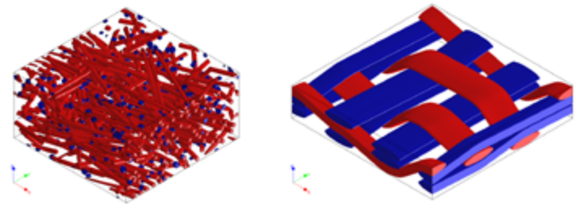


Predicting mechanical properties of polymeric materials with fillers

Determination of the properties of polymeric composite materials until recently required only appropriate experiments for an existing material, or the use of analytical methods, which had relatively high limitations and often did not give appropriate results. More recently, the possibility of computerized techniques for predicting the microstructural properties of composites using, among other things, homogenization methods has been developed and developed.

Calculations using homogenization methods can significantly reduce the number of time-consuming and expensive experiments on previously prepared samples of the material under study.

Methods and techniques:

- Methods for predicting the properties of filled polymer materials using Mori-Tanaka, Double Inclusion and numerical models

Apparatus available:

- DIGIMAT software

Al. Powstańców Warszawy 8, 35-959 Rzeszów
phone: +48 17 865 1505
e-mail: jus@prz.edu.pl
kpp.prz.edu.pl

Department Chair:
Maciej Motyka, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1538
e-mail: motyka@prz.edu.pl

Methods and techniques:

- Interpolation of test results using, among others: the Ostwald-deWaele power law, Cross, the Carreau-Yasuda equation, etc., taking into account Bagley and Rabinowitsch corrections, and the Arrhenius temperature coefficient
- on-line viscosity measurement during the injection molding process
- measurement of viscosity directly during the extrusion process

Apparatus available:

- Capillary rheometer (Instron Ceast Smart RHeo 2000)
- Priamus system
- ZAMAK EHP-25E extrusion meter for plastics

Standard compliance tests:

- ISO 11443
- ASTM D3835

Determination of rheological properties of polymeric materials

Performance of rheological tests according to ISO 11443, ASTM D3835 and equivalent using a capillary rheometer:

- measurement of flow and viscosity characteristics of plastics,
- evaluation of viscosity and elasticity of polymers in the plastic state,
- computerized data recording and data analysis allowing interpolation of test results using, among others: the Ostwald-deWaele power law, Cross, Carreau-Yasuda equation, etc. taking into account Bagley and Rabinowitsch corrections, and Arrhenius temperature coefficient in the range of operating conditions: temperature: (60 to 400)oC, shear rates: 0.5 to 11500 s-1, maximum piston pressure of 20 kN, the ability to perform tests at constant piston travel speed and constant shear rate, and the determination of pvT characteristics.
- Determination of the viscosity curve of plastics online during the injection process using the PRIAMUS system,
- Online determination of viscosity curve during extrusion using extrusion meter.

Al. Powstańców Warszawy 8, 35-959 Rzeszów
phone: +48 17 865 1505
e-mail: jus@prz.edu.pl
kpp.prz.edu.pl

Department Chair:
Maciej Motyka, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1538
e-mail: motyka@prz.edu.pl

Department of Materials Forming and Processing

Testing the thermal properties of plastics

Research capabilities:

- determination of phase transformations occurring in plastics, including: glass transition, melting, crystallization, crosslinking, onset of decomposition,
- identification of the type of plastic and additives on the basis of melting temperature,
- determination of degree of crystallinity and degree of crosslinking,
- determination of properties by DSC modulated option.

Methods and techniques:

- The device is equipped with a cooling attachment for plastics with a negative glass transition temperature and also has a closed cooling system that allows testing in the temperature range: -90°C to 550°C

Apparatus available:

- DSC scanning calorimeter (model Q-2000)

Al. Powstańców Warszawy 8, 35-959 Rzeszów
phone: +48 17 865 1505
e-mail: jus@prz.edu.pl
kpp.prz.edu.pl

Department Chair:
Maciej Motyka, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1538
e-mail: motyka@prz.edu.pl

Methods and techniques:

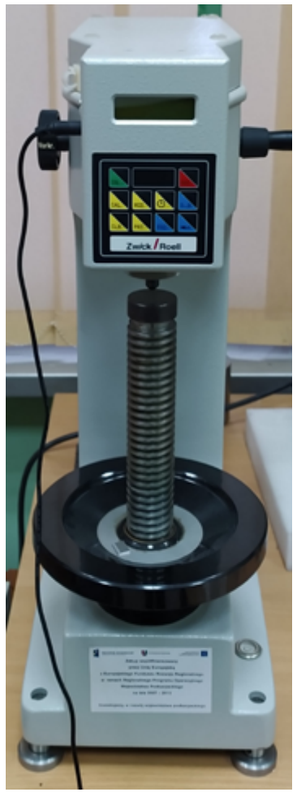
- Brinell method
- Rockwell method (for scale, L, M, P)
- Shore method (for A and D scales)

Apparatus available:

- Zwick hardness tester 3106

Standard compliance tests:

- ISO 2039-1



Hardness testing of plastics and polymer composites

The testing offer includes hardness testing of plastics and polymer composites in accordance with DIN ISO 2039-1 (Brinell method), testing according to the Rockwell method (for scales, L, M, P) and hardness testing according to the Shore method (A scale and D scale). Among other things, the equipment provides digital readout of results and allows statistical processing of a series of results.

Al. Powstańców Warszawy 8, 35-959 Rzeszów
phone: +48 17 865 1505
e-mail: jus@prz.edu.pl
kpp.prz.edu.pl

Department Chair:
Maciej Motyka, BEng, PhD, DSc, Assoc. Prof.
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e-mail: motyka@prz.edu.pl

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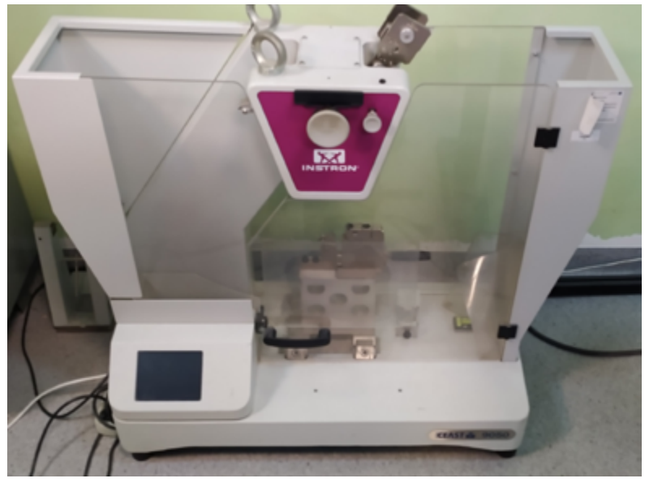


Impact and tensile strength testing of plastics

Implementation of impact tests according to the Charpy method and impact tensile according to Izood:

- range of destruction energy: 0.5 - 5.5 J,
- resolution of the position sensor: min. 0.075 degree,
- ability to store up to 100 test results in the hammer's internal memory.

Methods and techniques:

- Implementation of impact tests according to the Charpy method and impact tensile according to Izood

Apparatus available:

- Ceast 9050 pendulum hammer

Standard compliance tests:

- PN-EN ISO 8256

Al. Powstańców Warszawy 8, 35-959 Rzeszów
phone: +48 17 865 1505
e-mail: jus@prz.edu.pl
kpp.prz.edu.pl

Department Chair:
Maciej Motyka, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1538
e-mail: motyka@prz.edu.pl

Methods and techniques:

- uniaxial tension test
- compression test
- bending test

Apparatus available:

- Zwick/Roell Z030 testing machine
- Zwick/Roell Z100 testing machine
- Thermal chamber

Standard compliance tests:

- PN-EN ISO 527-1
- PN-EN ISO 604
- PN-EN ISO 178
- ASTM D 3039
- ASTM D 3518

Testing of mechanical properties of plastics

Determination of mechanical properties of thermoplastics, thermosets and composites in uniaxial tension, compression and bending tests. Tests are carried out at room temperature or variable temperature conditions in the range from -80°C to +270°C.
Determined quantities in uniaxial tensile testing:

- longitudinal modulus of elasticity,
- shear modulus (for long fiber reinforced composites),
- stress at yield,
- tensile strength,
- elongation at tensile strength,
- stress at failure,
- elongation at failure,
- Poisson 'a factor.

Determined quantities in the compression test:

- longitudinal modulus of elasticity,
- plastic flow stress in compression,
- compressive strength,
- relative shortening at compressive strength,
- compressive stress at failure,
- relative shortening at failure.

Determined quantities in the bending test:

- longitudinal modulus of elasticity/bending modulus,
- bending strength,
- bending stress at failure,
- deflection at failure.

Al. Powstańców Warszawy 8, 35-959 Rzeszów
phone: +48 17 865 1505
e-mail: jus@prz.edu.pl
kpp.prz.edu.pl

Department Chair:
Maciej Motyka, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1538
e-mail: motyka@prz.edu.pl

Department of Materials Forming and Processing

Methods and techniques:

- Studies of the effects of atmospheric factors: light, elevated temperature, rain on the surface of materials.

Apparatus available:

- Accelerated aging test chamber (Q-Lab) for plastics with equipment

Studies of the influence of atmospheric factors on the properties of plastics

Studies of the effects of atmospheric factors (xenon lamp light in the visible light range, elevated temperature, rain) on the properties of polymer plastics.

Tests within the scope defined by the purchaser are preceded by exposure of test samples in an aging chamber equipped with:

- Microprocessor controller, programming and automatic control of irradiance and surface temperature of the black standard,
- light source: air-cooled xenon torch of min. 2200 W,
- total sample area: about 1000 cm2.

The data recording system provides:

- continuous adjustment of light intensity in the spectral range of 300-800 nm,
- measurement and control of light intensity,
- measurement and display of air temperature in the working chamber.

The chamber equipment includes:

- light filter to simulate outdoor operating conditions,
- light filter to simulate natural sunlight,
- light filter to simulate light from behind window glass,
- a program for recording and archiving data,
- an irradiance meter in the 300-800 nm range.

Al. Powstańców Warszawy 8, 35-959 Rzeszów
phone: +48 17 865 1505
e-mail: jus@prz.edu.pl
kpp.prz.edu.pl

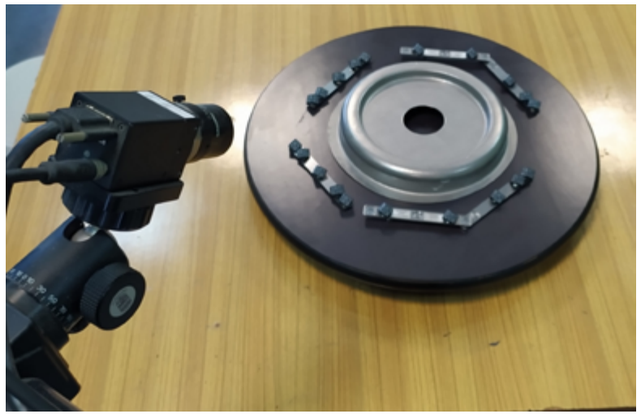
Department Chair:
Maciej Motyka, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1538
e-mail: motyka@prz.edu.pl

Methods and techniques:

- 3D optical metrology

Standard compliance tests:

- ISO 12004



Determination of limit deformability curves (KOG) of metals and alloys and evaluation of sheet deformation in plastic forming processes

The ARGUS forming analysis system supports optimization of the sheet metal forming process, taking into account correct material selection and tool optimization. The system allows detection of critical deformation areas, solution of complex forming problems, optimization of forming processes, verification of tools, and verification and optimization of numerical simulations. Research offer includes:

- possibilities of determining the boundary strain curves of sheet metal (KOG),
- determination of deformations associated with plastic forming processes of sheet metal,
- verification of the results of numerical analyses for the prediction of plastic deformation values,
- detection of critical deformation areas, solving complex forming problems,
- optimization of stamping processes, verification of tools.

Al. Powstańców Warszawy 8, 35-959 Rzeszów
phone: +48 17 865 1505
e-mail: jus@prz.edu.pl
kpp.prz.edu.pl

Department Chair:
Maciej Motyka, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1538
e-mail: motyka@prz.edu.pl

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Force and vibration measurements during process execution

Force and vibration measurements during milling processes and unconventional plastic forming methods, such as friction stir welding (FSW) and incremental sheet forming (ISF). Measurements of forces and vibrations are conducted during processes on a Makino PS95 CNC milling machine using a three-axis Kistler dynamometer, IMI vibration sensors, and a National Instruments data acquisition system with Signal Express and/or LabView software.

Methods and techniques:

- Force measurements using piezoelectric sensors
- Vibration measurements

Apparatus available:

- Makino PS95 CNC milling machine
- Kistler dynamometer
- IMI vibration sensors
- National Instruments DAQ data acquisition system
- NI Signal Express, NI LabView software

Al. Powstańców Warszawy 8, 35-959 Rzeszów
phone: +48 17 865 1505
e-mail: jus@prz.edu.pl
kpp.prz.edu.pl

Department Chair:
Maciej Motyka, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1538
e-mail: motyka@prz.edu.pl

Methods and techniques:

- Optical microscopy

Apparatus available:

- Struers Labotom saw
- Struers Citopress hot sample inlay press
- tools and materials for cold inlaying of samples
- Struers Tegramin grinder-polisher
- ATM Kristall 680 electrolytic polisher
- Leica DMi8c metallographic microscope

Metallographic studies of metallic materials

The available equipment allows preparation of cold or hot inlaid samples for metallographic examination by grinding and mechanical polishing or mechanical grinding and polishing/electrolytic etching methods, and observation of the specimens with a metallographic microscope. Observations in bright and dark field and polarized light are possible, along with digital image registration and analysis. The software has a function for measuring average grain diameter by incisal and planimetric methods.

Al. Powstańców Warszawy 8, 35-959 Rzeszów
phone: +48 17 865 1505
e-mail: jus@prz.edu.pl
kpp.prz.edu.pl

Department Chair:
Maciej Motyka, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1538
e-mail: motyka@prz.edu.pl

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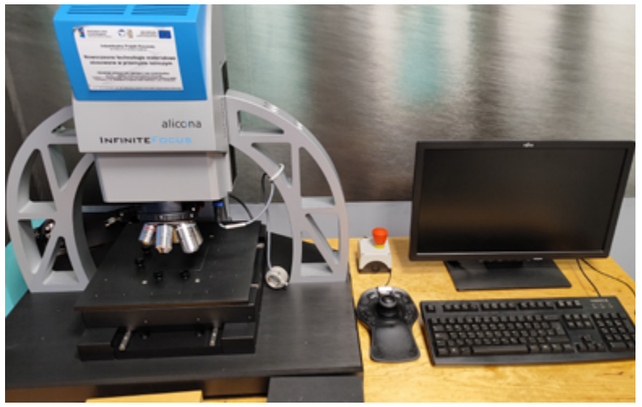

Measurement of the geometric structure of the surface

The measurement is performed with an Alicona InfiniteFocus G4 microscope, which uses focal differential technique. It allows 3D surface models to be made and then processed and geometric quantities measured, surface geometric structure measurements (2D and 3D roughness measurements) on shaped surfaces, differential measurements (e.g., wear tests) and cutting tool blade measurements. Measurement also can be carried out in mobile form using a wireless profilographometer, which allows the measurement of surface roughness and waviness.

Methods and techniques:

- contact measurement
- non-contact (optical) measurement

Apparatus available:

- Alicona InfiniteFocus G4 microscope
- profilografometr Mahr Marsurf M400

Standard compliance tests:

- ISO 4288

Al. Powstańców Warszawy 8, 35-959 Rzeszów
phone: +48 17 865 1505
e-mail: jus@prz.edu.pl
kpp.prz.edu.pl

Department Chair:
Maciej Motyka, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1538
e-mail: motyka@prz.edu.pl

Methods and techniques:

- hardness measurement by Vickers method
- Hardness measurement by Rockwell method
- hardness test by Brinell method

Apparatus available:

- Vickers Innovatest Falcon 400 micro hardness tester

Standard compliance tests:

- ISO 6507

Hardness measurements

Sample preparation and hardness measurements using the Vickers method with an Innovatest Falcon 400 hardness tester in the HV0.01 ÷ HV1 range in accordance with ISO 6507 and digital data recording.

Hardness measurements by Brinell and Rockwell methods using a conventional hardness tester.

Al. Powstańców Warszawy 8, 35-959 Rzeszów
phone: +48 17 865 1505
e-mail: jus@prz.edu.pl
kpp.prz.edu.pl

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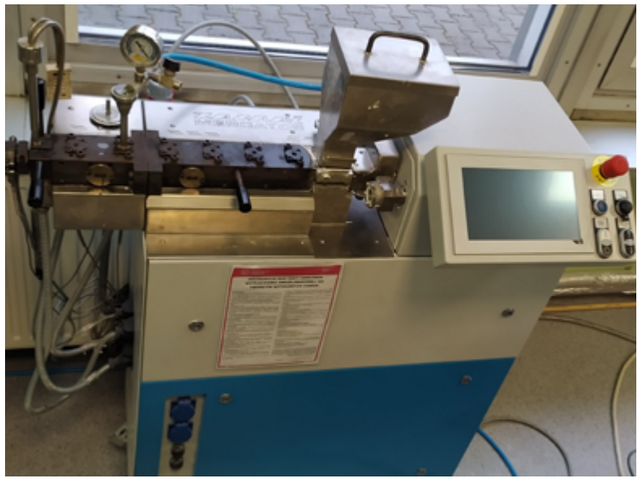
e-mail: motyka@prz.edu.pl

Department of Materials Forming and Processing



Production of polymer composite material properties with natural fillers

The offer includes the possibility of producing pilot quantities of polymer composites with natural fillers. The equipment and significant experience we have allows us to receive granulate for plastic processing from polymer and powder or fiber fillers of natural origin. Granulate is produced by extrusion using a single-screw or twin-screw extruder equipped with a cooling bath, granulator and extraction.

Methods and techniques:

- extrusion
- granulation

Apparatus available:

- ZAMAK EHP-25E single-screw extruder
- ZAMAK RES-2P12A Explorer twin-screw extruder
- Granulator G 13/32

Al. Powstańców Warszawy 8, 35-959 Rzeszów
phone: +48 17 865 1505
e-mail: jus@prz.edu.pl
kpp.prz.edu.pl

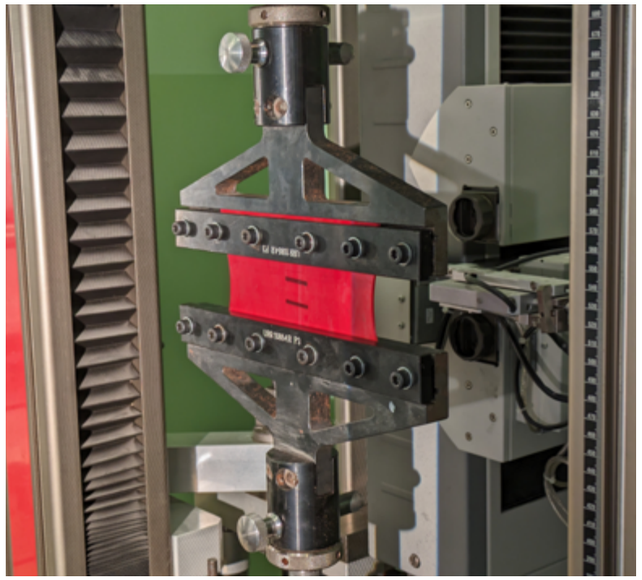
Department Chair:
Maciej Motyka, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1538
e-mail: motyka@prz.edu.pl

Methods and techniques:

- uniaxial tension test
- tensile test in plane strain condition
- shear test
- volumetric compression test

Apparatus available:

- Zwick/Roell Z030 testing machine
- Video strain gauge



Determination of elastomer properties in cyclic tests

Determination of characteristics of elastomers in cyclic tests enabling preparation of hyperelastic material models for numerical analyses under non-contact strain measurement conditions.

Tests performed:

- uniaxial tensile test,
- tensile test in plane strain condition,
- volumetric compression test,
- shear test.

Al. Powstańców Warszawy 8, 35-959 Rzeszów
phone: +48 17 865 1505
e-mail: jus@prz.edu.pl
kpp.prz.edu.pl

Department Chair:
Maciej Motyka, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1538
e-mail: motyka@prz.edu.pl

Department of Materials Forming and Processing

Methods and techniques:

- determination of the mass flow rate (MFR)
- determination of volumetric melt flow rate (MVR)

Apparatus available:

- Plastometr Ceast MFT 7024

Standard compliance tests:

- EN-ISO 1133
- DIN ISO 11333
- ASTM D1238
- BS 2782

Determination of MFR and MVR melt flow rates of plastics

Determination of melt flow rates of polymeric materials, i.e. melt mass flow rate (MFR) and melt volume flow rate (MVR), according to standards: EN-ISO 1133, DIN ISO 11333, ASTM D1238, BS 2782 temperature range: +30°C-400°C

Technical parameters:
Operating temperature range: 30°C - 400°C
Device dimensions: 540mm x 370mm x 475mm
Weight of the device: 50kg
Power consumption: 1000 W

Al. Powstańców Warszawy 8, 35-959 Rzeszów
phone: +48 17 865 1505
e-mail: jus@prz.edu.pl
kpp.prz.edu.pl

Department Chair:
Maciej Motyka, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1538
e-mail: motyka@prz.edu.pl

Methods and techniques:

- conventional backward extrusion method
- conventional forward extrusion method
- KOBO extrusion method

Apparatus available:

- backward extrusion press with a ram force of 5 MN
- KOBO forward extrusion press with a ram force of 2.5 MN
- QuantumX data acquisition system
- thermal imaging camera
- laser pyrometer

Research on the plastic forming capabilities of metals and alloys in extrusion processes

Research capabilities:

- performing backward extrusion processes (max. extrusion force – 5 MN)
- performing forward extrusion processes using the KOBO method (max. extrusion force – 2.5 MN)
- carrying out extrusion processes at room temperature and elevated temperatures up to 500 °C
- conducting KOBO forward extrusion with adjustable die rotation angles ranging from 6° to 10°
- research on the potential application of KOBO forward extrusion as an unconventional method of metallic waste recycling
- measurement and recording of extrusion forces during the process in relation to time and punch displacement
- measurement and recording of torque on the oscillating die in the KOBO method
- non-contact temperature measurement of the material at the die exit

Al. Powstańców Warszawy 8, 35-959 Rzeszów
phone: +48 17 865 1505
e-mail: jus@prz.edu.pl
kpp.prz.edu.pl

Department Chair:
Maciej Motyka, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1538
e-mail: motyka@prz.edu.pl

Department of Materials Forming and Processing

Impact testing using a drop-weight hammer

Research capabilities:

- impact testing of various materials, including metals, plastics, and composite materials at impact velocities ranging from 0.77 to 4.65 m/s and potential energy from 0.3 to 405 J
- impact tensile strength testing, Izod and Charpy impact strength testing
- puncture resistance testing and standardized CAI (Compression After Impact) test
- unconventional impact testing of functional components
- recording of experimental data (force, displacement, energy)

Methods and techniques:

- impact testing using a drop-weight method

Apparatus available:

- impact testing using a drop-weight method
- Apparatus available:
- Instron Ceast 9440 drop-weight impact tester
- force measurement heads (45 kN, 90 kN)
- sample mounting stand with adjustable height
- cone impactor with spherical tip, 6.35 mm
- spherical impactor, 16 mm diameter
- flat impactor, 70 mm diameter

Standard compliance tests:

- ASTM D7136/7136M
- Airbus AITM 1.0010
- EN 6038
- ISO 18352
- Boeing BSS 7260
- SACMA 2R-94

Al. Powstańców Warszawy 8, 35-959 Rzeszów
phone: +48 17 865 1505
e-mail: jus@prz.edu.pl
kpp.prz.edu.pl

Department Chair:
Maciej Motyka, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1538
e-mail: motyka@prz.edu.pl

Department of Manufacturing Processes and Production Engineering
Laboratory of Tribological Research

Methods and techniques:

- testing tribological properties of lubricants and testing wear resistance of materials

Apparatus available:

- control and measurement system
- research node

Standard compliance tests:

- ASTM D 2981
- ASTM D 3704
- ASTM G 77
- ASTM D 2714

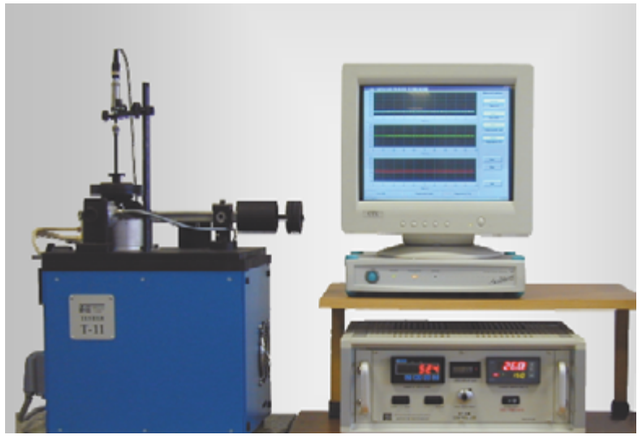
T-05 device

The T-05 device is designed to test tribological properties of lubricants such as greases, oils, plastic lubricants, as well as wear resistance of materials used for sliding machine components. The test contact consists of a stationary sample (pad), made of the material under test, pressed with a preset force P against a roller rotating at a preset speed in one direction or performing an oscillatory (reverse) motion with the appropriate frequency and amplitude. The contact under test can be concentrated (linear) or distributed. The friction steam is placed inside a tank equipped with a heating element, which allows heating the oil under test to a preset temperature before running. The temperature of the pad is measured using a thermocouple, the measuring tip of which is placed in a special hole. The T-05 device is equipped with a measurement and control system, which includes: - a set of measuring transducers, - a controller, - a digital measuring amplifier, - a computer with a special measuring and recording program installed. During the test run, the following quantities are measured, - friction force, - total linear wear of the friction node elements, - pad temperature, - temperature of the tested oil in the tank, - rotational speed, - time and number of roll revolutions (friction path). The waveforms of the measured values are displayed continuously on the monitor screen, and after the test run is completed, they are archived on the computer disk. The device's drive motor is automatically stopped when the preset time elapses, or when the preset friction path (number of roll revolutions) is reached. After the tests, a report can be printed showing graphs of changes in individual quantities as a function of time.

al. Powstańców Warszawy 8, 35-959 Rzeszów
phone: +48 17 865 1807
e-mail: spktmiop@prz.edu.pl
ktmiip.prz.edu.pl

Department Chair:
Professor Jarosław Sęp, BEng, PhD, DSc, Prof.Tit.
phone: +48 17 865 1512
e-mail: jsztmiop@prz.edu.pl

Department of Manufacturing Processes and Production Engineering
Laboratory of Tribological Research



T-11 device

The T-11 device with a pin-disk (or ball-disk) association is designed to evaluate the tribological properties of lubricants and materials used for sliding machine components operating at elevated temperatures. With its help, the wear resistance and coefficient of friction of any material association operating in sliding motion can be tested, depending on the presence and type of lubricant, ambient temperature of the friction node, sliding speed, surface pressures, type of gas in the test chamber and other factors. The device is especially designed for tribochemical testing under boundary lubrication conditions.

Methods and techniques:

- T-11 device with pin-disk (or ball-disk) association is designed to evaluate tribological properties of lubricants and materials used for sliding machine components operating at elevated temperatures.

Apparatus available:

- control and measurement system
- research node

al. Powstańców Warszawy 8, 35-959 Rzeszów
phone: +48 17 865 1807
e-mail: spktmiop@prz.edu.pl
ktmiip.prz.edu.pl

Department Chair:
Professor Jarosław Sęp, BEng, PhD, DSc, Prof.Tit.
phone: +48 17 865 1512
e-mail: jsztmiop@prz.edu.pl

Department of Manufacturing Processes and Production Engineering
Laboratory of Fatigue Research

Methods and techniques:

- accelerated transport tests, vibration simulation tests, combined vibration and climate tests, and seismic tests

Apparatus available:

- electrodynamic patterner
- control amplifier
- measuring apparatus
- vibroacoustic measuring unit

Standard compliance tests:

- MIL;ASTM;IEC;ISO;BS JIS

Armatura mocowania stołu wzbudnika ETS Solutions L620M

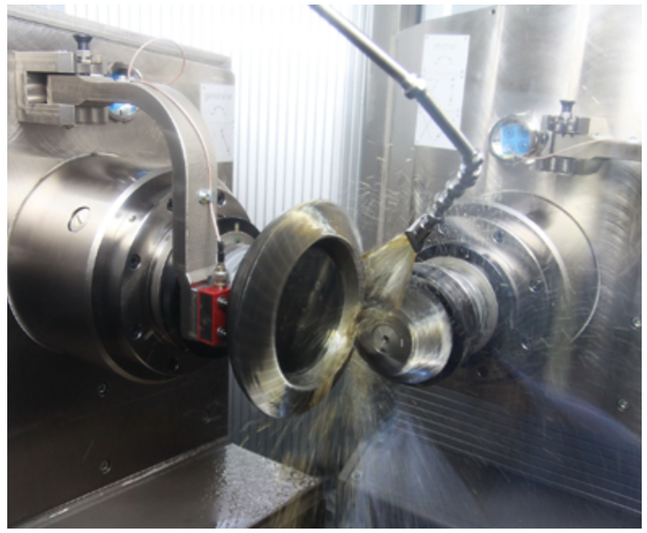
Accelerated fatigue tests

ETS' L620M electrodynamic exciter is ideal for testing electronic components, automotive components, mobile devices, storage devices, connectors and more. The ETS exciter system has a sinusoidal force of 600 kgf / 1322 lbs of force, a random force of 600 kgf / 1322 lbs of force and an impact force of 1200 kgf / 2645 lbs of force. ETS L620M solutions are designed to meet military and international test standards, including MIL, ASTM, IEC, ISO, BS and JIS. The fixture's large diameter of 7.9 inches and high lateral stiffness enables the proportional-head expander to test multiple specimens simultaneously while achieving good vibration transmission. The ETS L620M solution has a thrust axis with an eigenfrequency of <5 Hz. This device meets the requirements of transportation, vibration simulation, combined vibration and climate testing, and seismic testing.

al. Powstańców Warszawy 8, 35-959 Rzeszów
phone: +48 17 865 1807
e-mail: spktmiop@prz.edu.pl
ktmiip.prz.edu.pl

Department Chair:
Professor Jarosław Sęp, BEng, PhD, DSc, Prof.Tit.
phone: +48 17 865 1512
e-mail: jsztmiop@prz.edu.pl

Faculty Laboratory for Gear Research



Fatigue test and vibration analysis of bevel gear-box on TS-30 bench

The Departmental Gear Gear Research Laboratory has been established to meet the needs of the aerospace industry, including mainly Aviation Valley enterprises. The equipment installed in the laboratory will make it possible to undertake complex scientific and research work and implementation tasks in the field of aerospace propulsion systems, as well as comprehensive analysis in the areas of gear construction, technology, measurement and research. This is a continuation of scientific activities that have been carried out for many years and, at the same time, the use of the scientific potential of the University in an area where research has not been possible so far. Thanks to the implementation of previous projects and scientific work, a team of highly qualified employees has been created.

The range of work that can be performed using the laboratory significantly expands the offer that the University can make to other research institutes and industrial plants. The laboratory is not dependent on any aerospace manufacturer, which is intended to make it possible to reach out to new business entities intending to cooperate with the aerospace industry and facilitate their entry into this demanding market. The design and manufacture of innovative aerospace propulsion systems in-house will ensure that the skills of the scientific staff are constantly improved and maintained at the highest level, and, above all, the development of our own research methods and comprehensive cooperation with aerospace industry entities.

Methods and techniques:

- grinding of bevel gears
- strength and fatigue tests and vibration analysis of bevel gears
- measurement and quality control of bevel and spur gears
- design of planetary, bevel and helical gears
- evaluation of wear and carrying out repair and renovation works on gears

Apparatus available:

- Klingelberg G27 numerical grinding machine
- Klingelnberg P40 coordinate measuring machine
- Klingelnberg TS30 fatigue test stand
- KISSsoft software
- KIMOS software
- Inventor software

al. Powstańców Warszawy 8, 35-959 Rzeszów
phone: +48 17 865 1254
e-mail: k.kucharski@prz.edu.pl
gear-lab.prz.edu.pl

Department Chair:
Adam Marciniec, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1415
e-mail: amarc@prz.edu.pl

Methods and techniques:

- possibility of machining bevel gears with a maximum outer diameter of 300 mm and a module range from 0.7 to 8 mm
- machining of gear wheels with an axis angle range from 60° to 120°
- grinding of gear rims up to 60 mm wide
- tool spindle speed up to 7200 rpm
- possibility of finish machining of gears cut with continuous indexing (face hobbing) and intermittent indexing (face milling)
- possibility of grinding gears from solid material
- grinding of both concave and convex tooth flanks in the same setup
- equipped with grinding wheels with diameters from 2” to 9”
- independent numerical control of working axes
- direct drives of linear and rotary axes (including base angle axis)
- machine thermal stabilization system (cooling fluid temperature control and thermal compensation of all machine axes)
- eccentric grinding wheel function controlled by software
- ceramic spindle bearings
- Siemens 840D control system with Windows XP operating system for Siemens Simodrive 611 drives
- integrated machine monitoring system with temperature and vibration sensors

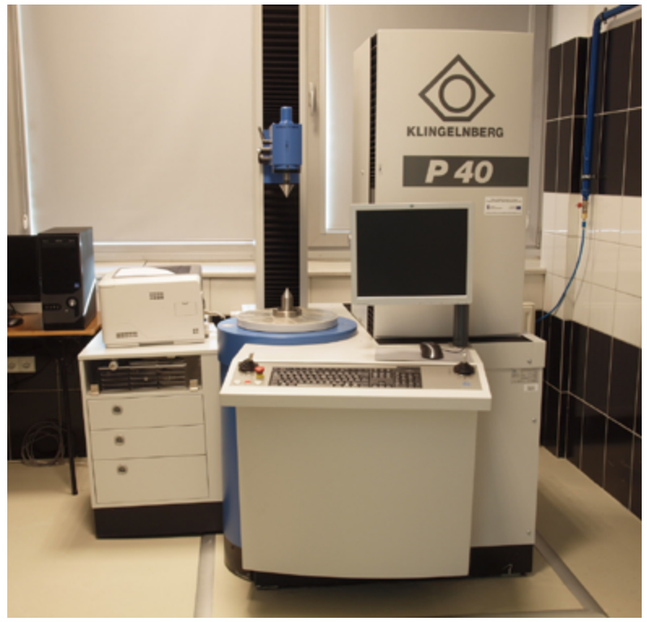
Klingelnberg G27 CNC grinding machine

The grinding machine is designed for the production of bevel gear teeth with the highest precision. It is intended for single and small-batch manufacturing of gears for testing purposes and industrial applications. This is the latest and one of the most advanced machines of its kind in Poland. Its software supports setting data for machines from various manufacturers, including classical Soviet-made machine tools. The grinding process can be designed using all known methods, including non-standard ones such as Palloid, Zyklo-Palloid, Hypoflex, and Spirokon. The machine operates in a closed feedback loop with the P40 measuring machine. In practice, this means that the finished gear is measured on the measuring machine, and based on the tooth flank surface topography, corrections are made to the grinding machine's settings. These corrections are automatically transferred to the machine’s controllers, allowing the correct tooth geometry to be achieved after just one trial grinding pass, ensuring extremely high accuracy.

al. Powstańców Warszawy 8, 35-959 Rzeszów
phone: +48 17 865 1254
e-mail: k.kucharski@prz.edu.pl
gear-lab.prz.edu.pl

Department Chair:
Adam Marciniec, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1415
e-mail: amarc@prz.edu.pl

Faculty Laboratory for Gear Research



Klingelnberg P40 coordinate measuring machine

ne of the most advanced measurement centers, operating in an automated cycle and intended for measuring gears and other machine components manufactured with high precision. The measuring center works in a feedback loop with the grinding machine – based on the measured tooth geometry, it generates corrections to the grinder’s settings, which are automatically introduced into the gear-cutting control program. This ensures that only one trial cut is needed to launch a production series that meets the design specifications. The purchased software enables the measurement of cylindrical gears, bevel gears, and shafts, and can be expanded with additional modules.

