



Łukasiewicz  
Institute  
of Aviation

# MATERIAL AND STRUCTURAL TESTING





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# GENERAL COMPANY INFORMATION

Łukasiewicz Research Network - Institute of Aviation is one of the most modern research institutions in Europe, with traditions dating back to 1926. The Institute closely cooperates with the world's tycoons of the aviation industry and institutions from the space industry. The strategic research areas of the Institute are aviation, space and unmanned technologies. Tests and services for domestic and foreign industry in the field of metallic and composite materials, additive, remote sensing, energy and mining technologies are also carried out here. Łukasiewicz Research Network - Institute of Aviation is made up of eight research centers:

- **AVIATION TECHNOLOGIES CENTER**  
develops technologies dedicated to aircraft design, aerodynamic testing and aircraft certification.
- **SPACE TECHNOLOGIES CENTER**  
conducts research and development in the field of space propulsion, rocket technologies, research of satellite systems and remote sensing.
- **UNMANNED AERIAL VEHICLE TECHNOLOGIES CENTER**  
conducts research and development in the field of drones and anti-drone systems.
- **MATERIALS AND STRUCTURES RESEARCH CENTER**  
offers material and structural elements testing at a broad range of loads and temperatures, and, through numerous certified test stations, it is a regional leader in the area of fatigue and strength testing.
- **COMPOSITE TECHNOLOGIES CENTER**  
provides solutions in the field of composite technologies and tests of composite materials for the aviation and space industry.
- **ENGINEERING DESIGN CENTER**  
is an engineering alliance between General Electric Company Polska Sp. z o.o. and Łukasiewicz Research Network – Institute of Aviation. The Center offers design, research and development services in the fields of aviation, gas power and renewable energy.
- **ENGINEERING SERVICES CENTER**  
provides support in the field of mechanical engineering and thermal strategic research and development projects.
- **ENERGY TECHNOLOGIES CENTER**  
focuses on engineering areas: designing, manufacturing, analyzing and servicing parts for high-power gas turbines and wind turbines. One of the main tasks of this center is to implement a new energy era that will build a cleaner future.



# OFFER

One of the main areas of activity of the Łukasiewicz Research Network - Institute of Aviation in the field of materials and structures tests is the implementation of state of the art research methods regarding strength tests of materials, aircraft engines components and other structures operating under high mechanical loads at a broad range of temperatures.

The Institute is one of the world leaders in strength testing. What makes it distinguished, is the high quality and standard-driven services provided, high-end testing stations and the most recent generation of test equipment. The Institute specializes in conventional as well as non-standard strength tests of materials and structures, subject tested objects to work in extreme conditions. It offers a full range of material tests, from specimens preparation, mechanical and material tests, as well as non-destructive diagnostics.

The scope of the Institute's activities in the field of materials and structural tests also includes services and complete solutions for products manufactured using additive technologies, including characterization of materials, from planning through testing, analysis of results, creation of material models and non-destructive diagnostics, design of elements with the optimization of their shape and parameters of the manufacturing process, prediction of imperfections and residual stresses and study of structures: programming and designing experiments, preparation of stands, analysis of results along with the delivery of conclusions and recommendations.

## **Scope of the offer:**

- Material testing.
- Non-destructive testing (NDT).
- X-ray diffraction testing (XRD).
- Manufacturing of material testing specimens.
- Structural elements testing.
- Vibration and acoustic testing.
- Structural and functional tests of landing gears and its components.
- High Velocity Impact tests (including. "Bird Strike").

**POLSKIE CENTRUM AKREDYTACJI**  
POLISH CENTRE FOR ACCREDITATION



Sygnatariusz EA MLA  
EA MLA Signatory

**CERTYFIKAT AKREDYTACJI**  
**LABORATORIUM BADAWCZEGO**  
ACCREDITATION CERTIFICATE OF TESTING LABORATORY

**Nr AB 792**

Potwierdza się, że: / This is to confirm that:

**SIEĆ BADAWCZA ŁUKASIEWICZ -**  
**INSTYTUT LOTNICTWA**  
ZESPÓŁ LABORATORIÓW BADAŃ MATERIAŁÓW I KONSTRUKCJI  
Aleja Krakowska 110/114  
02-256 Warszawa

spełnia wymagania normy PN-EN ISO/IEC 17025:2018-02  
meets requirements of the PN-EN ISO/IEC 17025:2018-02 standard

Akredytowana działalność jest określona w Zakresie Akredytacji Nr AB 792  
Accredited activity is defined in the Scope of Accreditation No AB 792

Akredytacja pozostaje w mocy pod warunkiem przestrzegania  
wymagań jednostki akredytującej określonych w kontrakcie Nr AB 792  
This accreditation remains in force provided the Laboratory observes  
the requirements of Accreditation Body defined in the Contract No AB 792

Akredytacji udzielono dnia 12.03.2007 r.  
Accreditation was granted on 12.03.2007



DYREKTOR  
POLSKIEGO CENTRUM AKREDYTACJI

*Lucyna Olborska*  
LUCYNA OLBORSKA

Warszawa, 18 lutego 2020

# CERTIFICATES

Łukasiewicz Research Network - Institute of Aviation in the field of materials and structural testing holds numerous certificates that confirm and guarantee the highest quality of provided services as well as laboratory and scientific personnel professionalism:

- Certificate of accreditation according to **PN-EN ISO/IEC 17025:2018** standard in the area of: strength tests of mechanical structures and their components, mechanical and non-destructive tests (certificates of accreditation number **AB 792** and **AB 131** issued by the Polish Center for Accreditation).
- Certificate granted by **General Electric for the Material Testing Laboratory**, confirming compliance with technical specification **GE S-400** dedicated for service and tests providers within the area of special processes in aviation.
- **The ACE (Achieving Competitive Excellence)** operating system implemented at the Silver level in the Materials and Structures Research Center, used among United Technologies Corporation (UTC) companies and their suppliers' network, which confirm the modern approach of managing the company, its processes and working culture.
- **Pratt & Whitney** mechanical test certification - in 2005-2008, the Institute obtained certificates in the field of mechanical tests and component tests. The certified tests are: Creep Rupture Testing, static and quasi static shaft tests - Tension / Torsion Shaft LCF Testing, Tube LCF Testing, Windmill Fan Blade Testing, High Cycle Fatigue Testing, Low Cycle Fatigue Testing).
- **GE Aviation Czech** certificate of a qualified supplier in the field of mechanical tests of materials and structures.



# MATERIAL TESTING

## FATIGUE AND STRENGTH TESTS

Łukasiewicz Research Network - Institute of Aviation has a great potential for material tests in the field of fatigue and strength tests. The tests are carried out on the state of the art, universal sets of servo-hydraulic axial fatigue machines of such reputable brands as MTS and INSTRON. The Institute has over 30 fatigue test stands in the load range from 500 N to over 250 kN.

Thanks to such selected test stands, it is possible to use various types of geometry of specimens, both small ones made of light alloys and large specimens made of super-durable aircraft alloys.

The temperature range of tests conducted from -180 ° C up to 1500 ° C fully covers the demand on the global fatigue testing market, in particular aviation alloys. It is possible due to specially designed specimen gripping systems, temperature controllers and appropriately selected furnaces. Extensometers for strain measurements are cooled by air or water.





MTS

4

810 Material



A wide variety of mechanical tests methods provided, such as: low-cycle fatigue load-controlled tests (LCF), tensile test (TENSILE), high-cycle fatigue load-controlled tests (HCF), low-cycle fatigue strain controlled tests (SCLCF), fracture mechanic tests (K<sub>Ic</sub>, da / dN, combined with the possibilities of testing at a broad range of temperatures of up to 1500 °C, makes that the Institute is at the forefront of laboratories in the world.

Tests are performed in accordance with the universal standards, such as: ASTM E606, ASTM E466, ASTM E399, ASTM E647 da / dN, and in accordance with the customer's specifications.

To meet the requirements of our customers, all devices and measuring equipments are calibrated in accordance with generally used standards, such as: ASTM E4, ASTM E467, ASTM E83, ASTM E1012, ASTM E220, ASTM E574. The laboratories and personnel of the Institute have numerous certificates and diplomas confirming the highest competences.

*The highest quality and best practices of tests provided are confirmed by certificates and qualifications, such as:*

- *Certificate of accreditation according to PN-EN ISO / IEC 17025: 2018 – number AB 792.*
- *Certificate of qualification according S-400 specification – issued by GE Aviation.*
- *Pratt & Whitney mechanical test certification.*

Available laboratory equipment:

- 11 MTS 100 kN fatigue testing machines.
- 6 INSTRON 100 kN fatigue testing machines.
- 4 MTS 250 kN fatigue testing machines.
- 2 MTS 25 kN fatigue testing machines.
- 6 MTS 50 kN fatigue testing machines.

Testing capabilities – fatigue and strength tests:

- Test frequency up to 60 Hz.
- Range of tests from -180°C to 1500°C.
- Tests in the range of loads from 500N to 250 kN.
- Strain-controlled tests up to 1 Hz.
- HCF tests up to 60 Hz.
- LCF tests up to 12 Hz.
- Static tensile tests.
- Testing in the field of fracture mechanics K<sub>Ic</sub>, da / dN.
- The ability to write individual complex programs that allow to simulate the real load course of the tested element in an unlimited way.
- Tests at a constant ambient temperature thanks to specially designed air conditioning in the room where the test stands are located.
- Power support system which allows to conduct continuous long-term tests without the risk of losing.



## CREEP TESTS

Łukasiewicz Research Network - Institute of Aviation has the ability to perform creep tests, which are one of the types of material tests. They are performed on creep machines, which uniaxial tension of the specimen is obtained by gravity using calibrated weights hanged on the creep frame arm.



#### Laboratory capabilities:

- 36 test stands (creep frames) which enable the conduct three types of tests:
  - with deformation registration.
  - with registration of the time to break.
  - performing LCF fatigue tests on 14 positions using elevators.
- Test temperature up to 1100°C realized by "S" type thermocouples
- Tensile force up to 50kN.
- Registration of specimen deformation using high-temperature extensometers.
- Supervision and registration of tests by computer system in a real time.
- Creep tests performed in accordance with ASTM E139, E292 and ISO 204.

Due to the long testing time, the creep laboratory is equipped with a UPS voltage backup system and air-conditioned rooms with temperature and air humidity registration.

#### Certificates:

- *Certificate of accreditation according to PN-EN ISO / IEC 17025: 2018 – number AB 792.*
- *Certificate of qualification according S-400 specification – issued by GE Aviation.*
- *Pratt & Whitney mechanical test certification.*



## IMPACT TESTS

Impact tests help to determine the resistance of the material to cracking at dynamic load. They are performed in order to determine the influence of the load speed and deformation on the mechanical properties of materials - they characterize the mechanical properties of the material that cannot be determined by static tests.

To conduct impact tests, devices which are used, the so-called impact hammers, enable the high-force application in a short period of time,. To perform such tests Institute is equipped with a standard Charpy pendulum machine as well as its instrumented version. It allows to determine not only the impact work, which is a measure of the material's fracture toughness, but also to determine the characteristics of the breaking force as a function of time.

In addition, the laboratory has special digitally controlled chambers that enable tests to be conducted on specimens with reduced or increased temperature - a cooling chamber (specimens cooled to a temperature of - 180 °C) and a heating chamber (tests up to a temperature of 300 °C).

Testing capabilities:

- Pendulum impact machine Charpy Proeti 300J.
- Instrumented pendulum machine Charpy Lab Test CHK 450J-I.
- Tests can be carried out at the temperature to - 180°C.
- Impact tests can be performed for standard specimens 10x10x55 mm as well as smaller specimens of 7.5x10x55 mm and 5x10x55 mm.



arta obsługi codzienna

Wzrost: 170 cm, Ciężar ciała: 70 kg, Ciężar serca: 300 g, Ciężar płuc: 500 g, Ciężar wątroby: 1500 g, Ciężar nerek: 200 g, Ciężar pęcherzyka żółciowego: 50 g, Ciężar pęcherzyka moczowego: 100 g, Ciężar prostaty: 20 g, Ciężar macicy: 50 g, Ciężar jajników: 50 g, Ciężar narządów wewnętrznych: 1000 g, Ciężar krwi: 5000 g, Ciężar mózgu: 1500 g, Ciężar serca: 300 g, Ciężar płuc: 500 g, Ciężar wątroby: 1500 g, Ciężar nerek: 200 g, Ciężar pęcherzyka żółciowego: 50 g, Ciężar pęcherzyka moczowego: 100 g, Ciężar prostaty: 20 g, Ciężar macicy: 50 g, Ciężar jajników: 50 g, Ciężar narządów wewnętrznych: 1000 g, Ciężar krwi: 5000 g, Ciężar mózgu: 1500 g

Organ	Waga (g)	Waga (% ciała)
Mózg	1500	2,3
Serce	300	0,45
Płuca	500	0,75
Wątroba	1500	2,3
Nerki	200	0,3
Pęcherzyk żółciowy	50	0,075
Pęcherzyk moczowy	100	0,15
Prostata	20	0,03
Macica	50	0,075
Jajniki	50	0,075
Narządy wewnętrzne	1000	1,5
Krew	5000	7,5





## STRUCTURAL ANALYSIS OF MATERIALS

Łukasiewicz Research Network - Institute of Aviation has experience and appropriate equipment to carry out tests in the field of material structure testing, material surface testing with determination of chemical composition, fractographic tests and measurements of material properties.

