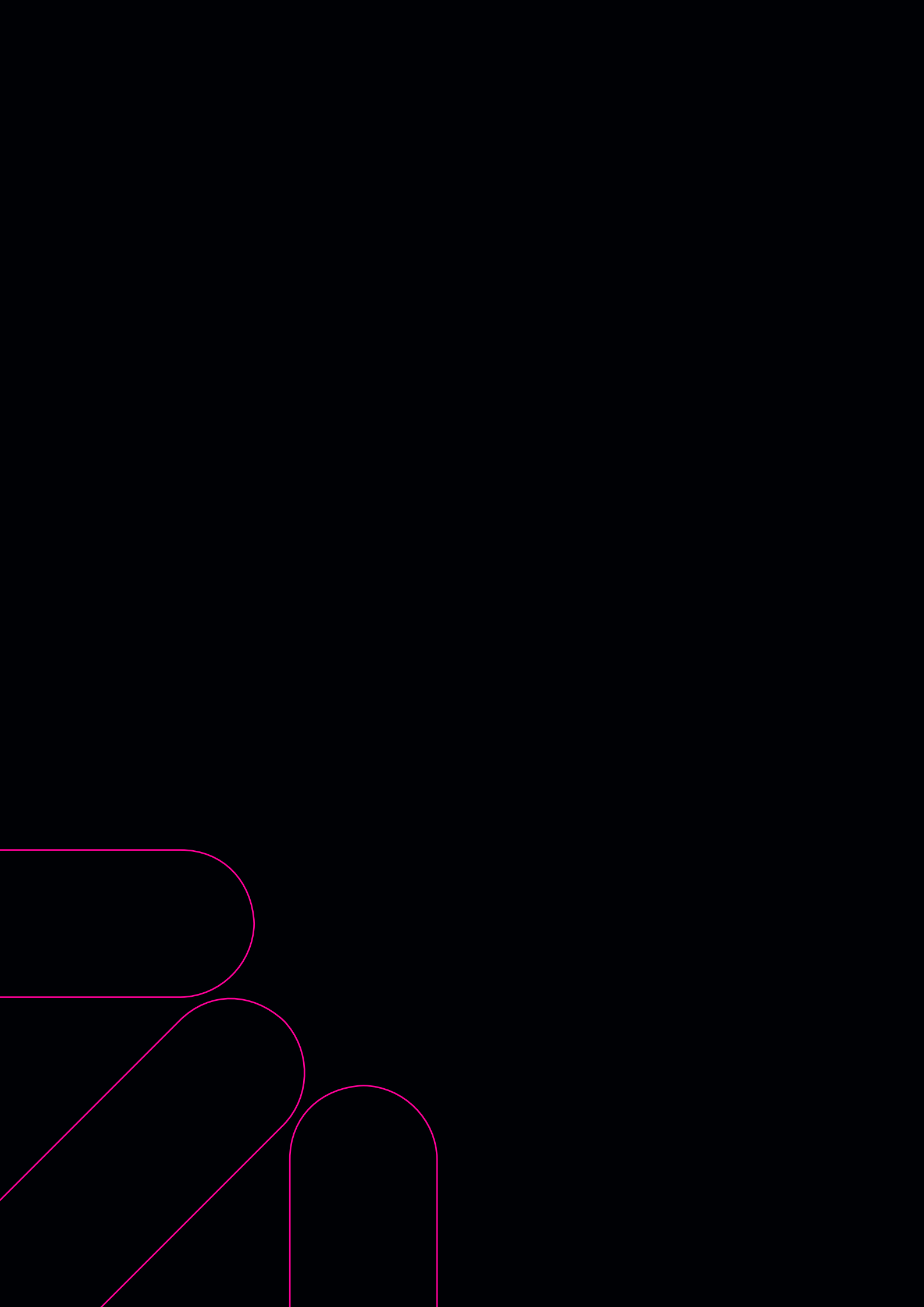
Łukasiewicz
Institute
of Aviation

COMPOSITE TECHNOLOGIES



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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 tests and structural elements testing in a wide range of loads and temperatures, and thanks to a large number of certified test stands, it is a regional leader in the field 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.