Measurement uncertainty:
gear measurement:
- profile according to VDI/VDE 2612: group I
- lead according to VDI/VDE 2612: group I
- pitch according to VDI/VDE 2613: group I

3D measurements:
• length measurement according to VDI/VDE 2617: U1 = 1.8 + L/250 µm
• rrotational and planar movement according to DIN 7184: <0.5 µm

Methods and techniques:

- measurement of cylindrical gear teeth, bevel gear teeth, and rotationally symmetrical objects with the possibility of expansion by additional software modules and equipment (e.g. for roughness measurement)
- workpiece clamping range HG<800 mm
- vertical measurement range with continuous measurement capability (Z-axis): Hz<550 mm
- horizontal measurement range with continuous measurement capability (X-axis): ±115 mm
- module (for cylindrical gears): 0.5 – 15 mm
- helix angle of gear teeth: 0 – 90°
- mounting and measuring diameter for cylindrical gears: up to 400 mm
- maximum permissible workpiece weight – up to 300 kg
- maximum permissible moment of inertia – up to 10 kg·m²
- actual positions of axes and K3D measuring head recorded by high-resolution measuring systems (up to <0.01 µm)
- positioning of measuring head via direct, backlash-free linear and rotary drives
- equipped with temperature compensation system for the measured workpiece
- high thermal stability of the machine, permissible temperature variation max. 2 ºC/h, ambient temperature range 15–35 ºC
- supports DIN and AGMA standards

al. Powstańców Warszawy 8, 35-959 Rzeszów
phone: +48 17 865 1254
e-mail: k.kucharski@prz.edu.pl
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Department Chair:
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e-mail: amarc@prz.edu.pl

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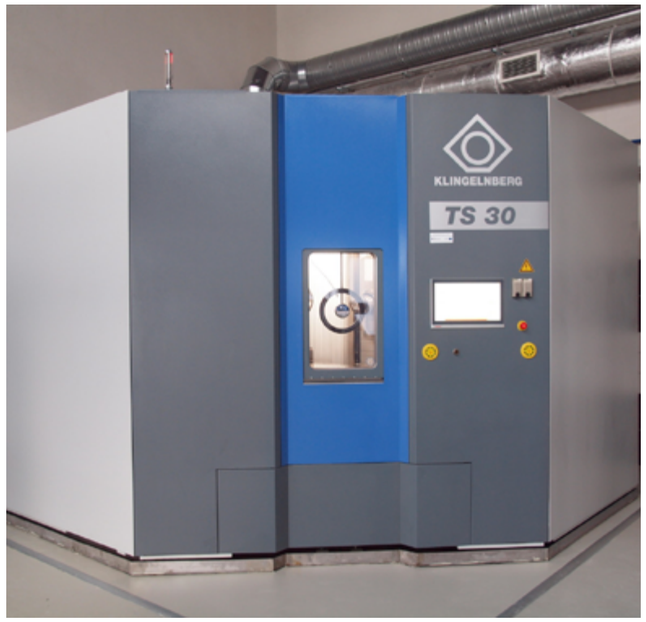
Methods and techniques:

- possibility of testing gear units with ring gear diameters from 50 to 300 mm
- support for test gears with modules from 1.5 mm to 5 mm
- support for gear units with transmission ratios from approx. 1.0 to approx. 2.5
- maximum permissible workpiece weight: up to 20 kg
- axis angle of tested gear units from 60° to 120°
- rotational speed up to 12000 rpm
- torque transmission up to 400 Nm at 1000–4500 rpm and up to 100 Nm at 12000 rpm
- measurement and recording of torque, power, noise emission, oil temperature, and oil flow
- function for single-flank testing and sound spectrum analysis
- telemetry system for dynamic measurement of tooth root stress
- fatigue strength testing for pitting and tooth root fracture
- equipped with a measuring system for monitoring set values related to the gears under test (pinion and gear mounting distances, axis angle, hypoid offset)
- automatic shutdown of the station when set limit parameters are exceeded
- control software with a PC-class computer
- gear unit operation observation under natural and stroboscopic light



Klingelnberg TS30 fatigue strength test bench

A unique test bench in Europe for the fatigue testing of bevel and hypoid gears. The station enables programming of test cycles that replicate real operating conditions of gear units. Laboratory tests allow for comprehensive evaluation of new designs in terms of load capacity, vibration emission, operating quality, and user safety, which is especially critical in aerospace applications. The bench enables testing of gear contact patterns and kinematic accuracy under load, determination of natural vibration frequencies of gear components (sound spectrum analysis), and dynamic measurement of tooth root deflection using a telemetry system. Performance measurements of the gear unit can be carried out in both ideal settings and with consideration of assembly errors and housing manufacturing deviations that may occur in practice. Test cycles can be individually programmed, and torque, power, and other parameters are recorded continuously.

al. Powstańców Warszawy 8, 35-959 Rzeszów
phone: +48 17 865 1254
e-mail: k.kucharski@prz.edu.pl
gear-lab.prz.edu.pl

Department Chair:
Adam Marciniec, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1415
e-mail: amarc@prz.edu.pl

Faculty Laboratory for Gear Research

KISSsoft software

KISSsoft, developed and endorsed by Gleason Corporation, is one of the world's leading software solutions for multi-level analysis of mechanical drives – both of complete systems and detailed issues of individual components. Its integrated modules allow for instant transfer of calculation results between parts and account for their influence on the performance of the entire mechanism.

Methods and techniques:

- geometry, strength, stiffness, thermal and friction analysis, as well as gear and meshing parameters evaluation for cylindrical, bevel, and hypoid gears
- assembly modeling of the entire mechanism and analysis of kinematic and dynamic properties
- analysis of shafts, bearings, and connecting elements (couplings, splines, expansion rings, bolted, welded, glued, and press-fit joints) in terms of geometry, strength, stiffness, and vibrations
- consideration of assembly errors, manufacturing tolerances, and deformations of the mechanism and housing under load – allowing for profile and lead modifications to reduce contact stress and dynamic overloads
- extensive database of materials in various heat and chemical treatment states, lubricants, bearings, and other standardized machine components
- tooth contact analysis (TCA) and the ability to optimize gear and entire mechanism parameters for selected objective functions
- modern and continuously updated computational methods based on ISO, DIN, and AGMA standards

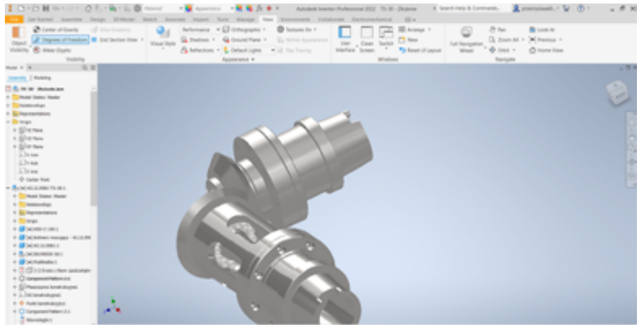
al. Powstańców Warszawy 8, 35-959 Rzeszów
phone: +48 17 865 1254
e-mail: k.kucharski@prz.edu.pl
gear-lab.prz.edu.pl

Department Chair:
Adam Marciniec, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1415
e-mail: amarc@prz.edu.pl

Faculty Laboratory for Gear Research

Methods and techniques:

- single-part mode – solid and surface modeling enabling the creation of complex geometries
- assembly mode – efficiently handles large assemblies thanks to a segmented database for fast loading and memory release
- 2D and 3D documentation mode – includes ready-to-use GD&T solutions
- FEA analysis of mechanical stresses, deformations, and vibrations
- graphically advanced modeling including motion simulation and assembly process visualization, along with a built-in collision detection tool
- parametric modeling for full dimensional control over the designed part and adaptivity that allows seamless dimension adjustment to existing components without dimensional analysis
- kinematic and dynamic analysis capabilities with a smooth transition to strength analysis based on force distribution



Inventor software

The software used for generating 3D and 2D geometry (CAD) as well as for structural analysis (FEA) is Inventor Professional by Autodesk.

al. Powstańców Warszawy 8, 35-959 Rzeszów
phone: +48 17 865 1254
e-mail: k.kucharski@prz.edu.pl
gear-lab.prz.edu.pl

Department Chair:
Adam Marciniec, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1415
e-mail: amarc@prz.edu.pl

Department of Computer Science

Modern technologies in management and production engineering

The Department of Computer Science is an organizational unit of the Faculty of Mechanical Engineering and Aeronautics at Rzeszów University of Technology. The department employs specialists in the application of modern information technologies in management and production engineering. Its industrial offering includes participation in all stages of project implementation: research, development, deployment, and testing.
The Department's extensive research portfolio includes, among others:

- modeling and simulation of material and information flow in processes, production lines, and supply chains
- application of simulation models in business process reengineering and decision support within an enterprise
- creation of visual models in CASE environments and their transformation into executable source code of an application solving the problem represented by the model
- data analysis using artificial intelligence and data mining tools, including classification and clustering, optimization methods in operations research, time series analysis, and computational intelligence
- advanced data analysis and mining in the context of Industry 4.0
- electronic processing of production data and electronic customer service
- surface geometry analysis, tribological testing of materials and coatings, surface topography reconstruction, analysis of surface parameter changes on machined surfaces
- design and implementation of modern computer networks
- application of agile methods and techniques in the specification of management information system requirements
- database creation and data analysis using modern big data and machine learning techniques

Software tools:

- Visual Basic for Application
- mySQL
- WordPress
- Microsoft Project
- R-studio
- Python
- Joomla!
- Enterprise Architect
- PHP
- Microsoft Excel
- Java Script
- Microsoft VirtualPC
- Vensim
- PowerBi
- MS SQL Serwer
- PowerBi
- Adonis

al. Powstańców Warszawy 8, 35-959 Rzeszów
phone: +48 17 865 1424
e-mail: renatas@prz.edu.pl
zi.prz.edu.pl

Department Chair:
Paweł Litwin, BEng, PhD
phone: +48 17 865 1521
e-mail: plitwin@prz.edu.pl

Department of Thermodynamics
PIV Laboratory

Methods and techniques:

Digital Particle Image Velocimetry uses a tracer (seed) that moves with the fluid to determine instantaneous velocity fields. The inoculation is illuminated by a laser plane and the image is recorded by digital cameras. The recorded images are then analyzed in DynamicStudio software to determine velocity vectors.

Apparatus available:

The PIV system has two lasers:
- Litron Bernoulli 200-15 laser with a frequency of 15Hz and energy of 200mJ
- Litron LD-527 25-1000 laser with a frequency of 1000Hz and energy of 25mJ.

Four cameras are included:
- three FlowSense EO9M-17 cameras with a resolution of 3388 x 2712 (9.2 Mpx) and 17 fps
- one AMETEK VEO 440 camera with a resolution of 2560 x 1600 (4.1 Mpx) and 1100 fps.

Liquid and particulate culture generator.

Digital image anemometry (Particle Image Velocimetry)

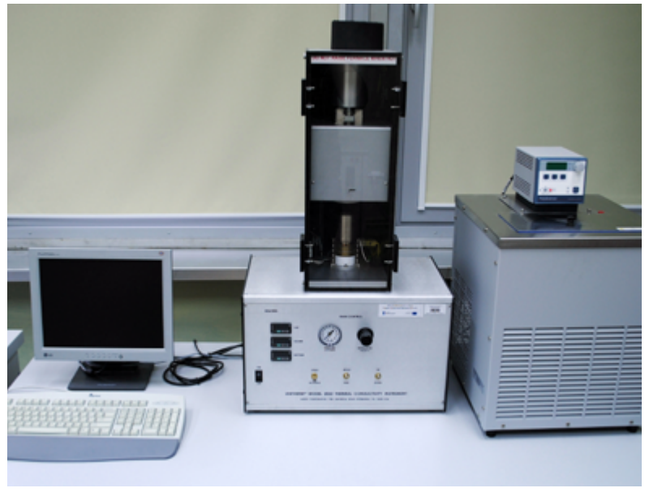
The Particle Image Velocimetry (PIV) method is used to measure the flow velocity field. It takes advantage of the scattering of laser light on the seed particles following the flow. The scattered light is recorded by a camera. For one measurement of the velocity field, it is required to illuminate the measurement plane twice and record two frames of images in a very short time interval, which is accomplished by a synchronizer that controls the laser pulses and the camera. The data from the two images are analyzed in a computer program by using appropriate algorithms. By identifying the culture particle and determining its displacement in the two images, it is possible to determine the velocity of this particle because the time between the two images from the synchronizer is known. The PIV system consists of a laser, laser beam transmission optics and laser plane formation, CCD camera, culture generator, synchronizer and computer. The maximum measurement area is 1 m2, while the flow velocity is in the range of 0-300m/s.

The PIV measurement system from DantecDynamics allows velocity field measurements:
- 2D-2C - measurement of two components of the velocity vector in a 2-dimensional plane.
- 2D-3C (stereo PIV) - measurement of three components of the velocity vector in the 2-dimensional plane.
- 3D-3C (tomo PIV) - measurement of three components of the velocity vector in a 3-dimensional plane.
- 2D-2C (time-resolved) - measurement of two components of the velocity vector in a 2-dimensional plane as a function of time.

al. Powstańców Warszawy 8, 35-959 Rzeszów
phone: +48 17 865 1288
e-mail: joanwilk@prz.edu.pl
zt.w.prz.edu.pl

Department Chair:
Joanna Wilk, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1288
e-mail: joanwilk@prz.edu.pl

Department of Thermodynamics



Measurement of thermal conductivity

The UnithermTM 2022 instrument from Anter (now TA Instruments) is used to measure the thermal conductivity of materials such as polymers, ceramics, composites, glasses, rubber, some metals and other materials with low thermal conductivity. Measurements are made using the so-called "guarded heat flow meter" method in accordance with ASTM1530. The device measures thermal conductivity from 0.1 W/m2K to 40 W/m2K. The temperature range at which the apparatus operates is from -20°C to 300°C. Specimens supplied for testing should be disc-shaped with a diameter of 2 inches (50.8 mm) and a thickness of 2 to 20 mm. The measuring section of the apparatus consists of a cylindrical-shaped sample placed between the upper and lower plates. Above the upper plate is the top radiator, which forces heat through the sample to the cooler, while below the lower plate is located the heat flux density meter (calorimeter). The lower radiator acts as a heat flow stabilizer for the required temperature difference of the measuring stack. A radiator is installed under the lower radiator, which is connected to the ultrathermostat. Outside the measuring section are compensation heaters, the power of which is adjusted to reduce heat loss from the side surfaces of the samples. To minimize and stabilize the contact resistance between the test sample and the plates, the measuring stack is mechanically compressed using a pneumatic cylinder. The compression pressure of the measuring stack is 172.3 kPa (25 PSI). In addition, in order to minimize contact resistance, the surfaces of the samples are covered with thermally conductive paste. The conductivity coefficient test is carried out under steady-state conditions.

Methods and techniques:
- shielded hotplate method

Apparatus available:
- UnithermTM 2022

Standard compliance tests:
- ASTM1530

al. Powstańców Warszawy 8, 35-959 Rzeszów
phone: +48 17 743 2382
e-mail: rafalgalek@prz.edu.pl
zt.w.prz.edu.pl

Department Chair:
Joanna Wilk, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1288
e-mail: joanwilk@prz.edu.pl

Apparatus available:

- calorimeter bomb
- analytical balance

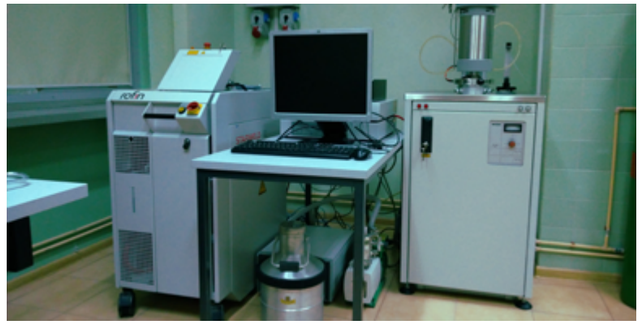
Measurement of heat of combustion of solid fuels

Measurement of the heat of combustion is carried out using a device commonly called a calorimetric bomb. This is a sealed vessel made of acid-resistant steel with reinforced walls, which allows the burning of solid fuel placed in it. The calorimetric bomb is placed in a calorimeter filled with a certain amount of water and the result of the measurement is the value of the temperature by which the water has been heated as a result of complete combustion of the sample in an atmosphere of oxygen and at its high overpressure (about 20 at). Samples for the apparatus should be a bulk material, from which lozenges are obtained on a mechanical press. In these lozenges is placed a spirally twisted resistance wire , which under the influence of an electrical impulse ignites the sample. Prepared samples as well as the resistance wire used for ignition are weighed on an analytical balance with an accuracy of 0.00001 g, which allows to accurately determine the heat of combustion of the test sample as well as to eliminate the error associated with the thermal effect of the burned part of the ignition wire. The calorimetric bomb measures the heat of combustion and calculates the calorific value of solid fuels, e.g. coal, lignite, wood, energy crops. The stand is automated and the measurement data is transferred to a computer.

al. Powstańców Warszawy 8, 35-959 Rzeszów
phone: +48 17 743 2382
e-mail: rafalgalek@prz.edu.pl
www.zt.prz.edu.pl

Department Chair:
Joanna Wilk, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1288
e-mail: joanwilk@prz.edu.pl

Department of Thermodynamics



Measurement of thermal diffusivity of materials by laser pulse method

The measurement is performed with a NETZSCH LFA 427 apparatus using laser flash analysis to measure the thermal diffusivity of materials. It makes it possible to determine the thermal diffusivity of a sample subjected to a laser pulse on the basis of the course of variation of the sample's temperature value in response to this forcing and the dimension (thickness) of the sample. The analytical model describing the heat transfer inside the sample and between the sample and the environment is compared with the experimentally recorded course of temperature variation on one of the sample surfaces, so it is possible to reproduce the value of thermal diffusivity of the tested material. Depending on the experimental conditions used and the sample material, the model should take into account such phenomena as heat loss by convection and radiation, finite laser pulse time or radiation heat transport in the sample material. In the software supporting the NETZSCH LFA 427 apparatus, there is a choice of models: adiabatic (Parker), taking into account heat loss (Cape-Lehmann, Clark-Taylor, Cowan), and radiation (Mehling), among others. The apparatus is equipped with a measurement chamber that allows experiments in the temperature range of 20 1575°C for samples with thermal diffusivity from about 0.01 mm2/s to about 1000 mm2/s. The excitation is generated by an Nd-YAG laser with a maximum energy reaching 20 J per pulse. The measurement chamber can be filled with an externally supplied gas during the measurement in order to perform the experiment under conditions of an atmosphere with specific properties - e.g. oxidizing or inert. In addition, the apparatus allows measurement of specific heat by a comparative method, in which the reference material is, for example, sapphire or graphite, as well as measurement of thermal contact resistance for multilayer samples. A standard material sample to be measured with the NETZSCH LFA 427 has a circular cross-section of 12.5 mm in diameter or a square cross-section of 10x10 mm and a thickness in the range of 1-6 mm.

Methods and techniques:

- laser pulse method for measuring thermal diffusivity using models including: adiabatic (Parker), accounting for heat loss (Cape-Lehmann, Clark-Taylor, Cowan), and radiation (Mehling),
- comparative method for measuring specific heat

Apparatus available:

- NETZSCH LFA 427 camera
- Rofin STARWELD 40 laser,
- TASC 414/4 and Pu 1.851.08 controllers,
- Julabo MC F32 ultrathermostat

al. Powstańców Warszawy 8, 35-959 Rzeszów
phone: +48 17 743 2382
e-mail: rafalgalek@prz.edu.pl
www.zt.prz.edu.pl

Department Chair:
Joanna Wilk, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1288
e-mail: joanwilk@prz.edu.pl

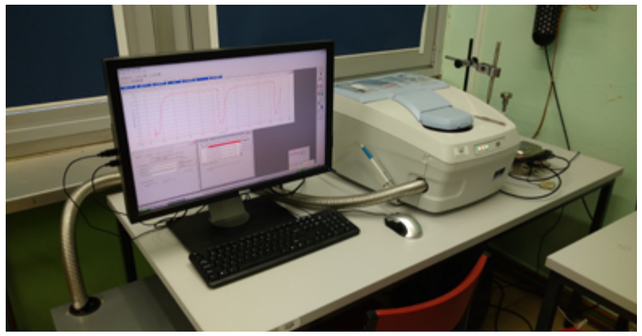
Department of Thermodynamics

Methods and techniques:

- Differential scanning calorimetry for enthalpy of phase transformations and chemical reactions and specific heat measurements,
- StepScan method for measuring enthalpy of phase transformations and chemical reactions and specific heat measurements

Apparatus available:

- PerkinElmer DSC 8000 calorimeter,
- Intracooler 2 calorimeter chamber cooler



Differential scanning calorimetry

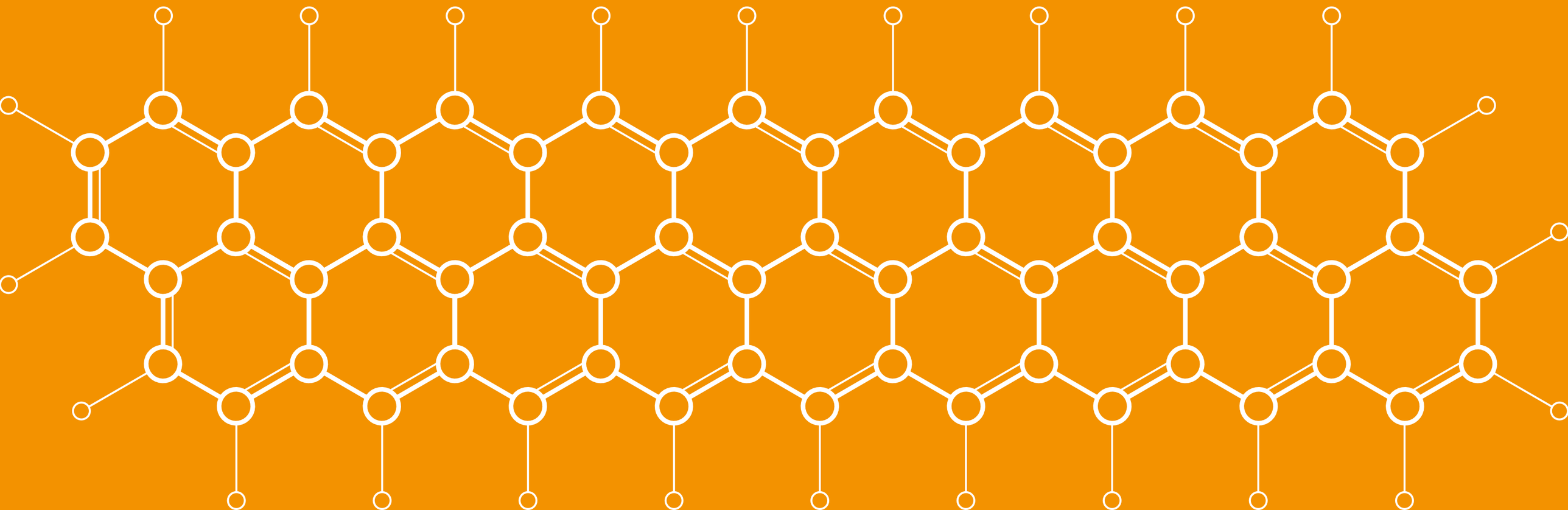
The measurement is carried out using a PerkinElmer DSC 8000 differential scanning calorimeter, the principle of which is based on measuring the difference between the thermal power supplied to the test sample and the thermal power supplied to the reference sample to keep them at the same temperature. It makes it possible, in particular, to measure the heat of phase transitions and chemical reactions, as well as the specific heat of materials and their characteristic temperatures, such as melting point or glass transition temperature. It is also possible to analyze the purity of a sample or determine its degree of crystallinity. Differential scanning calorimeters operating on the basis of thermal power compensation, which include the DSC 8000 model, are distinguished from calorimeters operating on the principle of measuring heat flux density by the smaller heat capacity of the chamber housing the sample, which gives them much better dynamic properties: the ability to respond almost instantaneously to endothermic or exothermic reactions in the sample material, a smaller time constant, and the possibility of using much higher heating and cooling rates. Among their advantages, moreover, is the fact that they measure directly the value of heat output, which, when integrated, represents the value of the energy of a phase transformation or chemical reaction, which is often the ultimate goal of calorimetric measurement. In addition to measurements using the typical differential scanning calorimetry method, the software that operates the DSC 8000 also has the ability to make measurements in StepScan mode allowing for more accurate measurement of specific heat than the traditional method, and to separately observe the effects of the change in specific heat with temperature and the effects of phase transformations or chemical reactions. The DSC 8000 calorimeter allows measurements in the temperature range from -180°C to 750°C at heating rates from 0.01 K/min to as much as 300 K/min. A standard material sample to be measured with the PerkinElmer DSC 8000 calorimeter has a diameter on the order of 3-5 mm and a thickness of about 1 mm.

al. Powstańców Warszawy 8, 35-959 Rzeszów
phone: +48 17 743 2382
e-mail: rafalgalek@prz.edu.pl
zt.w.prz.edu.pl

Department Chair:
Joanna Wilk, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1288
e-mail: joanwilk@prz.edu.pl

Powstańców Warszawy 6, 35-959 Rzeszów
e-mail: chemia@prz.edu.pl
chemia.prz.edu.pl

FACULTY OF
CHEMISTRY
RZESZÓW UNIVERSITY OF TECHNOLOGY



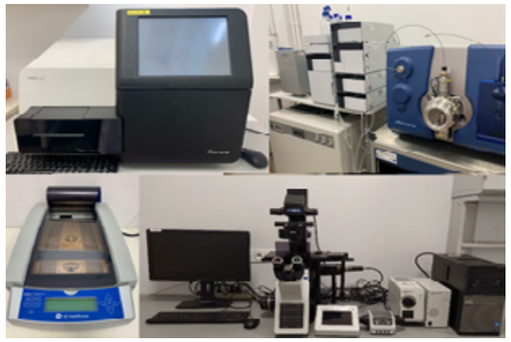
Department of Biotechnology and Bioinformatics

Methods and techniques:

- mammalian cell cultures
- fluorescence in situ hybridization
- Western blot
- ELISA
- 1D and 2D electrophoresis
- colorimetry and zymography
- microbiological methods according to JIS Z 2801:2010 (E), PN-EN ISO 846, PN-EN 1276
- next-generation sequencing (Illumina, ONT)
- genotyping by sequencing
- RNA-seq
- plant genomics
- in vitro cultures of plants

Apparatus available:

- Illumina MiSeq genome sequencer
- Shimadzu Nexera chromatograph coupled with QTRAP 4500 spectrometer
- Olympus IX83 inverted microscope
- Cytiva ÄKTA start liquid chromatograph
- ThermoFisher Varioskan Lux microplate reader



Mammalian cell culture laboratory

Studies of cytotoxicity of chemical compounds and drug carriers, apoptosis, chromosomal changes on mammalian cells. Coordinator: Ewa Ciszkowicz, PhD, eciszkow@prz.edu.pl

Protein analysis laboratory

Phospholipase A2 (PLA2) analyses for industrial applications. Analyses of peptides with cytotoxic and antibacterial properties. Cell penetrating peptides (CPPs) - potential drug carriers (D). Proteomic and immunological analysis of venom. Coordinator: Aleksandra Bocian, BEng, PhD, DSc, bocian@prz.edu.pl

Microbiology laboratory

Testing antibacterial activity and efficacy of coatings, plastics, chemical disinfectants and antiseptics, food products. Oxford Nanopore technology: enzyme optimization and genomic data analysis for commercial applications. Bacillus sp. bacteriocins: optimization of properties and modifications to increase commercial potential

DNA analysis laboratory

Preparation and sequencing of DNA fragment libraries customized for research. Illumina de novo sequencing of microorganisms. Comparative analyses of transcriptomes. Study of changes in the quantitative and qualitative composition of microorganisms. Construction of genetic maps, association analyses.

Bioinformatics analysis workstation

Bioinformatics analysis of genomics, proteomics and metabolomics data. In-silico optimization of biomacromolecules with biotechnology potential for improving their biotechnological properties. Molecular modeling of compounds mainly with potential applications in pharmaceuticals and plastics processing.

al. Powstańców Warszawy 6, 35-959 Rzeszów
phone: +48 +48 17 865 1745
e-mail: czaporj@prz.edu.pl
cb.prz.edu.pl

Department Chair:
Professor Mirosław Tomasz Tyrka, BEng, PhD, DSc, Prof.Tit
phone: +48 +48 17 865 1927
e-mail: mtyrka@prz.edu.pl

Department of Physical Chemistry

Qualitative and quantitative analysis of mixtures

Combined techniques make it possible to separate the test sample into individual components and to identify and quantify them unambiguously. As a result of GC-MS analysis, information on the molecular weight of the substance and fragment ions is obtained. The obtained mass spectrum makes it possible to determine the structure of the compound. It is also possible to compare the obtained spectrum with a database. GC-MS is a fast and accurate method. A gas chromatograph is equipped with an FID detector, while EI ionization takes place in the mass spectrometer.

Methods and techniques:

- Qualitative and quantitative analysis of the composition of mixtures.
- Analysis of organic compounds.
- Non-aqueous samples

Apparatus available:

- 6890N gas chromatograph coupled to a 5973A Mass Selective Detector from Agilent Technologies

al. Powstańców Warszawy 6, 35-959 Rzeszów
phone: +48 48 17 865 16 52
e-mail: chemia@prz.edu.pl
kchf.portal.prz.edu.pl

Department Chair:
Professor Paweł Chmielarz, BEng, PhD, DSc, Prof.Tit
phone: +48 17 865 1809
e-mail: p_chmiel@prz.edu.pl

Department of Physical Chemistry

Methods and techniques:

- qualitative and quantitative analysis of the composition of mixtures containing organic compounds.
- ESI or APCI ionization

Apparatus available:

- Agilent 1200 Series liquid chromatograph coupled with 6460 Triple Quad mass spectrometer

Qualitative and quantitative analysis of organic compound mixtures

Combined techniques allow for the separation of the sample into individual components, followed by their identification and quantitative determination. LC-MS analysis provides molecular weight information of the analyte. ESI ionization is a soft ionization method and yields only molecular weight data. The analyte must contain an ionizable functional group. LC analysis is performed using reversed-phase columns with eluents such as methanol, water, acetonitrile, isopropanol, and their mixtures. APCI ionization is a hard ionization technique, with a mass range from 10 to 2000 Da. It is used for non-polar or slightly polar compounds that do not contain acidic or basic functional groups. The sample must be dissolved in volatile solvents, and the analyte must be thermally stable. Tandem mass spectrometry (MSMS) enables operation in modes such as SCAN, SIM, Product Ion, Precursor Ion, and MRM. The liquid chromatograph equipped with a DAD detector enables UV-Vis spectrum recording.

al. Powstańców Warszawy 6, 35-959 Rzeszów
phone: +48 48 17 865 16 52
e-mail: chemia@prz.edu.pl
kchf.portal.prz.edu.pl

Department Chair:
Professor Paweł Chmielarz, BEng, PhD, DSc, Prof.Tit
phone: +48 17 865 1809
e-mail: p_chmiel@prz.edu.pl

Department of Physical Chemistry

Molecular structure analysis

Analysis of the structure of organic compounds, including but not limited to polymers. Possibility to study liquid substances, using slides or cuvettes of NaCl crystals and ATR reflectance technique, as well as solid substances, using transmission (lozenge possibility) or reflectance technique.

Analysis of intramolecular interactions and intermolecular interactions

Structural studies in terms of intramolecular and intermolecular interactions, including but not limited to hydrogen bond formation.

Methods and techniques:

- Transmission technique (thin film, solution in NaCl cuvette, KBr lozenge)
- ATR reflection technique (diamond crystal)

Apparatus available:

- NICOLET 6700 FTIR IR spectrophotometer

al. Powstańców Warszawy 6, 35-959 Rzeszów
phone: +48 48 17 865 16 52
e-mail: chemia@prz.edu.pl
kchf.portal.prz.edu.pl

Department Chair:
Professor Paweł Chmielarz, BEng, PhD, DSc, Prof.Tit
phone: +48 17 865 1809
e-mail: p_chmiel@prz.edu.pl

Department of Physical Chemistry

Methods and techniques:

- registration of UV-Vis spectra in the range of 200-800 nm
- determination of absorbance values at a given wavelength
- studies of reaction kinetics (cyclic measurement up to 24 hours)
- analysis of derivatives of UV-Vis spectra

Apparatus available:

- UV-Vis spectrophotometer HP 8453

Structural analysis of UV and Vis absorbing compounds

Analysis of absorption bands in the 200-800 nm range, qualitative studies.

Quantitative analysis

Quantitative research using, among other things, the calibration curve method.

Studies of reaction kinetics

Cyclicalal testing over a specified time interval in a thermostated measuring vessel.

Studies using derivative spectra (1-4)

al. Powstańców Warszawy 6, 35-959 Rzeszów
phone: +48 48 17 865 16 52
e-mail: chemia@prz.edu.pl
kchf.portal.prz.edu.pl

Department Chair:
Professor Paweł Chmielarz, BEng, PhD, DSc, Prof.Tit
phone: +48 17 865 1809
e-mail: p_chmiel@prz.edu.pl

Department of Physical Chemistry

Methods and techniques:

- quantitative analysis of elements.
- Set of 6 lamps for determination of individual elements: Cu, Fe, Mn, Cu, Ru and V.

Apparatus available:

- iCE 3000 Series atomic absorption spectroscope (AAS) from Thermo Fisher Scientific with flame and electrothermal atomizer
- Start D microwave oven from Milestone

Quantitative analysis of metallic elements

Atomic absorption spectroscope allows determination of the concentration of 6 elements in trace amounts (Cu, Fe, Mn, Cu, Ru and V). The apparatus has a radiation source in the form of cavity cathode tubes and the ability to atomize the test sample by the flame method (F-AAS) using an acetylene-air torch and by the electrothermal method (ET-AAS) using a resistance-heated graphite cuvette. With the possibility of microwave pre-mineralization using a Teflon bomb, it is also possible to analyze samples in their original solid form.

al. Powstańców Warszawy 6, 35-959 Rzeszów
phone: +48 48 17 865 16 52
e-mail: chemia@prz.edu.pl
kchf.portal.prz.edu.pl

Department Chair:
Professor Paweł Chmielarz, BEng, PhD, DSc, Prof.Tit
phone: +48 17 865 1809
e-mail: p_chmiel@prz.edu.pl

Department of Physical Chemistry

Methods and techniques:

- corrosion studies
- studies of the mechanism and kinetics of electrochemical reactions
- studies of the process of electrodeposition of metals and alloys, electrolytic preparation of composite coatings, and for electrochemical characterization of the surface morphology of materials

Apparatus available:

- Princeton Applied Research M370 electrochemical scanning microscope (SECM) composed of PG580R bipotentiostat, M370 positioning station, SCV370 control unit and camera with LCD monitor

Studies of corrosion processes Studies of material surfaces

The electrochemical scanning microscope (SECM) allows characterization of local properties, surface imaging and investigation of the chemical activity of various materials. The measurement system can operate in 3 or 4 electrode mode using one or two potentiostats. The measurements use platinum ultramicroelectrodes (UMEs) with diameters of 10, 15 and 25 µm. The positioning station allows the UMEs to be repositioned with a resolution of 1 µm.

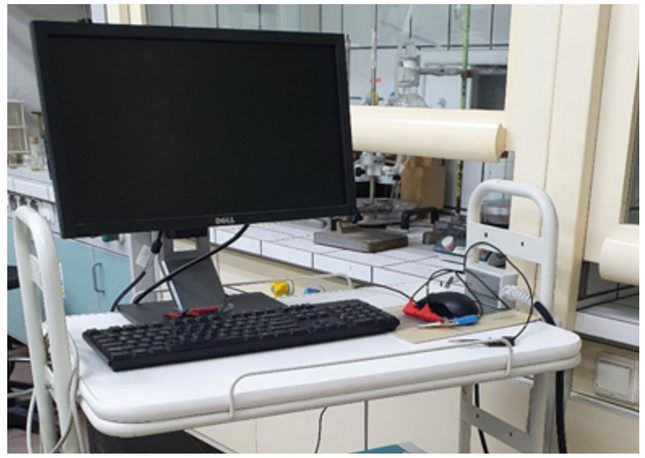
Types of tests performed:

- potentiometric tests
- cyclic voltammetry (CV) using an ultramicroelectrode (UME)
- imaging of redox activity of conductive and non-conductive surfaces (analysis of topography or changes in composition) in Feedback Mode and using a bipotentiostat in Generation/Collection Mode

al. Powstańców Warszawy 6, 35-959 Rzeszów
phone: +48 48 17 865 16 52
e-mail: chemia@prz.edu.pl
kchf.portal.prz.edu.pl

Department Chair:
Professor Paweł Chmielarz, BEng, PhD, DSc, Prof.Tit
phone: +48 17 865 1809
e-mail: p_chmiel@prz.edu.pl

Department of Physical Chemistry



Studies of oxidation-reduction properties of substances, voltammetric measurements, chromoamperometry/chromopotentiometry

The Autolab/PGSTAT302N is a top-of-the-line modular potentiostat/galvanostat for high currents (2 A limit, or 20 A with a BSTR20A amplifier) and WE-CE voltages up to 30 V. For cyclic voltammetry, the maximum sweep rate is 250,000 V/s for instruments equipped with a combination of SCAN250 and ADC10M modules. For "chrono"-methods, the interval between measurement points can reach 100 ns, using the ADC10M module and NOVA software. Application areas:

- batteries, fuel cells, supercapacitors
- coatings and corrosion testing
- conductive polymers and membranes
- dielectrics
- electrocatalysis
- electrodeposition
- semiconductors

Methods and techniques:

- Allowing measurements in aqueous and non-aqueous environments. Used for testing oxidation-reduction properties of substances, voltammetric measurements and chromoamperometry/ chromopotentiometry. Electrodes used: glassy graphite (GCE), gold, platinum and spinning disk electrode.