The scope of the Institute's offer includes the following services:

- Metallography.
- Fractography using a scanning microscope (break points, material homogeneity control).
- Determining the chemical composition by the EDS method (identification of materials, impurities and assessment of the concentration of elements on the specimen surface).
- Microstructure analysis - metallographic and optical microscopy.
- Surface analysis.
- Roughness.
- Hardness and microhardness.

### **METALLOGRAPHY - Preparation of metallographic**

Equipment:

- Cutting machine (with manual and automatic cutting function with cooling system).
- Mounting press for specimens with a maximum diameter of  $\phi$  40 mm.
- Grinding and polishing machine with the possibility of preparing up to 6 specimens simultaneously.

### **FRACTOGRAPHY, SEM - Scanning Electron Microscope**

Scope:

- Evaluation of grain size, surface roughness, porosity, particle distribution, material homogeneity, non-metallic inclusions, diffusion of elements.
- Fatigue analysis:
  - Location of impurities, microcracks.
  - Fatigue failure assessment, fracture studies.

Equipment:

- SEM Zeiss EVO 25 MA with BSD and SE detectors.
- Q150R specimen preparation system.

### **EDX ANALYSIS OF THE CHEMICAL COMPOSITION**

Scope:

- Analysis of the chemical composition of the specimen.
- Material identification.
- Contamination identification.
- Determination of the relative concentration of the elements on the specimen surface.

Equipment:

- EDX XFlash 5010 Bruker detector (resolution energy 125 eV).

## MICROSCOPY

Scope:

- Software enabling analysis, processing of digital images, measurement of geometric quantities.
- The microscope enables three-dimensional imaging of specimens surface topography.
- In the range of 100-500x magnification, the possibility of observation in a bright and polarized light field.
- From 100 to 1000 x: DIC darkfield observation possible.
- Lenses enabling observation at a magnification of 20 to 5000x (digital zoom).

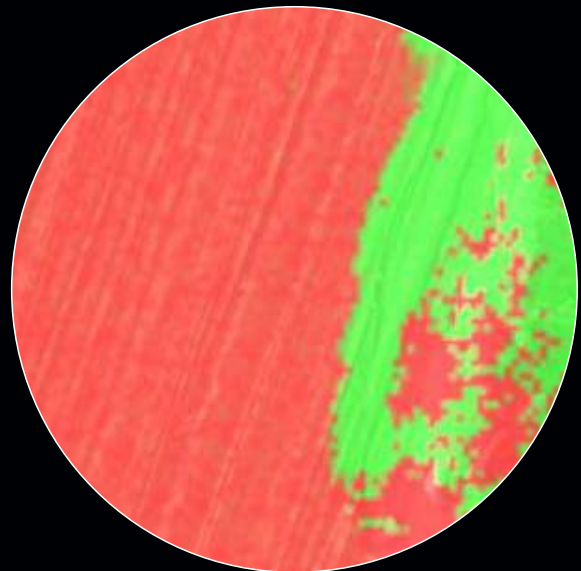
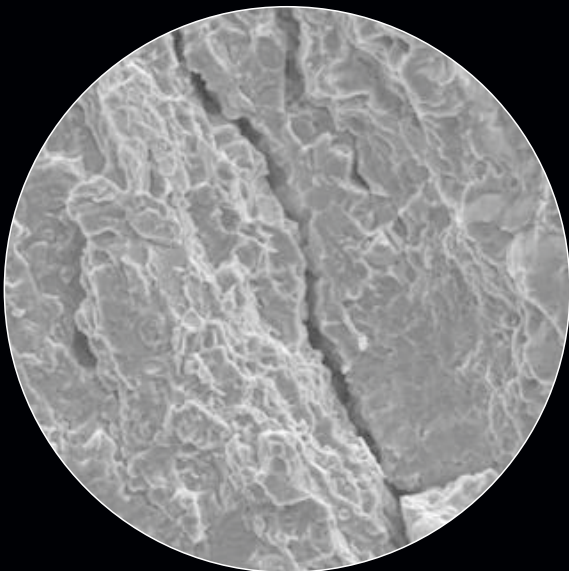
Equipment:

- Keyence digital microscope VHX 6000.

## HARDNESS AND MICRO HARDNESS

Equipment and scope:

- Nexus Innovatest hardness tester with the following ranges:
  - 0.02 - 0.1 kgf Vickers microhardness.
  - 0.2 - 5 kgf Vickers hardness at low forces.
  - 10 - 30 kgf macrohardness Vickers hardness.
- Falcon Innovatest digital hardness tester with a range of 0.001-31.25 Vickers hardness with the possibility of automatic measurements.
- Zwick Roell hardness tester with ranges: 10 kg.
- Rockwell hardness 60 kg, 100 kg, 150 kg.
- Mitutoyo portable hardness tester - Leeb scale with the possibility of conversion to HV, HB, HRC, HRB scale.





# NON-DESTRUCTIVE TESTING

Łukasiewicz Research Network - Institute of Aviation as part of the Design Research Laboratory, it has many years of experience in non-destructive testing, mainly used to detect and determine the configuration, distribution and size of defects arising in the production process and during operation. The tested objects can be the entire structure, parts or fragments of structural elements or semi-finished products. Typical examples of detected defects are: fatigue cracks, corrosion, bubbles, inclusions, leakage, welding defects. The personnel performing Non-destructive testing is qualified and certified in accordance with PN-EN ISO 9712 "Non-destructive testing - Qualification and certification of non-destructive testing personnel".

The scope of the Institute's offer includes the following non-destructive methods:

- CT computed tomography.
- Eddy currents (ET).
- Penetration (PT).
- Ultrasonic (UT).
- Magnetic (MT).
- Visual (VT).
- X-ray (RT).

## *Certificates:*

- *Certificate of accreditation according to PN-EN ISO / IEC 17025: 2018 – number AB 792.*
- *Personnel certificates for non-destructive testing.*

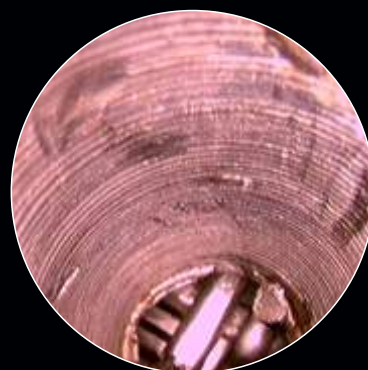
## VISUAL METHOD (VT)

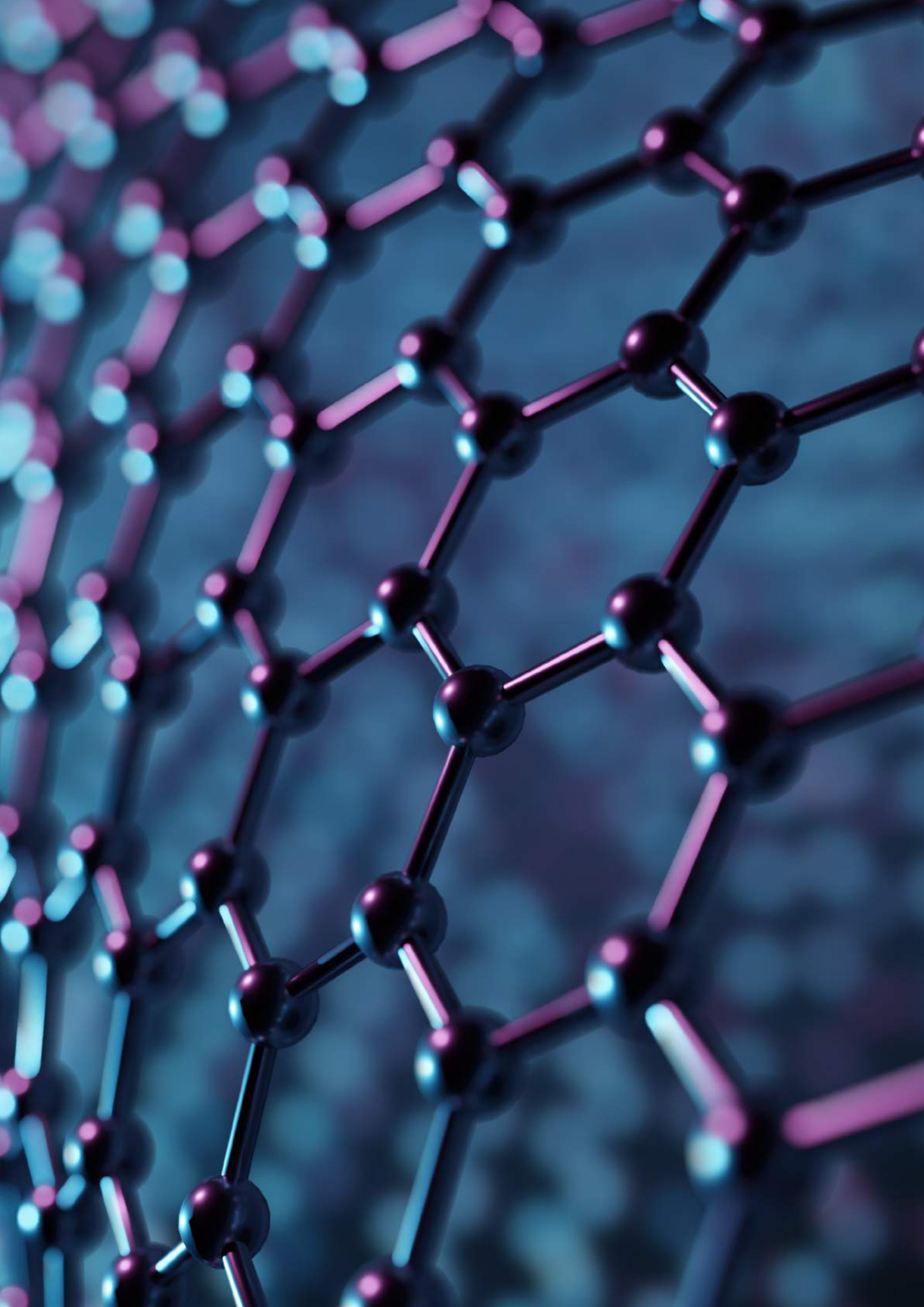
Testing capabilities:

- Detection of surface defects.
- Types of detected discontinuities - fatigue cracks, heat treatment cracks, operational damage, welding imperfections.
- Endoscopy and boroscopy - detection of defects in inaccessible places.

Equipment:

- Olympus fiberscope system.
- Everest borescope system.







Ciężar w kg  
 $0.38 \pm 0.01$

## PENETRATION METHOD (PT)

Testing capabilities:

- Examination of surface discontinuities of non-porous materials (metal and non-metallic) - steel and its alloys, non-ferrous metals, ceramics, glass, plastics.
- Types of detected discontinuities - cracks (e.g. fatigue, grinding), porosity, scratches, delamination, lapping, rolling, corrosion (point, surface), leaks, welding incompatibilities.

Equipment:

- Magnaflux penetration kits.
- UV and white light illuminators.
- Reference samples.
- light and UV radiation intensity meters.

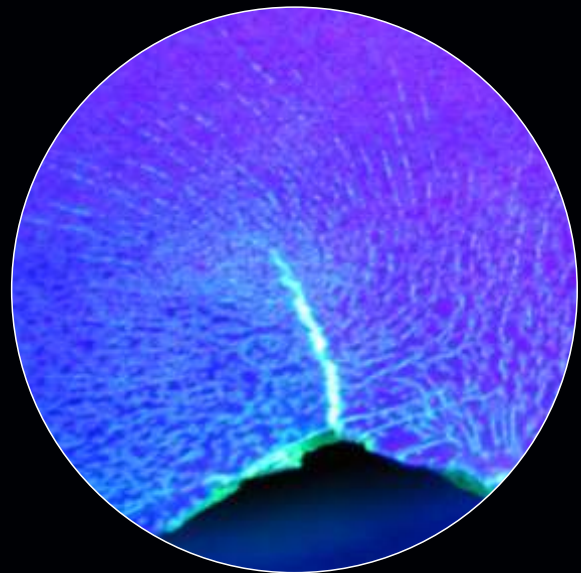
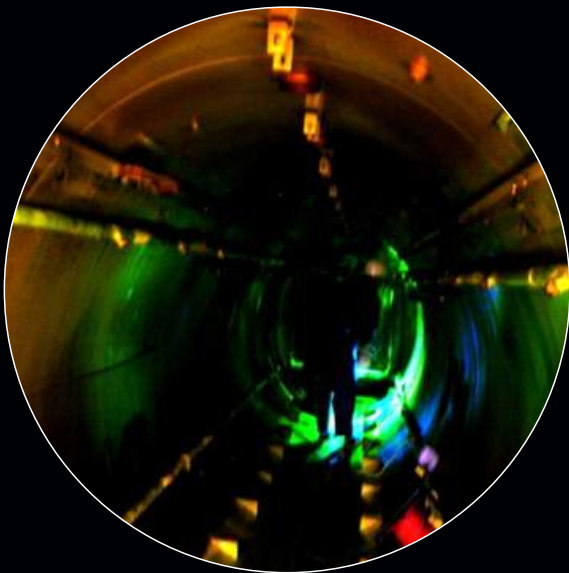
## EDDY CURRENT METHOD (ET)

Testing capabilities:

- Testing of materials showing electrical conductivity.
- Detection of surface and subsurface defects - cracks, (fatigue, hardening, grinding) inclusions, corrosion, coating thickness measurement, comparative structural tests.