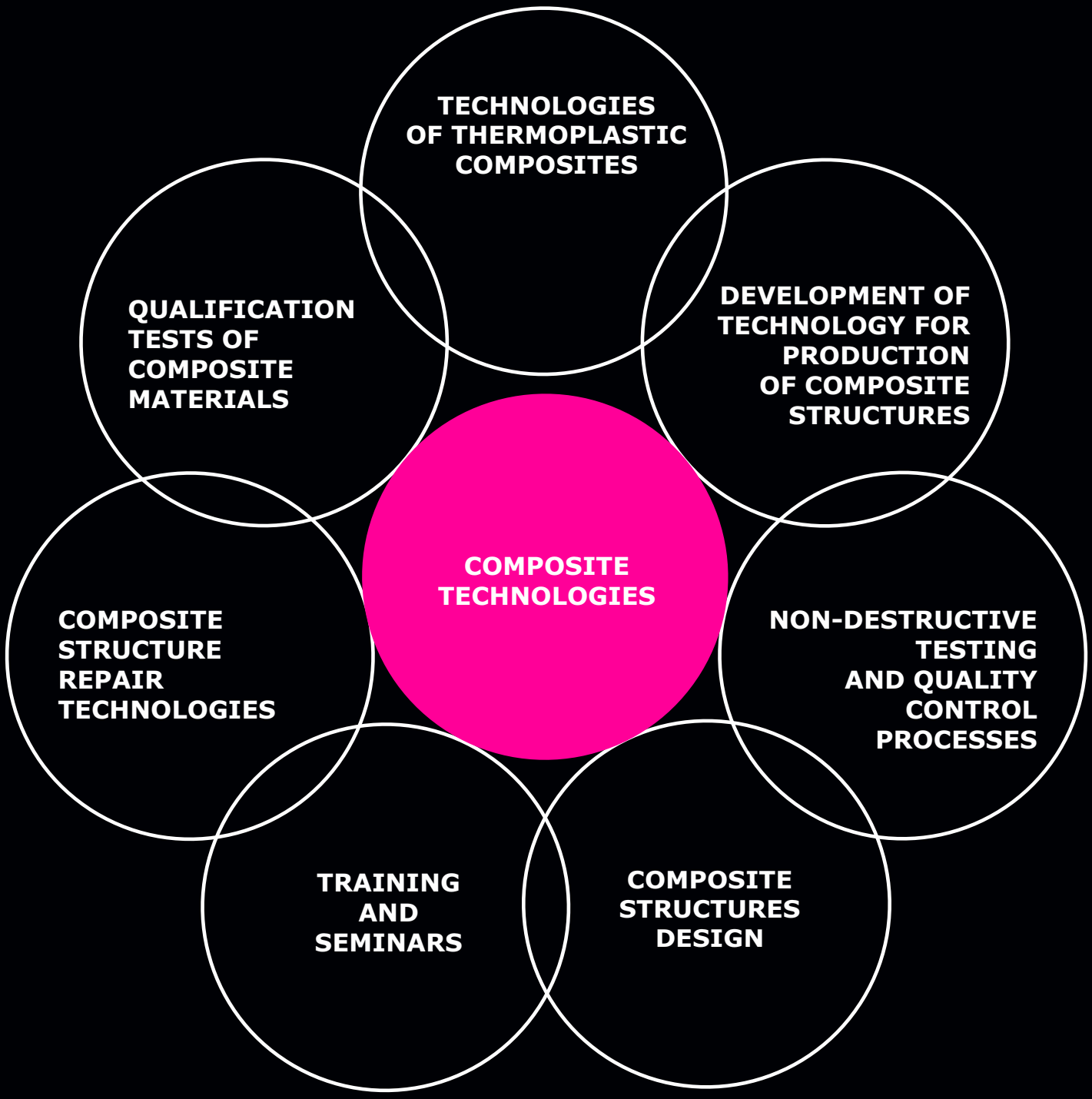
- ENGINEERING SERVICES CENTER
  provides support in the field of mechanical engineering and thermal strategic research and development projects.