Apparatus available:

- Autolab PGSTAT 302N electrochemical analyzer

al. Powstańców Warszawy 6, 35-959 Rzeszów
phone: +48 48 17 865 16 52
e-mail: chemia@prz.edu.pl
kchf.portal.prz.edu.pl

Department Chair:
Professor Paweł Chmielarz, BEng, PhD, DSc, Prof.Tit
phone: +48 17 865 1809
e-mail: p_chmiel@prz.edu.pl

Department of Physical Chemistry

Methods and techniques:

- instrument designed for determining molecular weights and molecular weight distribution of low- and high-molecular-weight chemical compounds

Apparatus available:

- SHIMADZU CBM-40 gel permeation chromatograph

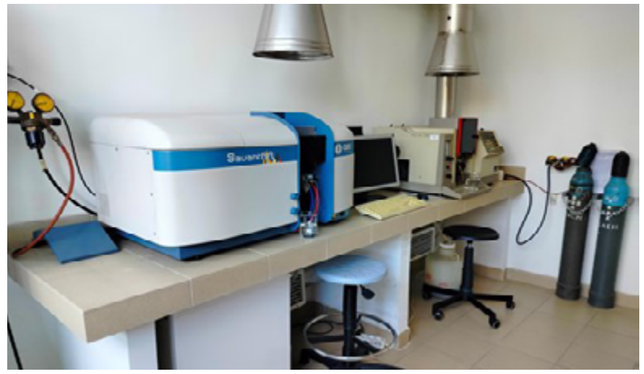
Determination of molecular weights and distribution of low- and high-molecular-weight chemical compounds

SHIMADZU CBM-40 gel permeation chromatograph equipped with SIL--40C autosampler, RID-20A refractive index detector, CTO-20A column oven, LC-40D dual-plunger pump, DGU-403 three-channel degasser, and a set of three columns (1 × 100 Å and 2 × 3000 Å, 10 µm) with a 10 µm precolumn from PSS Polymer. The mobile phase is N,N-dimethylformamide with 10 mM LiCl.(10 µm) firmy PSS Polymer. Jako fazę ruchomą stosujemy N,N-dimetyloformamid z 10 mM LiCl.

al. Powstańców Warszawy 6, 35-959 Rzeszów
phone: +48 48 17 865 16 52
e-mail: chemia@prz.edu.pl
kchf.portal.prz.edu.pl

Department Chair:
Professor Paweł Chmielarz, BEng, PhD, DSc, Prof.Tit
phone: +48 17 865 1809
e-mail: p_chmiel@prz.edu.pl

Department of Inorganic and Analytical Chemistry
Laboratory of Atomic Absorption Spectrometry



Analysis of metallic element content in various types of materials

Analysis of metallic elements in materials such as agricultural products; chemical products; construction products, materials, and structures; structural products and materials; air; fuels; furniture; glass and ceramics; other goods; paper and cardboard; pharmaceutical products; plastic and rubber products; food; textiles and leather; tobacco products; toys; wood. The samples are first mineralized to convert them into solution form. The method used is flame atomic absorption spectroscopy (FAAS), with excitation in a C_2H_2/air or C_2H_2/N_2O flame.

Methods and techniques:

- Digestion of samples with removal to solution.
- Flame atomic absorption spectrometry (FAAS).

Apparatus available:

- ASA spectrometers:
- Perkin-Elmer 3100
- GBC Savant-AA

al. Powstańców Warszawy 6, 35-959 Rzeszów
phone: +48 17 865 1564
e-mail: akuzniar@prz.edu.pl
zchnia.prz.edu.pl

Department Chair:
Bogdan Papciak, BEng, PhD
phone: +48 17 865 1508
e-mail: bpapciak@prz.edu.pl

Department of Chemical and Process Engineering
Laboratory of Powder Properties

Methods and techniques:

- determination of particle size distribution by laser diffractometry and sieve analysis methods
- determination of physicochemical parameters of deposits of bulk materials and granulates
- determination of mechanical and rheological properties of dry and hydrated bulk materials
- testing of processing properties of bulk materials in granulation and dry coating processes
- computer simulations of processes involving powder materials

Apparatus available:

- Mastersizer 2000 laser diffractometer
- Hosokawa Micron Powder Characteristics Tester
- Gunt CE 255 disc granulator
- direct shear apparatus (Jenike's cell)
- ICF Welko Star fluidization multiprocessor
- Ring rotary rheometer
- Set of mills and mixers (including drum, planetary, hopper)

Standard compliance tests:

- ISO 13320
- ASTM D6393
- ASTM D6128

Studies of physical and chemical properties of bulk materials

Studies of processing properties of powders and granules

The laboratory performs tests on powder materials, including measurements of particle size distribution by laser diffraction and sieve analysis, tests of processing properties of powder materials and granules, i.e.: angle of natural discharge, bulk density, compressibility, cohesiveness (cohesion), vane angle, homogeneity, dispersibility, etc.., determinations of mechanical and rheological properties of dry and hydrated bulk materials (including melt flow limit, melt flow index, angle of internal friction, compressive strength, tensile strength). In addition, the laboratory offers implementation studies of technological processes related to bulk material processing (including grinding, granulation, dry coating), as well as computer simulations of processes using the discrete element method DEM.

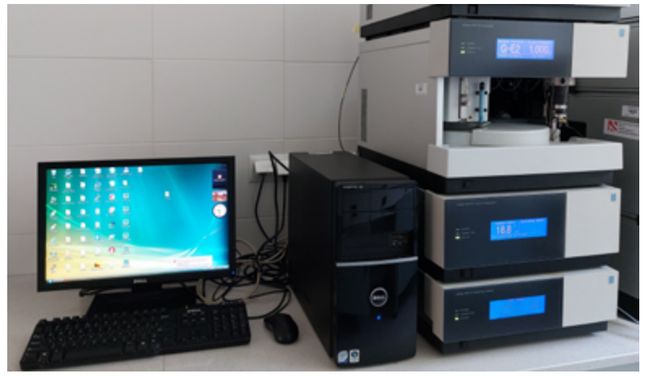
The Laboratory's research team has participated in a number of projects including the development of compositions and technologies for the production of fertilizer granules and mechanochemical improvement of the processing properties of pharmaceuticals.

The Laboratory constantly cooperates with other scientific centers (among others: the Institute of Agrophysics of the Polish Academy of Sciences, the University of Leeds, the Max Planck Institute Magdeburg) and business entities (among others: Stalprodukt S.A., KGHM Polska Miedź S.A., Polpharma S.A., ICN Polfa S.A.).

al. Powstańców Warszawy 6, 35-959 Rzeszów
phone: +48 17 865 1737, 17 865 1380
email:chemia@prz.edu.pl
wch.prz.edu.pl

Department Chair:
Marcin Chutkowski, BEng, PhD
phone: +48 17 865 1737
e-mail: marcin.chutkowski@prz.edu.pl

Department of Chemical and Process Engineering
Laboratory of Advanced Liquid Chromatography



The following services are possible at the Laboratory of Advanced Liquid Chromatography Techniques of Rzeszów University of Technology:

Training in the theory and practice of liquid chromatography:
- theoretical basics of liquid chromatography,
- operation and use of the chromatograph,
- advanced chromatographic techniques such as ion exclusion chromatography (IEC), supercritical chromatography (SFC), hydrophilic interaction chromatography (HILIC), etc.
- Computer support in selecting and optimizing chromatographic systems and transferring the scale of this operation from analytical to preparative conditions.

Completion of research assignments in the field of mixture separation:
- separation of multicomponent mixtures of proteins involving:
- preparative chromatography,
- single-step extraction in aqueous two-phase ATP system,
- multistage extraction,
- ultrafiltration.
- Separation of racemates involving preparative chromatography,
- separation of mixtures of organic compounds involving crystallization,
- chromatographic analyses of samples performed according to the methodology provided by the customer

Methods and techniques:

- preparative chromatography
- single-step extraction in an aqueous two-phase ATP system
- multistage extraction
- separation of racemates involving preparative chromatography,
- separation of mixtures of organic compounds involving crystallization
- chromatographic analyses of samples performed according to the methodology provided by the Customer

Apparatus available:

- Primade HPLC liquid chromatograph
- Merck HPLC liquid chromatograph
- HPLC prime plus liquid chromatograph
- SPOT CPC centrifugal counter-current extractor
- SMB system for continuous protein chromatography (AKTA purifier)
- Ultimate3000 biocompatible high-pressure liquid chromatograph (UPLC)
- HP4750 Stirred Cell perpendicular protein filtration kit

al.Powst.Warszawy 6, 35-959 Rzeszów
phone: +48 17 865 2020
email: w.marek@prz.edu.pl
wch.prz.edu.pl

Department Chair:
Professor Dorota Antos, BEng, PhD, DSc, Prof.Tit.
phone: +48 17 865 1853
e-mail: ichda@prz.edu.pl

Department of Polymer Composites

Methods and techniques:

- testing the resistance of polymeric materials to accelerated aging

Apparatus available:

- Xenotest Alpha+ Atlas aging test chamber

Aging tests

Accelerated aging of materials is tested in the Xenotest Alpha+ Atlas chamber using near-natural conditions, i.e. sunlight, humidity, simulated rainfall. Aging cycles are conducted with UV lamp irradiation of up to 180 W/m2 in the wavelength range of 300 - 400 nm. The test temperature in the chamber and relative humidity are determined according to the type of material. Sample exposure area: 1320 cm2, holder for 11 samples. Radiant intensity and temperature are measured and controlled directly on the surface of the sample.

al. Powstańców Warszawy 6, 35-959 Rzeszów
phone: +48 17 743 2508
e-mail: molek@prz.edu.pl
www.kkp.prz.edu.pl

Department Chair:
Professor Mariusz Oleksy, BEng, PhD, DSc, Prof.Tit.
phone: +48 17 743 2508
e-mail: molek@prz.edu.pl

Department of Polymer Composites

Flammability determination

The combustion properties test is carried out using a cone calorimeter. It determines: heat release rate per unit area of the sample - HRR [kW/m2], maximum heat release rate - pHRR, [kW/m2], mass loss - PML [%], effectively released heat - EHC, [MJ/kg], and total released heat - THR [MJ/m2]. It is carried out for samples with dimensions of 100x100 mm and a thickness of about 2.4 mm. Determination of the oxygen index (LOI) is carried out for 100 x 10 x 4 mm samples, as the maximum concentration of oxygen in the oxygen-nitrogen mixture. Flame resistance testing is carried out on 12.7 x 100 mm specimens in a UL 94 chamber in a vertical and horizontal combustion test.

Methods and techniques:

- study of the effect of combustion conditions of samples made of polymeric materials on the effect of flame retardancy
- determination of flame resistance of polymeric materials by V-method and HB-method
- determination of the oxygen index LOI

Apparatus available:

- cone microcalorimeter
- flammability test chamber UL 94
- apparatus for determining the oxygen index LOI

Standard compliance tests:

- ISO 13927
- PN-EN ISO 4589-2,3
- PN-EN 60695-11-10

al. Powstańców Warszawy 6, 35-959 Rzeszów
phone: +48 17 743 2508
e-mail: molek@prz.edu.pl
www.kkp.prz.edu.pl

Department Chair:
Professor Mariusz Oleksy, BEng, PhD, DSc, Prof.Tit.
phone: +48 17 743 2508
e-mail: molek@prz.edu.pl

Methods and techniques:

- viscosity testing with a rotational rheometer
- gelation time test

Apparatus available:

- RheoStress 6000 rotational rheometer
- Discovery HR-2 rotational rheometer

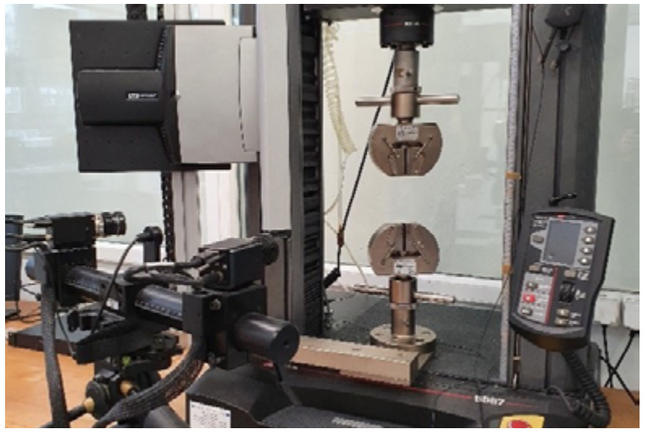
Testing of rheological properties

The viscosity testing of mixtures is carried out using a Rotational Rheometer in plate-to-plate or cone-to-plate systems. It is possible to test samples at room temperature or elevated temperature. Rotational speed up to 1500 [rpm], tension 200 [nNm]-200 [mNm], oscillation frequency 0.0001-100 [Hz]. The measurement consists in examining the shear stresses acting in the sample and the value of dynamic viscosity at a given shear rate and generating graphs of these relationships. Gelation time measurement is carried out using a Discovery HR-2 rheometer in oscillatory mode with a plate-to-plate measuring system. This rheometer has an automatic temperature control system at the bottom and top of the measuring system. The results of the measurements are the values of the moduli: conservative G' and loss G'', as well as the composite viscosity as a function of the test time.

al. Powstańców Warszawy 6, 35-959 Rzeszów
phone: +48 17 743 2508
e-mail: molek@prz.edu.pl
www.kkp.prz.edu.pl

Department Chair:
Professor Mariusz Oleksy, BEng, PhD, DSc, Prof.Tit.
phone: +48 17 743 2508
e-mail: molek@prz.edu.pl

Department of Polymer Composites



Determination of mechanical properties

Static tensile, three-point bending, shear strength and compression tests are carried out on an Instron 5967 testing machine operating under the control of Bluchill 3 software.The dimensions of the test specimens and test parameters are defined by the relevant standards. Determination of Charpy and Izod impact strength is carried out using a PSW GEHARD ZORN impact testing hammer. The kinetic energy of the impact, is selected according to the tested material in the range of 0.5-4 [J]. Beam-shaped test specimens should have dimensions of 80 x 10 x 4 mm (according to PN-EN ISO 179-1). Brinell hardness determination is carried out using a Zwick/Roell 3106 hardness tester.

Methods and techniques:

- static tensile test
- three-point bending test
- shear strength with Kirchhoff modulus
- Brinell hardness test
- Charpy and Izod impact test

Apparatus available:

- testing machine INSTRON 5967
- Zorn impact testing hammer
- Zwick/Roell hardness tester

Standard compliance tests:

- PN-EN ISO 527-4
- PN-EN ISO 14125
- ASTM D7078-12
- EN 10109-1
- PN-EN ISO 179-1

al. Powstańców Warszawy 6, 35-959 Rzeszów
phone: +48 17 743 2508
e-mail: molek@prz.edu.pl
www.kkp.prz.edu.pl

Department Chair:
Professor Mariusz Oleksy, BEng, PhD, DSc, Prof.Tit.
phone: +48 17 743 2508
e-mail: molek@prz.edu.pl

Department of Polymer Composites

Methods and techniques:

- injection molding of thermoplastics, including high-temperature plastics (PEEK)
- extrusion of thermoplastics (componding, 3D printing filaments, sleeve film)
- 3D printing using the FDM method
- pressing of thermoplastic and thermosetting plastics
- obtaining laminates by infusion, light LRTM, and vacuum bagging methods
- rolling

Apparatus available:

- Manufacturing and modification of polymer composites is carried out by the following methods:
- Battenfeld Plus injection molding machine,
- Krauss Maffei ClassiX CX 50-180 injection molding machine
- Haake ThermoScientific twin-screw microextruder
- Haake ThermoScientific microinjection machine
- extrusion filament lines
- extrusion lines for films, profiles
- co-rotating twin-screw extruder
- 3D printer
- Schwabenthan twin-screw machine

Manufacturing and modification of polymer composites

Manufacturing and modification of polymer composites is carried out by the following methods:

- extrusion of plastic in the form of sleeve films up to 50 cm in diameter, 3D printer filaments, or injection molding pellets, among others. This process can be carried out on a large scale, with a plastic extrusion capacity of up to 10 [kg/hr], or on a small scale, using materials from 7 [g].
- Injection molding of test specimens in the form of standardized shapes, such as paddles, beams and plates.
- Obtaining fiber composites by infusion, LRTM, and vacuum bagging. In this method, composites are obtained in the form of plates with maximum dimensions of 50 x 50 cm.
- processing of rubber mixtures (e.g. natural rubber, synthetic rubber, with additives) using a two-roller machine. Depending on the type of mixture, different mixing temperatures, roller rotation speeds and gap widths are used, among other things.
- The production of three-dimensional objects using the FDM method, is carried out with a 3D printer. Filaments used for this include PLA, ABS, PETG, as well as high-temperature materials such as PEEK. The maximum working area of the 3D printer, is: 400 mm (X) x 600 mm (Y) x 500 mm (Z), is equipped with a tool changer with 5 independent heads, including 1 for 450^{o}C
- pressing process - it produces materials in the form of plates with maximum dimensions: 30 x 30 cm, with a pressing force of up to 30 tons. With the help of the press it is possible to process thermoplastic and thermosetting materials thanks to functions such as heating or cooling of the press plates.

al. Powstańców Warszawy 6, 35-959 Rzeszów
phone: +48 17 743 2508
e-mail: molek@prz.edu.pl
www.kkp.prz.edu.pl

Department Chair:
Professor Mariusz Oleksy, BEng, PhD, DSc, Prof.Tit.
phone: +48 17 743 2508
e-mail: molek@prz.edu.pl

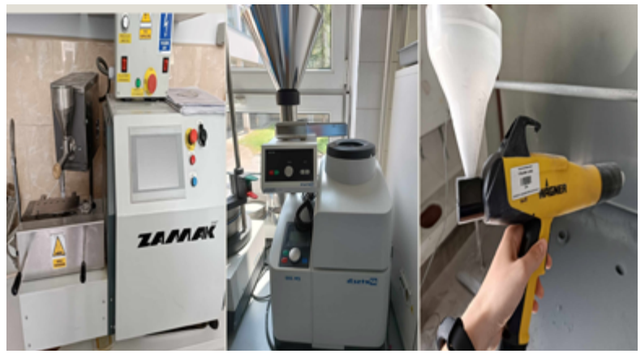
Department of Polymers and Biopolymers

Methods and techniques:

- powder paint application: the Corona method
- low and high temperature technique
- hardening with UV light

Apparatus available:

- laboratory extruder, Manufacturer: ZAMAK
- finger mill with sieve separation and vibrating sifter
- Corona PEM-X1 CG powder paint application gun
- Dymax UVC-5 compact light-curing belt conveyor with 120 mm wide belt



Process line for the preparation of paints and powder coatings

Laboratory extruder designed for extrusion of plastics, composites, powder paints.

The RETSCH ultra centrifugal mill with the symbol ZM 200 is used for rapid grinding of medium-hard and fibrous materials. Due to its efficient grinding technique and a wide range of accessories, the ZM 200 guarantees gentle preparation of analytical samples in a very short time.

The Corona PEM-X1 CG Powder Coating Gun Lab Kit with cup is a useful, handy and very effective equipment for painting details and small quantities for testing purposes.

Dymax UVC-5 compact light-curing conveyor belt for UV light curing of coatings. The instrument is ideal for curing smaller parts and can cure materials applied to a variety of substrates, including paper, plastic, metal, glass, laminated materials, print circuit boards.

al. Powstańców Warszawy 6, 35-959 Rzeszów
phone: +48 17 865 1269
e-mail: lbyczynski@prz.edu.pl
wch.prz.edu.pl

Department Chair:
Łukasz Byczyński, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1269
e-mail: lbyczynski@prz.edu.pl

Methods and techniques:

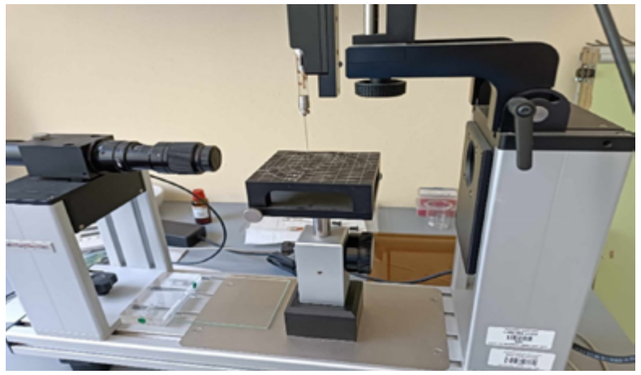
- static and dynamic wetting angle
- surface free energy
- interfacial tension - IFT
- gloss measurement at an angle of 20°, 60°, 85°
- adhesion by the notch grid method
- elasticity - bending method on a cylindrical mandrel
- hardness - Koenig and Persoz pendulum method

Apparatus available:

- optical goniometer OCA 15EC (DataPhysics) with software
- DT-523 rotational abrasion tester
- micro-TRI-gloss meter µ pendulum method hardness tester
- CLEMEN scratch resistance tester, etc.

Standard compliance tests:

- PN-EN 828



Laboratory for testing polymer coatings

In the laboratory, it is possible to perform a number of analyses for evaluating the properties of polymer coatings, including, among others, tests:

- wetting angle and determination of surface free energy (SEP) (PN--EN 828)
- abrasion resistance (PN-EN ISO 77784-1:2008)
- gloss at an angle of 20°, 60°, 85° (PN-EN ISO 2813)
- adhesion to substrate (PN-EN ISO 2409)
- elasticity (PN-EN-ISO 1519)
- relative hardness (PN-EN ISO 1522)
- resistance to scratching (PN-EN ISO 1518)
- formability (PN-EN ISO 1520)
- roughness (PN-EN ISO 12085), etc.

al. Powstańców Warszawy 6, 35-959 Rzeszów
phone: +48 17 865 1269
e-mail: lbyczynski@prz.edu.pl
wch.prz.edu.pl

Department Chair:
Łukasz Byczyński, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1269
e-mail: lbyczynski@prz.edu.pl

Department of Polymers and Biopolymers

Thermogravimetric analysis (TGA) laboratory

Thermogravimetric analysis makes it possible to study, among other things:

- thermal stability of materials
- resistance of materials to oxidation
- composition of composite systems
- estimated useful life of materials
- kinetics of thermal decomposition of materials
- the influence of the atmosphere on the reactivity or corrosion of materials
- content of moisture and volatile components in materials

Methods and techniques:

- thermogravimetric analysis (TGA)
- analysis of material degradation kinetics

Apparatus available:

- TGA/DSC1 thermoanalyzer (Mettler Toledo)

Standard compliance tests:

- ISO 11358-1

al. Powstańców Warszawy 6, 35-959 Rzeszów
phone: +48 17 865 1269
e-mail: lbyczynski@prz.edu.pl
wch.prz.edu.pl

Department Chair:
Łukasz Byczyński, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1269
e-mail: lbyczynski@prz.edu.pl

Methods and techniques:

- determination of specific torsion

Apparatus available:

- Jasco P-2000 digital polarimeter

Digital Polarimeter

The automatic digital polarimeter equipped with a computer with the "Spectra Manager II" software allows rapid measurement, reading and archiving of data in various modes of operation and is used to measure the angle of rotation formed by passing polarized light through optically active substances. The apparatus directly measures torsion, specific torsion, concentration, sugar content, Brix and optical purity. It can be used to test the effectiveness of catalysts and asymmetric synthesis processes, and to analyze the quality of raw materials and finished products.

al. Powstańców Warszawy 6, 35-959 Rzeszów
phone: +48 17 865 1093
e-mail: abajek@prz.edu.pl
ktmich.prz.edu.pl

Department Chair:
Beata Mossety-Leszczak, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1750
e-mail: mossety@prz.edu.pl

Department of Industrial and Materials Chemistry

Qualitative and quantitative analysis of compounds organic and inorganic compounds in solutions using the UV-Vis method

The laboratory is equipped with:

- Camera equipped with LCD display with possibility of connecting
- via RS-232C communication cable to a computer with "UV-Solutions" software.
- The cuvette holder has 4 positions.
- Measuring range 190-1100 nm, light source: lamps W1 and D2 (automatic change at 340 nm).

Methods and techniques:

- selection of wavelengths and concentrations of standard solutions
- determination of concentration by the standard curve method

Apparatus available:

- UV-Vis spectrophotometer,
- Hitachi U-1900

al. Powstańców Warszawy 6, 35-959 Rzeszów
phone: +48 17 865 1093
e-mail: abajek@prz.edu.pl
ktmich.prz.edu.pl

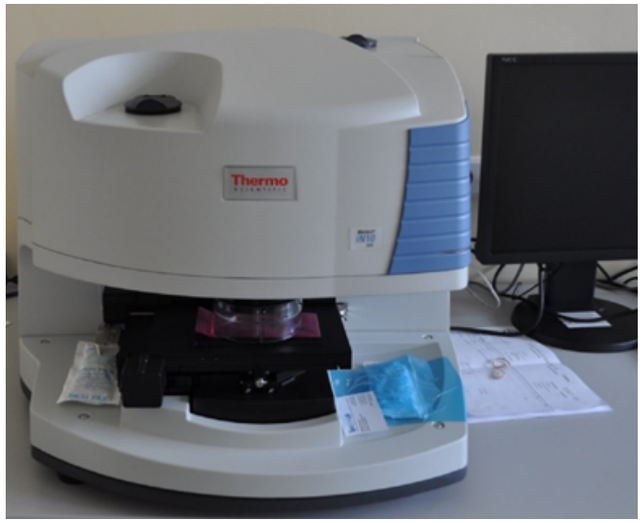
Department Chair:
Beata Mossety-Leszczak, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1750
e-mail: mossety@prz.edu.pl

Methods and techniques:

- FTIR spectrometer and microscope can be used to characterize and identify organic and inorganic compounds and materials by FTIR techniques in solid and liquid phases
- measurement techniques - transmission (KBr tablet), ATR (liquid, solid) and DRIFT (powder materials).
- The Nicolet iN10MX FTIR microscope allows recording FTIR spectra by transmission, ATR and reflection for samples of inorganic and organic materials, including composites, along with mapping the intensity distribution of characteristic bands on the sample surface. The apparatus is additionally equipped with a diamond measuring microcell for microscopic samples.
- The ability to identify the composition of a material based on available library databases.

Apparatus available:

- Nicolet 8700 research spectrometer
- Nicolet iN10MX integrated FTIR microscope



Molecular Spectrometry Laboratory

The laboratory is equipped with:

- Research spectrometer with two computer selectable and switchable radiation sources (tungsten lamp for the range of 27000-2000 cm-1 and ceramic source for the range of 9600-20 cm-1), beamsplitter: XT-KBr for the range of 11000- 375 cm-1, DLaTGS detector for the range of 12500-350 cm-1, resolution capability better than 0.09 cm-1. Enables measurement of spectra by transmission technique (KBr tablet, 4000-400 cm-1), ATR technique (diamond attachment, 4200-650 cm-1) and diffuse scattering technique (DRIFT attachment, 4000-400 cm-1). Libraries of spectra available. Purchased in 2011.
- An integrated stand-alone FTIR microscope operating independently without the need to connect an external FTIR spectrometer equipped with a Ge/KBr multilayer beam splitter interferometer for a range of at least 7,600 - 375 cm-1, a DLaTGS detector providing measurements over a spectral range of at least 7600 - 450 cm-1, allowing guaranteed measurement of samples as small as 50 µm, MCT-A matrix detector providing measurements in the range of at least 7600 - 715 cm-1, ATR "slide-on" germanium crystal, basic microscope sample preparation kit (at least: tweezers, scalpel, 13 mm BaF2 salt plates, 1 "x 3" microscope slides for transmission and reflection measurements). Purchased in 2011.

al. Powstańców Warszawy 6, 35-959 Rzeszów
phone: +48 17 865 1338, 17 865 1098
e-mail: mossety@prz.edu.pl
ktmich.prz.edu.pl

Department Chair:
Beata Mossety-Leszczak, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1750
e-mail: mossety@prz.edu.pl

Department of Industrial and Materials Chemistry

Methods and techniques:

- qualitative and quantitative analysis of organic and inorganic compounds in solutions using UV-Vis method

Apparatus available:

- Helios BETA UV-Vis spectrophotometer

UV-Vis Spectrophotometry Laboratory

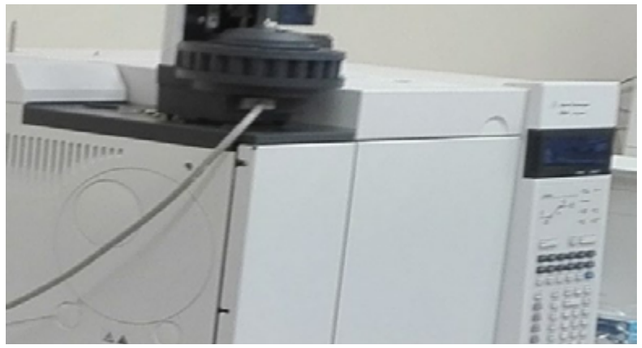
The laboratory is equipped with a Thermo Scientific Helios BETA single beam UV-Vis spectrophotometer with a multi-position sample changer (carousel). The instrument is equipped with an LCD display with connection to a computer with VisionNite software. The apparatus has a carousel for 7 cuvettes. Measuring range 190-1100 nm, light source: lamps W1 and D2.

al. Powstańców Warszawy 6, 35-959 Rzeszów
phone: +48 17 8651338, 17 8651098
e-mail: latibrp@prz.edu.pl
ktmich.prz.edu.pl

Department Chair:
Beata Mossety-Leszczak, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1750
e-mail: mossety@prz.edu.pl

Methods and techniques:

- Chromatographic (GC) analysis of the qualitative and quantitative composition of various classes of volatile organic compounds, including some classes of chiral compounds. The range of tests depends on the type of chromatographic column installed. The chromatographic laboratory is equipped with the following capillary columns HP-1, HP-5, HP-5MS, HP-50+, HP-FFAP, DB-WAX and HP-Chiral and Chiraldex G-TA.
- possible analysis of volatile compound samples from over solutions (HEADSPACE technique)
- chromatographic analysis (HPLC) of the qualitative and quantitative composition of various non-volatile organic compounds, including, among others, some groups of chiral compounds and other bioactive compounds. The chromatographic laboratory is equipped with the following chromatographic columns: PL Mixed gel C, Chiralcel OD, (R)-α-Burkle-2, Eclipse XDB-C18, (3R,4S)-Pirkle 1-J.
- Currently, one liquid chromatograph is mainly used for analyzing the molecular weight distribution of polymers.



Laboratory for the Study of the Structure of Compounds Chemicals, Nanocomposites and Nanofunctional Catalytic Materials

The laboratory is equipped with:

- HP 5890 dual-channel gas chromatograph with two split-splitless dispensers and two FID detectors. The chromatograph was purchased in 1992.
- Agilent Technologies 7890A dual-channel gas chromatograph equipped with two split/splitless dispensers, autosampler, flame ionization detector (FID) and electron capture detector (ECD), and Agilent Technologies 7694E HEADSPACE attachment. Chromatograph purchased in 2011.
- HP 5890 gas chromatograph with split-splitless dispenser, FID detector and autosampler. Year - 1992.
- Agilent Technologies 7890A gas chromatograph equipped with split/splitless dispenser, autosampler, flame ionization detector (FID). Purchased in 2012.
- Agilent Technologies 7890A gas chromatograph equipped with 2 split/splitless dispensers, autosampler, flame ionization detector (FID), Agilent Technologies 5975E MS detector (electron or chemical ionization). Purchased in 2013.
- Agilient 1100 HPLC liquid chromatograph equipped with four-channel pump, diode array detector, refractometric detector with automatic solvent saving valve) with HPLC 3D ChemStation and 2D ChemStation software, including GPC module.
- Agilient 1260 Infinity HPLC analytical chromatograph with quadruple pump and UV-Vis detector and autosampler. HPLC ChemStation software. Purchased in 2013.

al. Powstańców Warszawy 6, 35-959 Rzeszów
phone: +48 17 865 1799
e-mail: latibrp@prz.edu.pl
ktmich.prz.edu.pl

Department Chair:
Beata Mossety-Leszczak, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1750
e-mail: mossety@prz.edu.pl

Department of Industrial and Materials Chemistry

LABORATORIUM
ANALIZY TERMICZNEJ I BADANIA
REAKTYWNOŚCI POLIMERÓW
POLITECHNIKI RZESZOWSKIEJ

Laboratory for thermal analysis and testing polymers reactivity

The DMA method allows the determination of thermomechanical parameters such as conservative, lossy and composite modulus for several measurement modes (compression, tension, bending, shear) and the ability to determine the corresponding moduli for these modes. Dynamic mechanical analysis makes it possible to determine the glass transition temperature, estimate the degree of cross-linking and determine whether the material is fully cured.

With DSC methods, the laboratory offers the ability to determine phase transition temperatures (melting, crystallization, glass transition) and detect impurities, identify substances (especially polymers), approximate and determine their composition. A variation of DSC with temperature modulation makes it possible to separate reversible and irreversible effects that overlap, which is particularly useful when analyzing complex mixtures. Using the DSC method, we also determine the specific heat of small- and large-molecule materials and study chemical reactions (especially crosslinking).

An optical microscope equipped with a heating table and polarization option allows observation of materials over a wide temperature range for all materials and detection and determination of the nature of the liquid crystal phase.

The laboratory is also equipped with a device that allows the generation of a homogeneous magnetic field and high induction and research using it.

Methods and techniques:

- dynamic mechanical analysis DMA
- differential scanning calorimetry DSC
- TOPEM®DSC temperature-modulated differential scanning calorimetry
- optical and polarization microscopy with heating and cooling options
- homogeneous magnetic field testing

Apparatus available:

- DMA/SDTA861e dynamic thermomechanical analyzer, Mettler Toledo
- DSC822e differential scanning calorimeter, Mettler Toledo
- DSC1 differential scanning calorimeter, Mettler Toledo
- OPTA TECH LAB40 metallographic and polarization microscope coupled to Linkam LTS420 heating table
- RTM1 homogeneous magnetic field generation device

Standard compliance tests:

- PN-EN ISO 11357-1

al. Powstańców Warszawy 6, 35-959 Rzeszów
phone: +48 17 865 1799
e-mail: latibrp@prz.edu.pl
ktmich.prz.edu.pl

Department Chair:
Beata Mossety-Leszczak, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1750
e-mail: mossety@prz.edu.pl

Faculty Spectrometry Laboratory

Methods and techniques:

- 1H, 13C, 11B, 31P, 15N, 19F spectra of organic compounds and natural and synthetic polymers are recorded
- the configuration of the spectrometer allows recording NMR spectra using measurement techniques such as DEPT, COSY, HSQC, HMBC, HETCOR, NOESY, ROESY and others.
- Available deuterated solvents: chloroform, water, dimethyl sulfoxide, acetone, benzene, dimethylformamide, ethanol, methanol, sulfuric acid, acetonitrile, toluene.

The laboratory is equipped with:

Bruker Avance II 500 MHz FT-NMR spectrometer with ULTRASHIELD 500 PLUS type superconducting magnet with a magnetic field strength of 11.7440 T.

The NMR spectrometer makes it possible to study the structure of a compound by first dissolving it in a suitable deuterated solvent, then placing the sample in a strong magnetic field generated by a superconducting magnet, delivering through a transmitter in the probe the energy to the atomic nuclei through an electromagnetic pulse, rapidly recording the fading electromagnetic induction with a detector. The result obtained in this way is processed by means of a Fourier transform obtaining a classical 1D-NMR spectrum. The technique belongs to non-destructive methods of the sample, which can often be recovered after the measurement. The high value of the magnetic field generated by the magnet makes it possible to obtain satisfactory spectral resolution of the spectrum.

al. Powstańców Warszawy 6, 35-959 Rzeszów
phone: +48 +48 17 865 13 63
e-mail: r.ostatek@prz.edu.pl
wch.prz.edu.pl

Department Chair:
Agnieszka Bukowska, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 13 38
e-mail: abuk@prz.edu.pl

Faculty Spectrometry Laboratory

SAXS

The laboratory is equipped with:

- Bruker Nanostar-U low-angle diffractometer operating in transmission geometry with a copper lamp (1.54 Å radiation).
- Optics (crossed Goebel mirrors) allowing to obtain a parallel beam with a diameter of 500 microns.
- A two-dimensional detector allowing rapid registration of signals, and capturing anisotropy in the structure of grains, crystallites, or the direction of stresses caused by, for example, pressure.
- A temperature attachment allowing operation from room temperature to 350 ºC,
- A strain gauge attachment allowing measurements as a function of elongation or stress (up to 600 N),
- Attachment for making measurements (SAXS) by grazing incidence method.
- Allows measurements to be made in an inert gas shield.

The SAXS-type apparatus makes it possible to observe structures with very high periodicity such as polymeric materials in particular nanofillers and polymer nanocomposites, as well as molecular crystals and biological materials. Low-angle scattering analysis also provides information on the dimensions and geometry of nanoparticle objects. The method is used to study the shape of inhomogeneities, clusters, proteins, percolations, etc.In some cases (such as powders), the scattering function allows you to count the dimensionality of the percolation (whether it is a chain or a grain).The SAXS measurement method provides information such as particle size, size distribution from 1 to 700 nm, orientation in liquids, powders and in large-size samples.

Methods and techniques:

- 2D observation and study of the morphology of two-phase systems with very high periodicity in polymeric materials (in particular, nanofillers and polymer nanocomposites).
- 2D observation and study of morphology of molecular crystals and biological materials.
- morphology studies of two-phase systems in the temperature range from ambient to 300 °C.
- morphology studies of two-phase systems using a strain gauge attachment.
- low-angle scattering analysis and interpretation of results.

Apparatus available:

- Bruker Nanostar-U low angle diffractometer

al. Powstańców Warszawy 6, 35-959 Rzeszów
phone: +48 17 865 16 52
e-mail: chemia@prz.edu.pl
wch.prz.edu.pl

Department Chair:
Agnieszka Bukowska, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1338
email:a.buk@prz.edu.pl

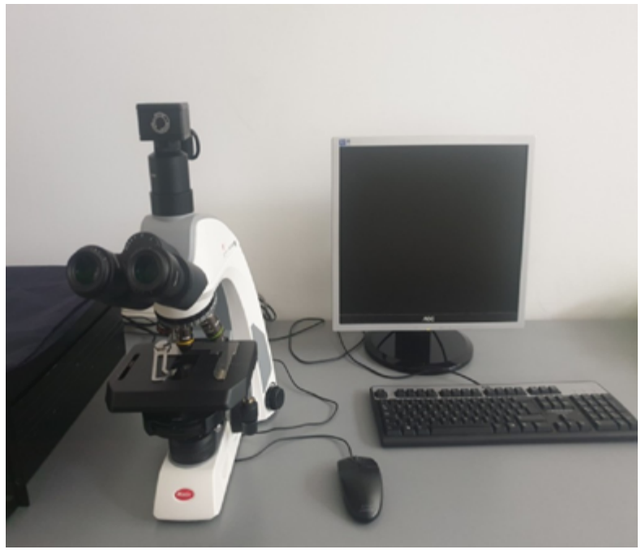
Department of Organic Chemistry

Methods and techniques:

- the observation technique used in the microscope is the bright-field method
- standard magnification 40x, 100x, 400x and 1000x

Apparatus available:

- biological microscope, Pantera series by Motic



Biological microscope

Observing polyurethane samples (structure, number and size of pores). Taking pictures of samples along with measurements.