Equipment:

- Eddy current flaw detector GE Inspection Technologies Phasec 3d with sets of specialized probes.
- Reference samples and specific electrical conductivity samples.



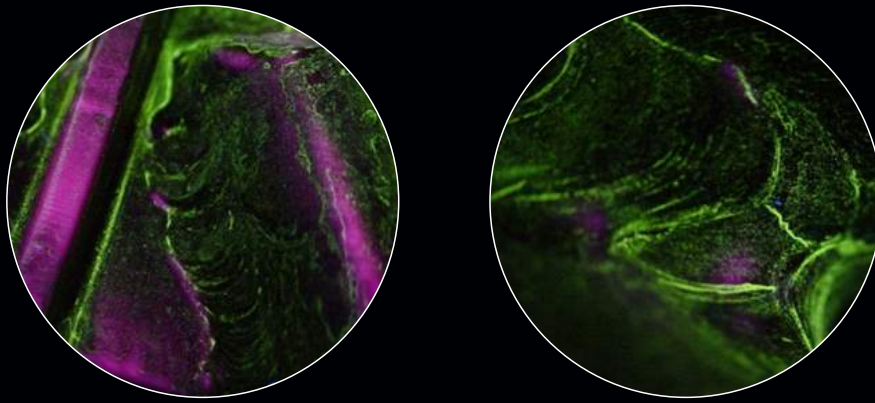
## MAGNETIC METHOD (MT)

Testing capabilities:

- Detection of surface and subsurface defects of all ferromagnetic materials.
- The basic detected surface defects are fatigue cracks, cracks resulting from thermal and mechanical treatment - grinding, hardening cracks, etc., welding incompatibilities.
- Sub-surface defects include all kinds of inclusions, pores and bubbles.

Equipment:

- Magnaflux, Parker zygomatic flaw detectors.
- Fluorescent and black Magnaflux suspensions.
- UV and white light illuminators.
- Magnetic field meters and indicators.



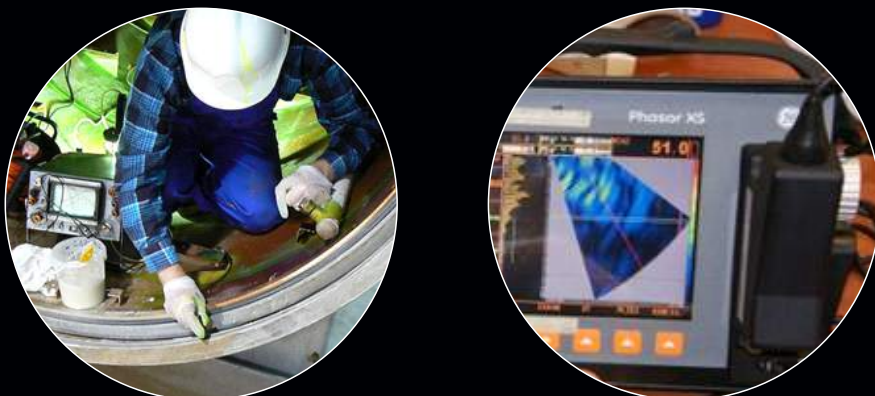
## ULTRASONIC METHOD (UT)

Testing capabilities:

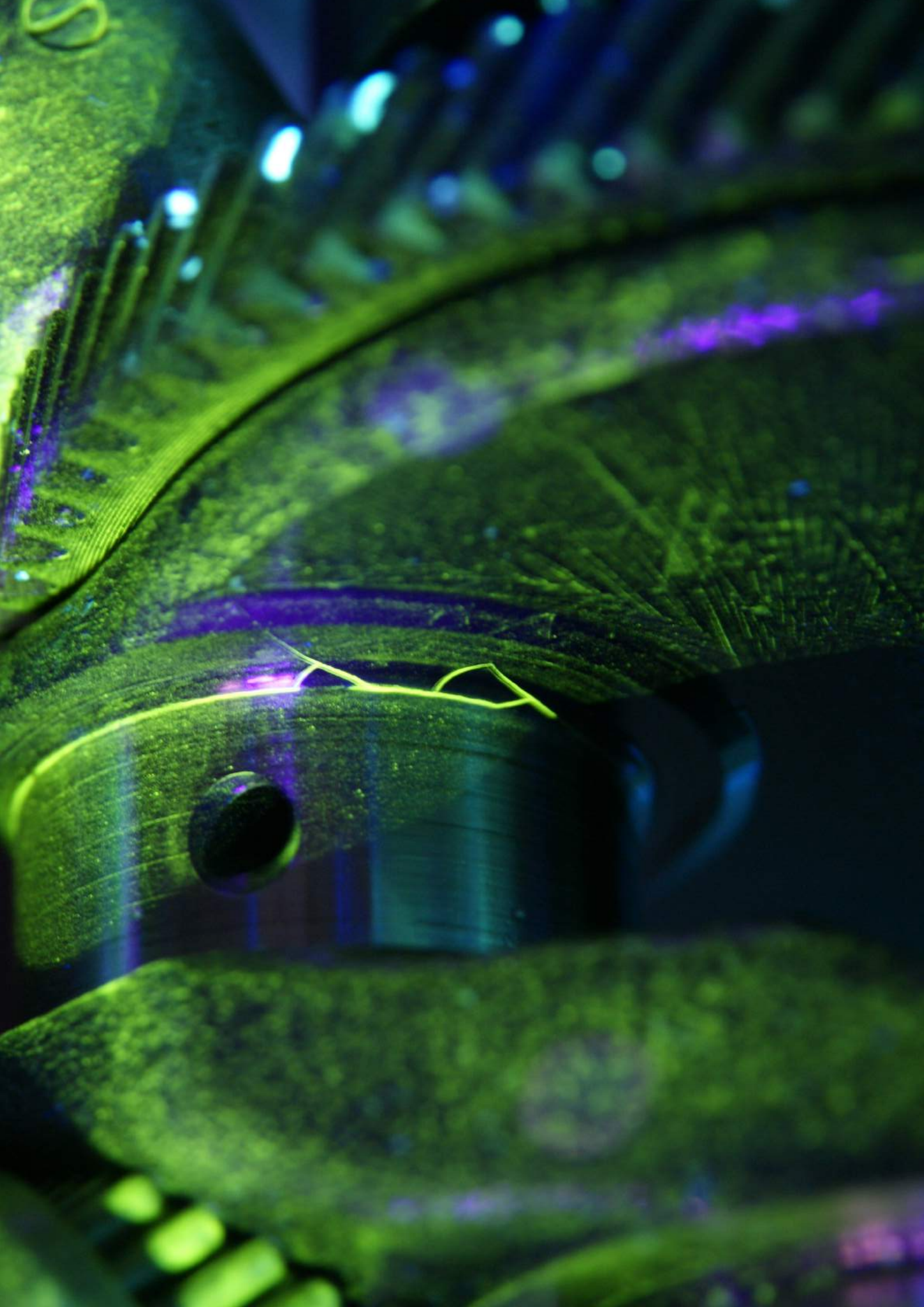
- Detecting defects in the internal structure and determining their location, configuration and size. These are: cracks, blisters, inclusions and a number of other discontinuities in metal, non-metal and composite materials, welds.
- For measuring material thickness, testing distant places, invisible surfaces, cross-sections, determining certain properties of the material.

Equipment:

- GE Inspection Technologies Phasor XS defectoscope with Phased Array.
- Specialized heads and reference samples.









## COMPUTER X-RAY TOMOGRAPHY (RT), (CT)

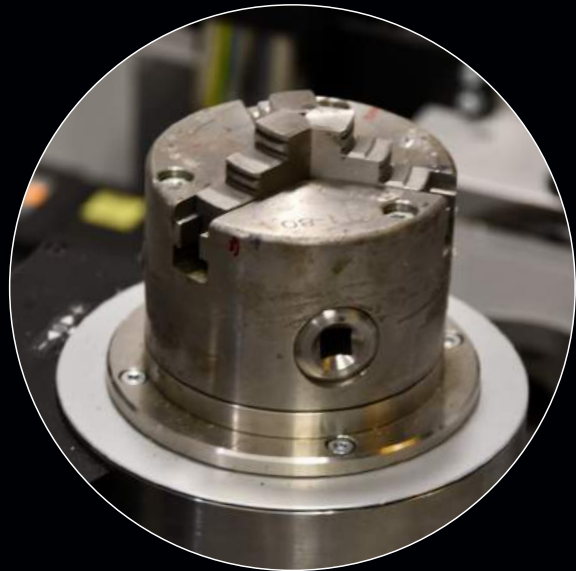
Testing capabilities:

- Mainly for detecting internal structure defects in any materials.
- Volumetric testing of objects.
- Dimensioning of internal elements.
- Testing the correctness of assembly.
- Weld tests.

### X-RAY TUBE 240 kV / 320 W

Scope:

- 1  $\mu\text{m}$  detail detectability.
- Max. 2  $\mu\text{m}$  resolution.
- Max. object size (height x diameter) 410 mm x 300 mm.
- Max. object weight 10 kg.





# X-RAY DIFFRACTION TESTING

Łukasiewicz Research Network - Institute of Aviation has a research infrastructure in the field of X-ray diffraction, which specializes in the use of X-ray diffraction phenomenon to measure stress, texture and phase composition. Measurements are performed both on especially prepared specimens as well as on real structural elements, such as engine valves, turbine blades or gears; both on elements produced with traditional methods and for elements produced with 3D printing. The implementation of the electropolishing method allows to define the above-mentioned parameters in-depth, and the extensive equipment of the laboratory allows the implementation of measurements for complex geometries and complex issues.

## EMPYREAN PANALYTICAL X-RAY DIFFRACTOMETER

Testing capabilities:

- Quantitative and qualitative testing of phase composition, monitoring the contamination degree of the material.
- Measurement and analysis of crystallographic texture.
- Measurement and analysis of the residual stress level on the surface and determination of the stress gradient deep into the specimens / component.
- Measurement of grain size and micro-stresses.
- Measurements for thin layers of a given thickness.
- Particle size and pore size analyses (small angle scattering method SAXS).
- Determination of layer thickness and roughness (X-ray reflectometry).

X-ray tubes:

- Cu - phase identification, quantitative analysis, high resolution diffraction.
- Mn - residual stress analyses for austenitic steels, nickel alloys, copper and cobalt.
- Cr - residual stress analyses for steel, aluminum alloys, materials with large lattice parameters, such as minerals, organic materials and ceramic superconductors.

Detectors:

- Proportional detector - more accurate, consisting of a cylindrical chamber filled with a mixture of xenon and methane; it has a beryllium window with dimensions of 20 mm x 24 mm.
- PIXcel 1D – faster X-ray detection system designed based on the Medipix3 semiconductor technology.

Accessories for stress measurement, texture and phase analysis of irregularly shaped specimens, including printed elements:

- Parallel beam mirror for Cu and Cr radiation.
- Parallel beam lenses - focus the entire power of the X-ray beam at a specific point without losing intensity while forming a quasi-parallel beam.
- 5-axes cradle – which is an Eulerian cradle with 5 motorized movements (chi, phi, x, y and z).