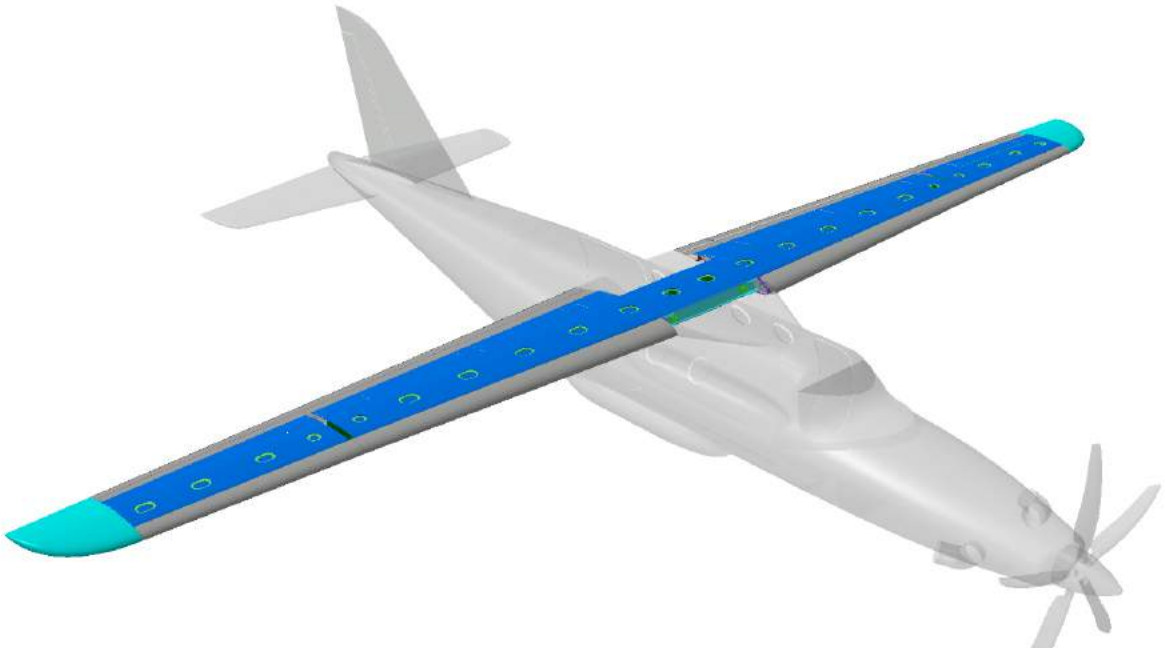
- ENERGY TECHNOLOGIES CENTER
  focuses on engineering areas: designing, manufacturing, analyzing and servicing parts for high-power gas turbines and wind turbines. One of the main tasks of this center is to implement a new energy era that will build a cleaner future.