Microscope designed for laboratory research work It is equipped with eyepieces with a wide field of view of 25 mm . It has a powerful halogen illumination (100W) for Köhler transmitted light work. The focusing knob has a resolution of 1 µm. The coded turret bowl "remembers" the illumination brightness level for each lens position. The environmentally friendly ECO function is an automatic energy-saving mode that protects the sample from excessive heat. In addition, it is equipped with an integrated USB port for powering the camera and an LED indicator of the illumination intensity in the objective turret.

al. Powstańców Warszawy 12, 35-959 Rzeszów
phone: +48 17 865 1244
e-mail: b.krzykowska@prz.edu.pl
www.chorg.prz.edu.pl

Department Chair:
Professor Iwona Zarzyka, BEng, PhD, Dsc, Prof.Tit.
phone: +48 17 865 1762
e-mail: izarzyka@prz.edu.pl

Department of Organic Chemistry

Methods and techniques:

- flammability testing of polymeric materials
- determination of oxygen index percentage

Apparatus available:

- apparatus for determining the oxygen index (flammability of plastics) LOI from Concept Equipment, England

Standard compliance tests:

- ISO 4589 Part:2-1996
- PN-EN 4589-2:2006/ A1:2006 (U)
- ASTMD 2863-06a

Determination of the oxygen index (LOI) of plastics

The oxygen index (LOI) is a basic parameter that determines the relative flammability of polymeric materials such as plastics, rubber or textiles. During the test, combustion of a small sample of the material in a controlled atmosphere of oxygen and nitrogen is performed. As a result of the test, the minimum concentration of oxygen in the nitrogen mixture at which the combustion of the material is still sustained is determined.

Operating range of the device:

- 0-100% Measurement range Accuracy of oxygen concentration measurement: 0,1%
- Nitrogen and oxygen supply from a cylinder

al. Powstańców Warszawy 12, 35-959 Rzeszów
phone: +48 17 865 1244
e-mail: ewelinachmiel@prz.edu.pl, b.krzykowska@prz.edu.pl, m.szpilyk@prz.edu.pl
www.chorg.prz.edu.pl

Department Chair:
Professor Iwona Zarzyka, BEng, PhD, Dsc, Prof.Tit.
phone: +48 17 865 1762
e-mail: izarzyka@prz.edu.pl

Department of Organic Chemistry Elemental Analysis and Gas Chromatography Laboratory

Methods and techniques:

UNICUBE is optimized to analyze the content of the following elements in the material under study, modes of operation:

- CHNS
- CHN
- CNS
- CN
- Cl
- O

Apparatus available:

The UNICUBE and RapidOXYcube series elemental analyzer from Elementar, Germany, analyzes the percentage of elements in the material under study:

- carbon (UNICUBE)
- hydrogen (UNICUBE)
- nitrogen (UNICUBE)
- sulfur (UNICUBE)
- chlorine (UNICUBE)
- oxygen (Rapid OXY cube)

Standard compliance tests:

- Safety standards according to EU Directive 2006/42/EG
- The apparatus complies with CE standards in accordance with CE directives: EMC 89/336/EEC, LVD 73/23/EEC

Elemental analysis: Determination of the percentage content of the elements C, H, N, S, Cl, O in the tested material

Designed for analysis of all organic and most inorganic samples, both solid and liquid.

Determination of percentage of elements: C, H, N, S, Cl, O in organic compounds, pharmaceuticals, polymers, catalysts, oils, cosmetics, rubbers, dyes, fertilizers, plant material, soils, food, compost, sewage sludge, waste, biomass and many others.

Separation of the measured components on a column with selective beds separate for the components to be determined, absorbing from the reaction gas mixture only the specific element in the form of oxide formed in the oxidation-reduction reaction into a form detectable by the detector . The bed stores entirely the analyte of a given element obtained after combustion of a given sample. Carrier gas: helium.

Detectors: Thermal conductivity detector (TCD), Infrared (IR) detector for sulfur analysis, Electrochemical detector for chlorine analysis.
Measurement ranges:
C : 0 - 14 mg vale or 0 - 100%.
H ; 0 - 2 mg. wt. or 0-100%
N : 0 - 10 mg. wt. or 0-100%
S : 0 - 3 mg worth of anhydrous or 0-100%
O : 0 - 6 mg worth of anhydrous or 0-100%
Cl :0 - 1.2 mg value anhydrous or 0-100%
Standard deviation : <0.1%

al. Powstańców Warszawy 12, 35-959 Rzeszów
phone: +48 17 865 1244, 17 865 1995
e-mail: ewelinachmiel@prz.edu.pl, b.krzykowska@prz.edu.pl,
m.szpilyk@prz.edu.pl
www.chorg.prz.edu.pl

Department Chair:
Professor Iwona Zarzyka, BEng, PhD, Dsc, Prof.Tit.
phone: +48 17 865 1762
e-mail: izarzyka@prz.edu.pl

Department of Organic Chemistry Elemental Analysis and Gas Chromatography Laboratory

Gas chromatography GCMS: Study of qualitative and quantitative composition of complex mixtures of chemical compounds

Gas chromatography with FID and MS detection is a specialized analytical technique that allows accurate determination of the molecular weight of the compound under study, its structure and quantity in the material under study. The analytical procedure based on the MS technique involves several steps starting with the ionization of the sample in the source, the separation of the resulting ions in the analyzer based on their mass-to-charge ratio (m/z), followed by their identification in the detector and the interpretation of mass spectra, which are the final result of the analyses performed. In a coupled GC/MS system, a gas chromatograph allows the analyzed mixture to be separated into components over time. In turn, the mass spectrometer records their mass spectra, from which each of the components of the separated mixture can be identified.

Methods and techniques:

- GCMS-an analytical method using mass spectrometry to identify test substances in a sample
- FID- flame ionization detection. The detector allows detection of most hydrocarbons, the exceptions being formaldehyde and formic acid

Apparatus available:

- Agilent 7890A gas chromatograph with FID and MS detector (MS with EI and CI (positive and negative chemical ionization)

al. Powstańców Warszawy 12, 35-959 Rzeszów
phone: +48 17 865 1244
e-mail: ewelinachmiel@prz.edu.pl, m.szpilyk@prz.edu.pl
www.chorg.prz.edu.pl

Department Chair:
Professor Iwona Zarzyka, BEng, PhD, Dsc, Prof.Tit.
phone: +48 17 865 1762
e-mail: izarzyka@prz.edu.pl

Department of Organic Chemistry
NMR Spectrometry Laboratory

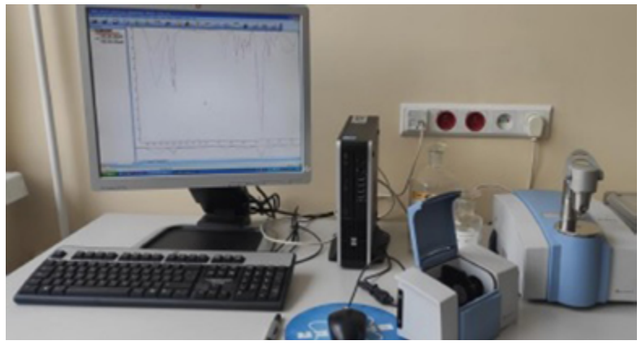
Methods and techniques:

Sample analysis technique
by methods:

- ATR: mainly for liquid/ resin substances
- KBr lozenge transmission: a method of analyzing a sample (usually a solid sample) by pressing the sample into a lozenge form

Apparatus available:

- ALPHA FT-IR spectrometer from BRUKER, Germany with OPUS software

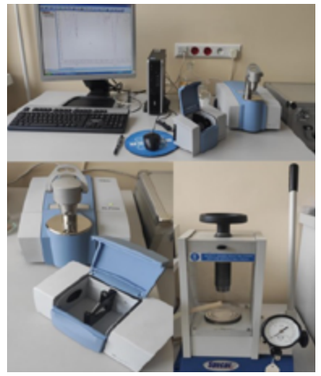


Analysis of a variety of materials using infrared (IR)

Equipped with a diamond crystal ATR attachment for testing solids and liquids, and a transmission attachment for testing compressed lozenge samples Standard measurement parameters in the range: 450 cm-1 to 4000 cm-1 , resolution of 4 cm-1 , averaging of 64 scans.
Type of tests performed:

Performance of infrared spectra by technique:

- ATR (possibility to study solids and liquids in a wide range of pH),
- Transmissive in KBr lozenge (study of solids such as polymers),
- Comparative analysis.



al. Powstańców Warszawy 12, 35-959 Rzeszów
phone: +48 17 865 1244, +48 17 865 1995
e-mail: ewelinachmiel@prz.edu.pl, b.krzykowska@prz.edu.pl,
m.szpilyk@prz.edu.pl
www.chorg.prz.edu.pl

Department Chair:
Professor Iwona Zarzyka, BEng, PhD, Dsc, Prof.Tit.
phone: +48 17 865 1762
e-mail: izarzyka@prz.edu.pl

Department of Organic Chemistry

Methods and techniques:

- mixing
- cutting
- emulsifying
- heating
- indirect cooling using a vacuum system

Apparatus available:

- Stephan UMC 5 mixer

Stephan UMC 5 mixer

The Stephan UMC 5 mixer is used for performing multiple operations with a single machine, such as grinding, mixing, cutting, emulsifying, heating, and indirect cooling using a vacuum system down to 100 mbar, with constant temperature control. The bowl can hold between 0.5 and 3 liters of material, and the maximum operating temperature of the mixer is 95°C. The machine can operate at speeds ranging from 300 to 3000 rpm.

al. Powstańców Warszawy 12, 35-959 Rzeszów
phone: +48 17 865 1244
e-mail: b.krzykowska@prz.edu.pl, m.szpilyk@prz.edu.pl
chorg.prz.edu.pl

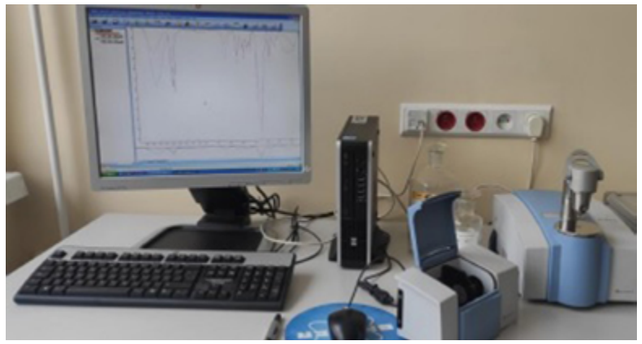
Department Chair:
Professor Iwona Zarzyka, BEng, PhD, Dsc, Prof.Tit.
phone: +48 17 865 1762
e-mail: izarzyka@prz.edu.pl

Methods and techniques:

- observation techniques: BF, DF, PHC, POL, MMC, Epifluorescence
- standard magnifications: 40x, 100x, 400x, and 1000x
- observation type: transmitted light

Apparatus available:

- polarizing microscope, Pantera series by Motic
- Motic Images Plus 3.0 ML software
- Motic Images Multi-Focus Pro 1.0



Polarizing microscope

Observation of plastic samples, mainly polyurethane (structure, number and size of pores). Photography of samples with measurements.

he polarizing microscope is used for the observation of plastic samples, mainly polyurethane (structure, number, and size of pores). It also allows for photographing samples with measurements. The microscope is designed for research work in laboratories and is equipped with wide-field eyepieces (25 mm). It features strong halogen illumination (100 W) for transmitted light work in the Köhler setup. The focusing knob has a resolution of 1 µm. The encoded revolving stage "remembers" the light intensity for each objective position. The ECO function is an environmentally friendly automatic energy-saving mode that protects the sample from overheating. Additionally, the microscope is equipped with an integrated USB port for camera power and a LED light intensity indicator in the objective turret.

al. Powstańców Warszawy 12, 35-959 Rzeszów
phone: +48 17 865 1244, +48 17 865 1995
e-mail: ewelinachmiel@prz.edu.pl, b.krzykowska@prz.edu.pl,
m.szpilyk@prz.edu.pl
www.chorg.prz.edu.pl

Department Chair:
Professor Iwona Zarzyka, BEng, PhD, Dsc, Prof.Tit.
phone: +48 17 865 1762
e-mail: izarzyka@prz.edu.pl

Department of Organic Chemistry

PTXL Ultramicrotome: PowerTome RMC Boeckeler

The PTXL Ultramicrotome: PowerTome allows for the perfect preparation of thin and ultra-thin samples of materials to be studied using STEM or TEM techniques. A diamond knife is used for sectioning the sample. The device allows control of cutting speed and feed step regulation. The resulting samples have a thickness range from 5 nm to 10 µm.

Methods and techniques:

- sample sectioning within a thickness range from 5 nm to 10 µm

Apparatus available:

- PTXL ultramicrotome: PowerTome RMC Boeckeler

al. Powstańców Warszawy 12, 35-959 Rzeszów
phone: +48 17 865 1244, +48 17 865 1995
e-mail: ewelinachmiel@prz.edu.pl, b.krzykowska@prz.edu.pl,
m.szpilyk@prz.edu.pl
www.chorg.prz.edu.pl

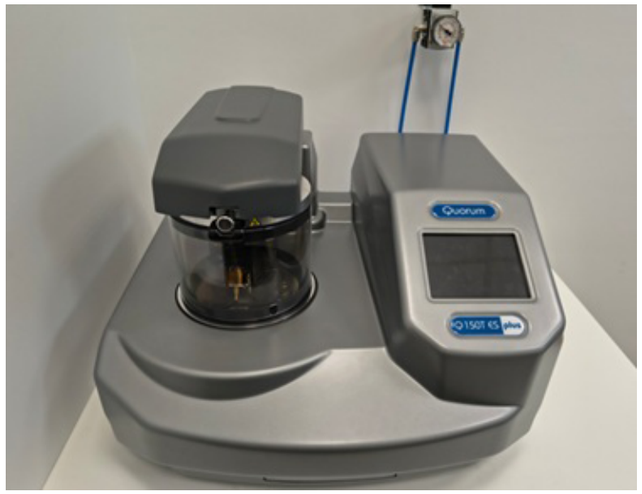
Department Chair:
Professor Iwona Zarzyka, BEng, PhD, Dsc, Prof.Tit.
phone: +48 17 865 1762
e-mail: izarzyka@prz.edu.pl

Methods and techniques:

- deposition of carbon (C), gold (Au), platinum (Pt), silver (Ag), copper (Cu), nickel (Ni), and gold/palladium (Au/Pd) mixtures onto the surface of non-conductive samples

Apparatus available:

- high-vacuum sputter coater Q150T E plus



High-vacuum sputter coater Q150T E plus Quorum Technologies

The high-vacuum sputter coater allows for the deposition of thin, amorphous layers of carbon (C), gold (Au), platinum (Pt), silver (Ag), copper (Cu), nickel (Ni), or gold/palladium (Au/Pd) mixtures with high purity and density onto the surface of non-conductive samples. This is done to improve the electrical conductivity of the samples analyzed using scanning electron microscopy (SEM) and to prepare the samples for scanning transmission electron microscopy (STEM) studies.

al. Powstańców Warszawy 12, 35-959 Rzeszów
phone: +48 17 865 1244, +48 17 865 1995
e-mail: ewelinachmiel@prz.edu.pl, b.krzykowska@prz.edu.pl,
m.szpilyk@prz.edu.pl
www.chorg.prz.edu.pl

Department Chair:
Professor Iwona Zarzyka, BEng, PhD, Dsc, Prof.Tit.
phone: +48 17 865 1762
e-mail: izarzyka@prz.edu.pl

Department of Organic Chemistry

Multiwave 3000 microwave oven

The technique of conducting chemical reactions in closed vessels helps to shorten reaction time by allowing the use of higher temperatures while preventing the loss of volatile analytes. The resulting low reagent consumption saves time, reduces costs, and helps minimize exposure to corrosive gases and hazardous solvent vapors. The Multiwave 3000 is a microwave-assisted extraction (MAE) device, which significantly shortens reaction time compared to conventional methods, such as Soxhlet. The Multiwave 3000 evaporates acids and pre-concentrates aqueous solutions directly from reaction vessels in fully controlled cleanroom conditions. Additionally, the Multiwave 3000 microwave oven performs gentle drying without carbonization or contamination of samples in a shorter time compared to conventional techniques.

Methods and techniques:

- digestion – sample dissolution with acids used in environmental analysis and material testing
- leaching – studying the reaction of materials to alkali using US-EPA and ASTM methods
- microwave-assisted extraction (MAE)
- evaporation
- drying

Apparatus available:

- Anton Paar Multiwave 3000 microwave oven

al. Powstańców Warszawy 12, 35-959 Rzeszów
phone: +48 17 865 1244, +48 17 865 1995
e-mail: ewelinachmiel@prz.edu.pl, b.krzykowska@prz.edu.pl,
m.szpilyk@prz.edu.pl
www.chorg.prz.edu.pl

Department Chair:
Professor Iwona Zarzyka, BEng, PhD, Dsc, Prof.Tit.
phone: +48 17 865 1762
e-mail: izarzyka@prz.edu.pl

Methods and techniques:

- angle of rotation measurement
- International Sugar Scale without temperature compensation
- International Sugar Scale with temperature compensation for the correct angle of rotation

Apparatus available:

- AP-300 ATAGO polarimeter

Optical rotation angle measurement

The optical rotation angle measurement using the AP-300 ATAGO polarimeter is used for analyzing chemical compounds, especially organic compounds such as sugars, amino acids, or certain pharmaceuticals. The device is applied in chemistry, pharmacy, biology, and the food industry (e.g., for determining sugar content in solutions).

The AP-300 ATAGO polarimeter allows for the measurement of rotation angle, specific rotation angle, concentration, and purity of the tested solution. Measurement range of rotation angle: -89.99 to 89.99°; International Sugar Scale range: -130.00 to +130.00°Z. Measurement accuracy: ± 0.01°. Wavelength used: 589 nm (D).

al. Powstańców Warszawy 12, 35-959 Rzeszów
phone: +48 17 865 1244, +48 17 865 1995
e-mail: ewelinachmiel@prz.edu.pl, b.krzykowska@prz.edu.pl,
m.szpilyk@prz.edu.pl
www.chorg.prz.edu.pl

Department Chair:
Professor Iwona Zarzyka, BEng, PhD, Dsc, Prof.Tit.
phone: +48 17 865 1762
e-mail: izarzyka@prz.edu.pl

Department of Organic Chemistry

ZEISS GeminiSEM 360
Scanning electron microscope with field emission

The scanning electron microscope enables imaging of conductive, non-conductive, dia-, para-, and ferromagnetic samples with magnification up to 200,000x
allows for surface condition analysis and morphology assessment
operates in high vacuum (HV) and variable pressure (VP) modes
equipped with the following detectors:

- Secondary Electron (SE) detector for imaging sample topography
- Secondary Electron detector for variable pressure (VPSE) mode, enabling analysis and imaging of non-conductive, highly outgassing, and wet samples
- InLens SE Secondary Electron detector for primary surface topography information
- diode, five-segment Backscattered Electron (BSD) detector
- aSTEM transmission electron detector, allowing operation in DF, BF, ODF, HAADF modes, used for composition and topography imaging of ultrathin samples

The microscope is equipped with an EDS attachment for element detection from Be to U. It enables elemental mapping and distribution, with results given in weight and atomic percent .

The microscope is integrated with a DEBEN cooling stage operating in the range of -25°C to 160°C.

Methods and techniques:

The microscope is equipped with detectors:

- InLens SE
- SE
- VPSE
- BSD
- aSTEM

Apparatus available:

- GeminiSEM 360 ZEISS scanning electron microscope
- Ulti Max 65 EDS attachment Oxford Instruments
- DEBEN CoolStage

al. Powstańców Warszawy 12, 35-959 Rzeszów
phone: +48 17 865 1244, +48 17 865 1995
e-mail: ewelinachmiel@prz.edu.pl, b.krzykowska@prz.edu.pl,
m.szpilyk@prz.edu.pl
www.chorg.prz.edu.pl

Department Chair:
Professor Iwona Zarzyka, BEng, PhD, Dsc, Prof.Tit.
phone: +48 17 865 1762
e-mail: izarzyka@prz.edu.pl

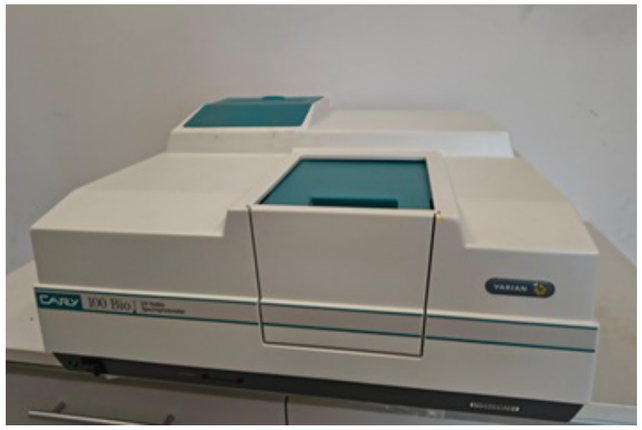
Department of Organic Chemistry

Methods and techniques:

- recording UV-Vis spectra in the range 190–900 nm
- determination of absorbance values at a given wavelength
- UV-Vis spectra analysis

Apparatus available:

- CARY 100 Bio UV-Vis spectrophotometer



Analysis of the structure of UV and Vis absorbing compounds

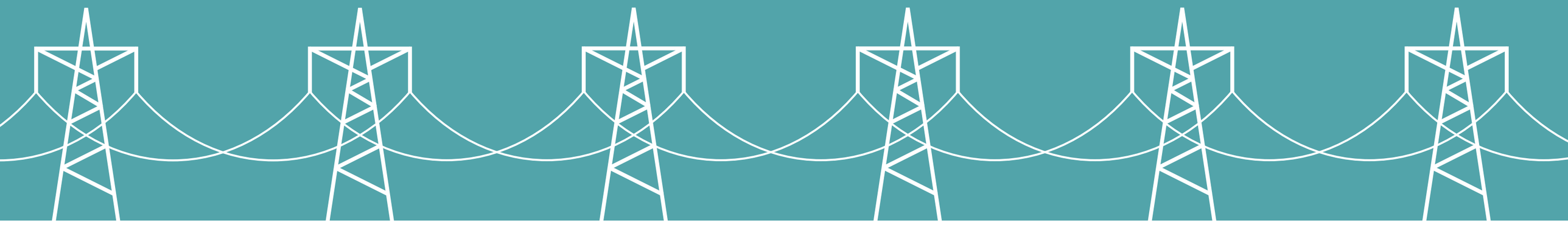
The CARY 100 Bio UV-Vis spectrophotometer is used to measure the absorption and transmittance properties of a sample, providing data on the composition and chemical properties of the analyzed material. Measurement is performed in the wavelength range from 190 to 900 nm with an accuracy of ±2 nm. The light sources are a tungsten-halogen lamp and a deuterium lamp. The device is equipped with temperature regulation, as well as holders for both liquid and solid samples.

al. Powstańców Warszawy 12, 35-959 Rzeszów
phone: +48 17 865 1244, +48 17 865 1995
e-mail: ewelinachmiel@prz.edu.pl, b.krzykowska@prz.edu.pl,
m.szpilyk@prz.edu.pl
www.chorg.prz.edu.pl

Department Chair:
Professor Iwona Zarzyka, BEng, PhD, Dsc, Prof.Tit.
phone: +48 17 865 1762
e-mail: izarzyka@prz.edu.pl

Wincentego Pola 2, 35-959 Rzeszów
e-mail: dwe@prz.edu.pl
weii.prz.edu.pl

FACULTY OF
ELECTRICAL
AND COMPUTER ENGINEERING
RZESZÓW UNIVERSITY OF TECHNOLOGY



Department of Electrical and Computer Engineering Fundamentals

Methods and techniques:

- tests using standardized test strokes reflecting the direct and indirect effects of lightning,
- direct exposure of the device under test or coupling of the excitation in the wires reaching it,
- measuring time responses using current and voltage probes and a digital oscilloscope, or using a measuring fiber optic system and a PC

Apparatus available:

- TGUN - 300 surge voltage test stand
- generator of long-lasting lightning surges GUP - 10/1000
- Surge arrester testing system GUP 100 - 8/20
- current surge generator GUP - 80/10
- single surge generator MIG0618SS
- Impact series generator MIG0600MS
- Surge generator series MIG-OS-MB
- set of six fiber optic measurement links

Standard compliance tests:

- RTCA/DO-160

Study of lightning impacts

The test stand, equipped with a unique system of voltage and current surge generators, allows testing the resistance of individual devices and entire aircraft systems to the indirect effects of lightning. The MIG0618SS, MIG0600MS and MIG-OS-MB generators from EMC Partner AG (Switzerland) included in the test stand enable the generation and galvanic, capacitive or inductive coupling of single test strokes, series of strokes and series of burst pulses to equipment connectors or wiring harnesses of aircraft systems. The simulated disturbances meet with excess the requirements of the RTCA/DO-160 standard in terms of peak levels and shapes of dedicated excitations. Parameters of generated strokes by owned generators:

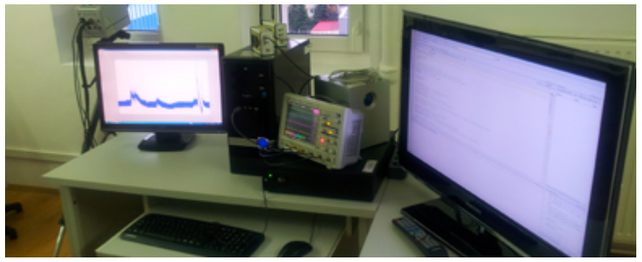
- WF1 surge 6.4/69 µs (max. current 4 kA),
- WF2 stroke 0.1/6.4 µs (voltage max. 1.6 kV),
- WF3 1 or 10 MHz surge (voltage max. 3.2 kV),
- WF4 6.4/69 µs surge (voltage max. 3.2 kV),
- WF5A surge 40/120 µs (voltage max. 3.2 kV or current max. 5 kA),
- WF6 surge 0.224/4 µs (max. current 160 A).

A set of mobile voltage and current surge generators provides the opportunity to conduct field and laboratory tests of the effectiveness of lightning and surge protection systems for ground facilities and tests of the effects of lightning current pulses on conductive composite materials. The first area of capability is testing the resistance of objects to a 1.2/50 µs voltage surge with an amplitude of up to 300kV. The second area is testing with a lightning current surge of long duration from 10 to 100 ms and with a current amplitude of up to 100 A. It is also possible to test with current surges: type 1 - an oscillatory waveform with a current amplitude of up to 100 kA, type 2 - an 8/20 µs aperiodic waveform with a peak current of up to 60 kA, and type 3 - a 10/350 µs aperiodic waveform with a peak current of up to 3 kA.

ul. Wincentego Pola 2, 35-959 Rzeszów
phone: +48 17 865 1253
e-mail: maslowski@prz.edu.pl
www.pei.prz.edu.pl

Department Chair:
Grzegorz Masłowski, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1253
e-mail: maslowski@prz.edu.pl

Department of Electrical and Computer Engineering Fundamentals



Electromagnetic field recording and high-speed video recording of lightning discharges

The test stand equipped with a set of lightning electromagnetic field antennas and a high-speed video camera allows to study the phenomena accompanying the development of natural and artificially triggered lightning. The complete measurement system consists of two functional blocks: an electromagnetic field recording block and an optical recording block. The lightning registration system has the option of parallel operation of these two operational blocks. In addition, it is possible to synchronize the registration process with UTC time with an accuracy of 1 µs.

Registration of lightning electric field can be carried out in the range from 0 Hz to 10 Hz with the use of slow-variable electric field antennas, the so-called mills, as well as in the frequency band from 0.5 Hz to 3 MHz with the use of fast-variable electric field antennas. The fast-variable lightning field antennas have two measurement ranges with 40 dB difference in gain. The maximum operating range of the antennas is an area with a radius of up to 50 km from the measurement point, with the optimal distance from the discharge being between 5 km and 15 km. The antennas also have a measurement function with and without 50 Ω wave matching used when the signal is far away from the signal recorder. It is also possible to generate TTL standard pulses during a lightning discharge for triggering other recording equipment.

A set of two high-speed video cameras: Photron SA5 and Chronos 1.4 gives the possibility to record the process of lightning channel development. High-speed video recording can be performed with the Photron SA5 camera at up to 7,000 frames/second at 1024 x 1024 pix resolution and up to 1 million frames/second at reduced resolution. The Chronos camera allows image acquisition at 1280 x 1024 resolution at 1 thousand frames/s . Image recording for both cameras is done in RGB standard.

Methods and techniques:

- measurement of the electromagnetic field generated from natural lightning discharges using slow- and high-speed field antennas, a set of measurement cards and a PC
- video registration of the development process of natural lightning discharges using high-speed video cameras and a dedicated optical system

Apparatus available:

- lightning discharge recording system
- antennas for measuring slow-change electric field
- antennas for measuring high-speed electric field
- Chronos 1.4 camera
- omnidirectional optical system

ul. Wincentego Pola 2, 35-959 Rzeszów
phone: +48 17 865 1253
e-mail: maslowski@prz.edu.pl
www.pei.prz.edu.pl

Department Chair:
Grzegorz Masłowski, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1253
e-mail: maslowski@prz.edu.pl

Department of Electrical and Computer Engineering Fundamentals

Methods and techniques:

- Measurement of frequency characteristics of electrical equipment using the SFRA (Sweep Frequency Response Analysis) method - frequency response analysis with "sweep" of frequencies over a wide range

Apparatus available:

- 4-channel measurement system

Differential measurement of high-voltage electrical signals

The PicoScope 4444 1000 V CAT III mains voltage and current measurement kit includes a high-resolution differential oscilloscope with four PicoConnect 442 25: 1 passive differential probes and four TA368 2000 A AC Rogowski current probes, both of which are capable of measuring electrical signals up to 1000 V in CAT III category. It also includes one D27-BNC single-ended TA271 adapter. The PicoScope 4444 oscilloscope uses specially designed passive voltage probes that have smaller and lighter housings and that allow it to make multiple differential measurements at the same time, while drawing power from a smart probe interface called the Pico D9. The Pico D9 interface automatically configures the display in the PicoScope 6 software to the correct probe range.

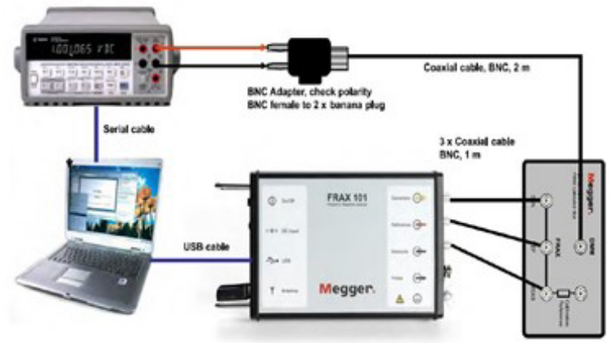
The 12-bit resolution of the PicoScope 4444 provides greater vertical measurement detail, while the 256 MS deep capture memory provides greater horizontal resolution. The kit is used for measurements that do not relate to ground potential, safe measurement of single-phase and 3-phase voltages and currents, measurement of power consumed by mobile and IoT devices, hybrid and electric vehicles, motor drives and inverters. The TA271 D9-BNC adapter allows the use of traditional differential voltage probes and current probes, as well as measurements when raised to ground potential.

Dedicated PC software such as PicoScope, and PicoLog allow recording, in user-supervised mode, as well as in automatic mode. There is also the possibility of advanced configuration of the measurement station using a set of libraries dedicated to Matlab.

ul. Wincentego Pola 2, 35-959 Rzeszów
phone: +48 17 865 1253
e-mail: maslowski@prz.edu.pl
www.pei.prz.edu.pl

Department Chair:
Grzegorz Masłowski, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1253
e-mail: maslowski@prz.edu.pl

Department of Electrical and Computer Engineering Fundamentals



Measurement of frequency characteristics impedance

A test stand consisting of Megger FRAX 101 analyzer and a dedicated control unit, together with a set of necessary measurement probes, allows testing the frequency characteristics of electrical equipment. The device is dedicated in particular to testing transformers. Among other things, it allows the detection of displacements and damages to windings, as well as defects in the transformer core. The measurement is performed automatically on the basis of a pre-set range using the SFRA (Sweep Frequency Response Analysis) method - frequency response analysis with "sweeping" of frequencies over a wide range. The range of the analyzer's most important features and capabilities include its multifunctionality in the context of diagnostic testing of transformers and substation equipment, high measurement accuracy, compact and lightweight design. An important functional feature is also the full galvanic separation between the measuring instrument and a laptop using Bluetooth communication, as well as the galvanically separated USB port important for the safety of the equipment user.

Key equipment features include:

- frequency measurement in the range of 0.1 Hz to 25 MHz, selectable by the user
- frequency resolution: 0.01%
- measurement error: 0.01%
- number of measurement points up to 32,000, user-selectable
- distribution of measurement points: logarithmic, linear or mixed
- 1 analog output channel up to 25 Vpp
- 2 analog input channels 50 Ω with sampling frequency 100 MS/sec.
- short circuit protection
- possibility to create own measurement templates

Methods and techniques:

- Measurement of frequency characteristics of electrical equipment using the SFRA (Sweep Frequency Response Analysis) method - frequency response analysis with "sweep" of frequencies over a wide range

Apparatus available:

- automatic registration station

ul. Wincentego Pola 2, 35-959 Rzeszów
phone: +48 17 865 1253
e-mail: maslowski@prz.edu.pl
www.pei.prz.edu.pl

Department Chair:
Grzegorz Masłowski, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1253
e-mail: maslowski@prz.edu.pl

Department of Electrical and Computer Engineering Fundamentals

Methods and techniques:

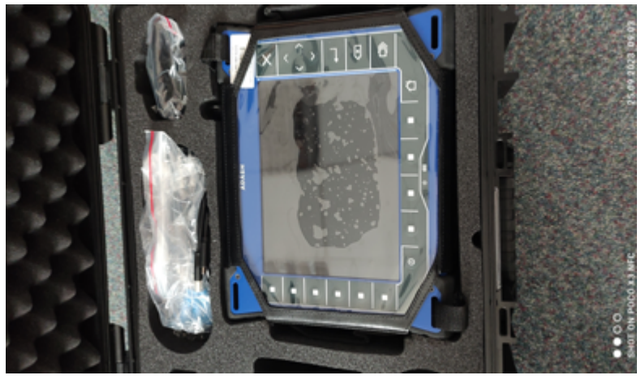
- vibration measurements of CNC machines and electric motors and generators.
- compilation and parameterization of measurement paths
- creation and parameterization of measurement paths,
- realization of functions of a digital recorder of raw signals for further analysis,
- analysis of the state of degradation of bearings based on their characteristic frequencies,
- detection of natural frequencies of tested structures and mechanical systems,
- generation of diagnostic reports.

Apparatus available:

- vibration measurement system (Adash)

Standard compliance tests:

- E.g. PN-EN ISO 9612:2011
- ISO 10816/20816



Measurement of machine vibrations

The vibration measurement system (Adash) consists of Polish-language modular diagnostic software and a system for building and operating databases for collecting and archiving measurements and results of conducted analyses (unlimited number of databases).

ul. Wincentego Pola 2, 35-959 Rzeszów
phone: +48 17 865 1253
e-mail: maslowski@prz.edu.pl
www.pei.prz.edu.pl

Department Chair:
Grzegorz Masłowski, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1253
e-mail: maslowski@prz.edu.pl

Department of Electrical and Computer Engineering Fundamentals

Measurement of parameters of electrical installations

Multifunctional meter of parameters of electrical installations Sonel MPI-540-PV- is an advanced tool created for measuring the parameters of photovoltaic installations. With the help of a single device it is possible to perform a whole range of tests on the DC and AC side in accordance with the guidelines of PN-EN 62446. In addition, Sonel MPI-540-PV is also used to carry out all measurements to determine the safety status of domestic, as well as industrial electrical installations.

Methods and techniques:

- measuring the parameters of photovoltaic installations,
- automatic measurement of protection elements of photovoltaic installations,
- automatic measurement of insulation resistance of 3-, 4-, and 5-wire cables.