## XSTRESS 3000 G2R PORTABLE DIFFRACTOMETER (STRESTECH)

### Testing capabilities:

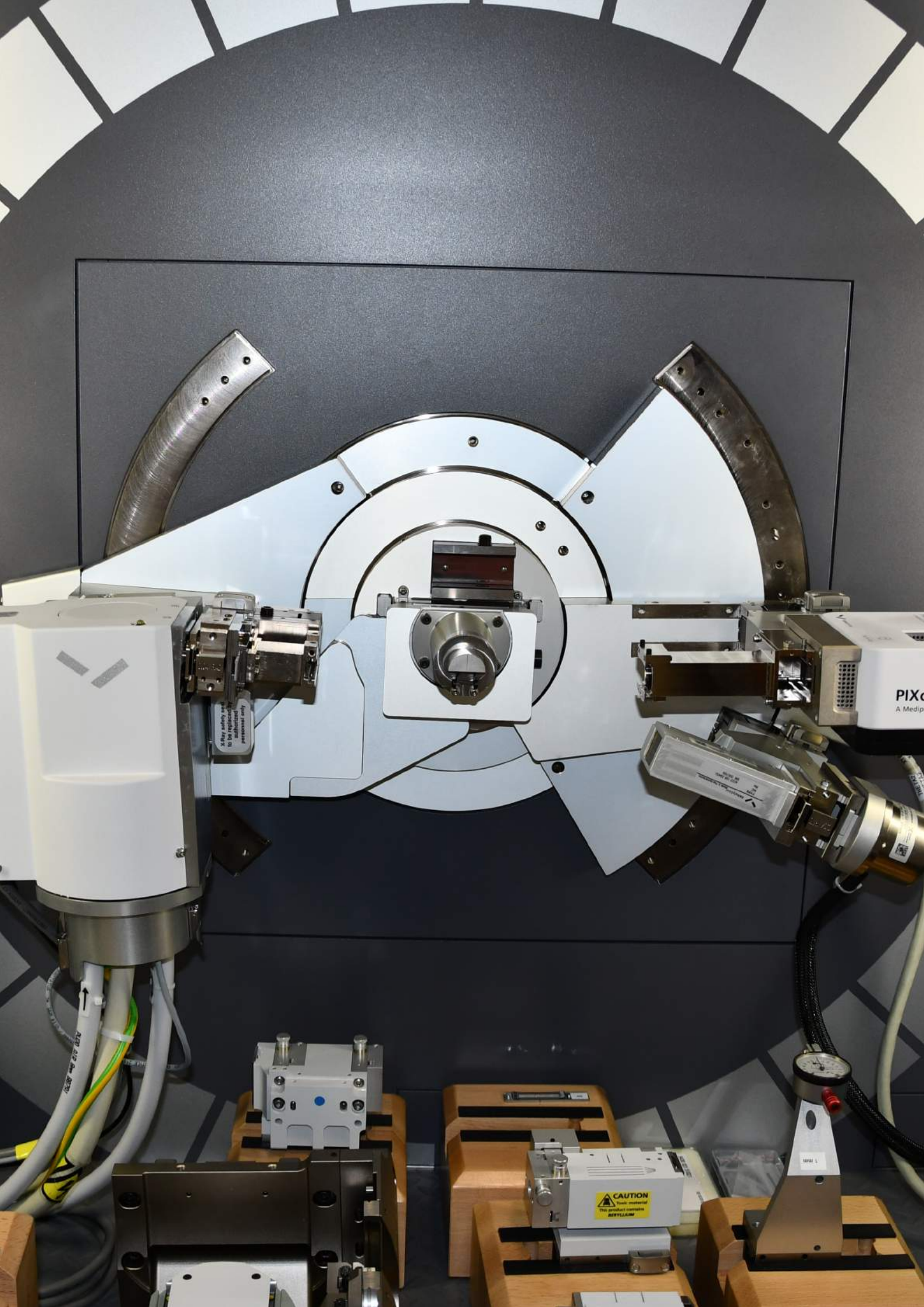
- Fast residual stress analyses for specimens with complex shapes and large sizes.
- Portable device - the possibility of measurements both in the laboratory and in the field.
- Possible measurement of actual stresses applied to determine the characteristics of a specific material.
- Automated X-Y table - measurement of stress distribution on the specimen surface, automatic measurement of many specimens.
- Collimators (spot size) - from 0.5 mm to 5 mm.

### X-ray tubes:

- Mn - measurement of residual stresses for austenitic steels, nickel alloys, copper and cobalt.
- Cr - especially dedicated to the measurement of residual stresses in ferritic steels and aluminum alloys.
- Ti - analyses of residual stresses in titanium alloys.
- V - other, complementary applications.

### Detectors:

- Two symmetrically positioned NMOS position sensitive detectors, standard detector width 15°.



PIXO

A Medip

For safety, this device must be repaired by authorized personnel only

CAUTION  
High voltage  
This product contains  
BERTHLEIM

100 PSI





## DEEP MEASUREMENTS - ELECTROPOLISHING

### Instrumentation:

- Portable electropolishing machine - Kristall 650.
- Mitutoyo stand with granite plate and digital depth gauge with a resolution of 0.0005 mm.

## VALIDATION AND REFERENCE SAMPLES

- Tensile machine for validation of stress measurements with diffraction methods.
- Certified annealed samples (Fe-Aust, Al, Ti, Mg, Inconel 718, Cu, Fe-Ferr, Ni).
- Certified sample with known stress level.
- Standard Reference Samples (National Institute of Standards and Technology NIST certified).
- Lanthanum hexaboride 660c powder (line position and line shape standard).
- 640e silicon powder (line position and line shape standard).
- 1976b corundum plate (position and intensity of diffraction peaks verification).

### Examples of experiments carried out in the X-ray Diffraction Laboratory:

- Measurement of the stress gradient around rivets in sheets made of aluminum alloy (as part of the project on improving the fatigue life of riveted joints).
- Measurement of residual stresses at the thread bottom of a titanium alloy screw.
- Measurement of residual stresses on specimens made of Inconel 718 / steel, dedicated to fatigue testing.
- Residual stresses measurements on a bottom land of gear made of AMS 6265 alloy (low carbon steel) Testing the influence of markings made with laser and vibropene on the stress level in specimens made of nickel alloy.
- Measurement of residual stresses on specimens intended for testing the phenomenon of erosive failure for 17-4PH stainless steel.
- Measurement of residual stresses on a wheel made of 13-8PH steel.
- Phase analysis and texture measurement for thin layers made of Ni / SiC composite.
- Phase analysis and stress measurement on printed specimens made of Inconel 718, CoCr and SS316L alloys.
- Measurement of the stress distribution for the heat shield element made of nickel alloy.
- Phase analysis of the GENx liner aft nugget plugging Residual stress measurements on the surface of two dove-tail blade roots made of Inconel 178 Stress measurement near fracture for aero engine blades made of titanium alloy.
- Measurement of stresses on the surface of valves made of steel after hardfacing and nitriding with prior phase analysis.
- Stress measurement around RFSSW joints for 7075 aluminum alloy sheets.

# SPECIMEN PREPARATION

Łukasiewicz Research Network - Institute of Aviation in addition to a wide range of material tests, provides the possibility of making specimens for all types of tests offered, such as strength tests (static tensile test, creep tests, impact tests, stress rupture tests) or fatigue tests (low and high cycle tests) as well as the machining of metal and hardly-machinable materials used in aircraft engines, such as nickel and titanium alloys. Specimens are made on the basis of international standards (including ASTM) or in accordance with the customer's specification.

Machining workshop equipment:

- Universal CNC cylindrical grinder - Studer S33.
- Universal centre-type grinder for shafts and holes RUP 280.
- Flat surface grinder FSG 1640 ADII.
- AVIA Turn 35 CNC lathe.
- DMG MORI NLX 2000 lathe.
- FNE 40 CNC milling machine.
- Mitsubishi BA8 wire EDM machine.
- ZAP-BP-09d wire EDM machine with an attachment for starting holes.
- Automatic device for longitudinal grinding.
- Equipment for checking dimensions and surfaces.

*Certificates:*

*Łukasiewicz Research Network - Institute of Aviation is qualified by General Electric Aviation to perform specimens for monotonic (creep, static tensile test) and fatigue (low and high-cycle) tests in accordance with the requirements of S-400.*

## UNIVERSAL CNC CYLINDRICAL GRINDER - STUDER S33

Scope:

- CNC grinder for grinding external surfaces of cylindrical objects (shafts).
- Possibility to grind threads and contours.
- Integrated grinding wheel dressing.
- Possibility of external programming (CAD / CAM Mastercam system).
- 175 mm (6.9 ") claw rise.
- Distance between centers 650 mm (25.5 ").
- Max. item weight 80 kg (176 lb).
- Circularity achieved 0.0004mm (0.000016 ").
- Min increment 0.0001mm (0.000004 ").
- RPM range 1-1000 min<sup>-1</sup>.



STUDER

UNITED GRINDING

## UNIVERSAL CENTRE-TYPE GRINDER FOR SHAFTS AND HOLES RUP 280

### Scope:

- Max. external grinding diameter: 280 mm.
- Max. external grinding length: 500 mm.
- Max. internal grinding diameter: 200 mm.
- Max. internal grinding length: 120 mm.
- Max. weight of the item between centers: 125 kg.
- Max. weight of the item in a clamp: 20 kg.

## FLAT SURFACE GRINDER FSG 1640 ADII

### Scope:

- Semi-automatic.
- Table size: 400mmx1000mm (15.7" x 39.3").
- Max grinding length: 1015mm (40").
- Max width of grinding: 405mm (16").

## AVIATURN 35 CNC LATHE

### Scope:

- Max turning diameter: 220 mm (8.5").
- Max turning length: 380 mm (14,5").
- Max spindle revolutions: 5000 RPM.
- Number of tools in the head: 12.
- Possibility of external programming (CAD / CAM system Mastercam).

## DMG MORI NLX 2000 LATHE

### Scope:

- Max. turning diameter: 220 mm (8,5").
- Max. turning length: 430 mm (16,5").
- Max. spindle revolutions: 5000 RPM.
- Max. revolutions of driven tools  $5000 \text{ min}^{-1}$ .
- Number of tools in the head 12.
- Tools and frame cooled by liquid.
- Possibility of external programming (CAD / CAM Mastercam system)..
- Exceptional stiffness.
- High precision.
- Powered tools (possibility of milling).

## FNE 40 CNC MILLING MACHINE

### Scope:

- CNC 3-axial.
- Heidenhain controller.
- Spindle: vertical and horizontal.
- Table size: 400mmx800mm (15,7"x 30,4").
- Max. table load: 400 kg.
- Crossing: X=620mm (24,4"); Y=420mm(16,5"); Z=400mm(15,7").
- Possibility of external programming (CAD / CAM Mastercam system).



## MITSUBISHI BA8 WIRE EDM MACHINE

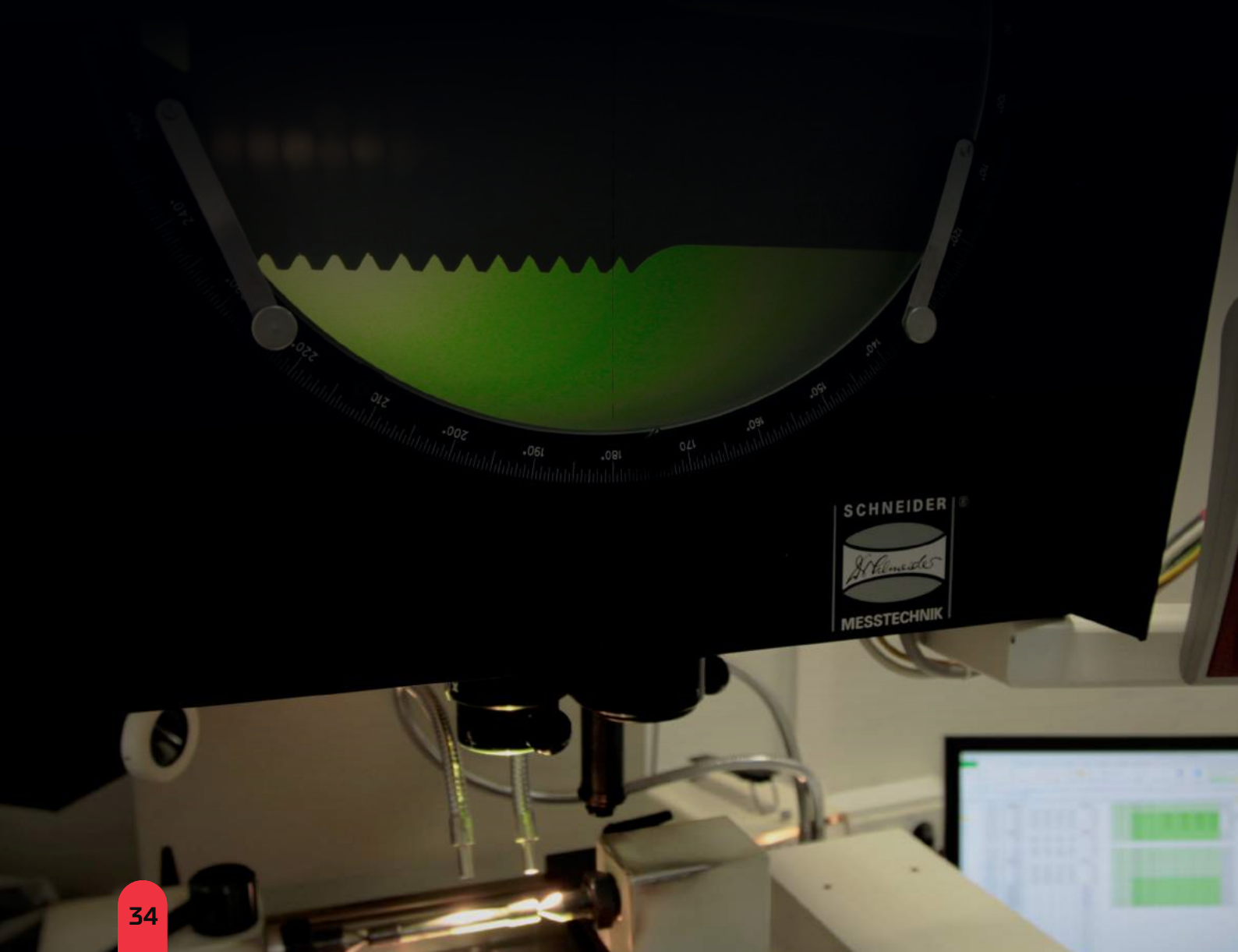
### Scope:

- Max. dimensions of the workpiece: 700 mm x 550 mm x 170 mm (27.5" x 21.5" x 6.7").
- Max. workpiece weight 500 kg (1100 lb).
- 5-axial.
- Automatic wire threading of diameter 0.1-0.3 mm (0.04-0.1 ").
- V-350 high speed generator.
- 64 bit CNC-PC-controller.
- 10 kg (22 lb) - wire spools.
- Automatic centering in the hole.