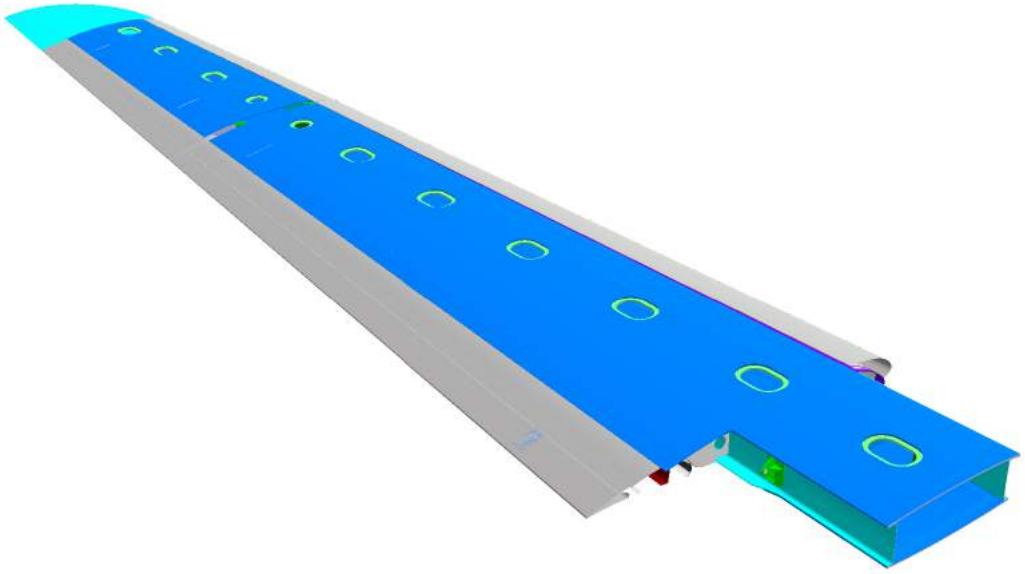
OFFER

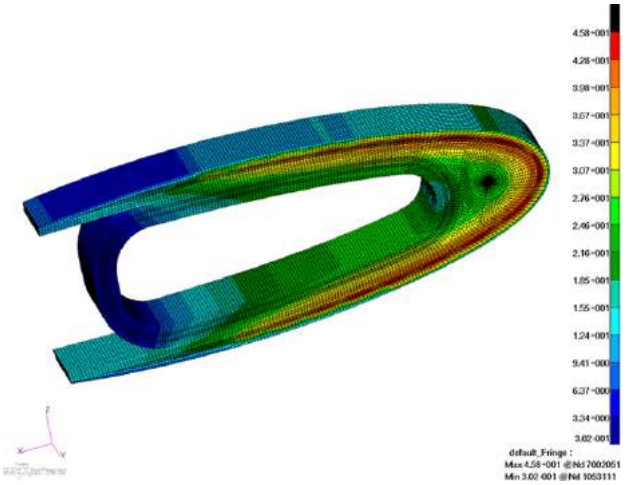
The main activities of the Łukasiewicz Research Network - Institute of Aviation in the field of composite technologies are: to provide testing services, develop new manufacturing technologies for industry and conduct research and development projects. The Institute has PCA and NADCAP accredited Composite Testing Laboratory and advanced equipment for production of composite structures.

Offer in the field of composite technologies:





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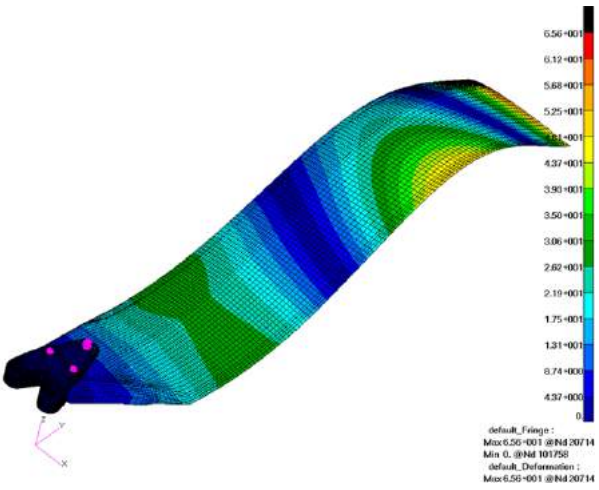
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COMPOSITE STRUCTURES DESIGN

Łukasiewicz Research Network - Institute of Aviation has extensive experience in design of aerospace composite structures. Design works are carried out in accordance with commonly recognized design methodologies using specialized software.