Apparatus available:

- Multifunction meter of electrical installation parameters Sonel MPI-540-PV

Standard compliance tests:

- E.g. PN-EN ISO 9612:2011
- AutoISO-1000C

ul. Wincentego Pola 2, 35-959 Rzeszów
phone: +48 17 865 1253
e-mail: maslowski@prz.edu.pl
www.pei.prz.edu.pl

Department Chair:
Grzegorz Masłowski, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1253
e-mail: maslowski@prz.edu.pl

Department of Electrical and Computer Engineering Fundamentals Acoustics Laboratory

Methods and techniques:

- flow of an acoustic wave through a sample

Apparatus available:

- ultrasonic disintegrator

Ultrasonic disintegrator in technology

Ultrasonic disintegrator (sonicator) with maximum power of 750 watts. Equipped with an automatic pulser and timer. This is a high-powered sonicator model. The set, consisting of a disintegrator with a "solid" type tip, is recommended for nanotechnology and similar sample mixing (dispersion) applications. Applications: Disintegration of bacterial cells, spores and tissues; acceleration of catalytic reactions; extraction of serums, toxins, enzymes and viruses from organic sources; solubilization of difficult compounds; emulsification down to 0.01 mm; homogenizing liquids; microscope sample preparation and particle size analysis.

ul. M. C. Skłodowskiej 8\2, 35-959 Rzeszów
phone: +48 17 865 1074
e-mail: edytap@prz.edu.pl
www.pei.prz.edu.pl

Department Chair:
Grzegorz Masłowski, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1253
e-mail: maslowski@prz.edu.pl

Department of Electrical and Computer Engineering Fundamentals Acoustics Laboratory

Noise measurement

The apparatus allows you to make measurements of traffic noise, at the workplace, at the place of residence. It is possible to create noise maps with its help. The device allows to measure noise generated by elements of technical equipment, for example: generators, pumps, elevators, water supply or sewage systems. Measurements can be made using frequency correction curves suitable for the study. It is possible to test and record sounds using different time constants. The apparatus also allows frequency analysis (in octave or thirds bands) and sound recording, followed by the determination of a number of detailed parameters: Leq, Lmin, Lmax, Lpeak, etc. The device has a removable SD card.

Methods and techniques:

- direct method of noise measurement
- indirect noise measurement method

Apparatus available:

- Bruel&Kjaer continuous noise monitoring equipment

Standard compliance tests:

- Np. PN-EN ISO 9612:2011
- PN-B-02151/02:1987/ Ap1:2015-05

ul. M. C. Skłodowskiej 8\2, 35-959 Rzeszów
phone: +48 17 865 1074
e-mail: edytap@prz.edu.pl
www.pei.prz.edu.pl

Department Chair:
Grzegorz Masłowski, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1253
e-mail: maslowski@prz.edu.pl

Department of Electrical and Computer Engineering Fundamentals Acoustics Laboratory

Methods and techniques:

- active vibration reduction
- measurement of dimensionless damping coefficient
- measurement of vibrations of one- and two-dimensional structures
- actuator efficiency testing

Apparatus available:

- active vibration reduction test apparatus

Active vibration reduction

The stand for active vibration reduction makes it possible to study the efficiency of vibration reduction of one- and two-dimensional mechanical systems. The apparatus also gives the possibility to measure the vibration of the structure (without a regulator) and to study parameters related to the structure itself (e.g., determination of the dimensionless damping coefficient). The mounting of the structure is set on a flange, which gives the possibility to test systems with dimensions not exceeding 0.85 m. A 900 W loudspeaker is used as the vibration inductor, while the actuators (actuators) can be, for example, piezoelectric, MFC, magnetostrictive elements, etc. The vibration signal is measured with an optoNCDT laser sensor (with a range of 2mm or 10 mm) with a sampling frequency of up to 20 kS/s. The bench is also equipped with an NI USB-6212 measurement card with BNC terminals and a GWInstek AFG-2225 function generator. The apparatus also includes a compact Polytec CLV-2534 laser sensor. The signal sent to the actuators can be amplified through 3 available Piezo Systems Piezo Linear Amplifier EPA-104. The apparatus also includes piezoelectric actuators of various shapes (rectangular, circular, asymmetrical).

ul. M. C. Skłodowskiej 8\2, 35-959 Rzeszów
phone: +48 17 865 1074
e-mail: edytap@prz.edu.pl
www.pei.prz.edu.pl

Department Chair:
Grzegorz Masłowski, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1253
e-mail: maslowski@prz.edu.pl

Department of Electrical and Computer Engineering Fundamentals Acoustics Laboratory

Methods and techniques:

- Measurements of acoustic parameters of material samples using a set of impedance tubes;
- Two-microphone transition function method;
- Four-microphone transition function method.

Apparatus available:

- apparatus for measuring acoustic properties of Bruel&Kjaer material samples

Standard compliance tests:

- ISO 10534-2
- PN-EN ISO 10534-2:2003

Measurement of acoustic properties of samples materials

The apparatus allows to perform measurements of acoustic properties of the provided materials by the transition function method. Among other things, it is possible to measure sound absorption coefficient, TL coefficient, acoustic impedance. The frequency range of the described tests is from 50 to 6400 Hz (two samples must be tested). These tests can be performed both for single materials and for systems. The tests carried out allow to assess the usefulness of a given material for acoustic adaptation of rooms. The measurements are carried out using PULSE software. It is possible to export the obtained data to MS Excel and then process them according to the user's requests.

ul. M. C. Skłodowskiej 8\2, 35-959 Rzeszów
phone: +48 17 865 1074
e-mail: edytap@prz.edu.pl
www.pei.prz.edu.pl

Department Chair:
Grzegorz Masłowski, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1253
e-mail: maslowski@prz.edu.pl

Department of Power Electronics and Power Engineering Laboratory of Lighting Technology

Methods and techniques:

- easurements of luminous flux and luminous efficacy of light sources using an integrating sphere
- luminance distribution measurements of luminaires using an arm goniometer
- luminance distribution measurements using a spot or matrix meter
- measurements of illuminance distribution using single and multihead meter
- measurements of spectral distributions of light sources
- determination of light color parameters based on measurement of spectral distribution

Apparatus available:

- C- γ type photometric goniometer
- Ulbricht sphere with a diameter of 2 m
- matrix luminance meter LMK 5
- multi-head illuminance meter Konica Minolta CL-200
- Konica Minolta CS-2000 spectroradiometer

Tests of light distribution of luminaires

Light distribution test stand with C- γ photometric goniometer with α-β measurement capability. Possibility of determining photometric solids of luminaires with the maximum dimension of the luminous element up to 2m.

Luminous flux tests

Light flux test stand with Ulbricht sphere. A sphere with a diameter of 2m for determining the luminous flux of light sources and luminaires and the efficiency of luminaires. Ability to determine luminous efficacy.

Luminance distribution tests

Luminance distribution test stand with a luminance matrix meter for determining luminance distributions in architectural illumination, road lighting, etc..

Illuminance distribution tests

Illuminance distribution test stand using Konica Minolta CL-200 multi-head illuminance meter with adapters for meter and heads and a set of 9 measurement heads with spectral correction. The ability to analyze the uniformity of illumination of the visual work plane. Use of the station for indoor and outdoor lighting studies.

Colorimetric and radiometric tests

Light source test stand with Konica Minolta CS-200 and CS-2000 spectroradiometers. Use of the stand for testing spectral distributions of radiation, color, etc.

ul. Wincentego Pola 2, 35-959 Rzeszów
phone: +48 17 865 1219
e-mail: dsobczyn@prz.edu.pl
keie.prz.edu.pl

Department Chair:
Tomasz Binkowski, BEng, PhD
phone: +48 17 865 1771
e-mail: dsobczyn@prz.edu.pl

Department of Computer and Control Engineering Computer Vision Laboratory, Laboratory of Intelligent Interactive Systems

Computer vision, human–computer interaction

The laboratory conducts research in the areas of sign language recognition, human–computer interaction, development of IT systems supporting people with disabilities, vision-based device control, image processing and recognition, and digital image quality assessment. Selected topics explored in the laboratory include:

- IT system supporting communication in Polish Sign Language (PJM) in public institutions
- intelligent communicators supporting deaf individuals
- multimedia game for children to learn and improve Polish Fingerspelling Alphabet (PAP)
- recognition of letters in the Polish Fingerspelling Alphabet
- recognition of words and sentences expressed in Polish Sign Language
- bidirectional translation between Polish Sign Language and spoken Polish
- computer control using hand gestures
- interaction with virtual objects through hand gestures
- collection and annotation of extensive corpora of signed utterances and corresponding Polish texts for training AI systems
- PJM utterance synthesis by combining video fragments with interpolation to eliminate abrupt transitions between frames
- vision-based method for determining aircraft attitude during spin recovery and horizon line detection
- assessment of digital image quality

Methods and techniques:

- modalities used: RGB, depth images, skeletal data, point clouds
- classifiers based on artificial intelligence methods and tools
- deep neural networks

Apparatus available:

- RGB-D sensor kit – Kinect
- 2 RGB-D Xtion 2 sensors
- Swiss Ranger 4000 depth camera
- 2 Leap Motion controllers
- STH-MDCS-C stereoscopic camera
- 2 Bumblebee2 stereoscopic cameras
- 3 Flea2 cameras
- AXIS network camera set
- FDR-AX100EB camera
- GoPro Hero5 camera
- 2 Wacom Intuos 4 tablets
- multimedia set (wide-angle projector + frame + rear projection screen)
- deployable screens to ensure appropriate background for image capture

ul. Wincentego Pola 2, 35-959 Rzeszów
phone: +48 17 865 1791
e-mail: tomekkap@prz.edu.pl
kia.prz.edu.pl

Department Chair:
Mariusz Oszust, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1681
e-mail: marosz@prz.edu.pl

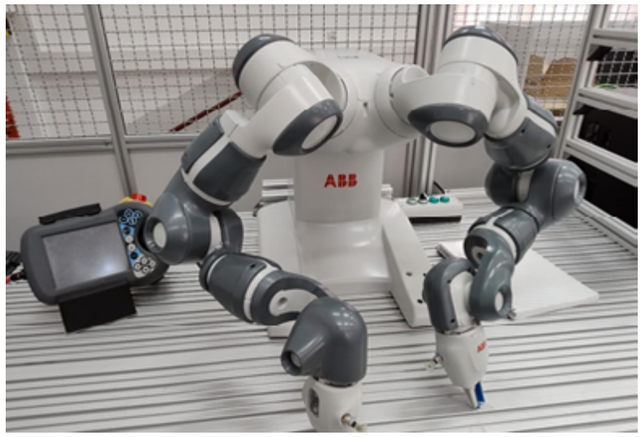
Department of Computer and Control Engineering
Laboratory of Automation, Robotics and Control

Methods and techniques:

- vibrodiagnostic measurements
- roughness and hardness measurements
- artificial intelligence methods

Apparatus available:

- ABB YuMi collaborative robot with vision system
- Siemens S7-1500 PLC (1513-1) with IO modules and MTP700 panels
- PAC Beckhoff C6920 with EL3632/ELM3602 modules (Condition Monitoring)
- Dytran, Hansford Sensors accelerometers (100 mV/g)
- Beckhoff CX9020 PLC with IO modules
- Mitsubishi Electric iQ-F PLC with IO modules, GOT2000 panels, D700 inverters, MR-JE-10C servomotors
- Allen Bradley Compact GuardLogix5380 PLC with PowerFlex 527 inverter
- IO-Link Mastery from Balluff for Profinet, EtherCAT, CC-Link, EtherNetIP
- Weintek cMT3071 HMI panels
- Balluff HF 13.56 MHz RFID system
- Intralogistics station for Euro pallets (turntable + 3m conveyor)
- Mitutoyo SURFTEST SJ-210 profilometer, NOVOTEST-UCI-LAB hardness tester, Micro-Epsilon IFC2421 + IFS2407-0.1 confocal sensor
- Software: SEE Electrical V8R2, Emulate 3D, FactoryIO



Research in automation, vibrodiagnostics, and intelligent diagnostic systems

The laboratory is equipped with modern tools for industrial automation and material testing. It features PLC controllers from manufacturers such as Siemens, Beckhoff, Mitsubishi Electric, and Allen Bradley, as well as a wide selection of inductive, capacitive, contrast, ultrasonic, photoelectric sensors, and IO-Link masters. This equipment enables PLC programming, communication with HMI panels, inverters, servo drives, and the creation of advanced automation systems. Also available are devices for vibrodiagnostic measurements: data loggers based on Beckhoff PAC C6920, Dytran and Hansford Sensors accelerometers, IEPE signal conditioner MMF M72A1, and E3632/EM3602 measuring modules. The laboratory also includes a profilometer, hardness tester, and a Micro-Epsilon confocal sensor for comprehensive surface studies. A dual-arm ABB YuMi collaborative robot with integrated vision system is also part of the lab's infrastructure. The team specializes in designing and implementing machine monitoring and diagnostic systems. It has experience in applying artificial intelligence in manufacturing processes such as milling, turning, grinding, and cold forging. The team also has access to a Haas VF-1 CNC milling machine with sensor systems, and a hardware-software platform for real-time acquisition and processing of measurement signals.

ul. Wincentego Pola 2, 35-959 Rzeszów
phone: +48 17 865 1766
e-mail: tomz@prz.edu.pl, gpiecuch@prz.edu.pl
kia.prz.edu.pl

Department Chair:
Mariusz Oszust, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1681
e-mail: marosz@prz.edu.pl

Department of Metrology and Diagnostic Systems
EML Research and Calibration Laboratory

Calibration of measuring instruments

The Laboratory of Research and Calibration LABBiKAL is a stationary calibration laboratory providing calibration services for measuring instruments used for electrical measurements. It holds PCA accreditation no. AP 226 in accordance with the requirements of the PN-EN ISO/IEC 17025 standard for the calibration of instruments for measuring DC and AC voltages and currents, as well as DC resistance.

Accredited calibration areas:

- DC voltage up to 1000 V
- DC current up to 20 A
- AC voltage up to 1000 V
- AC current up to 20 A
- DC resistance up to 100 MΩ

Objects calibrated within the scope of accreditation:

- digital multimeters
- digital meters
- power supplies
- calibrators measurement cards (PCI, PXI, SCXI, cDAQ, USB)

Methods and techniques:

- wzorcowania realizowane metodą bezpośrednią, wykorzystujące procedury własne oparte na wytycznych zawartych w dokumencie Euramet cg-15 v. 3.0

Apparatus available:

- multimetry referencyjne Fluke 8588A, Fluke 8508A, Keysight 3458A
- kalibratory wielofunkcyjne Fluke 5522A oraz Fluke 6100B
- rubidowy atomowy wzorzec częstotliwości GPS-89

ul. Wincentego Pola 2A, 35-959 Rzeszów
phone: +48 17 865 1188, +48 667 801 415
email: labbikal@prz.edu.pl
labbikal.prz.edu.pl

Department Chair:
Jakub Wojturski, BEng, PhD
phone: +48 17 865 1989
email: wojtur@prz.edu.pl

Department of Metrology and Diagnostic Systems
LABMETRON Metrology Laboratory

Methods and techniques:

- measurements and testing of electrical, non-electrical, thermal, and mechanical quantities
- measurements and testing of DC and AC voltages and currents, resistance, capacitance, inductance, frequency, active, reactive, and apparent power, as well as temperature and pressure

Apparatus available:

- Keysight DAQ970A data acquisition system
- Keysight B2901B and Keithley 2450 source meters
- Keithley 6517B electrometer
- Fluke 9102S temperature calibrator
- Hart Scientific 9150 temperature dry-well
- ASL F650 and ASL F700 thermometer bridges
- Keysight DSOX4024A oscilloscope
- Agilent 53132A frequency and time counter
- Keithley 7510 reference multimeter
- Bruel & Kjaer 4294 vibration and shock calibrator
- ScanSense AAH-004 system for calibrating pressure switches and transducers

Research, training, and metrological expertise

LABMETRON Metrology Laboratory is a stationary research and measurement laboratory providing research, measurement, training, and metrological expertise services.
Research and measurements conducted in the laboratory:

- multi-channel recording of slow and fast-changing voltage, current, and resistance signals from systems, sensors, and measuring transducers
- metrological expertise in compliance with the production specification or metrological specification
- determination of voltage and current characteristics of electronic components and systems as a function of temperature
- measurement of surface and volume resistivity of semiconductor and dielectric materials
- simulation of voltage and resistance signals from voltage, current, resistance, temperature, and pressure sensors and transducers
- measurement of roughness and color of material surfaces
- measurement and recording of active, reactive, and apparent power of single-phase receivers
- time and frequency analysis of voltage signals

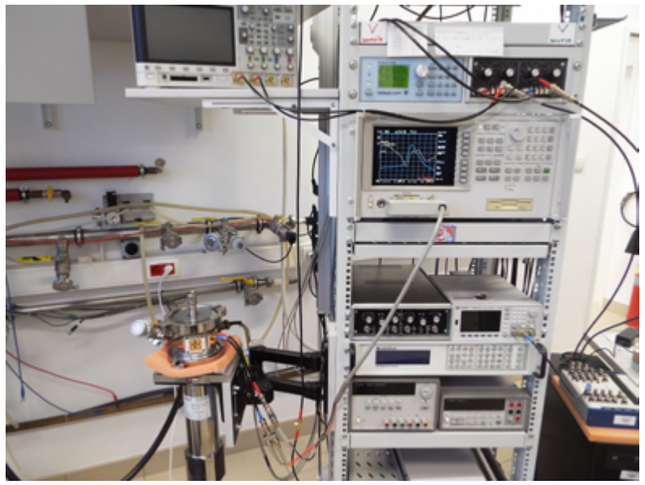
Training conducted in the laboratory:

- operation of measuring equipment (digital oscilloscope, multimeter, function generator, power supply, clamp meter, frequency counter, spectrum analyzer)
- calibration of measuring equipment
- estimation of measurement uncertainty
- programming of measuring instruments

ul. Wincentego Pola 2A, 35-959 Rzeszów
tel.: 17 865 1989, 667 801 415
email: labmetron@prz.edu.pl
facebook.com/labmetron

Department Chair:
Jakub Wojturski, BEng, PhD
phone: +48 17 865 1989
email: wojtur@prz.edu.pl

Department of Electronics Fundamentals



Methods and techniques:

- direct measurement of parameters
- **C-V characterization**

Apparatus available:

- impedance analyzers
- RLC bridge
- helium and nitrogen cryostats
- dedicated software

Determination of impedance parameters

The bench makes it possible to determine (measure) the impedance and phase modulus and determine the equivalent parameters of the selected model of the object under study as a function of various parameters, e.g. frequency (in the range of 20 Hz to 110 MHz), DC voltage, excitation parameters. Impedance characterization of devices, materials and instruments, including electronic components at temperatures in the range from 0.3 K to 325 K is possible.

ul. Wincentego Pola 2, 35-959 Rzeszów
phone: +48 17 865 1446
e-mail: zawislak@prz.edu.pl
www.kpe.w.prz.edu.pl

Department Chair:
Andrzej Kolek, BEng, PhD, DSc, Prof.Tit.
phone: +48 17 865 1114
e-mail: akoleknd@prz.edu.pl

Department of Electronics Fundamentals

Methods and techniques:

- constant-current method
- alternating-current method
- direct measurement of resistance fluctuations
- croscorrelation methods
- higher order spectra
- low-frequency noise spectroscopy

Apparatus available:

- spectrum analyzers
- preamplifiers and low-noise amplifiers
- phase-sensitive amplifiers
- anti-aliasing filters
- variable resistance bridges
- data acquisition cards
- helium and nitrogen cryostats
- dedicated software

Noise measurements of electronic components

The test stand performs measurements of voltage or current noise by direct-current (DC) or alternating-current (AC) methods in the range from 1 mHz to 1 MHz. The bench allows operation in the temperature range from 0.3 K to 800 K. The test object can be, in particular, electronic components such as detectors and sensors, power instruments, photovoltaic cells, etc.

ul. Wincentego Pola 2, 35-959 Rzeszów
phone: +48 17 865 1446
e-mail: zawislak@prz.edu.pl
www.kpe.w.prz.edu.pl

Department Chair:
Andrzej Kolek, BEng, PhD, DSc, Prof.Tit.
phone: +48 17 865 1114
e-mail: akoleknd@prz.edu.pl akolekndakol@prz.edu.pl

Department of Electronics Fundamentals

Measurements of electric transport

Measurements of currents and voltages in the current intensity range of 1 pA - 10 A are performed on the test stand. It is possible to characterize the conductivity of materials and instruments, including electronic components at temperatures in the range from 0.3 K to 325 K in the presence o magnetic fields up to ±12 T.

Methods and techniques:

- constant-current method
- alternating-current method
- direct resistance measurement
- I-V characterization of C

Apparatus available:

- SMU current-voltage sources
- digital multimeters
- transimpedance amplifiers
- phase-sensitive amplifiers
- alternating current resistance bridges
- helium and nitrogen cryostats
- dedicated software

ul. Wincentego Pola 2, 35-959 Rzeszów
phone: +48 17 865 1446
e-mail: zawislak@prz.edu.pl
www.kpe.w.prz.edu.pl

Department Chair:
Andrzej Kolek, BEng, PhD, DSc, Prof.Tit.
phone: +48 17 865 1114
e-mail: akoleknd@prz.edu.pl, akolekndakol@prz.edu.pl

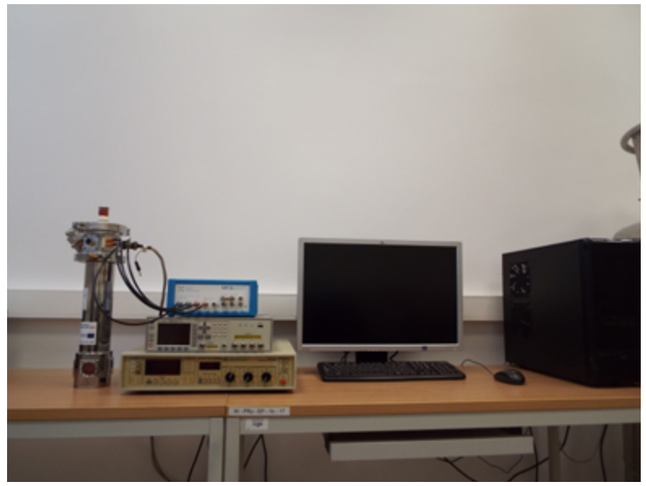
Department of Electronics Fundamentals

Methods and techniques:

- direct measurement of capacitance changes

Apparatus available:

- impedance analyzers
- RLC bridge
- helium and nitrogen cryostats
- dedicated software



Determination of defect parameters in semiconductor materials

On the test bench, measurements are made to determine the concentration of defects and their parameters (capture active cross-section and activation energy) in semiconductor devices using the DLTS method, i.e. measuring the change in capacitance under non-stationary conditions.

ul. Wincentego Pola 2, 35-959 Rzeszów
phone: +48 17 865 1446
e-mail: zawislak@prz.edu.pl
www.kpe.w.prz.edu.pl

Department Chair:
Andrzej Kolek, BEng, PhD, DSc, Prof.Tit.
phone: +48 17 865 1114
e-mail: akoleknd@prz.edu.pl, akolekndakol@prz.edu.pl

Department of Electrodynamics and Electromechanical Systems

Load testing of electric machines and drives in static and dynamic states

The Magtrol dynamometer system with controller enables the loading of motors at speeds up to 50,000 rpm. The dynamometer controller allows for precise control of the load torque, e.g., as a function of time, and can be operated via external software (e.g., LabView). The WT1600 and WT1800 power analyzers by Yokogawa are six-channel measuring devices that allow for precise measurement of currents, voltages, power (DC, active, reactive, apparent), power factor, and efficiency (of drives and frequency converters) in DC and AC circuits powered by converter systems. Additionally, these analyzers are equipped with motor modules that enable simultaneous measurement of speed, torque, and mechanical power of the motor.

The integrated test station with a DC machine allows the tested machine to be coupled and tested in static and dynamic states, with the possibility of regenerative operation. The station is equipped with a drive control system.

For real-time recording of current, voltage, speed, torque, temperature, and frequency waveforms, the DL850 oscilloscope recorder by Yokogawa is used, enabling simultaneous recording of 16 parameters. Furthermore, the recorder enables FFT analysis of recorded waveforms and is equipped with a module for executing 30 mathematical functions in real time.

Methods and techniques:

- testing parameters of classical and special electric machines (measurement of mechanical power, electrical power, torque and speed, insulation resistance, operating temperature, determination of mechanical characteristics)
- testing electric drives in both motoring and generating modes in steady-state conditions (at constant speed) and dynamic conditions (variable rotational speed, variable load torque)
- possibility of vibration and noise testing

Apparatus available:

- Magtrol dynamometers: 2PB43 and 2WB43
- Yokogawa WT1600 and WT1800 power analyzers
- Yokogawa DL850 oscilloscope recorder (up to 16 isolated channels enabling synchronous measurement

ul. Wincentego Pola 2, 35-959 Rzeszów
phone: +48 17 865 1245
e-mail: pbogu@prz.edu.pl
zeise.prz.edu.pl

Department Chair:
Mariusz Korkosz, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1389
e-mail: mkosz@prz.edu.pl

Department of Electrodynamics and Electromechanical Systems

Methods and techniques:

- measurement of displacement, velocity, and vibration acceleration (RMS, 0-P, P-P), cavitation – harmonic analysis of displacement, velocity, and acceleration
- bearing damage detection using the Shock Pulse Method
- measurement of temperature, rotational speed, DC and AC signals, single-plane balancing
- multi-channel vibration measurement with excitation waveform recording
- four-channel simultaneous measurement of vibration and sound, with the possibility of frequency analysis of the measured waveform in octave bands, third-octave bands, or using FFT

Apparatus available:

- Pruftechnik Vibscanner portable vibration analyzer
- PCB Piezotronics set for simultaneous four-channel vibration measurement, additionally equipped with a modal hammer (fifth channel for excitation signal recording)
- SVANTEK SVAN 958 Class 1 portable four-channel vibration and sound analyzer

Vibration and noise measurements

The vibration and noise levels of operating equipment should be kept below permissible values for the given working conditions. Exceeding allowable vibration levels results in very rapid failure of the drive system. Vibration measurements should be carried out regularly. In machines equipped with rolling bearings, attention should also be paid to bearing diagnostics. Detecting the initial stage of developing bearing damage requires supplementing basic vibration tests with other measurement techniques, such as the Shock Pulse method, envelope detection, crest factor, listening to the bearing operation using dedicated headphones in cooperation with the vibration analyzer, as well as harmonic analysis of the vibration and sound signals.

In drive systems with adjustable rotational speed, it is important to determine the natural vibration frequencies. Knowing these frequencies makes it possible to exclude them from the working range, which significantly reduces undesirable vibrations in the drive system.

The available portable analyzers enable vibration and noise measurements, for example, of electromechanical systems. It is possible to determine the natural vibration frequencies with simultaneous recording of the excitation signal.

ul. Wincentego Pola 2, 35-959 Rzeszów
phone: +48 17 865 1389
e-mail: mkosz@prz.edu.pl
zeise.prz.edu.pl

Department Chair:
Mariusz Korkosz, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1389
e-mail: mkosz@prz.edu.pl

Department of Electrodynamics and Electromechanical Systems

Testing of DC power sources

The available equipment enables the testing of DC power sources such as batteries, UPS systems, DC power supplies, battery chargers, alternators, DC generators, and fuel cells (only if equipped with the necessary supporting apparatus, i.e., controller, installation, hydrogen). The applied equipment makes it possible to determine capacity, internal resistance, and to evaluate the current parameters relative to the nominal parameters of the battery under various currents, resistances, or load powers. During the measurements, it is possible to synchronously measure the temperature along with other recorded parameters.

It is also possible to test power sources in cooperation with other devices, e.g., those powered by the tested source or operating together with other power sources (hybrid power supply). The load of the tested power sources can be set with an AC component of different shapes and frequencies. During the tests, it is possible to record multiple values simultaneously over different time intervals (even up to 30 days). As part of the measurement process, it is also possible to determine the efficiency of the tested power sources under previously specified operating conditions.

The presented equipment also allows for performing non-standard tests of devices operating in DC circuits.

Methods and techniques:

- testing of DC power sources under constant current load, constant voltage load, constant power load, and constant resistance load
- determination of internal resistance of batteries (Pb – WET, VRLA, AGM, NiCd, NiMH, Li-ion, LiPol, LiFePO4, Na-ion)
- determination of the internal impedance of batteries for AC components of the load current
- temperature measurement of the tested battery during charging/discharging processes

Apparatus available:

- Chroma 63203 unidirectional DC electronic load
- ITECH IT-6012B bidirectional DC electronic load
- Yokogawa DL850 oscilloscope recorder (up to 16 isolated channels enabling synchronous measurement of voltage, current, temperature, frequency, among others)

ul. Wincentego Pola 2, 35-959 Rzeszów
phone: +48 17 865 1245
e-mail: pbogu@prz.edu.pl
zeise.prz.edu.pl

Department Chair:
Mariusz Korkosz, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1389
e-mail: mkosz@prz.edu.pl

Department of Electronic and Telecommunications Systems RFID Laboratory

Main apparatus
(https://eit.prz.edu.pl/rfid)

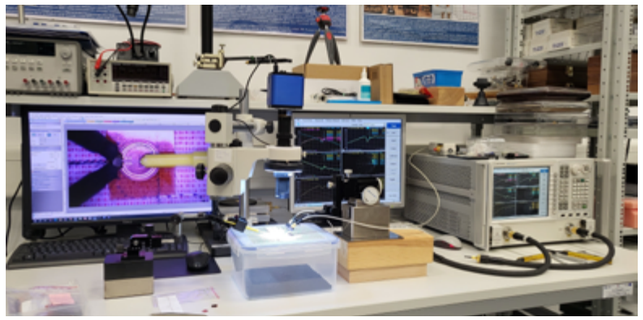
- Voyantic Tagformance Pro (RAIN RFID, HF RFID, NFC)
- Rainford Anechoic Chamber (80 dB, 100 kHz - 40 GHz)
- MVG SG32L Multi-Probe System (400 MHz - 18 GHz)
- TDK Anechoic Chamber (up to 18 GHz) with equipment
- Rainford EQ7922-01 Anechoic Chamber with equipment
- CT Epsilometer (3 MHz - 6 GHz), QWED SPDR (1.1 GHz and 2.45 GHz)
- R&S TS-EMF Portable Measurement System and other portable instrumentation
- VNA Keysight, R&S, MegiQ, LA Techniques, Copper Mountain and others.
- Telecommunications apparatus from Tektronix, R&S, Keysight, Aaronia and others.
- Positioners, conveyors, turntables
- Satimo antennas, RFspin, A.H. Systems, R&S and others.

Selected software:

- EMCoS Studio, Antenna VLab
- Siemens HyperLynx 3D EM
- MVG Wave Studio
- Mathcad, Matlab, Scilab, LabView and others.

Research, among other things, on

- ISO/IEC 18000, 14443, 15693
- ETSI EN, FCC
- EPCglobal, RAIN RFID, NFC
- Bluetooth, WiFi, ZigBee
- IoT, IoTT, IoE



Radio object identification technology
Antenna technology
Electronic and telecommunication systems

The RFID radio object identification technology laboratory conducts theoretical and experimental R&D&W work, in line with global trends that aim to overcome implementation barriers that directly result from practical application problems. Comprehensive research in RFID technology:

- Determination of parameters of LF, HF and UHF band RFID devices;
- testing of single and multiple, passive, semi-passive and active RFID systems in static and dynamic states;
- design, prototyping and testing of system de-vices;
- planning of automatic object identification processes;
- training personalized to the needs of the audi-ence;
- expert work in market analysis and develop-ment and implementation of RFID systems in all areas of application.

Comprehensive research in antenna technology: design and prototyping of antennas;

- Antenna design and prototyping;
- field and laboratory measurements of radio communication systems;
- high-speed spherical measurements of radio equipment parameters.

Support for electronic and telecommunications systems:

- determination of the complex electrical permeability of dielectrics;
- studies of radio communication processes;
- testing of radio paths in electronic systems;
- evaluation of cell phone base station projects;
- substantive assistance in solving investment problems concerning the installation of cell phone base stations;
- field measurements of electromagnetic field parameters of radio communication systems of various purposes.

ul. Wincentego Pola 2, 35-959 Rzeszów
phone: +48 17 865 1239
e-mail: pjanko@prz.edu.pl
eit.prz.edu.pl

Department Chair:
Piotr Jankowski-Mihułowicz, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1234
e-mail: pjanko@prz.edu.pl

Department of Electronic and Telecommunications Systems HYBRID Laboratory

Micro- and nanoelectronic technologies

The development strategy of HYBRID's professional laboratory for integrated electronic micro- and nanotechnologies assumes the possibility of realizing the designed electronic structure in a single manufacturing process combining a variety of manufacturing methods. The HYBRID laboratory's extensive equipment allows the use of various electronic technologies:

- thick-film (including mainly LTCC and HTCC, using photosensitive materials) and thin-film (PVD);
- jet printing of metal and active components (ink-jet);
- multilayer PCB, including on flexible substrates;
- assembly of SMD, BGA and bare semiconductor integrated structures;
- fabrication of textronic devices.

The availability of a wide range of control and measurement equipment makes it possible to conduct circuit synthesis with consideration:

- Analysis of temperature fields in static and dynamic states;
- reliability and environmental resistance issues;
- EMC electromagnetic compatibility;
- parameter control of optoelectronic devices and optical fibers;
- structural analysis of microelectronic and non-electronic components;
- identification of radiocommunication determinants.

The research and development activity of the technology team is mainly concerned with solutions used in RFID and EMC technology, and is closely related to the activities of the other CSEiT laboratories: the RFID laboratory and the EMC laboratory. Together, tasks are carried out in the design and manufacture of electronic structures that are dedicated to non-standard applications, including tags and reader/programmer components, antennas and antenna assemblies, power and matching circuits, digital control systems, sensors for various physical quantities, MEMS and others.

Methods and techniques:

- multilayer hybrid structures on ceramics, LTCC
- multilayer PCBs, including for RF and microwave circuits
- jet printing on rigid and flexible substrates
- assembly of SMD, BGA, mBGA, CSP, bare die electronic components
- fabrication and surface imaging of nanoelements
- diagnostics of electronic circuits

Apparatus available:
(https://eit.prz.edu.pl/hybrid)

- KEKO/Hibridas' complete line of LTCC chips
- PixDro LP50 streaming printer
- Trotec Finemarker Hybrid Strong laser system
- LPKF ProtoMat S100 PCB plotter for printed circuits
- VJ ELECTRONIX SUMMIT 400R semi-automatic workstation
- SEF GmbH 548.04 reflow soldering flow oven
- SPM NT-MDT NTEGRA Prima atomic force microscopy system
- PVD PREVAC vacuum sputtering machine
- FLIR SC7600MB thermal imaging camera
- Yokogawa AQ6370B optical spectrum analyzer
- Feutron KPK 400V climate chamber

ul. Wincentego Pola 2, 35-959 Rzeszów
phone: +48 17 865 1239
e-mail: pjanko@prz.edu.pl
eit.prz.edu.pl

Department Chair
Mariusz Węglarski, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1239
e-mail: wmar@prz.edu.pl

Department of Electronic and Telecommunications Systems EMC Laboratory

Methods and techniques:

- measurement of disturbance emissions according to selected civil, aeronautical, military standards (100 Hz - 18 GHz)
- measurement of disturbance voltage at power supply terminals (load capacity up to 63 A/ phase; 9 kHz - 200 MHz)
- measurement of disturbance voltage at telecommunication ports (9 kHz - 30 MHz)
- measurement of harmonic emissions of supply currents and fluctuations and flickering of light for single- and three-phase receivers (up to 60 kVA)
- measurement of susceptibility of devices to homogeneous radiated electromagnetic field (up to 10 V/m with modulation; system - antenna distance: 1 m - 3 m; 80 MHz - 6 GHz)
- measurement of immunity of single- and three-phase devices to strokes, collapses, fades, voltage changes, and other standardized types of electromagnetic disturbances
- measurement of resistance of devices to electrostatic discharge

Apparatus available:
(https://eit.prz.edu.pl/emc)

- TDK anechoic chamber (30 MHz - 18 GHz with equipment

Standard compliance tests:

- EN 61000-3-2, -3, -11, -12,
- EN 61000-4-2,-3, -4, -5, -6, -7, -8, -9, -10, -11, -12, -16, -27, -28, -29
- DO 160, MIL STD 461 D/E/F
- EN 55011, 55015, 55014, 61547, 55032, 55035

Electromagnetic compatibility

The EMC electromagnetic compatibility laboratory prepares conditions for the implementation of comprehensive theoretical and experimental work in the identification of disturbance propagation processes in electronic systems and the immunity of selected electrical and electronic devices to standardized types of electromagnetic disturbances. The topics of the undertaken research of electrical and electronic devices and systems include:

- identification of the determinants of immunity and emission of electromagnetic disturbances in electronic structures;
- analysis of the determinants of electromagnetic disturbance propagation in distributed communication bus systems;
- elimination of network current harmonics introduced by power systems of electronic and electrical devices;
- analysis of the determinants of the distortion of voltage and current in the power grid by electricity consumers.

The EMC laboratory uses test and measurement equipment from the world's leading manufacturers (Rohde & Schwarz, EMTest, COMTest, ETS-LINTGREN, BONN, Schwarzbeck, and others), which allows testing in accordance with the requirements of national and international EMC standards. The base for testing is TDK's semi-anechoic chamber, which enables measurement of conducted and radiated disturbance emissions, determination of equipment immunity to electromagnetic fields, and testing of equipment immunity to standardized types of conducted disturbance.

ul. Wincentego Pola 2, 35-959 Rzeszów
phone: +48 17 865 1239
e-mail: pjanko@prz.edu.pl
eit.prz.edu.pl

Lab Coordinator:
Wiesław Sabat, BEng, PhD
phone: +48 17 865 1239
e-mail: wsabat@prz.edu.pl

Department of Complex Systems
Laboratory of Security ICT Systems

Research in the field of security of ICT systems ICT, time and space considerations of processing in complex systems

The ICT systems security research laboratory in its scope offers research related to strengthening the protection of operating systems: Windows, Solaris, OpenSuse, design and analysis of ICT system security, design and testing of ICT system intrusion detection systems, modeling and statistical analysis of computer systems and networks, research on the impact of long-range dependencies (temporal and spatial) on the performance and security of computer systems, research on non-extensive phenomena - research on applications of non-extensive thermodynamics elements in computer systems, research on complex graph networks: small-world structures and scale-free networks, research on self-similarity phenomena and their impact on the throughput of computer systems. The laboratory also offers specialized software in the form of Selfis statistical analysis tools, Benoit analysis of fractal and self-similar phenomena, MultiSIM package, Origin software and Network Workbench complex network analysis software.