## ZAP-BP-09D WIRE EDM MACHINE

### Scope:

- Max. dimensions of the workpiece: 300 mm x 180 mm x 180 mm (11.8" x 7" x 7").
- Max. workpiece weight 100 kg (220 lb).
- 2-axial.
- Wire diameter 0.25 mm (0.01 ").
- A handy machine for straight cuts.



## CNC DEVICE FOR LONGITUDINAL GRINDING

Scope:

- Fully automatic device.
- Max. specimen dimensions:  $D = 20 \text{ mm}$  (0.8 "),  $L = 200 \text{ mm}$  (7.8").
- Different axial travel speeds.
- Adjustable clamping force.
- Device meets requirements of GE S-400 specification.

## BANDSAW PTS400

Scope:

- Semi-automatic band saw.
- Max cutting dimensions:  $400\text{mm} \times 400\text{mm}$  or  $D = 400\text{mm}$  (15.7 ").
- Different bands can be used depending on the cutting material.
- Adjustable cutting speed and feed.
- Max weight of the cut material 10Kn.

## MEASURING EQUIPMENT EXAMPLES

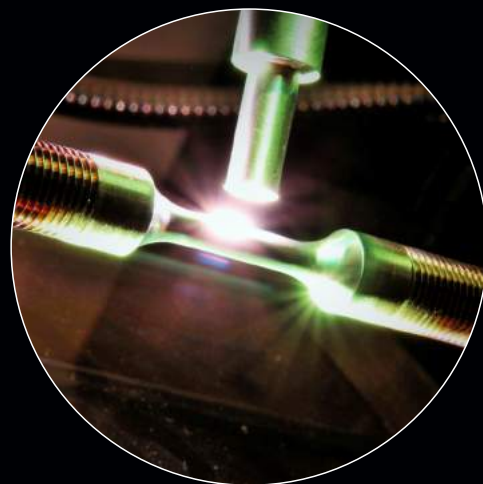
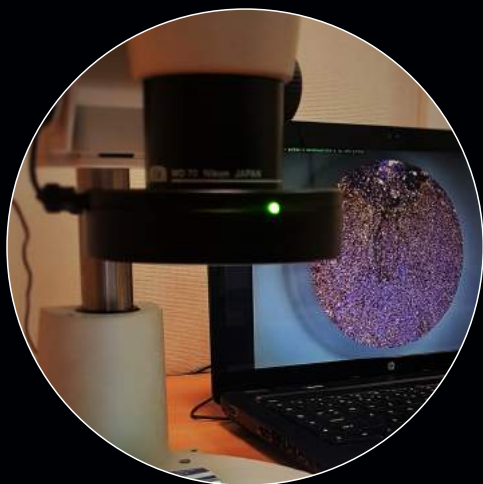
- Micrometers for measuring the outer diameter during production and final inspection.
- Innovatest IN-PJ 30A measuring projector for non-contact measurements, e.g. control of HCF specimens during longitudinal grinding and after process completion.
- 20x and 50x magnification.

## DIMENSIONS AND SHAPE CONTROL

- ST-360 V Dr. Schneider projector for non-contact measurements. Magnification range: 10-100x.

## CONTROL OF ROUGHNESS AND STRUCTURE OF THE SURFACE

- Nikon SMZ800 stereoscopic microscope. Magnification in the range of 10-63x.



# STRUCTURAL TESTING

Structural Testing Laboratory, as a part of Łukasiewicz Research Network - Institute of Aviation, has extensive facilities for performing static and fatigue tests of components, sub-assemblies, and full-scale test articles. Extensive instrumentation is provided for load and deflection measurements, strain gauging, crack growth monitoring and data acquisition.

## *Certificates:*

- *Certificate of accreditation according to PN-EN ISO / IEC 17025: 2018 – number AB 792.*
- *Pratt & Whitney Mechanical Test Certification.*

## STATIC AND FATIGUE TESTS

- Static and fatigue tests of complete structures or their components.
- Functional tests of unloaded and loaded structures with measurement of forces and deformations.
- Structure stiffness tests.
- Static and quasi-static tests of shafts of aircraft engines or other axisymmetric objects (simultaneous stretching and torsion), also at elevated temperature,
- Composite structure research.

## Scope of testing:

The Structural Testing Laboratory is technically prepared to carry out complex tests of large mechanical structures for the aviation, machinery, automotive and other industries.

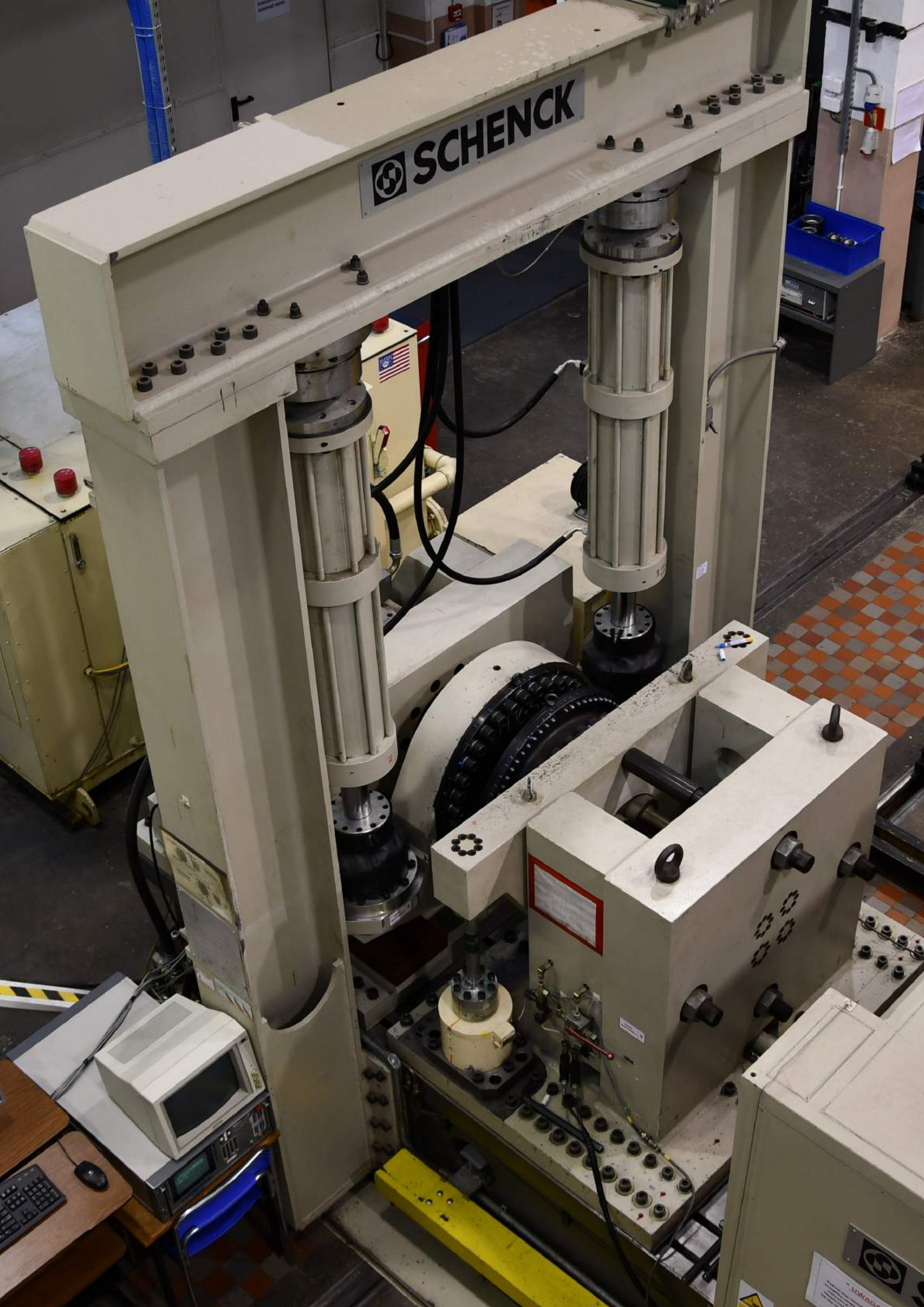
The laboratory offers testing services according to the Test Plan provided by the customer and comprehensive testing services including:

- Development of a Test Plan:
  - Test Stand design and manufacturing.
  - Test setup.
  - Test instrumentation.
  - Test execution.
  - Test data reduction and analysis.
  - Post Test documentation.





 **SCHENCK**



- Development of documentation and execution of a test stand.
- Assembly and installation of the test stand and object.
- Calibration of measurement points.
- Performing research.
- Development and presentation of research results.
- Analysis of research results.

Basic testing equipment:

- Testing room with strong floor (40m x 10m).
- Separate, noise reduced, hydraulic power supply system with flow capability of about 600 l per minute at working pressure of 210 bar.
- Four load frames for static or durability tests of components (up to 450 kN range).
- High-load electro-hydraulic test stand for simultaneous tension and torsion testing of jet engines' shafts (or other axisymmetric objects).
- Test controllers:
  - 8 channels MTS FlexTest 60 Controller.
  - 2 channels MTS FlexTest 40 Controller.
  - Single channel MTS FlexTest & MTS 407 controllers.
- Servohydraulic actuators.
- Linear double and single sided, double acting servohydraulic actuators with built-in displacement transducers with the load ranges from 10 kN to 200 kN and strokes from 200 to 500 mm.
- Load cells with signal conditioners with nominal ranges from 2 kN to 450 kN.
- Displacement transducers with signal conditioners with ranges from 0.1 to 1000 mm (some of them are built into hydraulic actuators).
- Data acquisition systems - measurement and recording of:
  - Force.
  - Displacement.
  - Strain (using resistance strain gauges).
  - Temperature (thermocouples).
  - Number of measurement channels – 250.
- Resistance furnaces and climatic chambers with controls for tests at elevated or low temperatures.

### **MEASUREMENT TECHNIQUES:**

The basic measurement techniques used in the Laboratory are:

- Force measurement techniques.
- Strain gauge technique.
- Displacement measurement techniques.

All measurements performed during the research process are referenced to the national standard system and their uncertainty is determined.

### **IN THE FIELD OF RESISTANCE STRAIN GAUGE, THE LABORATORY CARRIES OUT:**

- Preparation of strain gauge measuring points in various required configurations.
- Measurements.
- Processing of the obtained results.

# VIBRATION AND ACOUSTIC TESTING

Vibration Testing Laboratory as part of the Łukasiewicz Research Network - Institute of Aviation, performs Ground Vibration Tests of aircraft and resonance tests other objects, also outside the aviation industry, the purpose of which is to determine the dynamic properties of the tested structure or its components.

In addition, for aircraft, based on the results of Ground Vibration Tests, numerical analyzes of aeroelasticity are carried out to determine the speed and modes of flutter, which is required by aviation regulations.

The laboratory also performs vibration tests, acoustic tests and measurements of other quantities and parameters characterizing the work and enabling the diagnosis of the condition of the machine, device, vehicle or aircraft under their operating conditions.

The laboratory carries out work commissioned by external Customers as well as its own research and projects carried out in Łukasiewicz Research Network - Institute of Aviation.

All elements of the laboratory equipment are mobile , therefore it is possible to perform tests in a location agreed with the Customer.

## INVESTIGATIONS INTO AEROELASTIC CHARACTERISTICS OF AIRCRAFT

Łukasiewicz Research Network - Institute of Aviation has over 40 years of experience in the field of aircraft Ground Vibration Testing (GVT), having tested several dozen types of airplanes, gliders and helicopters, as well as their components manufactured by the domestic and foreign aviation industry. The laboratory also conducts dynamic and aeroelastic analyzes, including flutter analyzes in accordance with the requirements of aviation regulations. The data for these analyzes are the results of GVT or the results of calculations obtained using the finite element method (FEM). The results of tests and analyzes carried out in Łukasiewicz Research Network - Institute of Aviation are recognized by both Polish and foreign aviation supervision authorities.

Scope of research:

- Ground Vibration Tests (GVT).
- Determination of the speed and shape of flutter on the basis of the GVT.
- Calculations of free vibrations and flutter using the finite element method (FEM).
- Preparation of the flutter test program in flight.
- Support for flutter tests in flight.
- Support for the certification of new or modified aircraft.