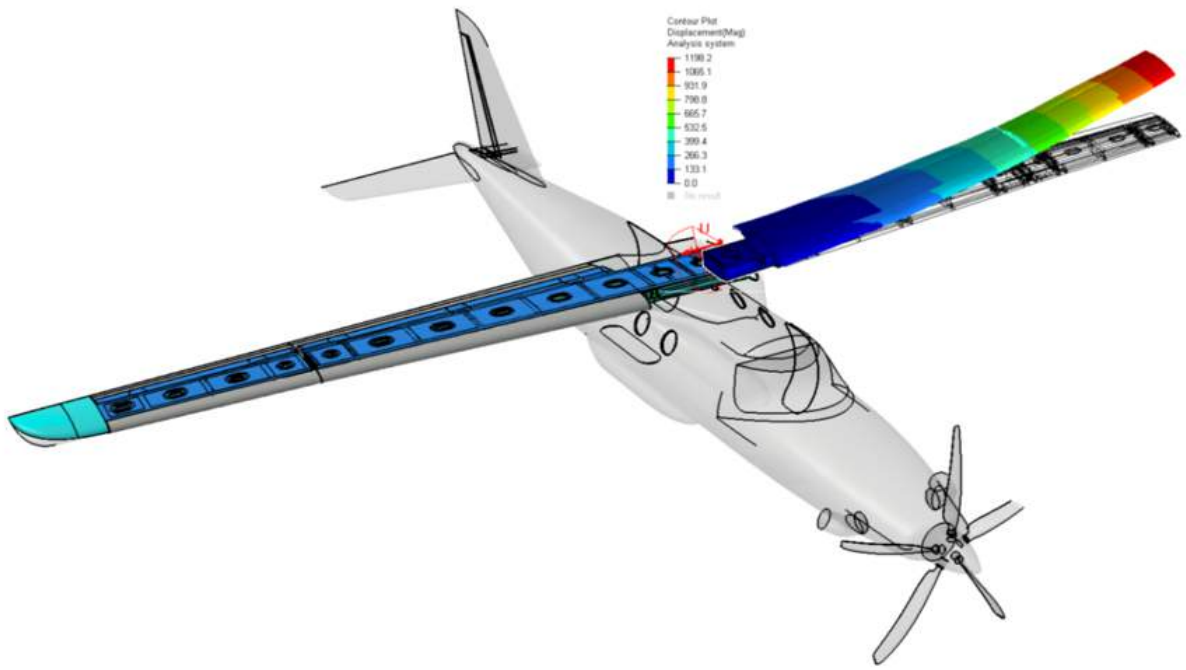
The scope of the Institute's offer includes the following services:

DESIGN OF STRUCTURES AND COMPOSITE PARTS IN THE CATIA ENVIRONMENT

- Definition of composite layer in the dedicated Catia CPD module allows for effective and flexible management of the structure at all stages of the project.
- Optimization of the layer system with regard to manual and robotic manufacturing processes.

NUMERICAL ANALYSIS USING NASTRAN, PATRAN AND HYPERWORKS

- Proven and implemented calculation methods allowing for accurate prediction of the strength of the structure, taking into account stresses and deformations in the layers.
- Linear (static strength, loss of stability) and non-linear (large displacements, progressive failure) calculations.
- Strength calculations for bolted and bonded joins.
- Buckling and vibration analysis, static and fatigue strength analysis.



DEVELOPMENT OF TECHNOLOGY FOR PRODUCTION OF COMPOSITE STRUCTURES

Łukasiewicz Research Network - Institute of Aviation has advanced technological facilities used for work on new technologies and for the production of prototype composite structures. As part of the research work for the designed construction solutions, manufacturing technologies are developed and the manufactured prototypes of structures are subjected to further tests.

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

DEVELOPMENT OF THE CURING PROCESS OF THERMOSET PREPREGS IN AUTOCLAVE AND OUT OF-AUTOCLAVE TECHNOLOGY. TECHNOLOGY OF AUTOMATED FIBER PLACEMENT.