Methods and techniques:

- vulnerability tests of ICT systems
- security analyses of ICT systems
- design and testing of intrusion detection systems in the ICT systems
- research on non-extensive phenomena - research on applications of non-extensive thermodynamics elements in computer systems,

Apparatus available:

- 15 computer stations: CPU: i5-7500,RAM memory: 32GB and HDD/SSD: 1 TB with Windows 10/11 systems installed
- server: Dell PowerEdge R430
- disk array: Dell PowerVault NX400,
- switch: Tp-Link T1600G-52TS
- Wi-Fi routers (FortiWiFi-30D)

ul. Wincentego Pola 2, 35-959 Rzeszów
phone: +48 17 865 11 06
e-mail: pawel.dymora@prz.edu.pl
zsz.prz.edu.pl

Department Chair
Dominik Strzałka, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 12 86
e-mail: strzalka@prz.edu.pl

Department of Complex Systems
Laboratory of Operating Systems

Methods and techniques:

- modeling and statistical analysis of computer systems and networks
- research on the impact of long-range (temporal and spatial) dependencies on the performance of computer systems
- development of expert opinions and implementation of PoC tests
- programming of network services in the environment of distributed communication systems

Apparatus available:

- 15 computer stations with OS: Windows 10,
- CPU: AMD Ryzen 5 3600 6-Core Processor 3.60 GHz, 16GB RAM memory and HDD/SSD: 1 TB
- network switches: OmniAccess 740, Cisco Catalyst 2960, OmniSwitch 6XXX
- routers and firewalls: Cisco 2800, OmniSwitch 9700 I 7700, WiFi FortiWiFi-30D
- Dell PowerEdge R430 servers
- extensive IT network infrastructure

Performance studies of enterprise-class systems in real and simulation environments

A research and teaching laboratory where work is carried out relating to issues concerning the analysis of phenomena occurring in computer systems and networks, particularly in the context of complex systems. The purpose of this work is to learn and understand the mechanisms that affect the functioning of computer systems and networks in relation to their efficiency and reliability. Among other things, physical and logical network structures are studied in detail in terms of performance, functionality and security analysis. In addition, high-performance transmission infrastructure and virtualization techniques can be studied in the laboratory. Equipped with high-power computing servers and the necessary network infrastructure, it provides a high-end test environment for work on traffic control and analysis, virtualization, performance of database environments, and security and new network services. The lab is equipped with the necessary communications infrastructure, as well as computer systems and network equipment. The wide range of available equipment allows the implementation of research work, teaching classes, as well as work carried out in cooperation with industry. The following issues are implemented: design, configuration and maintenance of test voice communication environments for SMEs, design and configuration of data processing systems, configuration of disk arrays, configuration and monitoring of SAN elements, implementation of cloud computing.

ul. Wincentego Pola 2, 35-959 Rzeszów
phone: +48 17 865 11 06
e-mail: marekb@prz.edu.pl; andrzejp@prz.edu.pl
zsz.prz.edu.pl

Department Chair
Dominik Strzałka, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 12 86
e-mail: strzalka@prz.edu.pl

Department of Complex Systems
Laboratory of Computer Networks

Research in the field of properties of network structures in real and simulation environments, and Internet of Things (IoE)

Research and teaching laboratory. The research carried out in the laboratory concerns a wide range of issues in the design and operation of complex communication systems, including efficient and failure-free data transmission in the environment of data communication networks. In the laboratory, research is carried out in the area of: analysis of network traffic, its properties and impact on network infrastructure; analysis of long-term processes occurring in computer networks; study of mechanisms for load balancing and maintaining reliability of network infrastructure, as well as ensuring fault tolerance of network structures implementing data transmission in critical infrastructures; automation of the management process of distributed systems, optimization of the use of transmission system elements (e.g. fault tolerance, load balancing). The laboratory also carries out tasks in the design and configuration of network infrastructures based on both homogeneous and heterogeneous computer network environments. The work includes testing of diverse configuration scenarios based on commonly accepted network standards and protocols, as well as proprietary and newly developed network mechanisms and solutions. The scope of work carried out relates both to issues related to Enterpise class networks, operator networks, as well as industrial networks used in Industry 4.0 and energy, among others. The laboratory's equipment also allows testing of finished solutions before they are implemented in production or operation in a proof of concept scenario.

Methods and techniques:

- research in the design, construction and operation of modern distributed data communication systems, especially computer networks
- development and testing of new data transmission mechanisms
- synthesis and analysis of network topologies for large-scale interconnection systems
- development of control mechanisms and control of flows in a converged network environment

Apparatus available:

- 15 computer workstations with AMD Ryzen 5 3400G processors, RAM: 32GB and 1TB drives with Windows 10 installed
- Internet of Things (IoE) workstation
- Cisco 2800, 2901, ASA 5505, OmniSwitch 9600 and 9700E routers and firewalls,
- Extreme networks WS-AP3825i access points, Linksys E1200, EA2700 IXIA Novus One Plus, Network Emulator II, PerfectStorm One
- OmniSwitch OS6350 and 6XXX series switches, Cisco Catalyst 2960, 3560, 3650, Extreme networks Summit X460-G2 24t and 48p GE4 and SSA-T8028-0652 switches

ul. Wincentego Pola 2, 35-959 Rzeszów
phone: +48 17 865 12 99
e-mail: pawel.dymora@prz.edu.pl
zsz.prz.edu.pl

Department Chair
Dominik Strzałka, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 12 86
e-mail: strzalka@prz.edu.pl

Department of Complex Systems
Laboratory of Virtual Reality

VR/AR/MR research, user interaction research in VR/AR/MR, application/game research for VR/AR/MR compatibility, conducting research requiring simulation in VR/AR/MR

The virtual reality laboratory offers a wide and modern infrastructure for virtual, augmented and mixed reality research projects using the latest equipment available on the market. There are high-performance computer workstations equipped with the latest generation of processors along with RTX series graphics cards from 20xx to 40xx. The stations have dedicated VR/AR/MR goggles ready for use. Each workstation can be reconfigured to meet the needs of research implementation. The SteamVR Trakcing system in both version 1.0 and 2.0 is used, depending on the user's needs. Computer game engines in the latest available versions (Unity and Unreal Engine) are installed on the workstations, as well as programs necessary for making 3D models. CAD, 3D programs (Autodesk series) are also available for installation and use. Conducted research on interaction in VR/AR/MR can be based on accessory elements available on the equipment in the form of Vive Trakcer, Face Trakcer, or Wrist Band Tracker allowing to significantly expand the possibilities of interaction with both virtual and physical objects.

Methods and techniques:

- Modeling of objects using 3D programs,
- Designing applications/games using virtual reality technology,
- designing applications using augmented reality,
- designing games/applications using mixed reality
- conducting research in the field of interaction in VR/AR/MR

Apparatus available:

- 7 computer workstations with high computing power compatible with VR
- HTC VIVE Pro/Pro2/Pro Eye goggles
- HTC VIVE XR goggles
- HTC Focus 3 goggles
- Oculus/Meta Quest 2 goggles
- Meta Quest Pro goggles
- Valve Index goggles
- PiMax 5k goggles
- Steam Tracking 1.0/2.0 system
- MS Hololens 2 goggles

ul. Wincentego Pola 2, 35-959 Rzeszów
phone: +48 + 48 17 865 14 64
e-mail: m.salach@prz.edu.pl
zsz.prz.edu.pl

Department Chair
Dominik Strzałka, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 12 86
e-mail: strzalka@prz.edu.pl

Powstańców Warszawy 8, 35-959 Rzeszów
e-mail: dwmifs@prz.edu.pl
wmifs.prz.edu.pl

FACULTY OF
MATHEMATICS AND APPLIED PHYSICS
RZESZÓW UNIVERSITY OF TECHNOLOGY

Department of Physics and Medical Engineering

Methods and techniques:

- microscopic observation at magnifications from 20x to 5000x in 4K resolution
- observation in modes: bright field, dark field, ring illumination, coaxial and mixed
- surface topography analysis
- image stacking and 3D surface model creation
- roughness measurement, grain size measurement, and contamination analysis
- elemental analysis using LIBS (Laser Induced Breakdown Spectrometry) technique

Apparatus available:

Keyence VHX-X1 4K digital microscope with two independent bases:

- Base 1: motorized revolving head with four objectives (20x–100x, 100x–500x, 500x–2500x, 2500x–5000x)
- Base 2: integrated head for laser elemental analysis (LIBS) EA-300 with camera and 20x–200x objective

Wybrane oprogramowanie

- Keyence system software for image acquisition and analysis with modules for 3D measurement, surface analysis, and elemental composition analysis

2D/3D surface microscopic imaging and elemental composition analysis using the LIBS technique

The advanced Keyence VHX-X1 digital microscope enables observation of objects at magnifications from 20× to 5000× and in 4K resolution. It combines high optical quality with an intuitive user interface and advanced image analysis. The system features two independent bases: one with a motorized revolving head with objectives from 20× to 5000×, and the other with an EA-300 head for elemental analysis. It is possible to smoothly switch between heads from the interface. The microscope offers various observation modes, including bright and dark field, as well as ring, coaxial, and mixed illumination. Thanks to depth composition and image stacking functions, clear images of samples and three-dimensional surface reconstruction can be obtained. This enables object measurements such as height, as well as other analyses, including roughness measurement, grain size evaluation, and contamination analysis. The integrated EA-300 module, which uses LIBS (Laser Induced Breakdown Spectrometry) technology, enables rapid identification of elements and determination of their concentrations over a wide range. The system is widely used in the study of biological and technical materials, as well as in surface analysis. The microscope offers various observation modes, including bright and dark field, as well as ring, coaxial, and mixed illumination. Thanks to depth composition and image stacking functions, clear images of samples and three-dimensional surface reconstruction can be obtained. This enables measurements of objects such as height, as well as other analyses, including roughness measurement, grain size evaluation, and contamination analysis. The integrated EA-300 module, using LIBS (Laser Induced Breakdown Spectrometry) technology, enables rapid identification of elements and determination of their concentrations over a wide range. The system is widely used in the study of biological and technical materials, as well as in surface analysis.

al. Powstańców Warszawy 8, 35-959 Rzeszów
phone: +48 17 865 1560
e-mail: m_trybus@prz.edu.pl
kfiim.prz.edu.pl

Department Chair
Mariusz Trybus, BEng, PhD
phone: +48 17 865 1910, 17 865 1560
e-mail: m_trybus@prz.edu.pl

Department of Physics and Medical Engineering

High-performance computing and simulation of physical processes

The Department of Physics and Medical Engineering offers high-performance computing related to modeling physical processes mainly at the atomic scale. At its disposal is a high-performance computing cluster is a unit consisting of five nodes equipped with nine AMD EPYC 7763 64-Core processors and two NVIDIA A100 Tensor Cores cards. In addition, each node contains a memory bank of 2TB RAM. The device can be used for continuous computing work by cooperating with a 50TB memory array. QuantumATK atomic-scale modeling software enables large-scale and thus more realistic simulations of materials, integrating state-of-the-art methods into an easy-to-use platform. QuantumATK accelerates research and development in semiconductors and broader solids.

Methods and techniques:

- atomic-scale modeling of materials and physical processes
- Complex analysis of experimental data including biomedical signals

Apparatus available:

- A high-performance computing cluster consisting of five nodes equipped with nine AMD EPYC 7763 64-Core processors and two NVIDIA A100 Tensor Cores cards

al. Powstańców Warszawy 8, 35-959 Rzeszów
phone: +48 17 865 1560
e-mail: m_trybus@prz.edu.pl
kfiim.prz.edu.pl

Department Chair
Mariusz Trybus, BEng, PhD
phone: +48 17 865 1910, 17 865 1560
e-mail: m_trybus@prz.edu.pl

Department of Physics and Medical Engineering

Methods and techniques:

- multi-position photogrammetry, where photos are taken simultaneously from many cameras positioned at different angles
- creation of a point cloud representing a three-dimensional model of the object
- texture mapping
- post-processing including surface smoothing and noise reduction

Apparatus available:

- Big Alice scanning system based on photogrammetry
- computer workstation with AMD Ryzen 9 5950X processor, 128 GB RAM, and RTX 3090 Ti 24 GB graphics card

Selected software:

- RealityCapture
- Blender
- Autodesk Inventor

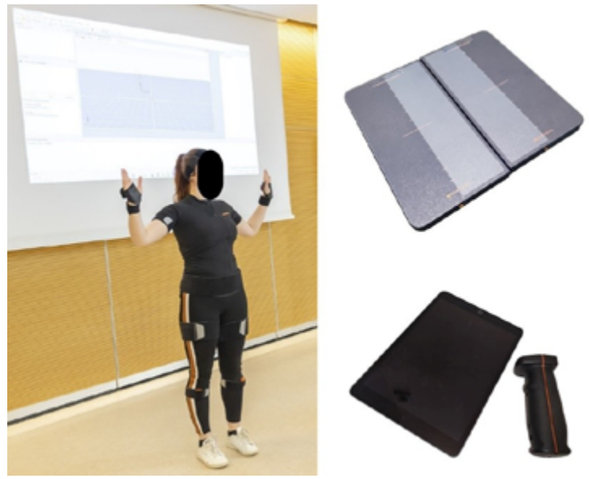
Digitization of people and large objects based on photogrammetry

The Department of Physics and Medical Engineering is equipped with a unique photogrammetric scanning system for people and large objects, including organic ones, opening new possibilities for research in engineering and medical fields. Photogrammetric systems use a series of images of an object taken from different angles, which are then digitally processed to create a 3D model. The software analyzes the relationships between the images, allowing for precise reproduction of the object's shape and dimensions. The Big Alice system is the largest photogrammetric scanning system in the 3Dcopysystems product family. It is equipped with 64 high-resolution digital SLR cameras. These cameras, with adjustable focal lengths, allow simultaneous capture of the object from 64 different angles under 2400 W lighting. With dimensions of 5 × 4 × 2.5 meters, the system can record up to six people at once or scan larger objects. The images obtained from scanning are processed in RealityCapture software to create a 3D model. In addition to the resulting 3D model, the Big Alice system generates a texture map. The models can be used for body measurements, posture analysis, and digital project editing. They can also be applied in medical engineering, such as designing personalized medical products like orthoses, as well as in computer animation and virtual reality.

al. Powstańców Warszawy 8, 35-959 Rzeszów
phone: +48 17 865 1560
e-mail: m_trybus@prz.edu.pl
kfiim.prz.edu.pl

Department Chair:
Mariusz Trybus, BEng, PhD
phone: +48 17 865 1910, 17 865 1560
e-mail: m_trybus@prz.edu.pl

Department of Physics and Medical Engineering



Modeling and biomechanical analysis of the musculoskeletal system

The Department of Physics and Medical Engineering has equipment and software dedicated to biomechanical assessment of human movement. The XSENS Awinda inertial Motion Capture system enables recording and analysis of body motion trajectories in three dimensions. It consists of 17 wireless inertial sensors operating at a sampling rate of 60 Hz, allowing real-time measurement of angles, velocities, and accelerations of body segments. The system is lightweight and portable, allowing studies to be conducted both in laboratory settings and natural environments. For motion dynamics analysis, a FreeMED pressure mat and a K-Force Grip handheld dynamometer are used, enabling precise grip strength measurement with an accuracy of up to 0.1 kg. The FreeMED mat is employed for both stability assessment and foot pressure distribution analysis, complemented by two portable, wireless K-Force Plates, particularly useful for stabilographic analysis and body balance evaluation. Thanks to the Anybody Modeling System – a musculoskeletal modeling package – it is possible to perform biomechanical analyses such as calculating muscle forces, joint loads, and ground reaction forces. In addition, ANSYS, an advanced numerical simulation tool, allows for structural analysis of tissues and behavior of anatomical structures under various loads, which is extremely useful in medical and orthopedic research. The availability of this equipment and software enables comprehensive research applicable to diagnostics, rehabilitation, orthopedics, and ergonomics analysis.

Methods and techniques:

- kinematic analysis of the musculoskeletal system
- motion dynamics analysis
- biomechanical modeling and motion simulation
- stabilographic analysis and body balance assessment

Apparatus available:

- XSENS Awinda inertial motion capture system
- FreeMED pressure mat
- K-Force Grip – handheld dynamometer
- K-Force Plates v3 – two portable wireless stabilometric platforms

Selected software:

- Anybody Modeling System
- ANSYS

al. Powstańców Warszawy 8, 35-959 Rzeszów
phone: +48 17 865 1560
e-mail: m_trybus@prz.edu.pl
kfiim.prz.edu.pl

Department Chair:
Mariusz Trybus, BEng, PhD
phone: +48 17 865 1910, +48 17 865 1560
e-mail: m_trybus@prz.edu.pl

Department of Physics and Medical Engineering

Methods and techniques:

- medical image segmentation
- 3D reconstruction
- 3D print preparation
- printing and post-processing

Apparatus available:

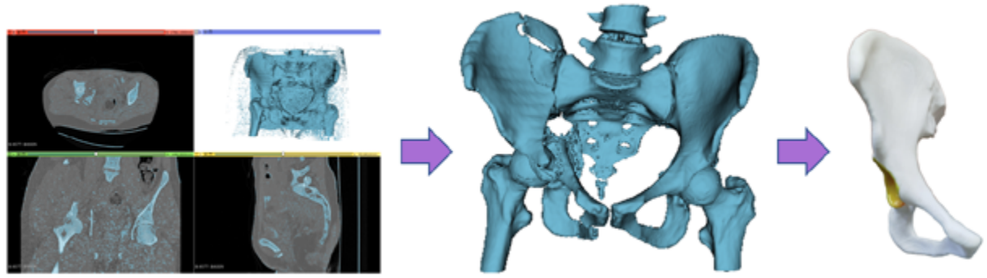
- computer workstation with AMD Ryzen 9 5950X processor, 128 GB RAM, and RTX 3090 Ti 24 GB graphics card
- 3D printers operating in MEM, FFF, FDM, and SLA technologies with post-processing devices and equipment, including Creality K1 Max

Wybrane oprogramowanie

- 3D Slicer
- Meshmixer
- Blender
- PrusaSlicer

Generation of digital and physical 3D models of anatomical structures based on CT or MRI imaging data

A computer workstation at the Department of Physics and Medical Engineering enables the preparation of personalized anatomical models based on diagnostic data from computed tomography (CT) and magnetic resonance imaging (MRI). Using software such as 3D Slicer, it is possible to digitally reconstruct selected organs and anatomical structures from medical images, accurately reflecting patient-specific geometry. For creating physical 3D models, the Department is equipped with printers operating primarily in FFF/FDM technology, allowing for the single-unit production of detailed anatomical models. These models have a wide range of applications – they are useful in surgical planning, education, and research on anatomy and biomechanics.



al. Powstańców Warszawy 8, 35-959 Rzeszów
phone: +48 17 865 1560
e-mail: m_trybus@prz.edu.pl
kfiim.prz.edu.pl

Department Chair:
Mariusz Trybus, BEng, PhD
phone: +48 17 865 1910, 17 865 1560
e-mail: m_trybus@prz.edu.pl

Department of Physics and Medical Engineering

Electrical property measurements

The workstation allows for the measurement of electrical properties (including resistance, conductivity, impedance, and permittivity) of solid materials across a wide temperature range (-120 to 150 K) and frequency range (20 Hz to 40 MHz). Within a limited temperature range, it is also possible to study liquid materials.

Methods and techniques:

- direct resistance measurement
- DC method
- AC method

Apparatus available:

- impedance analyzer
- RLC bridge
- current-voltage source
- temperature controller
- liquid nitrogen cryostat

al. Powstańców Warszawy 8, 35-959 Rzeszów
phone: +48 17 865 1560
e-mail: m_trybus@prz.edu.pl
kfiim.prz.edu.pl

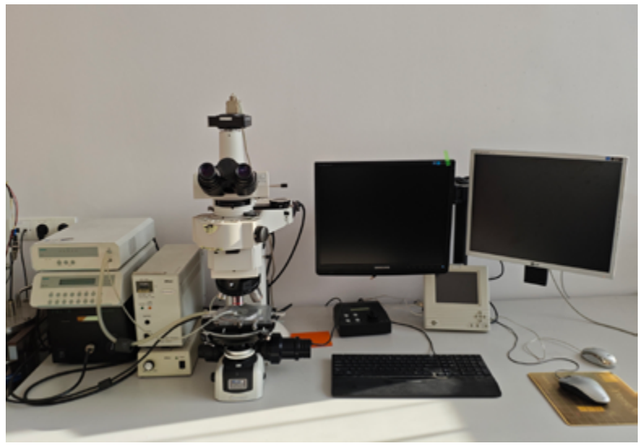
Department Chair:
Mariusz Trybus, BEng, PhD
phone: +48 17 865 1910, 17 865 1560
e-mail: m_trybus@prz.edu.pl

Methods and techniques:

- **optical and polarization microscopy with heating and cooling capabilities**

Apparatus available:

- Nikon Eclipse LV100 POL polarizing microscope
- Linkam THMS 600 heating and cooling stage



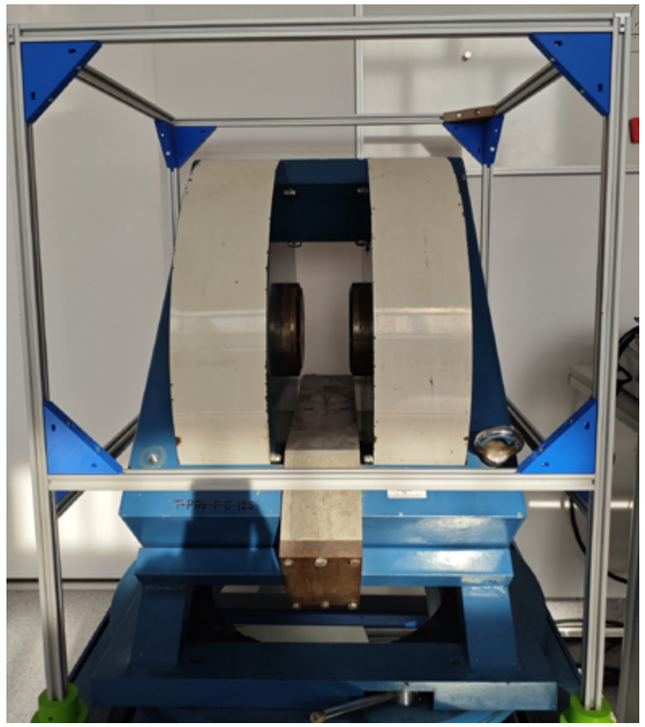
Microscopic observations in visible light

The workstation enables optical observation of samples in visible and polarized light. With the use of a heating and cooling stage, observations can be performed across a wide temperature range (120 K – 473 K). The microscope is compatible with dedicated software that allows for automation of the observation process and detailed analysis of the obtained images.

al. Powstańców Warszawy 8, 35-959 Rzeszów
phone: +48 17 865 1560
e-mail: m_trybus@prz.edu.pl
kfiim.prz.edu.pl

Department Chair:
Mariusz Trybus, BEng, PhD
phone: +48 17 865 1910, 17 865 1560
e-mail: m_trybus@prz.edu.pl

Department of Physics and Medical Engineering



Magnetic field source

The workstation enables the generation of a uniform magnetic field up to 0.7 T.

Methods and techniques:

- stałe pole magnetyczne

Apparatus available:

- elektromagnes Radiopan ER 1610 M
- zasilacz TDK Lambda GEN 60-55

al. Powstańców Warszawy 8, 35-959 Rzeszów
phone: +48 17 865 1560
e-mail: m_trybus@prz.edu.pl
kfiim.prz.edu.pl

Department Chair:
Mariusz Trybus, BEng, PhD
phone: +48 17 865 1910, 17 865 1560
e-mail: m_trybus@prz.edu.pl

Department of Physics and Medical Engineering
Laboratory of dielectric spectroscopy

Methods and techniques:

- Research in measuring the combined dielectric permeability.

Apparatus available:

- Dielectric spectrometer - Novocontrol concept 80 system.
- Agilent 4294A Precision Impedance Analyzer Flooded nitrogen cryostat with vacuum jacket,
- Leybold Vacuum turbomolecular vacuum pump model PT 151 KIT ON 100CF, ITR 90 DN 22K
- temperature controller by LakeShore Model 331 S
- MSO6034A digital oscilloscope from Agilent Technologies
- 7265 DSP Lock-in Amplifier from Signal Recovery
- sinusoidal pulse generator, along with an analytical system coupled to a computer,
- nitrogen cryostat with temperature controller

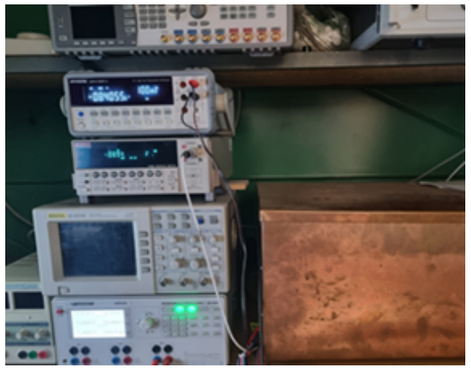
Dielectric measurements over a wide frequency range

In the laboratory it is possible to conduct research on materials in the solid and liquid phases in a wide range of temperatures (-150 to 300C) and frequencies (0.01 to 3GHz). This type of research allows characterization and determination of the dynamics of the molecules of the studied materials, which is the basis of methods related to the synthesis of dielectric materials used in materials engineering.

al. Powstańców Warszawy 8, 35-959 Rzeszów
phone: +48 17 865 1560
e-mail: m_trybus@prz.edu.pl
kfiim.prz.edu.pl

Department Chair
Mariusz Trybus, BEng, PhD
phone: +48 17 865 1910, 17 865 1560
e-mail: m_trybus@prz.edu.pl

Department of Physics and Medical Engineering
Laboratory of non-linear dielectrics



Electrical and thermoelectric measurements using the differential-charge method

The laboratory studies the mechanism of phase transition of TGS monocrystals. The laboratory includes a crystal culture station and computer measurement stations for characterizing samples. In addition to this, studies of thermoelectric phenomena of solid-phase systems are carried out with the use of computer stations for studying the response of samples to forcing with controlled temperature gradients and a system for long-term - remote supervision of the measurement experiment.

Methods and techniques:

- Studies of the mechanism and dynamics of the phase transition of TGS monocrystals.
- Studies of the thermoelectric phenomenon of systems in the solid phase.
- measurements of electrical properties of dielectric materials

Apparatus available:

- Computer workstation for testing temperature characteristics of pyroelectric coefficient by current measurement method,
- computer workstation for digital measurement of spontaneous polarization and pyroelectric coefficient by differential charge method,
- A stand for measuring temperature characteristics of dielectric permeability complex,
- a stand for testing the response of pyroelectric samples to dynamic forcing with given parameters,
- a stand for growing ferroelectric monocrystals from aqueous solutions,
- stand for mechanical processing of monocrystalline samples

al. Powstańców Warszawy 8, 35-959 Rzeszów
phone: +48 17 865 1560
e-mail: m_trybus@prz.edu.pl
kfiim.prz.edu.pl

Department Chair
Mariusz Trybus, BEng, PhD
phone: +48 17 865 1910, 17 865 1560
e-mail: m_trybus@prz.edu.pl

Department of Applied Optics

Methods and techniques:

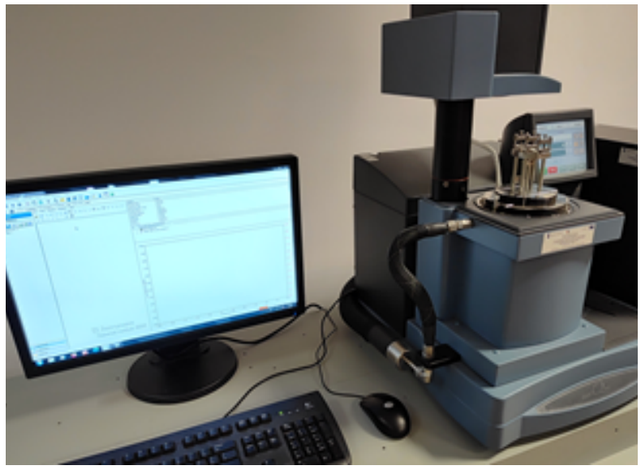
- dynamic mechanical analysis (DMA)
- diffraction measurements

Apparatus available:

- TA Instruments Q800 dynamic mechanical analyzer (DMA)
- diffraction measurement setup

Standard compliance tests:

- ISO 11111
- PN-EN: 000 0000
- DIN 000000

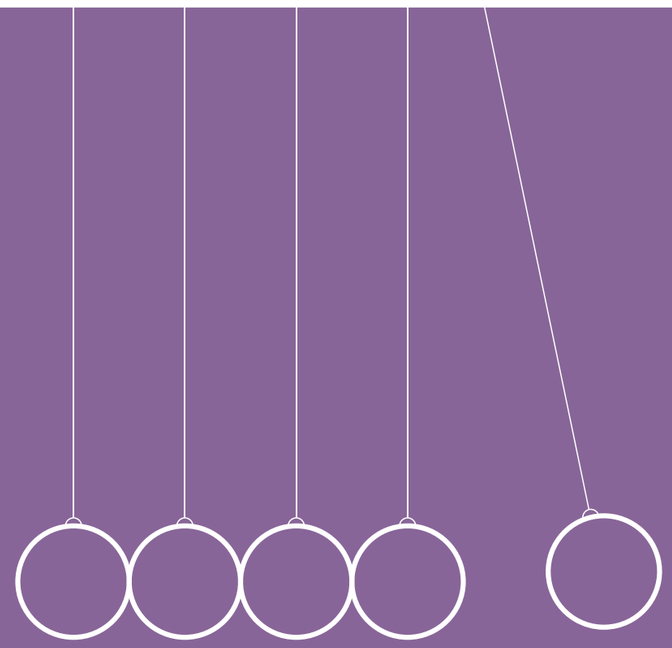


Dynamic mechanical analysis (DMA)

The dynamic mechanical analyzer (DMA – Dynamical Mechanical Analyzer) is a thermal analyzer (-150 to 600 °C) designed for testing the viscoelastic mechanical properties of a wide range of materials, from soft to highly rigid. The samples are placed in one of several available measurement clamps (e.g. Single/Dual Cantilever, 3-Point Bending, Film/Fiber Tension Clamp) and subjected to periodic deformation (0.01 to 200 Hz) to determine their mechanical (e.g. storage modulus, loss modulus) and thermal (e.g. glass transition temperature, estimated degree of crosslinking) properties.

Diffraction measurements

The laboratory performs measurements using laser light diffraction, including fiber diameter and mechanical parameters of materials (e.g. Young's modulus), employing the three-point bending method. These measurements are contactless and characterized by very high precision.

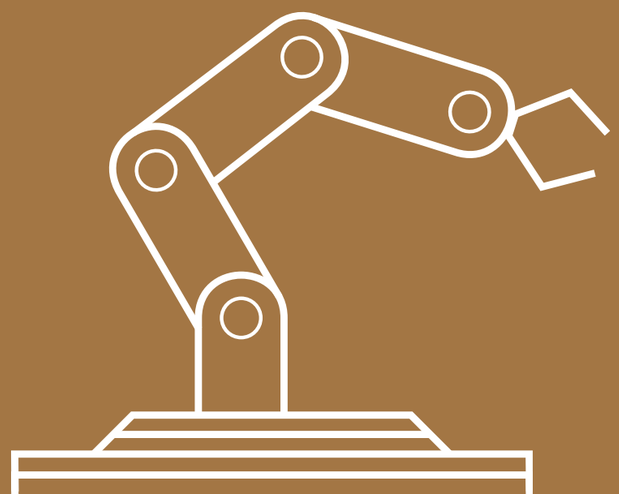


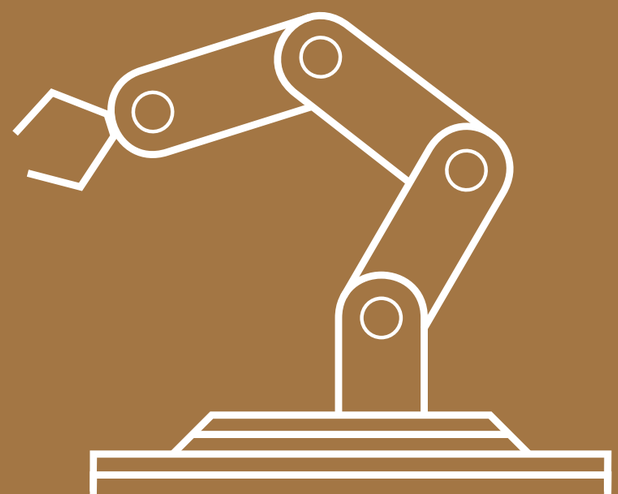
al. Powstańców Warszawy 6, 35-959 Rzeszów
phone: +48 17 865 1943
e-mail: l.pyziak@prz.edu.pl
zos.w.prz.edu.pl

Department Chair:
Leszek Pyziak, PhD
phone: +48 17 865 1943
e-mail: l.pyziak@prz.edu.pl

Kwiatkowskiego 4, 37-450 Stalowa Wola
e-mail: rk@prz.edu.pl
wmt.prz.edu.pl

FACULTY OF
MECHANICS
AND TECHNOLOGY
RZESZÓW UNIVERSITY OF TECHNOLOGY





Faculty of Mechanics and Technology
Laboratory

Methods and techniques:

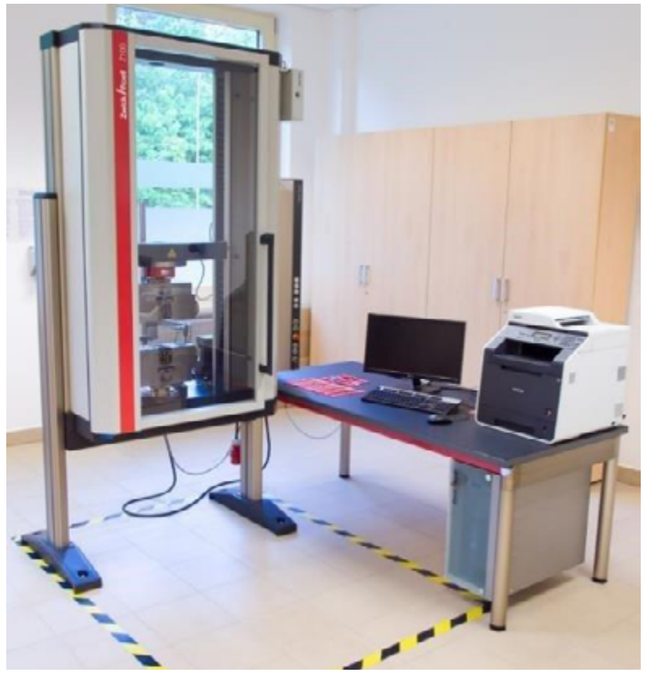
- Static tensile test at room temperature,
- static compression test,
- determination of Young's modulus E,
- static shear test,
- static three-point bending test.

Apparatus available:

- Zwick/Roell Z100 testing machine

Standard compliance tests:

- PN-EN ISO 6892-1 metoda B
- PN-EN ISO 4136
- PN-EN 876
- PN-EN ISO 9018
- PN-EN ISO 9018
- PN-EN 876
- PN-EN ISO 4136
- PN-EN ISO 7438



Testing the strength of materials

Static testing machine from Zwick, is designed for tensile, compression as well as shear tests at room temperature. Perform static tensile and compression tests for all materials used in industry. Mechanical property testing:

- conventional yield strength Rp,
- upper yield strength ReH,
- strength Rm,
- elongation A%,
- Z constriction.

Destructive testing of welds in metals:

- Tensile testing of cross and lap joints.
- Tensile test of longitudinal specimens from welded joints.
- Tensile testing of transverse specimens.

ul. Kwiatkowskiego 4, 37-450 Stalowa Wola
phone: +48 15 844 89 12
e-mail: mirek@prz.edu.pl
wmt.prz.edu.pl

Department Chair
Mirosław Tupaj, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 743 26 07
e-mail: mirek@prz.edu.pl

Faculty of Mechanics and Technology
Laboratory

Surface testing of welds and parts prepared for welding

Designed for testing in the field of:

- laser inspection of the geometry of welded components,
- laser inspection of welded joints,
- weld quality assessment,
- digital analysis of discrepancies.

Methods and techniques:

- Laser measurement of geometric quantities

Apparatus available:

- The system consists of a laser scanner, power supply, storage media, calibration standard, and software for analyzing the results.

ul. Kwiatkowskiego 4, 37-450 Stalowa Wola
phone: +48 15 844 89 12
e-mail: mirek@prz.edu.pl
wmt.prz.edu.pl

Department Chair
Mirosław Tupaj, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 743 26 07
e-mail: mirek@prz.edu.pl

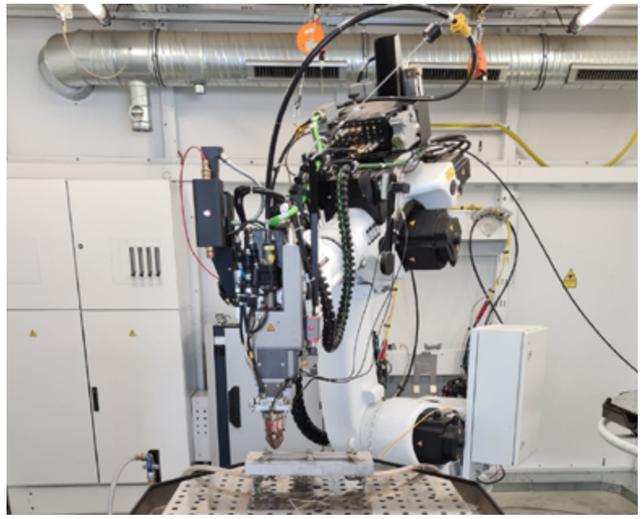
Faculty of Mechanics and Technology
Laboratory

Methods and techniques:

- Laser welding.
- Laser surfacing.
- Laser cutting.
- Laser surface heat treatment.
- Laser surface layer modification.