Software:

- MSC.Nastran.
- JG2 (IPPT PAN).
- ZAERO (ZONA Technologies Inc.).
- SAF (Subsonic Aerodynamic Flutter).
- MSC.Patran, Siemens FEMAP.



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## VIBRATION TESTS

The Vibration Testing Laboratory of Łukasiewicz Research Network - Institute of Aviation performs vibration tests and resonance tests of structures, devices and their components not only from the aviation industry, but also from other fields of technology, e.g. automotive, energy, railways or space industry. Measurements are carried out using a multi-channel data acquisition system with the use of accelerometers. The tests are performed under the operating conditions of the device or after excitation of object vibrations with a sinusoidal force, a force with a random course or a force impulse.

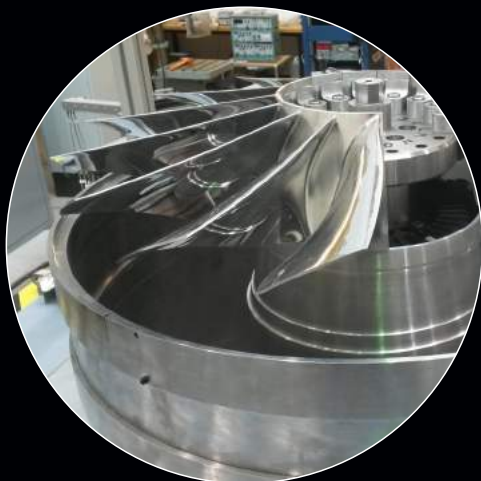
Both small objects, such as axial compressor blades, and large objects such as elevated helipads, where the dynamic properties of the structure as well as the impact of landing helicopters on the building, its equipment and people staying in it are tested.

Scope of services:

- Vibration measurements and analysis.
- Resonance tests of structures - measurement of modal parameters: frequency, generalized mass, damping, mode shapes.
- Testing of the object's response to excitation by a force impulse.
- Testing the object's response to excitation with a random signal.
- Object vibration tests on a shaker table,.
- Calculations and verification of vibration properties of the structure.

Equipment:

- Multi-channel analyzers and recorders (up to 256 channels in total, sampling up to 204kHz),
- Polytec PSV 500 3D laser vibrometer (non-contact vibration measurement),
- Accelerometers: (mass: 0.3 - 210 grams; frequency range: 0.5 Hz to 40,000 Hz; acceleration range: 0.001 g to 1000 g),
- Modal hammers (from 4.8 grams: 222N, up to 5.5 kg: 22 kN),
- Electrodynamic exciters (maximum force: 1600 N).









## ACOUSTIC TESTS

The Vibration Testing Laboratory of Łukasiewicz Research Network - Institute of Aviation also deals with measurements in the field of acoustics. In particular, the method of sound source localization using the so-called acoustic camera is used. In addition, the scope of the acoustic test offer includes a method for determining the sound power levels of noise sources using sound intensity measurements according to ISO 9614-1 and ISO 9614-2 standards, as well as determining sound levels and occupational noise exposure in the work environment by measuring the sound pressure level according to the standard PN-EN ISO 9612.

Scope of testing:

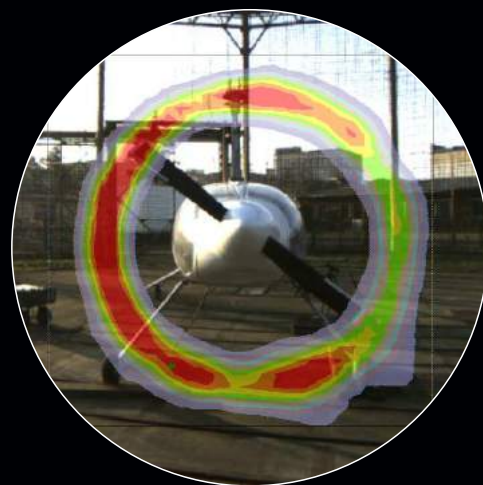
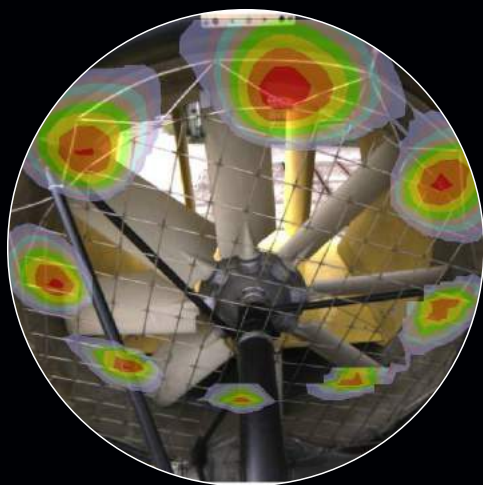
- Sound source localization.
- Determination of the sound power level.
- Sound intensity measurements.
- Measurements of the sound pressure level.

Equipment:

- MicrodB HDCamV2 acoustic camera (36 microphones).
- G.R.A.S. intensity probe 50AI-L.
- G.R.A.S. surface microphone 40LS (thickness 2.5 mm).
- 1 "free field microphones PCB 377 B02.
- SVAN 912AE portable sound and vibration analyzer.

## OPERATIONAL TESTS

The laboratory's testing offer also includes measurements of operational vibrations of machines, devices and vehicles under their operating conditions. The data acquisition system used for this purpose enables the measurement of vibration acceleration at many points (up to 256 channels), also, with the use of appropriate sensors, measurement and registration of other physical quantities needed to monitor the operation and assess the condition of the tested device. Inputs for voltage sensors ( $\pm 10V$ ), ICP / IEPE and strain gauge bridges (1/4-, 1/2-, and full bridge). The high sampling frequency of the measurement system (up to 204 kHz) enables the implementation of tests on fast-changing phenomena such as, for example, collisions with the structure of objects fired from a pneumatic cannon, or transient states such as starting or braking the device.



# LANDING GEARS TESTING

Łukasiewicz Research Network - Institute of Aviation is a leading center of excellence for design and testing of landing gear in Poland. Landing gears of most airplanes and helicopters produced by Polish manufacturers have been designed and tested by the Landing Gear Department and Landing Gear Laboratory respectfully, which offer a set of comprehensive engineering services, such as: design, analysis, research and supervision of prototypes.

Landing Gear Laboratory performs tests of the landing gears, brakes, friction materials, shock absorbers, dampers, and other mechanical devices tests for energy dissipation; static and dynamic strength; fatigue; dynamic and functional characteristics; impact load resistance. Tests can be made for number of industries: aviation, automotive, general industrial (CS, FAR, EASA, MIL, AP, PN EN ISO9001, PN EN ISO17025, AQAP 2110 regulations/standards compliant). Landing Gear Laboratory is accredited by the Polish Center for Accreditation (Certificate No. AB 131).

Measurement range (according to the accreditation):

- Force, range: 0.1 up to 400 kN.
- Displacement, range: 0.05 up to 2400 mm.
- Relative strain, range: 10 up to 15000  $\mu\text{m}/\text{m}$ .
- Rotational speed, range: 10 up to 20000 rpm.
- Acceleration, range: 0 up to 200  $\text{m}/\text{s}^2$ .
- Pressure, range: 0 up to 60 MPa.
- Temperature, range: -40 up to 1084°C.
- 

Methods:

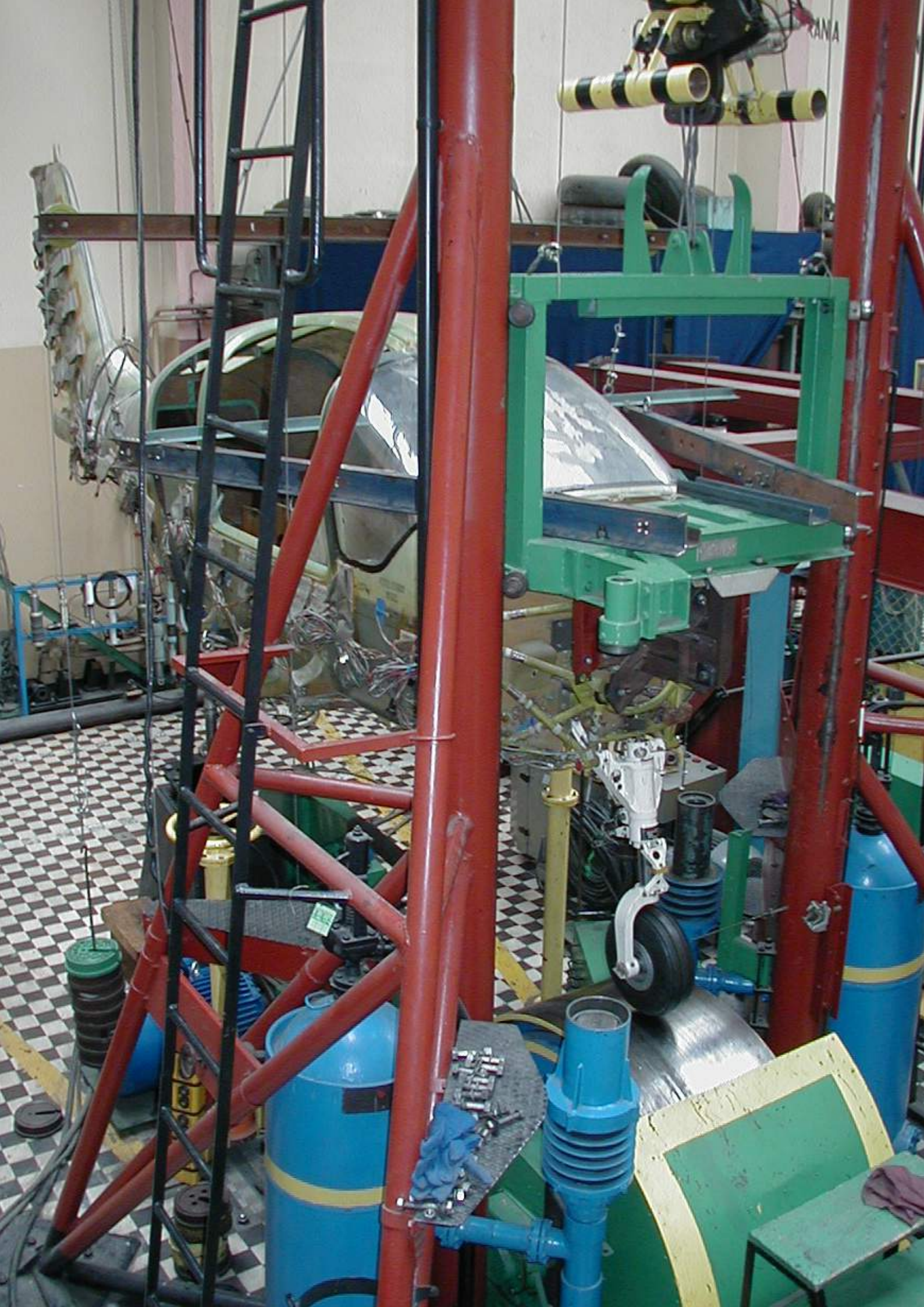
- Electrical based measurements.
- Thermography using FLIR SC645.
- (beyond accreditation).
- Fast camera measurements using Phantom VEO 410L (beyond accreditation).

Scope of testing:

- Aircraft landing gears.
- Brakes.
- Friction materials.
- Shock absorbers.
- Dampers.
- Energy absorption.
- Static and dynamic strength.
- Fatigue.
- Dynamic and functional characteristics.
- Resistance to shock loads.

Industries:

- Aviation, automotive, general industry.



### 3T DROP TESTS STAND WITH DRUM

Test stand is used for landing gear amortization testing in life-like conditions. Testing capabilities of the test stand include taxiing, shimmy, obstacle passing, brake, and wheel tests on the changeable inertia rotating drum. Test stand can be used in aviation, automotive and industrial tests.

Specification of the stand:

- Maximum mass of test object including mounting parts 3T (it can be extended to 6.5T for wheel testing).
- Maximum vertical force 118 kN.
- Drum maximal rotational speed 800 rpm.
- Drum maximal peripheral speed 58.6 m/s.
- Diameter / Width: 1400 mm/530 mm.
- Drum moment of inertia (adjustable):
  - I1 = 294 kgm<sup>2</sup>.
  - I2 = 550 kgm<sup>2</sup>.
  - I3 = 588 kgm<sup>2</sup>.
  - I4 = 843 kgm<sup>2</sup>.

Scope:

- Drop tests.
- Shimmy tests.
- Obstacle run tests.
- Brake tests.
- Wheel roll-on tests.

### 10T DROP TESTS STAND

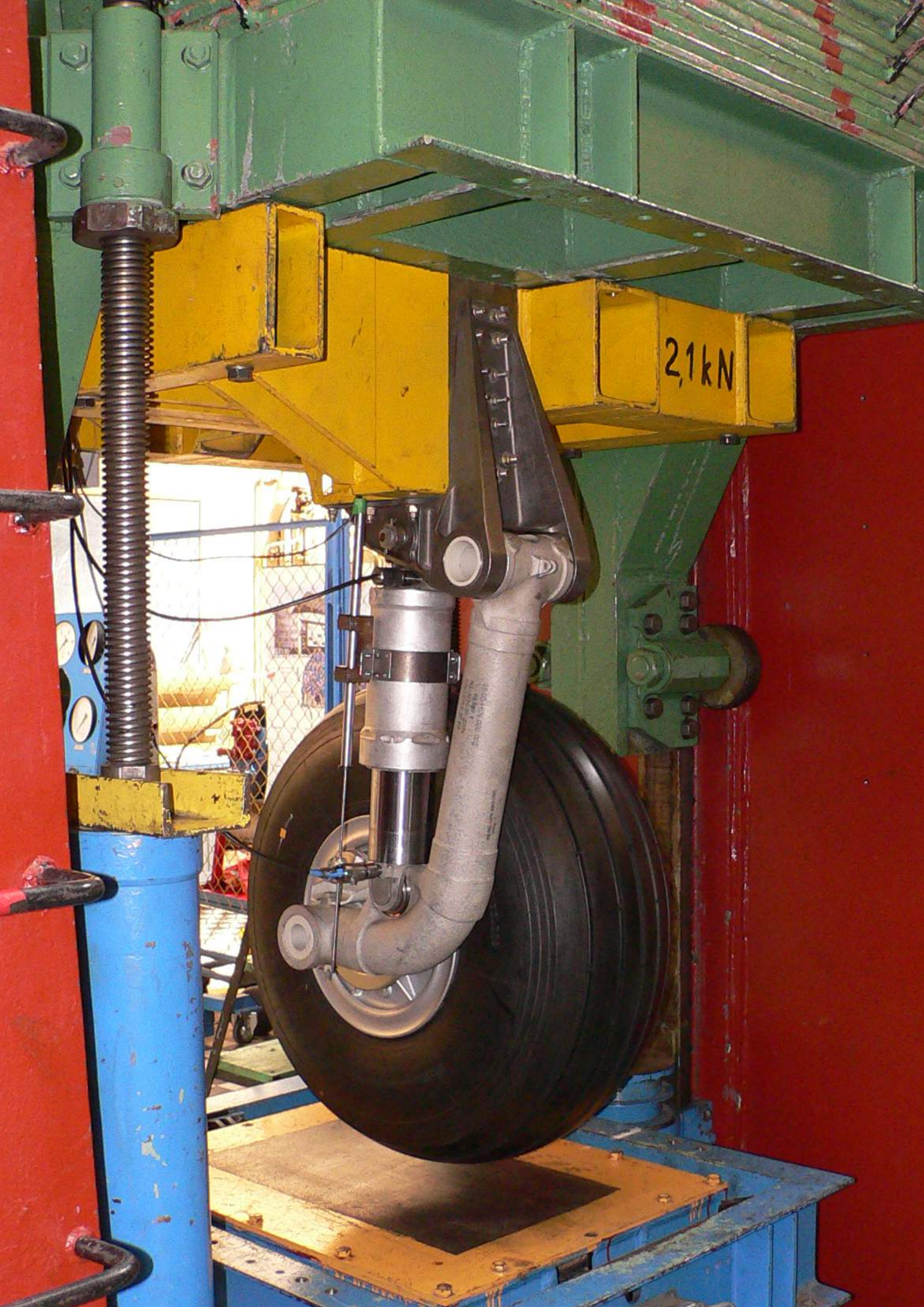
Test stand is used for landing gear amortization testing in life-like conditions. Testing capabilities of the test stand include impact test on dampers, shock absorbers, springs, etc. As well as tests determining the ability to absorb energy i.e. crash tests.

Specification of the stand:

- Maximum mass of test object including mounting parts 10T.
- Maximum forces in drop tests:
  - Vertical force 392 kN.
  - Horizontal force 196 kN.
  - Side force 157 kN.
- Maximum buffer pressure (lift) 3 MPa.
- Maximum wheel spin up velocity 111 m/s.
- Maximum free fall velocity up to 8 m/s – varies on test object height.

Scope:

- Drop tests.
- Wheel static tests.
- Functional tests.



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## UNIVERSAL STATIC TESTS STAND

Test stand is used for carrying out the static, strength, and functional tests of parts and the whole mechanical assemblies. Test stand can also be used as universal mounting platform due to the modularity of equipment used.

Specification of the stand:

- Platform dimensions 6.6 x 2.4m.
- Maximum compressive forces 20T – 5 lines.
- Maximum tensile forces 20T – 5 lines.

Scope:

- Static tests.
- Functional tests.
- Modular mounting/resarch platform for various tests.

## 40/20T PRESS

The press is used for quasistatic and low velocity tests of landing gears, wheels, materials, and other mechanical devices. System allow to make force-displacement characteristics in biaxial load states. Tests stand can be used in determining characteristics of various test objects such as: shock absorbers, dampers, material samples and more. Way of the mounting objects gives possibilities non-aviation object tests.

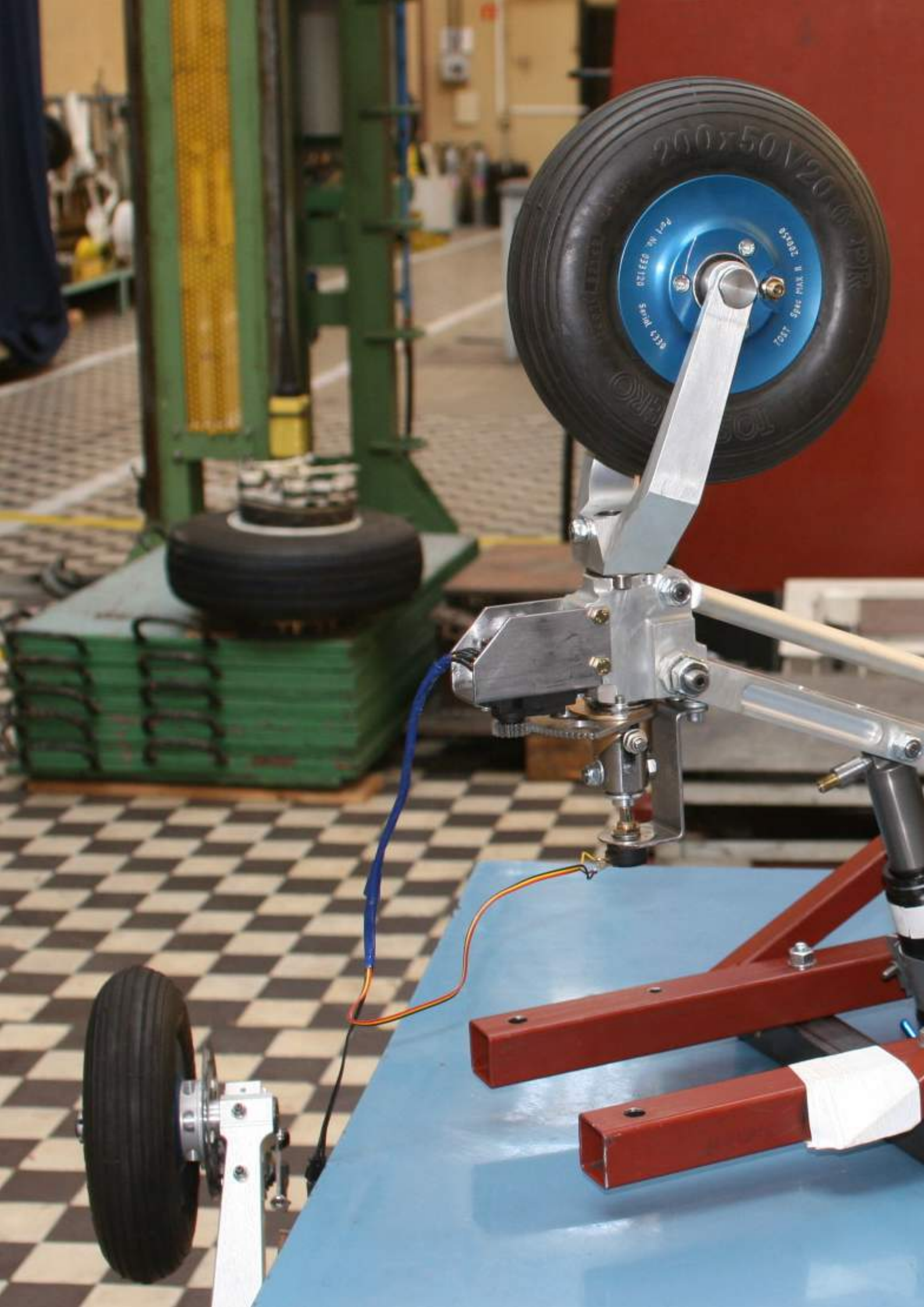
Specification of the stand:

- Vertical force up to 392 kN.
- Horizontal force up to 196 kN.
- Total vertical displacement 400 mm.
- Vertical velocity up to 300 mm/min.
- Horizontal velocity up to 600 mm/min.
- Horizontal work area 800 x 760 mm.
- Vertical work area 190 up to 2000 mm.
- Two modes of operation: force or displacement control (continuous or step).
- Full force and displacement acquisition (and up to 8 external analogue signals).

Scope:

- Static tests.
- Force-displacement characteristics.
- Characteristics of shock absorbers, dampers, material characteristics.
- Wheel static tests.









## IL-68 FRICTION MATERIALS STAND

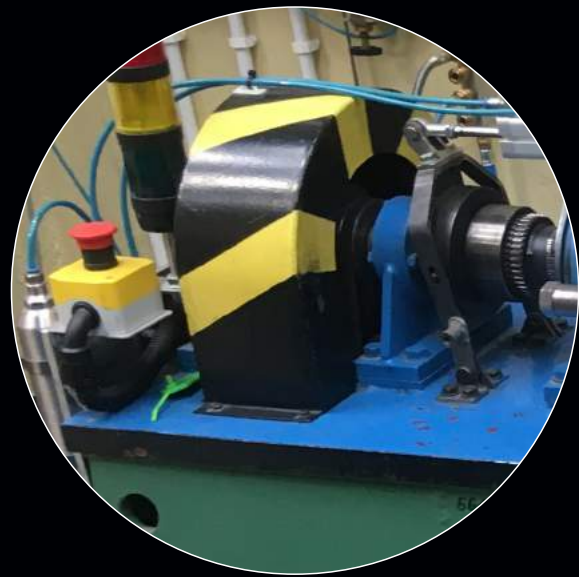
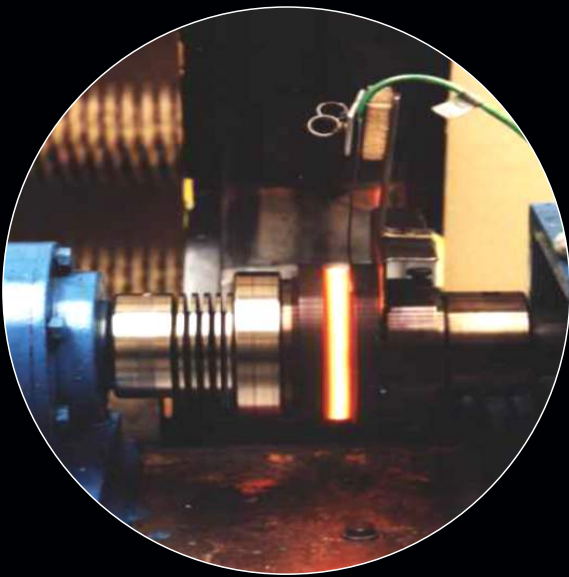
IL-68 tests stand allows to recreate phenomena occurring on friction surfaces of tested materials simultaneously measuring and recording number of parameters characterizing of the friction pair interaction (torque, braking force, temperatures, etc.). Also thermal endurance tests of friction materials (e.g. brake pads) are possible.