Apparatus available:

- heads: for welding, cutting and surfacing



Development of technological parameters for welding, cutting, surfacing and heat treatment using a laser beam

The workstation is equipped with three independent types of heads: for welding, cutting and surfacing. It also has software for designing welding processes, determining the actual position of welded edges and correcting the robot's path.

ul. Kwiatkowskiego 4, 37-450 Stalowa Wola
phone: +48 15 844 89 12
e-mail: mirek@prz.edu.pl
wmt.prz.edu.pl

Department Chair
Mirosław Tupaj, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 743 26 07
e-mail: mirek@prz.edu.pl

Faculty of Mechanics and Technology
Laboratory

X-ray examination - computed tomography (CT) scan.

The v|tome|x m X-ray microtomograph is a high-resolution CT system. The product has applications in both science and industry, e.g. geology, biology, materials science, chemistry, biomedical institutes. The system offers unique spatial resolution on a wide range of scanned materials - from small biological samples through large components made of metals. Specially selected base components are designed to achieve high resolution and stable operation. With the instrument, coordinate measurement, import of nominal CAD data in STP and IGES format and data comparison are possible. In addition, wall thickness analysis and porosity analysis in accordance with VW P201 are possible.

- Geometric magnification (3D): from 1.3x to 100x (microfocus lamp) to 200x (nanofocus lamp).
- Detectability of details:< 1 µm (microfocus lamp) < 0.2 µm (nanofocus lamp).
- Minimum voxel size:< 2 µm (microfocus lamp) < 1 µm (nanofocus lamp).
- Detector-lamp distance: 800 mm.
- Maximum CT scan range (diameter x height): 420x400 mm.
- Maximum object weight: 50 kg.

Methods and techniques:

- CT scan

Apparatus available:

- Lamp type: open type microfocus lamp,
- Maximum voltage/power: 240 kV/320 W; 300 kV/500 W,
- nanofocus open type lamp 180 kV/20 W,
- Granite-based 4-axis maniupulator,
- Detector type: dynamic41|200,
- Temperature stabilization of the lamp, detector,
- Software: phoenix datos|x.

Standard compliance tests:

- VW P201

ul. Kwiatkowskiego 4, 37-450 Stalowa Wola
phone: +48 15 844 89 12
e-mail: mirek@prz.edu.pl
wmt.prz.edu.pl

Department Chair
Mirosław Tupaj, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 743 26 07
e-mail: mirek@prz.edu.pl

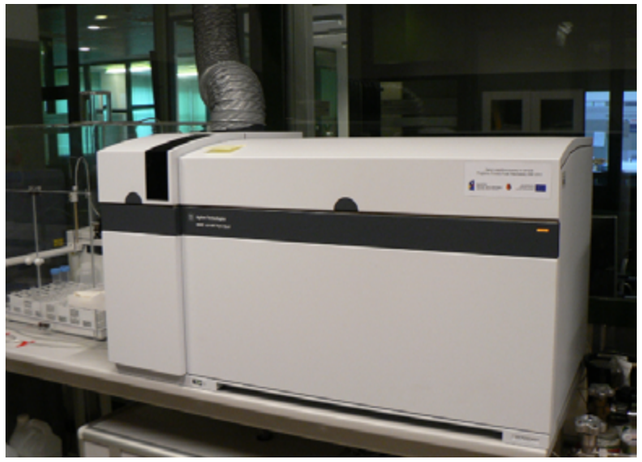
Faculty of Mechanics and Technology
Laboratory

Methods and techniques:

- Inductively coupled plasma ionization mass spectrometry (ICP-MS) with a laser ablation attachment,
- liquid chromatography (HPLC).

Apparatus available:

- Inductively coupled plasma ionization mass spectrometer (ICP-MS) with laser ablation attachment and liquid chromatograph.



Examination of elements at concentrations ranging from [ppt] to [ppm]

The setup consists of an inductively coupled plasma ionization mass spectrometer (ICP-MS) with a laser ablation attachment and a liquid chromatograph. This unique triple quadrupole system enables the best detection and quantification limits in the analysis of samples ranging from semiconductor materials and reagents to biological and clinical material, environmental samples and complex matrices. Determination of heavy metals in soil samples, food, etc., determination of the origin of varnish left in a breakage, detection of arsenic in hair (application in forensics), determination of elemental content in chemical compounds (e.g., metal content in complexes). The method is mainly used for the analysis of solids, and allows both the study of changes in the distribution of elements on the surface of the sample and the concentration gradient deep into the material under study.

ul. Kwiatkowskiego 4, 37-450 Stalowa Wola
phone: +48 15 844 89 12
e-mail: mirek@prz.edu.pl
wmt.prz.edu.pl

Department Chair
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e-mail: mirek@prz.edu.pl

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Hardness testing in hard-to-reach areas

Handy Esatest X - a portable hardness determination device using the patented Esatest method, for recording the hardness curve against penetration depth. Due to its small measuring head, it is especially appreciated in hard-to-reach areas such as keyways or the recesses of a gear wheel.

Dynatest SCX -Portable hardness tester with a unique head for dynamic application of high pressure anywhere, such as on the face, side or underside. Direct measurement of penetration depth and replacement of the indenter from diamond to ball indenter make it possible, among other things, to measure on the roughly prepared surface of steel forgings and on iron castings.

Methods and techniques:

- HV, HRA, HRB, HRC, HB5, HB10, HB30, HRF measuring scale.

Apparatus available:

- Handy Esatest X load: 1-10 kG (10-100 N),
- Dynatest SCX load: 100 kG (1000 N),

ul. Kwiatkowskiego 4, 37-450 Stalowa Wola
phone: +48 15 844 89 12
e-mail: mirek@prz.edu.pl
wmt.prz.edu.pl

Department Chair
Mirosław Tupaj, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 743 26 07
e-mail: mirek@prz.edu.pl

Methods and techniques:

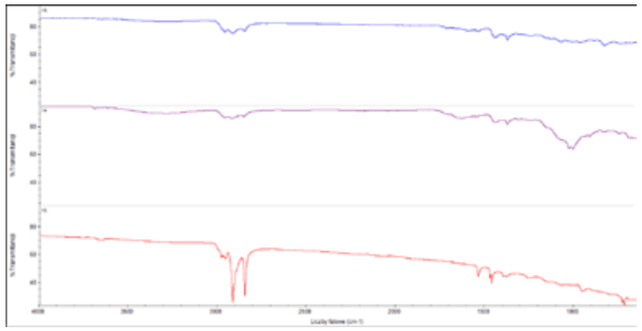
- transmission method,
- measurements with ATR attachment.

Apparatus available:

- Two radiation sources: tungsten lamp for the range 27,000-2,000 cm-1, ceramic source range 9,600-20 cm-1,
- Ceramic source with a maximum operating temperature of 1577 K, not requiring water cooling,
- resolution capacity better than 0.09 cm-1,
- scanning speed adjustable in the range of 0.16÷6.2 cm/s.

Fourier transform spectroscopic study

Universal set designed for Fourier transform spectroscopic measurements of solid and liquid samples in the infrared range (12,000 - 350 cm-1). The apparatus is equipped with a continuous Nd+3:YAG laser with excitation at 1064 nm and a germanium detector cooled with liquid nitrogen. The additional equipment, which is an infrared microscope, allows rapid mapping of compounds on the surface. In addition, it is also possible to obtain FTIR spectra characteristic of various substances and materials, enabling their identification, as well as comparative analysis of tested materials with reference spectra (e.g., quality control) and preliminary analysis of multicomponent materials, such as polymeric plastics in the direction of identifying the type of polymer and additives used. The device also allows FTIR-ATR spectra to be performed.



ul. Kwiatkowskiego 4, 37-450 Stalowa Wola
phone: +48 15 844 89 12
e-mail: mirek@prz.edu.pl
wmt.prz.edu.pl

Department Chair
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phone: +48 17 743 26 07
e-mail: mirek@prz.edu.pl

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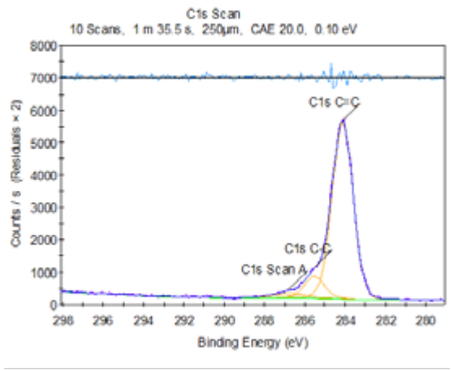
Study using the XPS K-Alpha photoelectron spectrometer

- possibility to analyze samples of the following types: metal alloys, semiconductors, glasses, polymers, organic substances, ceramics, oils,
- measurement of chemical composition (hydrogen and helium cannot be detected),
- identification of chemical states of elements, type of chemical bonds,
- determination of impurities present on the surface of the sample,
- it is possible to use ion etching and angular measurement increasing measurement capabilities.



Methods and techniques:

- X-ray photoelectron spectroscopy: qualitative and quantitative analyses are performed in the elemental range from boron to uranium based on the distribution of various components in the sample.

Apparatus available:

Thermo Fisher Scientific's XPS K-Alpha photoelectron spectrometer:

- 180° dual-focus hemispherical analyzer with 128-channel detector,
- X-ray source - micro-focused Al Kα monochromator with variable spot size,
- ion gun (200-4000 eV),
- charge compensation - dual beam source,
- 4-axis table, sample area 60x60 mm, maximum sample thickness 20 mm,
- options - vacuum transfer module, tilt module for ARXPS, sample deflection module.

ul. Kwiatkowskiego 4, 37-450 Stalowa Wola
phone: +48 15 844 89 12
e-mail: mirek@prz.edu.pl
wmt.prz.edu.pl

Department Chair
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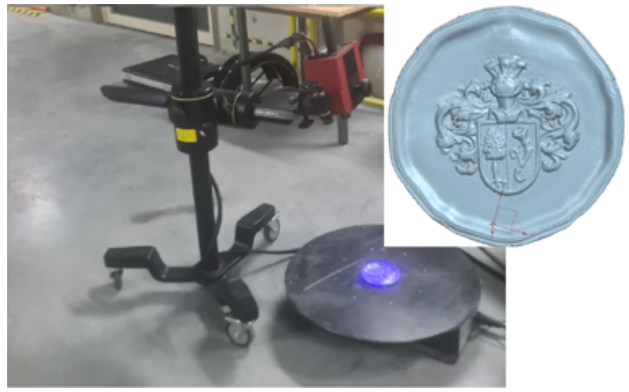
phone: +48 17 743 26 07
e-mail: mirek@prz.edu.pl

Methods and techniques:

- Blue light

Apparatus available:

- Turntable, tripod



Study of surface topography with a 3D scanner

ATOS Compact Scan devices can be used for all measurement tasks and for workpieces of all sizes. Whether for high detail resolution, highest accuracy or fast scanning of large measuring areas. The 3D scanner's scalable measuring area makes it possible to perfectly match any measuring task. It is also possible to create 3D models with the scanner

- minimum measurement area: 40x40 mm,
- maximum measurement area: 1200x1200 mm,
- measurement resolution: 0.017-0.481 mm,
- dimensions: 340x130x230 mm,
- scanner mounting on tripod.

ul. Kwiatkowskiego 4, 37-450 Stalowa Wola
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Department Chair
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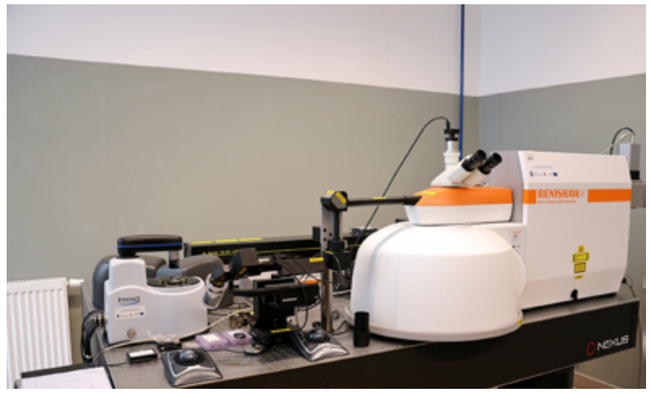
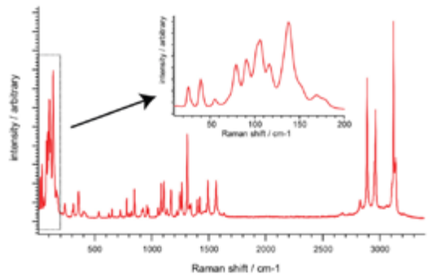
Faculty of Mechanics and Technology
Laboratory



Raman spectroscopic study

The design of the high-performance optics allows to obtain high-quality Raman data from both large samples and those with trace amounts of materials:

- focusing on the surface of the sample under examination in manual control mode,
- creating Raman maps of rough, uneven and curved surfaces,
- no requirements for sample preparation for analysis,
- displayed chemical Raman images in 3D and superimposed on topography views,
- no time-consuming pre-scanning of surfaces,
- maintaining focus during measurements during very long measurements.



Methods and techniques:

- creation of Raman maps of rough, uneven surfaces, analysis and identification of solids, powders, liquids, samples of organic and inorganic compounds,
- possibility to monitor impurities, determine the degree of homogeneity of the sample and analyze the chemical composition,
- layer profiling - testing possible for transparent and opaque samples.

Apparatus available:

- Single-beam Raman spectrometer, inVia confocal Raman microscope,
- excitation beam: 532 nm, 785 nm,
- spectral resolution: 0.3 cm-1 (FWHM),
- wavelength range: 200 nm to 2200 nm.

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e-mail: mirek@prz.edu.pl
wmt.prz.edu.pl

Department Chair
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Methods and techniques:

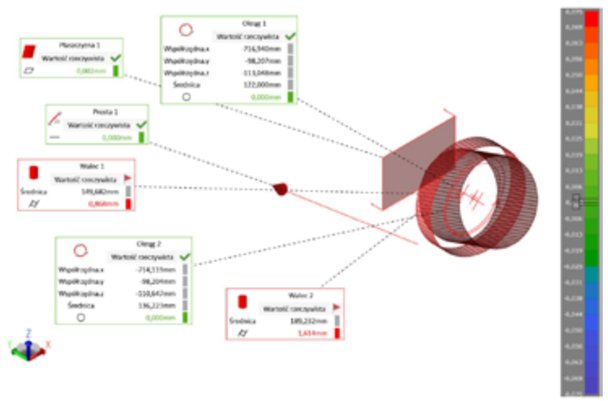
- 2.7 m measuring range,
- Repeatability 0.029 mm,
- Accuracy of 0.041 mm.

Apparatus available:

- smart sensor technology: warning of factors that can reduce performance
- intuitive built-in measurement system: built-in touch screen computer, QuickTools, basic measurements without a laptop,
- internal counterbalance mechanism: comfortable, fatigue-free operation,
- temperature sensors: allows the arm to respond to temperature changes.

Measurement of geometric quantities

Measuring arm used for inspection and quality control. It offers capabilities such as contact measurement of parts within the arm's length, and point cloud comparison with CAD data, rapid prototyping, reverse engineering and 3D modeling of free-form surfaces. The scanning head uses advanced red laser optical technology. FARO CAM software.



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wmt.prz.edu.pl

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Surface roughness test

The stationary device allows to perform meas-urements of roughness (R), waviness (W) and primary profile (P) parameters, according to ISO, DIN, JIS standards. It is also possible to perform complex measurements of surface layer roughness parameters in 3D (geometric structure of the SGP surface). For the meas-urement of roughness

- measuring sections lm: 0.40/ 1.25 /4.0/ 12.5 /40 mm or freely selectable,
- travel length it: 0.48 / 1.5 /4.8/ 15/48 mm or freely selectable from 0.1 to 200 mm,
- travel length: min. 120 mm,
- travel speed vt: 0.05 /0.15/ 0.5 mm/s (as-signed da It) or freely selectable from 0.01 to 2.0 (in steps of 0.01)

The portable profilometer is designed for quick and accurate checking of roughness parame-ters. With its compact and ergonomic design, the device can be easily and precisely posi-tioned on the workpiece under test in both horizontal, vertical and inverted positions. Us-ing the integrated printer, the measurement results can be presented as a quality certifi-cate.

- measuring range: +/- 80 µm; +/- 320 µm
- measurement resolution: 0.01 µm, 0.04 µm,
- elementary section: 0.08/ 0.25/ 0.8/ 2.5/8 mm,
- total measuring section: 0.48/1.5/4.8/15 mm.

Methods and techniques:

- Measurement of roughness (R), waviness (W) and primary profile (P),
- Measured roughness parameters: Ra, Rz(Rz4, Rz3, Rz2, Rz1), Rmax, Rt, Rq, RPc, RSm, Rmrc, Rp, Rpm, R3z, Rz-ISO
- Parameters from the load-curve: Rk, Rpk, Rvk, Mr1, Mr2

Apparatus available:

- Hommel-Etamic stationary profilometer T8000RC
- Hommel-TTESTER T1000 portable profilometer

Standard compliance tests:

- DIN EN ISO 4287, 13565

ul. Kwiatkowskiego 4, 37-450 Stalowa Wola
phone: + 48 15 844 89 12
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wmt.prz.edu.pl

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Methods and techniques:

- Measurement of both adsorption and desorption isotherms, specific surface area by BET, STSA, Langmuir method, determination of pore size and distribution, total volume and average pore radius

Apparatus available:

- NOVA 1200e by Quantachrome

Analysis of surface area and pore size

- can be used with most non-corrosive adsorption gases such as argon, CO2 and light hydrocarbons over a wide temperature range,
- fully automatic multi-point B.E.T. analysis in just minutes,
- analysis of up to 200 data points (100 adsorption points and 100 desorption points),
- analysis stations:1,
- area range: 0.01 m2 / g (no known upper limit),
- pore size range: 0.35 to >400 nm (3.5 to > 4000 Å),
- minimum pore volume: (liquid) 2.2 x 10-6 ml/g,
- minimum pore volume: (STP) 0.0001 cm3/g,
- methods: vacuum and flow.

ul. Kwiatkowskiego 4, 37-450 Stalowa Wola
phone: +48 15 844 89 12
e-mail: mirek@prz.edu.pl
wmt.prz.edu.pl

Department Chair
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phone: +48 17 743 26 07
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Methods and techniques:

- Max. sample volume - 135 cm3.

Apparatus available:

- ULTRAPYC 1200e by Quantachrome

Testing the actual volume and density of powders, foams and bulk materials

A device for measuring the actual volume and density of powders, foams and bulk materials. In addition, a temperature control option is available on the pycnometer, as well as measurements in hazardous environments such as a nuclear cell. The ULTRAPYC 1200e has the ability to purify the sample by vacuum. other methods (e.g., optical microscopy) has a number of advantages related to the fact that imaging has a high depth of field and high resolution.


Quantachrome
instruments

QUANTACHROME CORPORATION
Upyc 1200e V5.06
Analysis Report

Wed Aug 31 01:46:38 2016
User ID: 1881

Sample Parameters
Sample ID: LAGRUN
Weight: 70.6990 g
Description:
Comment:
Analysis Parameters
Cell Size = Large
V Added = Large: 81.1761 cc
V Cell: 150.0174 cc
Analysis Temperature: 23.8 C
Target Pressure: 19.0 psig
Type of gas used: HELIUM
Equilibration Time: Auto
Flow Purge: 1.0 min.
Maximum Runs: 15
Number Of Runs Averaged: 3
Deviation Requested: 0.0050 %

ul. Kwiatkowskiego 4, 37-450 Stalowa Wola
phone: +48 15 844 89 12
e-mail: mirek@prz.edu.pl
wmt.prz.edu.pl

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Methods and techniques:

- Accuracy: E0,MPE from: (1.7+0.3L/100) µm, E0,MPE: With SP25M: (1.7+4L/1000) µm; With TP200: (1.9+4L/1000) µm; With TP20: (2.2+4L/1000) µm; L = measured length [mm] Ø6.0 mm, length 47.0 mm.

Apparatus available:

- CRYSTA-Apex V544 CNC CMM,
- Workpiece weight: 180 kg,
- Range: 501 x 700 x 400 mm,
- Height of workpiece:545 mm,
- Resolution: 0.1 µm.

Measurement of geometric quantities - coordinate measuring machine

Portal CMM for highly accurate 3D geometric size measurement at high speed.

- Manual head with TP 20 probe and tip set.
- High accuracy.
- High travel speed and acceleration
- Temperature compensation function 16° to 26°C, including the measured object (2 contact sensors)
- Use of ABS scales (no need for zeroing and high resistance to environmental conditions)
- Travel speed: 519 mm/s (3 axes)
- 3D acceleration: 2,309 mm/s2 Ø6.0 mm, length 47.0 mm
- MCOSMOS software package to operate the machine.

ul. Kwiatkowskiego 4, 37-450 Stalowa Wola
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wmt.prz.edu.pl

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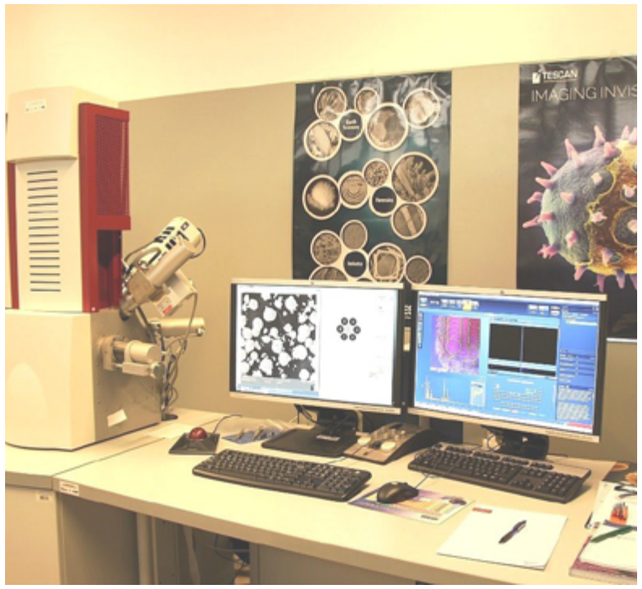

Surface examination by scanning microscope

An excellent tool in analyzing the properties of a variety of materials. This imaging method makes it possible to obtain high-resolution images of objects with sizes in the micrometer and nanometer range. Electron microscopy over other methods (such as optical microscopy) has a number of advantages related to the fact that imaging is characterized by high depth of field and high resolution.

- Chemical composition analysis - distinguishing elements and phases of which the material under study is composed (EDS X-ray spectroscopy attachment),
- maximum magnification of up to 1000000x,
- precise observation of surface topography at magnifications of several to even several million times with the ability to distinguish objects with diameters of less than 1 nm,
- large depth of field, making it possible to assess roughness,
- morphological analysis - evaluation of the shape, size and distribution of the elements that make up the material: grains, inclusions, phases (areas of similar chemical composition).

Methods and techniques:

- chemical composition analysis - distinguishing elements and phases of which the material under study is composed (EDS attachment),
- morphological analysis - assessing the shape, size and distribution of the elements that make up the material: grains, inclusions, phases.

Apparatus available:

- Scanning electron microscope (Mira3-FEG-SEM, Tescan) with field emission (Schottky emitter), equipped with SE, BSE, LVSTD detectors and X-ray energy dispersive spectrometer EDX (X-Act Oxford Instruments) and cooling table (Peltier cell) operating in the temperature range as low as -30°C. The microscope allows operation in high, low and variable vacuum modes.

ul. Kwiatkowskiego 4, 37-450 Stalowa Wola
phone: +48 15 844 89 12
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wmt.prz.edu.pl

Department Chair
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Methods and techniques:

- Measuring ranges from 0.1-80% Fe or 0.1 to 110 FN.

Apparatus available:

- FERITSCOPE® FMP30 by Fischer

Standard compliance tests:

- ISO 17655

Ferrite content test

Portable device for testing ferrite content, equipped with a set of measuring probes. This instrument can be used to measure ferrite content in Duplex steels, in welds of austenitic steels (pipes, sheets, tanks), ordinary steels clad with chromium alloy austenitic steel (heaters, tanks).

- Measurement accuracy for the range 0.1-5.0% - 0.1 indication,
- measurement accuracy for the range >5.0%-2% of the indication,
- ferrite content measurements according to ISO 17655 or "Basler Standard",
- measurement units: percentage "% Fe" and ferrite number "FN".

ul. Kwiatkowskiego 4, 37-450 Stalowa Wola
phone: +48 15 844 89 12
e-mail: mirek@prz.edu.pl
wmt.prz.edu.pl

Department Chair
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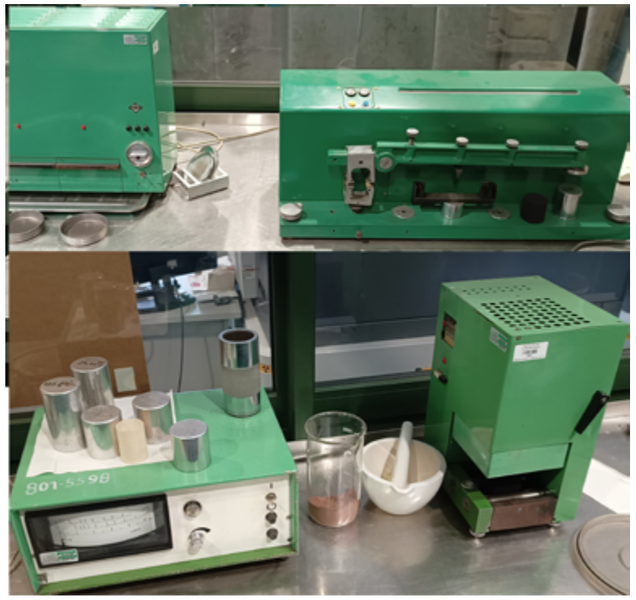

Testing of molding compounds and bulk materials

A set of equipment and workstations for comprehensive testing of molding sand and loose materials used in foundry engineering allows, among other things, to determine the tendency of sand to splinter from the surface of the mold or core, or to determine gas-forming, the tendency of sands surrounded by resins to clump, clump and fall off the heated model plate during the making of shell molds.

Methods and techniques:

- Measurement accuracy for the range 0.1-5.0% - 0.1 indication,
- measurement accuracy for the range >5.0%-2% of the indication,
- ferrite content measurements according to ISO 17655 or "Basler Standard",
- measurement units: percentage "% Fe" and ferrite number "FN".

Apparatus available:

- Circulator mixer,
- laboratory rammer
- Permeability measuring station with instrumentation,
- hardness tester for determining the degree of compactibility of molding sand,
- molding sand strength testing set with instrumentation for compressive, shear, tensile and bending strength tests,
- a device for testing the ossification of molding masses
- a stand for measuring the amount of gases emitted from molding masses.

ul. Kwiatkowskiego 4, 37-450 Stalowa Wola
phone: +48 15 844 89 12
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wmt.prz.edu.pl

Department Chair
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e-mail: mirek@prz.edu.pl

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Methods and techniques:

- qualitative and quantitative identification of phases,
- determination of crystallinity (degree of structural ordering of a solid),
- identification of crystallographic structure,
- determination of average size and size distribution of crystallites,
- monitoring (in situ) of changes occurring in a material sample under other than ambient temperature, pressure and/ or gas phase composition
- Epitaxy analysis, measurement of the thickness of thin films and multilayers

Apparatus available:

- Two types of x-ray tubes: Co, Cu,
- Ceramic x-ray tube with LFF focus (0.4x12 mm) and Kβ.infrared radiation filters (12,000 - 350 cm-1)

Analysis of powders, polycrystalline materials as well as weakly crystalline or amorphous materials, nanomaterials and thin films

The Empyrean X-ray diffractometer is designed for a wide range of analytical X-ray diffraction applications, such as qualitative X-ray phase analysis, quantitative X-ray phase analysis, texture measurement, stress analysis, Rietveld analysis, temperature measurements.

- lamp power min. 1.5 kW,
- goniometer radius of 240 mm, 2Theta angular range of at least -110˚ to 168˚.

ul. Kwiatkowskiego 4, 37-450 Stalowa Wola
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Welding/cladding technology study

This station is equipped with a set of equipment and tools designed for precision surfacing of injection molds, stamping dies, punches, models, model plates, metal molds using laser light. It is possible to remanufacture devices also made of high-alloy steels, aluminum alloys, bronze and titanium.

Methods and techniques:

- Welding/cladding

Apparatus available:

Laser with parameters:

- laser beam length: 1064 nm,
- laser source class: IV,
- rated power of the laser beam: 300 W,
- maximum pulse power: 12 kW,
- maximum pulse energy: 100 J,
- pulse time: 0.2-20 ms,
- laser spot diameter: 0.6-2 mm.

ul. Kwiatkowskiego 4, 37-450 Stalowa Wola
phone: +48 15 844 89 12
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wmt.prz.edu.pl

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Methods and techniques:

Measurement methods:
- Vickers,
- Knoop,
- Brinell

Measurement method options:
- Layer thickness,
- Grain limit.

Apparatus available:

- Qness 60M head; 8 position rotary head max. 3 indenters, max. 6 lenses (50x, 200x HV0.001-HV50, HK0.001-HK2, HBW1/1- HBW5/62.5
- Classic hardness tester, load: 10-187.5 kG (100-1875 N),

Standard compliance tests:

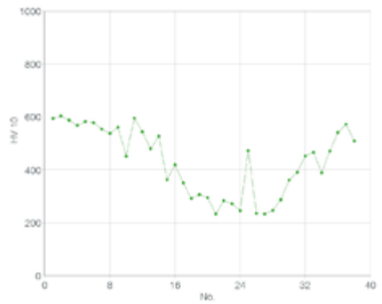
- DIN EN ISO 6507, ASTM E-92, ASTM E-384, DIN EN ISO 4545, DIN EN ISO 6506, ASTM E-10

Micro and macro hardness testing and microscopic observation

Microhardness tester

Load range; 0.25 g - 62.5 kg (0.00245- 613.1 N)
Head: 8 position rotating head max. 3 indenters, max. 6 lenses, Single imprints,
Working space / Working depth: 145 / 170 mm
Table movement: Tangentially movable
Table dimensions Ø 100 mm / 135 x 135 mm
Feed ranges: X 25 mm / Y 25 mm / Z 145 mm
Max. Sample weight: 50 kg
QPIX CONTROL software

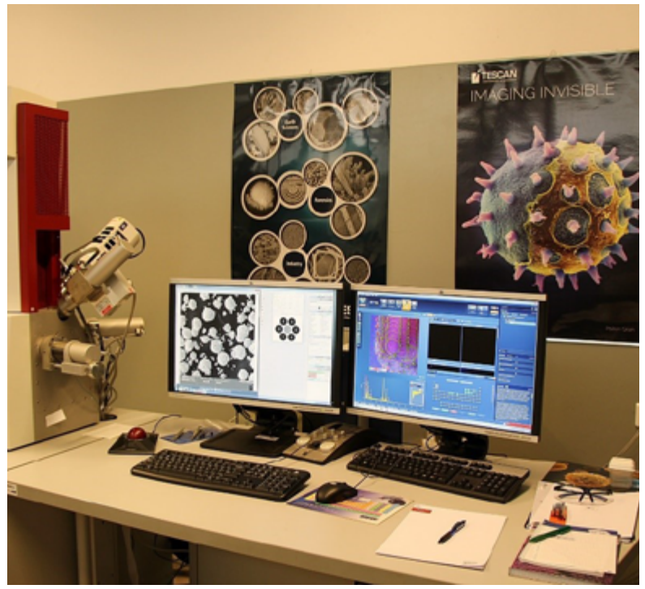
Classic hardness tester for accurate measurements on small parts. Exposed indenter design makes it easy to determine the precise measurement point.



ul. Kwiatkowskiego 4, 37-450 Stalowa Wola
phone: +48 15 844 89 12
e-mail: mirek@prz.edu.pl
wmt.prz.edu.pl

Department Chair
Mirosław Tupaj, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 743 26 07
e-mail: mirek@prz.edu.pl

Faculty of Mechanics and Technology
Laboratory



Material analysis using a scanning electron microscope

An excellent tool for analyzing the properties of various materials, this imaging method enables the acquisition of high-resolution images of objects in the micrometer and nanometer range. Compared to other methods (e.g., optical microscopy), electron microscopy offers a number of advantages, including a large depth of field and high resolution.
- Analysis of conductive materials (metals and their alloys) as well as non-conductive materials (ceramic, composite, and organic materials),
- qualitative and quantitative measurement of elements in tested samples, creation of distribution maps and layer analysis (EDS detector – X-ray spectroscopy)
- crystallographic identification of grains, phase composition, and determination of the degree of anisotropy of materials (EBSD detector).

Methods and techniques:

- imaging of conductive and non-conductive materials in high and variable vacuum conditions
- material morphology studies – assessment of the shape, size, and distribution of individual microstructural components: grains, phases, inclusions
- qualitative and quantitative elemental analysis – surface, point, line, and distribution maps of elements in micro-areas (EDS)
- identification and distribution of phases, mapping of grain size, shape, orientation, and boundaries, measurement of deformations – dislocation density (EBSD)

Apparatus available:

- MIRA3 scanning electron microscope Tescan with field emission, equipped with SE, BSE, EDS, and EBSD detectors. The microscope allows operation in high, low, and variable vacuum modes

ul. Kwiatkowskiego 4, 37-450 Stalowa Wola
phone: +48 15 844 89 12
e-mail: mirek@prz.edu.pl
wmt.prz.edu.pl

Department Chair
Mirosław Tupaj, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 743 26 07
e-mail: mirek@prz.edu.pl

Powstańców Warszawy 10, 35-959 Rzeszów
e-mail: rz@prz.edu.pl
wz.prz.edu.pl

FACULTY OF
MANAGEMENT
RZESZÓW UNIVERSITY OF TECHNOLOGY

Department of Finance, Banking and Accountancy

Methods and techniques:

- modeling (concepts for solutions to specific financial problems)
- simulations
- case study
- business plans
- financial analyses
- controlling analyses
- budgets
- cost accounts
- financial reports
- charts of accounts

Apparatus available:

- Digital Polarimeter, Jasco P-2000

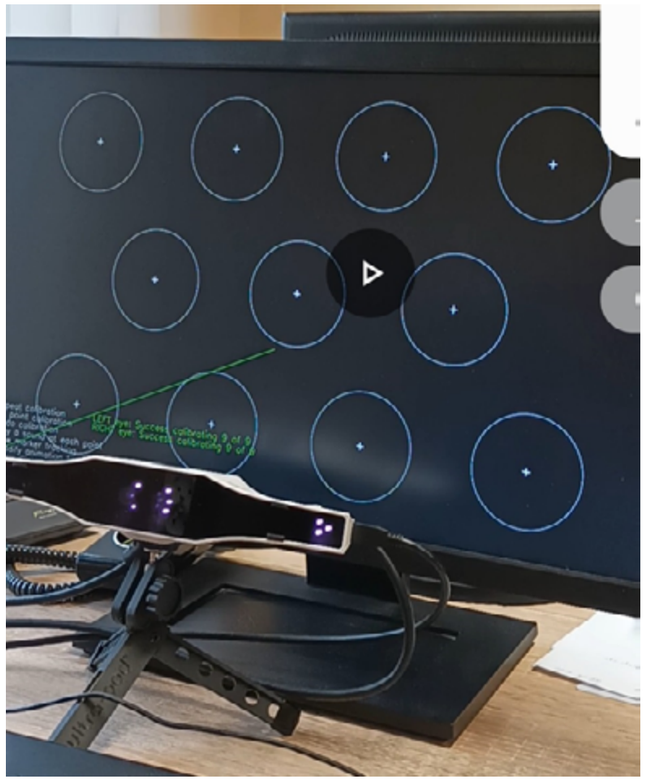
Implementation of new and evaluation of applied methods of financial performance management

As part of our services aimed at entrepreneurs, we propose to carry out an assessment of the quality and effectiveness of applied solutions in the area of financial accounting, management accounting, taxation and controlling in all processes occurring in business activities (including: purchasing, logistics, warehousing, sales, R&D, HR and payroll, customer relations). As part of the services, a report is prepared along with a summary and evaluation of existing solutions. Areas for improvement are indicated, as well as directions for further improvement of the solutions used in the areas studied. We also offer comprehensive assistance in identifying companies' exposure to market risk (e.g.: foreign exchange, interest rate). We ensure the implementation of tools to measure market risk, as well as the development of hedging strategies, including those using derivatives (including: forwards, vanilla and exotic options, option strategies, IRS, CIRS, Caps, Floor). We propose to adjust the organizational structure of the company to effectively implement market risk management activities. We also design and implement modern methods (tools) of management accounting, cost accounting and controlling in enterprises. The purpose of these activities is to increase the profitability of customer relations and sustainably improve financial performance in enterprises. We carry out these services based on substantive expansion of chart of accounts (especially in the area of revenues and costs), variable costing, multi-level and multi-block cost accounting, activity-based costing, budgeting, centers (centers) of responsibility, multi-faceted controlling analyses, management reporting (also using Excel) and integration with used or new financial and accounting systems. As part of this service, we create concepts for employee incentive systems and implement them.

ul. Akademicka 2, 35-959 Rzeszów
phone: +48 17 865 1914
e-mail: zfib@prz.edu.pl
www.zfbir.prz.edu.pl

Department Chair:
Grzegorz Lew, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1914
e-mail: lewgrzes@prz.edu.pl

Department of Marketing



Methods and techniques:

- The Gazepoint 3HD desktop eye tracker uses emitted infrared light, which, after being reflected from the eye's cornea, is captured by an optical sensor. Based on the aforementioned corneal reflection, as well as the position of the center of the pupil, the location of the eye's focus point is calculated.