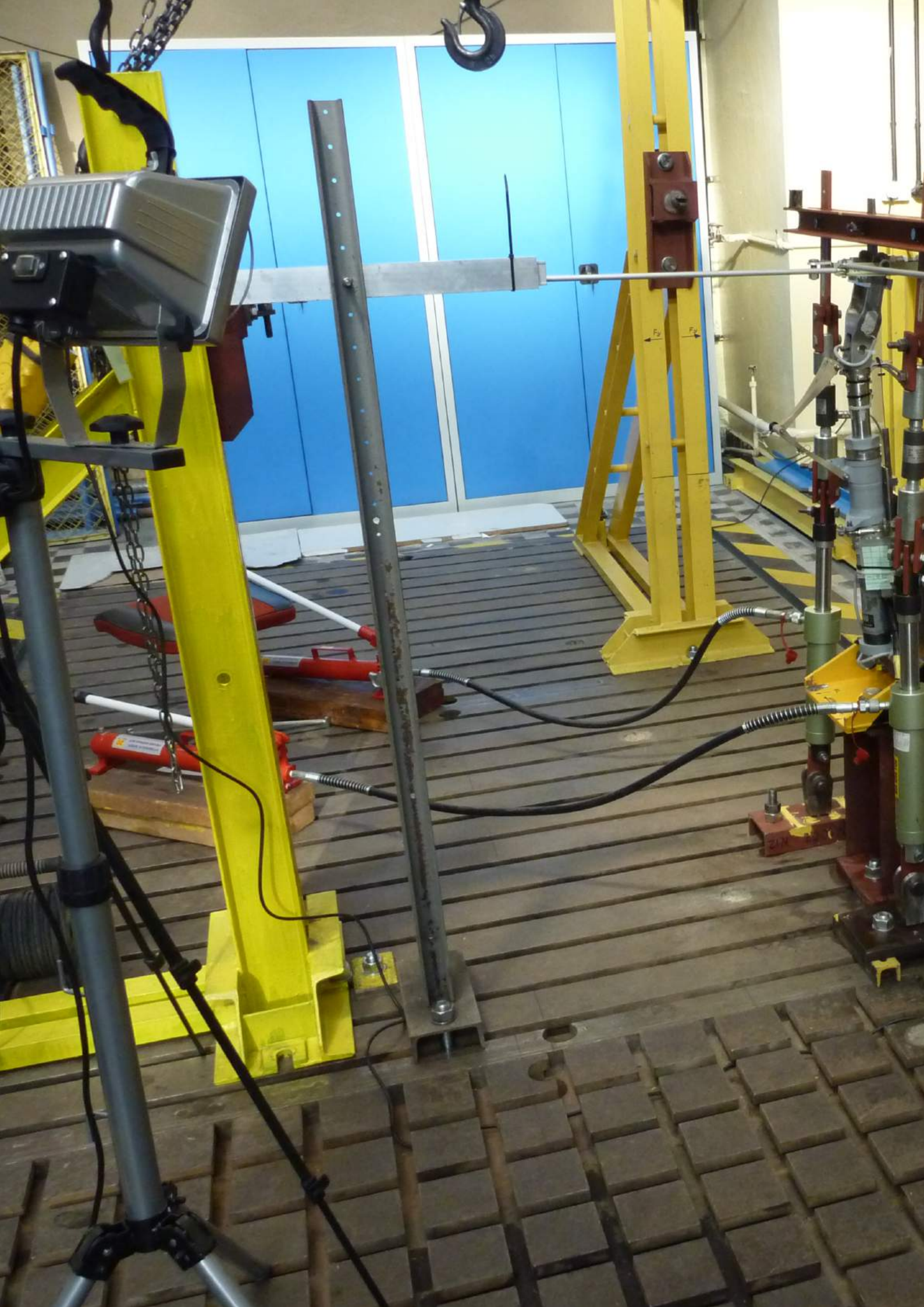
Specification of the stand:

- Maximum drive shaft rotation velocity 9000 rpm.
- Moment of inertia (adjustable) 0,154 up to 1,54 kgm<sup>2</sup> (0,098 kgm<sup>2</sup> step).
- Maximum load on the surface of the samples specimens 5,88 kN.

Scope:

- Friction materials wear.
- Friction pair behaviour (parameters):
  - Braking torque.
  - Braking force.
  - Temperature.
- Thermal endurance tests.





# IMPACT TESTS

Łukasiewicz Research Network - Institute of Aviation offers two pneumatic cannons that are used for impact tests. The pneumatic cannon is used to test the strength of structural elements in crash tests with objects moving in relation to them at high speeds. The cannons allow to shot objects, most often bird analogue gel projectiles, using the energy of compressed air stored in pressure tanks.







### 200MM PNEUMATIC CANNON FOR IMPACT TESTS

The cannon is used to test objects in Crash tests, (high-speed impact tests) – e.g. material specimens and aircraft structures or their components, e.g. floor panels, engine inlets.

Specification of the stand:

- Velocity up to 200 m/s (for 0.3 kg projectile mass).
- Test object diameter up to 200 mm.
- Projectile mass up to 5 kg.
- Remote firing.
- Compact design for working outside the laboratory.
- Data acquisition and measurement system.
- Phantom VEO 410L high-speed camera with tracking using TEMA Motion software.

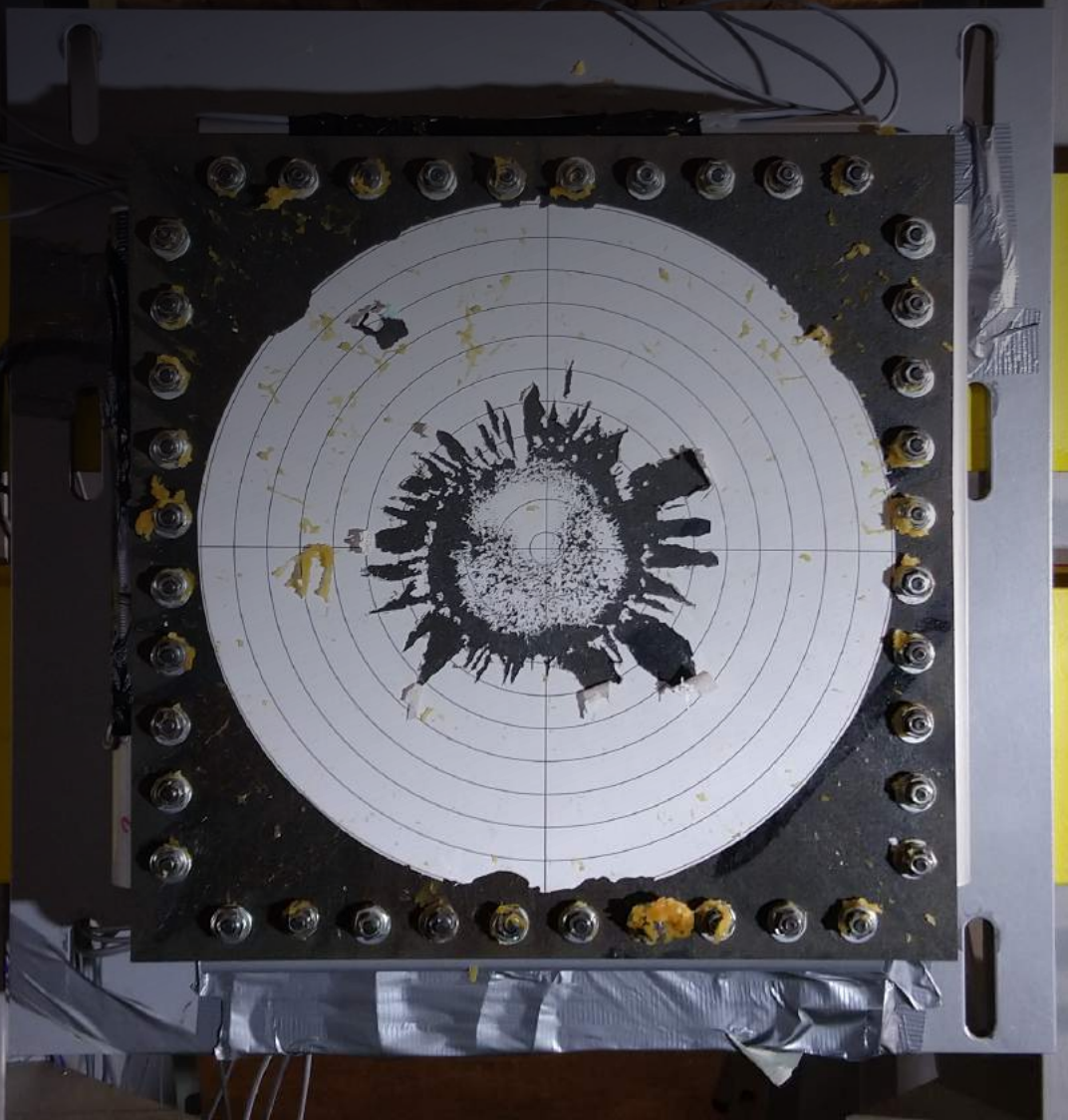
## DPZ-250 PNEUMATIC CANNON

### Device parameters:

- Maximum operating pressure 15 bar.
- The inner diameter of the barrel (caliber) 250 mm.
- Barrel length 8 m.
- Maximum throwing projectile speed 310 m/s (bullet weight 1 kg).
- Maximum projectile weight 15 kg (speed 230 m/s).

### Scope of services:

- Measurement of the velocity of thrown bullets using an optical gate or a high-speed camera (accuracy  $\pm 3\%$ ).
- Tensometric measurements at a frequency of 200kHz / 16 channels in a quarter, half or full bridge configuration.
- Strain gauge measurements (quarter, half or full bridge system) and other physical quantities, e.g. force, pressure, acceleration - up to 64 channels with sampling frequency up to 200 kHz.
- Preparation of gelatin bullets and more, weighing 1 kg, 1.81 kg, 3.63 kg according to ASTM F330 standard.
- Preparation of sabots.
- Non-destructive testing.
- FEM simulations of crash tests.
- Possibility to use additional high-speed cameras.



# COOPERATION

Łukasiewicz Research Network - Institute of Aviation has decades of experience in execution of commercial and development research in the field of testing materials and strength of the structures and its components. For many years, there has been regular cooperation with the largest producers of the aviation and machinery industry, thorough in Europe and outside the continent. Institute's strategic Customers are primarily such companies as General Electric Aviation, General Electric Energy, Pratt & Whitney (USA, Canada), Collins Aerospace, GE Avio Aero and Airbus. Among other customers there are also companies and institutions from Poland.

The main Customers of the Institute are representatives of the machinery industry, and in particular:

- Aviation industry, including engine manufacturers.
- Food processing industry (e.g. sugar factories).
- Automotive industry.
- Chemical industry.
- Railway industry
- Energy industry.

Within the framework of the international cooperation, Łukasiewicz Research Network - Institute of Aviation also executes projects and grants, such as:

<b>ESPOSA</b>	<b>TEBUK</b>
<b>EUREKA (IMPERJA)</b>	<b>TURBOREFLEX</b>
<b>TECHMATSTRATEG</b>	<b>INNOLOT</b>





### **ESPOSA - Efficient systems and propulsion for small aircraft.**

The main objective of the project was to develop new technologies for small turbine engines for local air transport but also for use of general aviation purpose or unmanned aerial vehicles. The role of the Łukasiewicz Research Network - Institute of Aviation experts under the ESPOSA project was to check the 169-250 KM power unit on the I-31T, which is a demonstrator of the new technology. One of the task was to provide resonance tests and analysis of aeroelastic demonstrators of technologies in order to determine the critical flutter speed.

### **TEBUK - Development of the technology for testing the resistance to damage of aviation and space composite load bearing structures.**

The main objective of the project was to develop a model methodology for assessing the impact of damage on the strength and durability of composite structures. Łukasiewicz Research Network - Institute of Aviation experts was involved in the project in area such as strength tests of technology demonstrator to monitor the state of strain of the object by strain gage resistance measurements during several-week tests of the aircraft structure.

### **EUREKA – IMPERJA (E3496!) – Improving the Fatigue Performance of Riveted Joints in Airframes.**

The goal of the project was to increase the fatigue life of the riveted joints in order to achieve an increase in the aircraft service life, a smaller number of inspections and, consequently, lower aircraft operating costs. This goal was achieved by the analysis and optimization of the riveting process as well as by improving the fatigue life prediction methods (crack initiation and propagation). The project outcomes enable a more precise fatigue life estimation and an increase in Time Before Overhaul (TBO) for currently used aircraft, as well as optimize the design of new aircraft from the fatigue point of view.

### **TURBOREFLEX - Turbomachinery Retrofits Enabling Flexible Back-up Capacity for the Transition of the European Energy System, TURBO-REFLEX, financed by the European Union , Grant agreement (GA) number: 764545.**

One of the parts of the project (WP 3) was the development and validation of the design system and improvement of the predictability of system components failure during the cyclic operation of thermally loaded gas turbine components (including mechanical tests for various metal alloys made with the additive method, microstructure analysis, SEM and CT).

Consortium members: 26 consortium members from 9 countries – apart from Łukasiewicz Research Network - Institute of Aviation, such as GE Additive; MAN Energy Solutions; Siemens, Mitsubishi Hitachi Power Systems Europe, technical universities from various countries.

### **TECHMATSTRATEG - Development of an innovative technology for the production of complex geometries, thin-walled aircraft engine components from nickel-based alloys.**

The aim of the project is to produce a geometrically complex thin-walled nickel alloy part for an aircraft engine and implement the developed technology into production. The components and specimens for testing were produced with additive methods.

Consortium members: Łukasiewicz Research Network - Institute of Aviation, Pratt & Whitney Kalisz, Wrocław University of Technology.

### **RASTAS SPEAR- Radiation-Shapes-Thermal Protection Investigations for high Speed Earth Re-entry.**

The main objective of the RASTAS SPEAR project, which was realized within the 7th Framework Programme, was to test and develop high speed re-entry vehicle technology for landers returning with test specimens from planets/asteroids (e.g. Mars). The Łukasiewicz Research Network - Institute of Aviation was represented by the Landing Gear Department and Landing Gear Laboratory and their task was to identify and test the materials absorbing/dissipating the landing energy of the re-entry vehicle lander capsule.



# CONTACT

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