Apparatus available:

- Gazepoint 3HD desktop eyetracker
- Gazepoint Analysis UX software

Studies of consumers' psychophysical responses to marketing stimuli (e.g. website design, advertising images)

The Gazepoint 3HD stationary eye tracker with Gazepoint Analysis UX software is used to analyze consumers' psychophysical responses to marketing stimuli presented on a computer screen, such as advertising images and videos, websites, and online ads. The studies involve identifying eye movement patterns in the form of static and dynamic scan paths, as well as heat maps that reflect these responses. The obtained insights allow for the modification of advertising message elements, resulting in more effective marketing strategies for businesses. The Gazepoint 3HD eye tracker with Gazepoint Analysis UX software supports stimulus presentation, data collection, import, and analysis.

ul. Akademicka 2, 35-959 Rzeszów
phone: +48 17 865 1671
e-mail: km@prz.edu.pl
kmi.prz.edu.pl

Department Chair:
Beata Zatwarnicka-Madura,BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1483
e-mail: bezat@prz.edu.pl

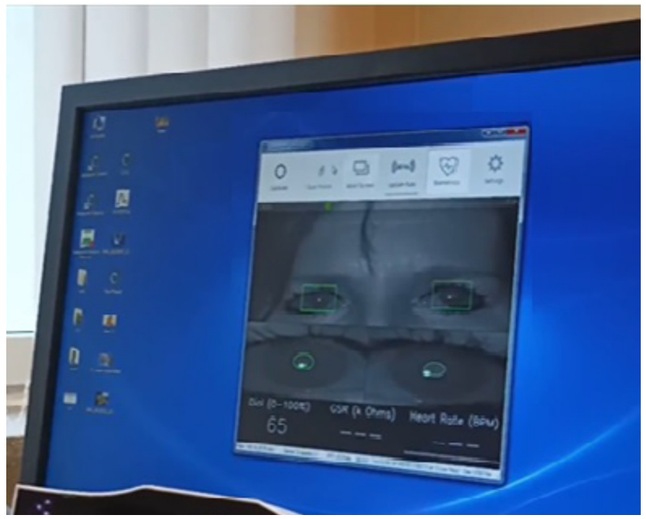
Department of Marketing

Methods and techniques:

- **survey (traditional and online)**
- **interview (individual and group)**
- **observation (participant and non-participant)**
- **mystery shopper method**

Apparatus available:

- Gazepoint 3HD stationary eye tracker with Gazepoint Analysis UX software



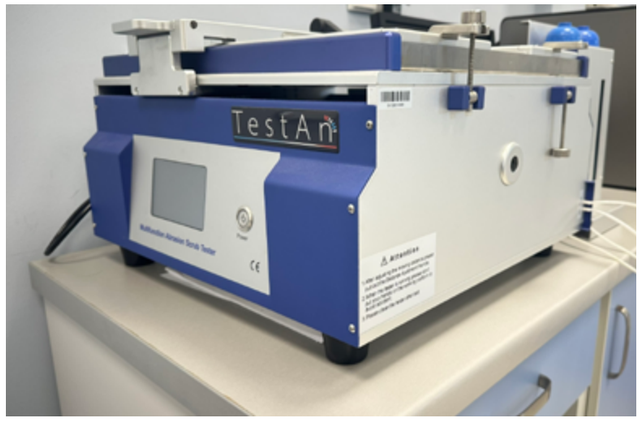
Research on the behavior of contemporary market entities: enterprises, non-profit organizations, and consumers

The staff of the Department of Marketing invite representatives of enterprises and non-profit organizations to collaborate in research on the market behavior of consumers, as well as commercial and non-commercial entities. The aim of this research is to provide practical insights that will enhance the effectiveness of their marketing strategies and actions, as well as support the achievement of market goals. Consumer behavior research includes the analysis of stages in the purchasing process for various types of products and services; identification of customer satisfaction levels with enterprises and non-profit organizations, their willingness to recommend them, and the causes and consequences of dissatisfaction with purchases; as well as the assessment of consumers' psychophysical responses to marketing stimuli using an eye tracker (evaluating responses to advertisements, packaging, and promotional messages). Research on the behavior of enterprises and non-profit organizations involves evaluating the effectiveness of promotional tools such as trade fairs, events, and influencer marketing campaigns; determining the effectiveness of social media management in building customer relationships; analyzing and evaluating product strategies, with particular emphasis on regional and ecological products; and analyzing and assessing development strategies of local government units, including the effectiveness of their promotion and efforts to build a positive public image.

ul. Akademicka 2, 35-959 Rzeszów
phone: +48 17 865 1671
e-mail: km@prz.edu.pl
kmi.prz.edu.pl

Department Chair:
Beata Zatwarnicka-Madura,BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1483
e-mail: bezat@prz.edu.pl

Department of Computer Engineering in Management



Abrasion and washability testing

This is an abrasion tester. By changing various abrasive heads, it can meet all standard test requirements for linear reciprocating abrasion, including wet scrubbing, sponge washability, scrub resistance, cleanability, dirt pickup resistance, and rub testing.

Test set for abrasion and washability – parameters:

- number of test channels: 2
- electronic setting of parameters: number of cycles, stroke speed, volume of dispensed liquid
- automatic positioning of the start point
- stroke length: 2–300 mm
- cycle speed: at least 5–95 cycles/min
- maximum number of cycles: 10,000
- test tray size: 35 × 45 cm
- ISO 11998 test tool (2 pcs.)
- universal test tool for sandpaper (1 pc.)
- ASTM D4750 test tool (1 pc.)

Apparatus available:

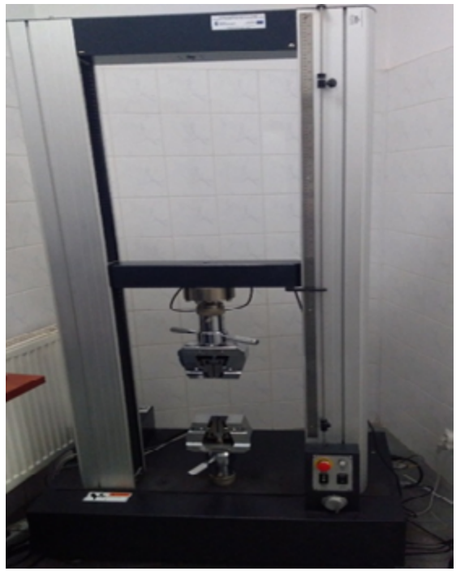
- abrasion and washability tester

al. Powstańców Warszawy 10, 35-959 Rzeszów
phone: +48 17 865 1894
e-mail: i_nowot@prz.edu.pl
ziwz.prz.edu.pl

Department Chair:
Irena Nowotyńska, PhD, BEng,
Krzysztof Tereszkiewicz, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1894
e-mail: i_nowot@prz.edu.pl

Apparatus available:

- universal testing machine



Tensile, compression, and bending tests

A 50 kN universal testing machine for tensile, compression, bending, and other mechanical tests.
Universal testing machine – parameters:

- load capacity: 50 kN
- load cell: 50 kN
- maximum crosshead travel: not less than 1100 mm
- maximum test space: approx. W420 (width)
- force resolution: 1/10000
- test speed: 0.2 – 500 mm/min
- data output: TCP/IP
- unit system: user-selectable
- safety: automatic fracture detection to protect system and load cell

al. Powstańców Warszawy 10, 35-959 Rzeszów
phone: +48 17 865 1894
e-mail: i_nowot@prz.edu.pl
ziwz.prz.edu.pl

Department Chair:
Irena Nowotyńska, PhD, BEng,
Krzysztof Tereszkiewicz, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1894
e-mail: i_nowot@prz.edu.pl

Department of Computer Engineering
in Management

Film shrinkage testing

The Hanatek film shrinkage tester enables quick and easy measurement of the effect of temperature on plastic film.
Film shrinkage tester – parameters:

- heated plate with temperature control accuracy of ±0.30 °C
- temperature stability achieved within 15 minutes
- LCD timer switch
- illuminated cooling surface
- direct shrinkage reading in mm or %

Apparatus available:

- film shrinkage tester

al. Powstańców Warszawy 10, 35-959 Rzeszów
phone: +48 17 865 1894
e-mail: i_nowot@prz.edu.pl
ziwz.prz.edu.pl

Department Chair:
Irena Nowotyńska, PhD, BEng,
Krzysztof Tereszkiewicz, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1894
e-mail: i_nowot@prz.edu.pl

Department of Computer Engineering in Management

Apparatus available:

- GL 60 glossmeter

Pomiar połysku powierzchni

The GL glossmeter is a device for measuring surface gloss. It can be used to measure and control coatings such as paints, galvanic layers, plastics, leather, prints, and any other surfaces where decorative gloss is important.

GL 60 glossmeter – parameters:

- measurement range: 0...1000 GU at 60°
- reading error: ±1.5 (0...120 GU); ±1.5% (120...2000 GU)
- repeatability: ±0.5 (0...120 GU); ±0.5% (120...2000 GU)
- measurement angle: 60°
- measurement aperture: 9 × 15 mm at 60°
- memory: 900 readings in 30 groups, microSD card (optional)
- interfaces: USB, printer port, Bluetooth

al. Powstańców Warszawy 10, 35-959 Rzeszów
phone: +48 17 865 1894
e-mail: i_nowot@prz.edu.pl
ziwz.prz.edu.pl

Department Chair:
Irena Nowotyńska, BEng, PhD.
Krzysztof Tereszkiewicz, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1894
e-mail: i_nowot@prz.edu.pl

Department of Computer Engineering in Management

Testing of metals, glass, and plastics

Measurement device for testing metals, glass, and plastics.

- Measurement range for F1 and N1 probes: 1250 µm ±(1+3%) µm of reading
- Display resolution: 0.1 µm
- Measurement accuracy: ±1.5 µm + 3% of reading
- Minimum surface area: Ø 3 mm
- Minimum substrate thickness: 0.2 mm
- Operating temperature range: 0–40 °C
- Humidity: 20–90%

Apparatus available:

- ultrasonic thickness gauge

al. Powstańców Warszawy 10, 35-959 Rzeszów
phone: +48 17 865 1894
e-mail: i_nowot@prz.edu.pl
ziwz.prz.edu.pl

Department Chair:
Irena Nowotyńska, PhD, BEng,
Krzysztof Tereszkiewicz, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1894
e-mail: i_nowot@prz.edu.pl

Department of Computer Engineering in Management

Apparatus available:

- hardness tester

Brinell, Rockwell, and Vickers hardness testing

Hardness tester for performing Brinell, Rockwell, and Vickers hardness tests.

- initial test force: 98.07 N (10 kg)
- dwell time control: 0–60 seconds, adjustable
- magnification: Vickers: 75×; Brinell: 37.5×
- maximum sample height: 200 mm, 140 mm, 140 mm
- maximum sample width: 165 mm

al. Powstańców Warszawy 10, 35-959 Rzeszów
phone: +48 17 865 1894
e-mail: i_nowot@prz.edu.pl
ziwz.prz.edu.pl

Department Chair:
Irena Nowotyńska, PhD, BEng,
Krzysztof Tereszkiewicz, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1894
e-mail: i_nowot@prz.edu.pl

Department of Computer Engineering in Management

Apparatus available:

- Parnas-Wagner apparatus for total protein content analysis in food products

Total protein content analysis in food products – Parnas-Wagner

The Parnas-Wagner apparatus is a laboratory device used for analyzing protein content in food samples. It operates based on acid hydrolysis, during which proteins are broken down into amino acids and subsequently measured. This method is primarily applied in food testing to accurately determine the amount of protein in various materials. The Parnas-Wagner apparatus is valued for its accuracy and reliability in protein composition analysis, making it an essential tool in scientific research and diagnostics.

- type of analysis: acid hydrolysis of proteins
- sample capacity: typically from 0.1 to 1 g of food sample
- reactor: made of acid-resistant materials, usually glass or stainless steel
- analysis duration: depending on the method, typically 3 to 24 hours
- operating temperature: 110 °C to 300 °C during acid hydrolysis
- chemical reagent: concentrated sulfuric and hydrochloric acids used to break down proteins into amino acids
- measurement accuracy: high precision with an error margin of 1–2%
- power supply: standard mains (230 V)

al. Powstańców Warszawy 10, 35-959 Rzeszów
phone: +48 17 865 1894
e-mail: i_nowot@prz.edu.pl
ziwz.prz.edu.pl

Department Chair:
Karolina Kowalczyk, PhD, BEng
Krzysztof Tereszkiewicz, BEng, PhD, DSc, Assoc. Prof.
phone: +48 533 330 398
e-mail: karolinakowalczyk@prz.edu.pl

Apparatus available:

- muffle furnace for food sample mineralization and trace element determination

Mineralization of food samples and trace element determination

A muffle furnace is a specialized laboratory device used for mineralizing food samples and determining trace elements such as minerals, heavy metals, or organic residues. The mineralization process involves the complete combustion of organic components in the sample at high temperature, transforming the organic material into ash, which is then subjected to further chemical analysis. The muffle furnace allows precise determination of mineral content such as calcium, magnesium, iron, or potassium, which are important for assessing the nutritional value of food products.

- minimum temperature: approx. 100 °C
- maximum temperature: 1200 °C – 1300 °C (depending on the model)
- temperature stability: ±1 °C
- chamber made of high-temperature-resistant ceramics or specialized materials such as silicon carbide (SiC)
- electric heating with heating elements placed either outside the muffle or inside the furnace for uniform heat distribution
- control: microprocessor temperature controller with programmable heating profiles (ramp, hold, and cool); digital display for temperature and operational parameters
- heating rate: typically 10 °C to 20 °C per minute, depending on model and settings

al. Powstańców Warszawy 10, 35-959 Rzeszów
phone: +48 17 865 1894
e-mail: i_nowot@prz.edu.pl
ziwz.prz.edu.pl

Department Chair:
Karolina Kowalczyk, PhD, BEng
Krzysztof Tereszkiewicz, BEng, PhD, DSc, Assoc. Prof.
phone: +48 533 330 398
e-mail: karolinakowalczyk@prz.edu.pl

Department of Computer Engineering
in Management

Total fat content determination in food products

The Soxhlet apparatus is a laboratory device used for extracting fat from food products in chemical analysis. The Soxhlet method involves continuous, repeated extraction of fat from a sample using a solvent such as petroleum ether. The solvent circulates through the system, dissolving the fat, which is then separated and weighed. The Soxhlet apparatus enables precise measurement of fat content, which is essential in food research and quality control.

- material: typically borosilicate glass, resistant to high temperatures and chemicals
- flask capacity: depending on the model, usually ranges from 100 ml to 1000 ml
- extractor size: standard Soxhlet extractor sizes range from 30 ml to 500 ml, depending on sample and solvent volume
- extraction frequency: each extraction cycle usually lasts 10 to 20 minutes; total analysis time ranges from several to over a dozen hours, depending on the sample and substance properties
- operating temperature: dependent on the solvent, most commonly between 60–80 °C (e.g. for petroleum ether)
- type of solvent: most commonly petroleum ether, hexane, or other organic solvents that dissolve fats
- power supply: if equipped with an electric heater, typically powered from the mains (230 V)
- condenser: cooling efficiency depends on condenser size; typically includes a built-in water condenser to maintain solvent vapor circulation

Apparatus available:

- Soxhlet apparatus for total fat content determination in food products

al. Powstańców Warszawy 10, 35-959 Rzeszów
phone: +48 17 865 1894
e-mail: i_nowot@prz.edu.pl
ziwz.prz.edu.pl

Department Chair:
Karolina Kowalczyk, PhD, BEng
Krzysztof Tereszkiewicz, BEng, PhD, DSc, Assoc. Prof.
phone: +48 533 330 398
e-mail: karolinakowalczyk@prz.edu.pl

Department of Technical Systems Engineering

Methods and techniques:

- simulation of VSP energy consumption
- measurement and archiving of parameters of selected means of transport
- measurement and simulation of energy consumption of means of internal transport
- optimization of transport processes in terms of efficiency and energy consumption
- selection of identification methods for a given transport task

Apparatus available:

- pallet scales
- laser scanners
- palletizing station equipped with Kawasaki RS10N robot, control and object recognition system
- system of remote monitoring of vehicles (GPS receivers)
- a set of autonomous mobile platforms AGV
- programs for simulation of transport processes DOSIMIS, ENTERPRISE DYNAMICS
- RFID gates
- set of measurement tools and data acquisition cards

Laboratory of research and simulation of processes transportation

The Department conducts 2 types of research. The first involves experimental research using the equipment in its possession. The second type of research is theoretical research aimed at designing and optimizing selected transportation processes. Research directions:

- Selection and optimization of internal transport routes,
- Energy intensity of transport processes,
- automation of selected logistics tasks - improvement of working conditions and efficiency,
- determination of energy characteristics of means of transport on selected routes,
- identification of moving products.

Equipment:

- Automatically guided transport vehicles with laser or optical navigation,
- cargo identification and recognition systems,
- palletizing station equipped with Kawasaki robot, control and object recognition system,
- laser scanners for object recognition and demarcation of protective zones,
- a vision system for License Plate Recognition (LPR),
- software for simulating transportation processes,
- systems for remote monitoring of transportation means,
- a set of autonomous mobile platforms,
- a set of pallet scales.

al. Powstańców Warszawy 8, 35-959 Rzeszów
phone: +48 17 865 2399
e-mail: zist@prz.edu.pl
www.zist.prz.edu.pl

Department Chair:
Mirosław Śmieszek, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1778
e-mail: msmieszk@prz.edu.pl

Department of Quantitative Methods

Socio-economic data analysis

At the center of the Unit's interests are broad economic and mathematical analyses in the field of socio-economic changes over the years. The aforementioned analyses concern the Podkarpackie region as well as areas on a macro scale. Statistical-econometric research is carried out on the basis of available data-bases and software that allows processing of large amounts of data such as STATISTICA, Gretl, R, etc. The staff of the Quantitative Methods Department also specializes in im-proving the quantitative-statistical tools nec-essary for the economic-mathematical evalua-tion of logistics issues. The main scope of these analyses concerns the modeling of socio-economic phenomena related to inventory management issues and risk assessment. The area of research interests of the staff of the Quantitative Methods Unit is also methods of risk assessment in the management of eco-nomic entities, the study of competitiveness or the use of econometrics tools in risk manage-ment processes. Recently, the Unit has been conducting extensive research on the energy market. This mainly involves the use of fore-casting methods, analysis of the so-called elas-ticity and demand for electricity. In addition, this type of research focuses attention on re-newable energy sources, so-called clean ener-gy and financial instruments related to this. In summary, the most important research direc-tions of ZMI include:

- Risk management,
- Energy market modeling,
- Financial and actuarial mathematics,
- Stochastic-economic modeling of resource gathering systems,
- Application of mathematical and stochastic methods in market research, medicine and demography,
- Taxonomic methods in regional studies,
- Spatial-temporal study of the level and quality of life.

Methods and techniques:

- stochastic-economic modeling of resource collection systems
- application of mathematical--stochastic methods in market research, medicine and demography,
- taxonomic methods in regional studies.

al. Powstańców Warszawy 8, 35-959 Rzeszów
phone: +48 17 865 1602
e-mail: kmi@prz.edu.pl
kmi.prz.edu.pl

Department Chair:
Grzegorz Mentel, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1906
e-mail: gmentel@prz.edu.pl

Department of Enterprise, Management and Ecoinnovation

Methods and techniques:

Strategic analysis of an enterprise is performed using a wide range of methods, including:

- stakeholder analysis,
- scenario analysis,
- PESTLE analysis,
- portfolio methods,
- balanced scorecard,
- SWOT analysis,
- SPACE analysis.

Apparatus available:

- digital polarimeter, Jasco P-2000

Standard compliance tests:

- Assessment of the compliance of the quality management system with the ISO 9001: 2015 standard

Development, evaluation, updating of strategies Implementation and improvement of management systems

The team of the Department specializes in the comprehensive strategic assessment of organizations of various types. Thanks to our extensive and comprehensive experience, we are prepared to carry out a comprehensive assessment of enterprises of different business profiles, public institutions and social organizations. We use diverse and advanced research methods that are always tailored to the expectations and situation of the organization under study. We also have experience in preparing strategies at various stages of an organization's development. Employees have extensive experience in the implementation and evaluation of management systems, including those certified to ISO standards (ISO 9001: 2015, ISO 14001: 2015) and the application of project management methodologies, as well as selected IT tools (analytical tools to support business management and artificial intelligence). As part of the research, it is possible to conduct management system audits and assess management strategies, as well as perform the necessary analysis and project work leading to their improvement.

ul. Akademicka 2, 35-084 Rzeszów
phone: +48 17 865 1165
e-mail: zpiz@prz.edu.pl
www.kpzie.prz.edu.pl

Department Chair:
Dariusz Wyrwa, BEng, PhD
phone: +48 17 865 11 65
e-mail: dwyrwa@prz.edu.pl

Department of Management Systems and Logistics

Laboratory of Logistics and Integrated Management Systems

In the laboratory, it is possible to carry out research on processes that support and optimize:

- transparent integration of all channels of sales and distribution of goods in the implementation of an integrated omnichannel strategy;
- the merchandising and flows within a distributed network of sales and distribution of goods using modern information systems and dedicated equipment, with particular emphasis on innovative ordering algorithms and Big Data;
- production logistics using modern IT systems and relevant equipment;
- logistics of high storage warehouses including support of online order processing functions, using modern information systems and relevant equipment;
- comprehensive management of a transportation company and in-depth analysis of its performance in the competitive market using a modern platform of industry business simulations.

Consulting:

- logistical management of transport and forwarding companies,
- recording of drivers' working time, and interpretation and implementation of current legislation in this area.

Methods and techniques:

- observation
- in-depth interviews, focus interviews
- CATI/CAWI surveys
- creative problem solving methods
- statistical methods and techniques of data analysis

Apparatus available:

- Lenovo TC M900z i5-6400 8GB 500GB microcomputer - 16 pcs.
- Cisco WS-C2960X-24TS-L - Catalyst 2960-X 24 GigE,4x1G SFP, LAN Base hub
- Motorola MC4597 data collector
- Motorola Zebra MC32N0 data collector
- Posnet Thermal HS EJ fiscal printer
- WLT price verifier
- scale DIBAL W-025S

ul. Akademicka 2, 35-084 Rzeszów
phone: +48 17 865 1081
e-mail: zszil@prz.edu.pl
kszil.prz.edu.pl

Department Chair:
Tadeusz Olejarz, BEng, PhD, DSc, Assoc. Prof.
phone: +48 17 865 1803
e-mail: tekst@prz.edu.pl

Department of Enterprise Management

Methods and techniques:

- observation
- in-depth interviews, focus interviews
- surveys
- creative problem solving methods
- Assessment Center/ Development Center
- statistical methods and techniques of data analysis

Apparatus available:

Software licenses:
- CiteSpace
- NVivo
- Statistica

Reserach offer

Employees of the Department will undertake cooperation in the field of broadly understood management of organizations (commercial and non--commercial). We offer to conduct research in the area designated by the client (along with analysis, formulation of practical conclusions and development of a report), consulting support in identifying and solving various organizational problems, developing new business models and improving existing ones. ZZP's offer includes research, consulting, and preparation and delivery of training in the following areas:

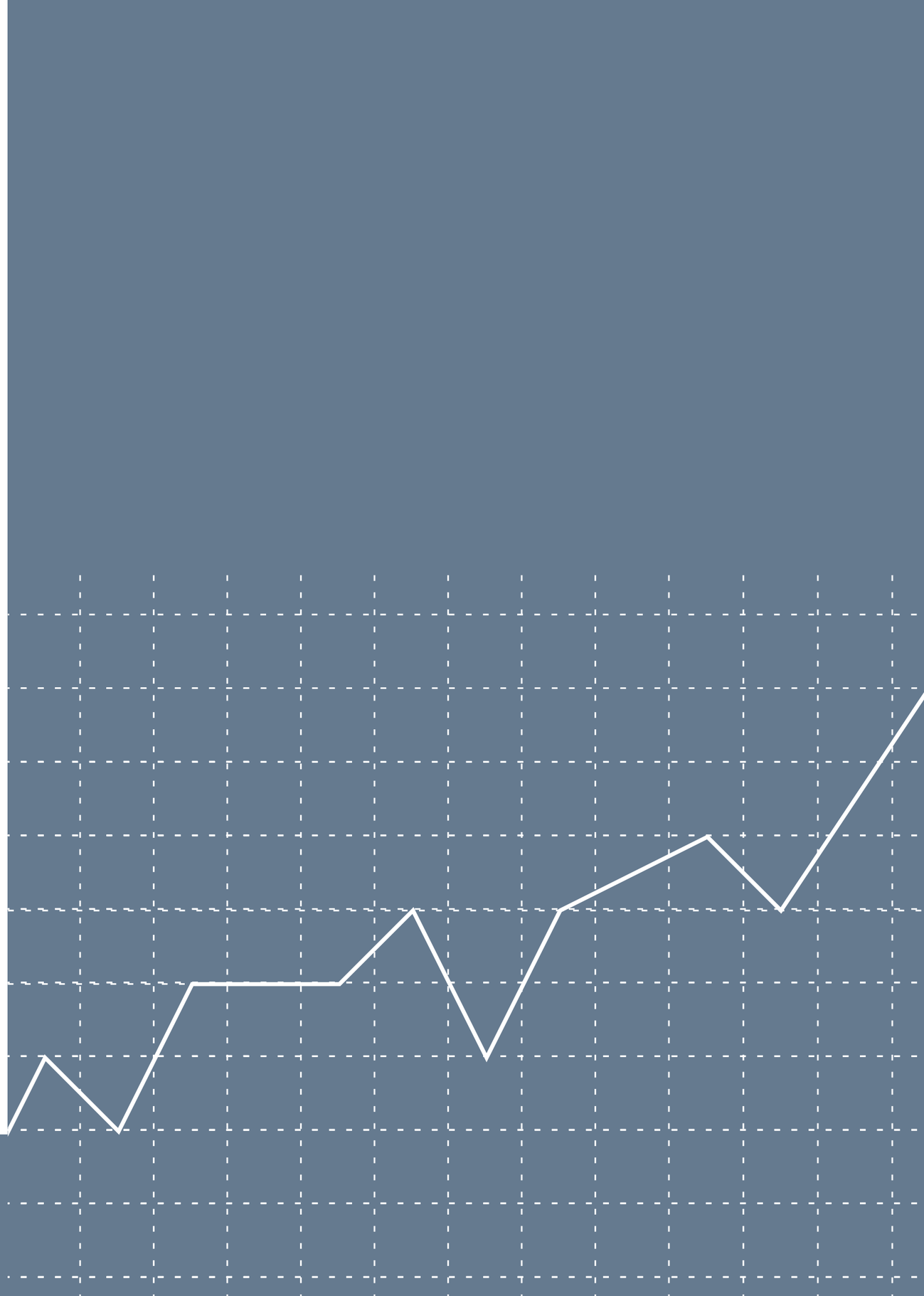
1. Strategic management, including:
- application of strategic analysis tools,
- design of business models,
- strategy development and strategic decision-making.

2. Team management, including:
- formation of team leadership skills,
- implementation and improvement of team development methods.

3. Human resource management, including:
- improving the recruitment and selection system, including the preparation of criteria for selection and evaluation of candidates,
- Development and conduct of Assesment Center sessions,
- Diagnosis of managerial competencies and preparation and implementation of Development Center sessions,
- Diagnosis of motivation systems and employee training and evaluation,
- Age and diversity management, ethical aspects of management.

4. Entrepreneurship and entrepreneurial behavior, including:
- training in developing proactivity, creativity and creative thinking techniques,
- diagnosis of entrepreneurial competencies,
- development of business plans for newly created companies.

5. Spplication of statistical analysis methods, including:
- multivariate statistical analysis in modeling the determinants of socio-economic development and sustainable development.



ul. Akademicka 2, 35-084 Rzeszów
phone: +48 17 865 3041
e-mail: zzp@prz.edu.pl
zzp.prz.edu.pl

Department Chair:
Krystyna Kmiotek, PhD, DSc, Assoc. Prof.
phone: +48 17 865 3041
e-mail: zzp@prz.edu.pl

Poznańska 2A, 35-959 Rzeszów
e-mail: csa@prz.edu.pl
csa.prz.edu.pl

CENTRE FOR
ACADEMIC SPORTS
RZESZÓW UNIVERSITY OF TECHNOLOGY

Laboratory of Biomechanics and Functional Diagnostics

Methods and techniques:

- measurement of pressure forces with strain gauge sensors located in inserts placed in the shoes of the test person;
- any measurement protocol - taking into account the conditions and time of measurement;
- preparation of reports in graphical and tabular form taking into account the ordered analysis;
- preparation of data in a file supported by ascii, Excel, C3D or Matlab.

Apparatus available:

- Medilogic Insoles - a set of wireless insoles for assessing the distribution of foot loading (includes 5 sets of insoles with strain gauges (in sizes 37/38 to 45/46).
- Noraxon's MyoResearch 3 (MR3) software - "myo PRESSURE" module.

Load distribution of human feet in any static position or in locomotory movements

A study involving the recording and registration of biomechanical parameters describing the distribution of load on the feet of a person standing in any static position or during movement (such as locomotion). The use of a system of strain gauge insoles placed in the shoe of the subject allows collecting information about the location and value of the vertical component of the ground reaction force, generated by the human foot during contact with the ground. Temporal parameters are expressed in milliseconds, spatial parameters in centimeters or degrees, and pressure force values in Newtons. The purpose of the test may be:

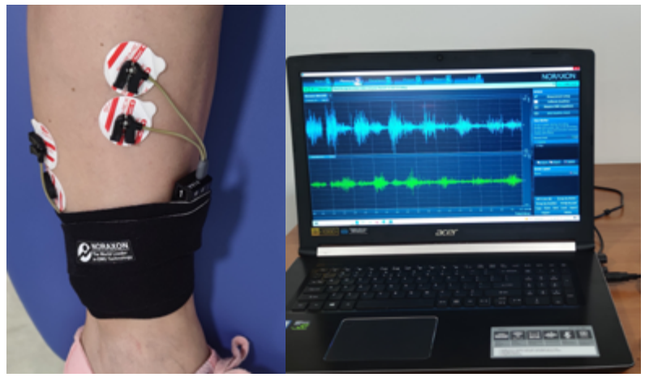
- Assessment of free locomotor movements and the asymmetries present in them;
- Assessment of body balance during static and dynamic activities;
- ergonomic evaluation of various workstations with identification of zones of increased foot loading;
- verification of how the feet are loaded by a person using various machines and prototype equipment that require prolonged standing;
- verification of foot load distribution when using various types of orthopedic and prosthetic equipment;

The test can be performed at the place indicated by the ordering party and in any conditions (indoors or outdoors). The size of the insoles can be selected according to the size of the test person's feet (in the size range from 37 to 46).

ul. Poznańska 2A, 35-959 Rzeszów
phone: +48 17 865 15 95
e-mail: csa@prz.edu.pl
csa.prz.edu.pl

Department Chair:
Grzegorz Sowa, BEng, MSc
phone: +48 17 865 15 95
e-mail: gsowa@prz.edu.pl

Laboratory of Biomechanics and Functional Diagnostics



Analysis of bioelectrical activity of selected human skeletal muscles

A test that involves recording and transcribing sEMG (surface electromyography) signals describing the activity of human skeletal muscles in any static position or during movement, such as locomotion or functional movements. The use of the Noraxon Mini DTS 4-K-MR kit allows the collection of synchronized information from surface EMG electrodes about the activity of up to 4 selected muscles and transmitting them wirelessly to a computer. Using the MR3 Noraxon software, the EMG signal recording can be pre-prepared for further analysis (subjected to filtering or rectification) or subjected to full analysis and presented in the form of reports. The purpose of the study can be:

- Analysis of the sequence of muscle activation in a specific movement;
- Assessment of fatigue of selected muscles;
- Evaluation of the amplitude and frequency of EMG signals compared;
- ergonomic evaluation of various workstations with identification of body positions that increase muscle tension;

The test can be carried out at the place indicated by the customer and in any conditions (indoors or outdoors). For non-standard tests, the course and protocol of measurement will be determined individually.

Methods and techniques:

- measurement of bioelectric activity of selected muscles by surface EMG method
- any measurement protocol - taking into account the time and conditions of measurement
- preparation of reports in graphical and tabular form taking into account the ordered analysis
- preparation of data file for use in any software, e.g. ascii, Excel, C3D, Matlab

Apparatus available:

- Noraxon Mini DTS 4-K-MR wireless sEMG measurement system
- Noraxon's MyoResearch 3 (MR3) software - the "myo MUSCLE" module

ul. Poznańska 2A, 35-959 Rzeszów
phone: +48 17 865 15 95
e-mail: csa@prz.edu.pl
csa.prz.edu.pl

Department Chair:
Grzegorz Sowa, BEng, MSc
phone: +48 17 865 15 95
e-mail: gsowa@prz.edu.pl

Laboratory of Biomechanics and Functional Diagnostics

Methods and techniques:

- Measurement of selected human psychomotor skills under uncontrolled overload conditions
- any measurement protocol - taking into account the conditions of measurement and time not longer than 5 min.
- preparation of a file in .csv extension with test results (execution time and number of correct answers) for use in any software.

Apparatus available:

- motorized gyroscope, allowing simulation of positive and negative overloads in the range from 1G to 3G.
- software - an application containing tests to assess psychomotor skills, including: Piórkowski test, Plaque, Figures, Psychotest 1, Psychotest 2, Psychotest 3.

Assessment of human psychomotor responses under uncontrolled overloads

The test involves recording the results of psychomotor tests, (performed on a tablet) during a 3D rotation session in a gyroscope. The purpose of the test can be to evaluate a person's response to being under overload conditions or under uncontrolled movements around three axes (3D). Repeating the test can be helpful, for example, in evaluating the progress of rehabilitation or in assessing the effects of exercises performed over a certain period of time. The tablet, which is integrated with the gyroscope, includes an application with tests to assess the subject's ability to memorize and identify shapes or numbers, hand eye-hand coordination, reaction time and perform simple mathematical calculations. The tests are performed while the gyroscope rotates the test person around three axes, simulating momentary overloads (alternating positive and negative). During the test, the test subject is in a seat placed in the inner rim of the gyroscope and is immobilized in it by means of seat belts. Placed in a special holder, a tablet is used to start the gyroscope and to perform on it the tasks prescribed in each test. The start of the test tasks automatically starts the motor, rotating the rims of the gyroscope. After completing the last test, the tester stops the gyroscope. The time of rotation in the gyroscope is integrally connected with the time of execution of the tests on the telepod. The test should be performed in the laboratory. For non-standard tests, the course and protocol of measurement will be determined individually.
It is possible to use the gyroscope without using the tablet as a simulator of uncontrolled overload conditions caused by rotational motion.

ul. Poznańska 2A, 35-959 Rzeszów
phone: +48 17 865 15 95
e-mail: csa@prz.edu.pl
csa.prz.edu.pl

Department Chair:
Grzegorz Sowa, BEng, MSc
phone: +48 17 865 15 95
e-mail: gsowa@prz.edu.pl

Research offer of the Rzeszów University of Technology

Rzeszów, 2025

POLITECHNICZNA SIEĆ VIA CARPATIA

RZESZÓW UNIVERSITY OF TECHNOLOGY

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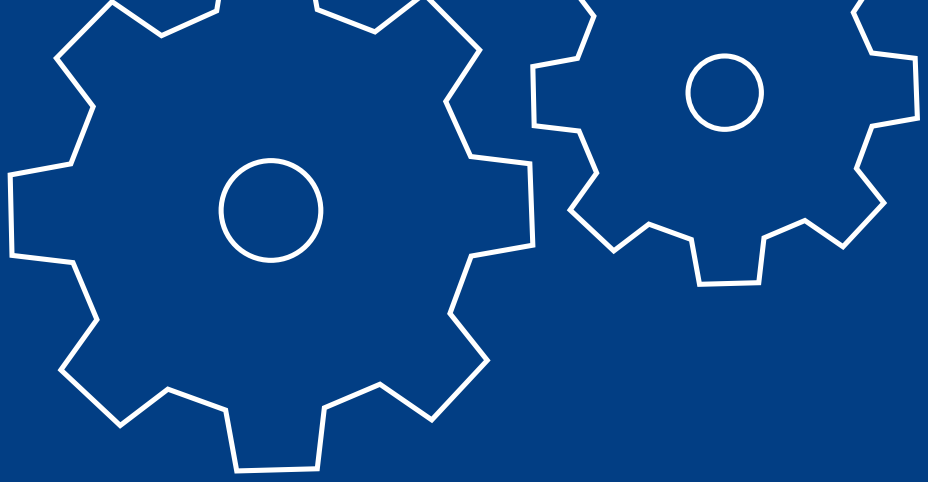

Technology Transfer Centre
Rzeszów University of Technology

Powstańców Warszawy 12, 35-959 Rzeszów
building V, floor II

tel.: 17 743 2116, 17 865 1689, 17 743 2168

przemysl.prz.edu.pl