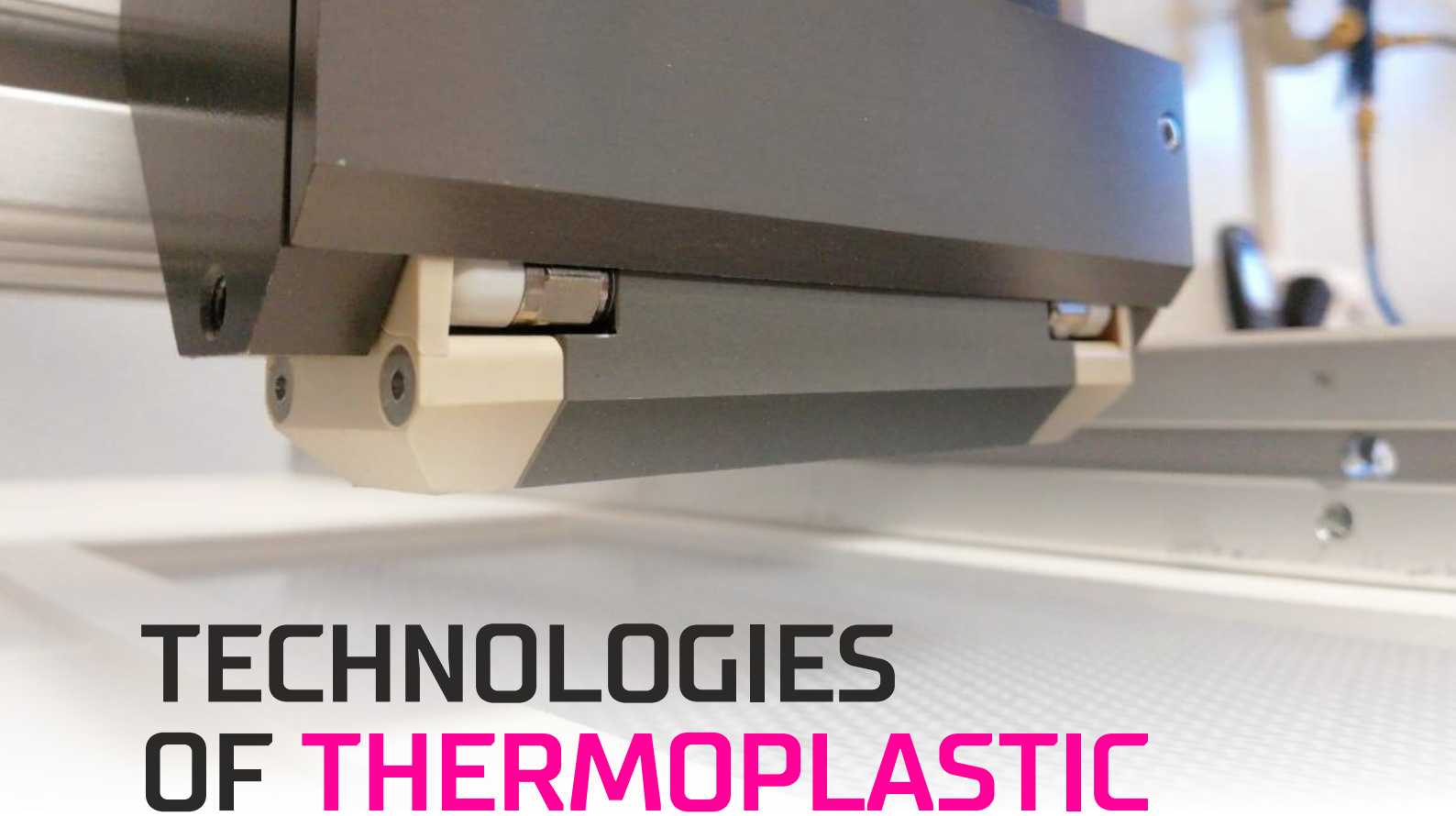
- Efficient environment of the *Automated Fiber Placement* at Łukasiewicz Research Network - Institute of Aviation, designed to develop modern industrial methods of composite parts manufacturing.
- Implemented methodology for quality validation of the work carried out.
- Developed processes for the production of thermoplastic and thermoset structures and automatic application of fibers for the infusion process.

BLADDER MOLDING AND INFUSION TECHNOLOGY

- Designing manufacturing processes in bladder molding and infusion technologies with a focus on optimization and integration of composite parts.
- Modern equipment allowing for efficient prototyping of manufacturing processes.

DESIGN AND MANUFACTURING OF MOLDS AND ASSEMBLY TOOLING FOR COMPOSITE STRUCTURES

- Many years of experience in preparing the manufacturing process of composite parts made of pre-pregs.
- Design and manufacturing of high-temperature molds for autoclave and out of autoclave processes.
- Assembly process of composite structures.



TECHNOLOGIES OF THERMOPLASTIC COMPOSITES

For over 30 years, thermoplastics have gained the technological market in the field of commercial applications in both civil and military structures, with particular emphasis on aircraft. In response to the continuous growth of interest in thermoplastic matrix composite materials, the Łukasiewicz Research Network - Institute of Aviation takes steps to develop technology in this area.

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

TECHNOLOGY OF CONSOLIDATION OF THERMOPLASTIC PREPREGS REINFORCED WITH CARBON OR GLASS FIBER

- Methodology of developing consolidation processes of thermoplastic prepregs based on non-destructive testing and laboratory tests.

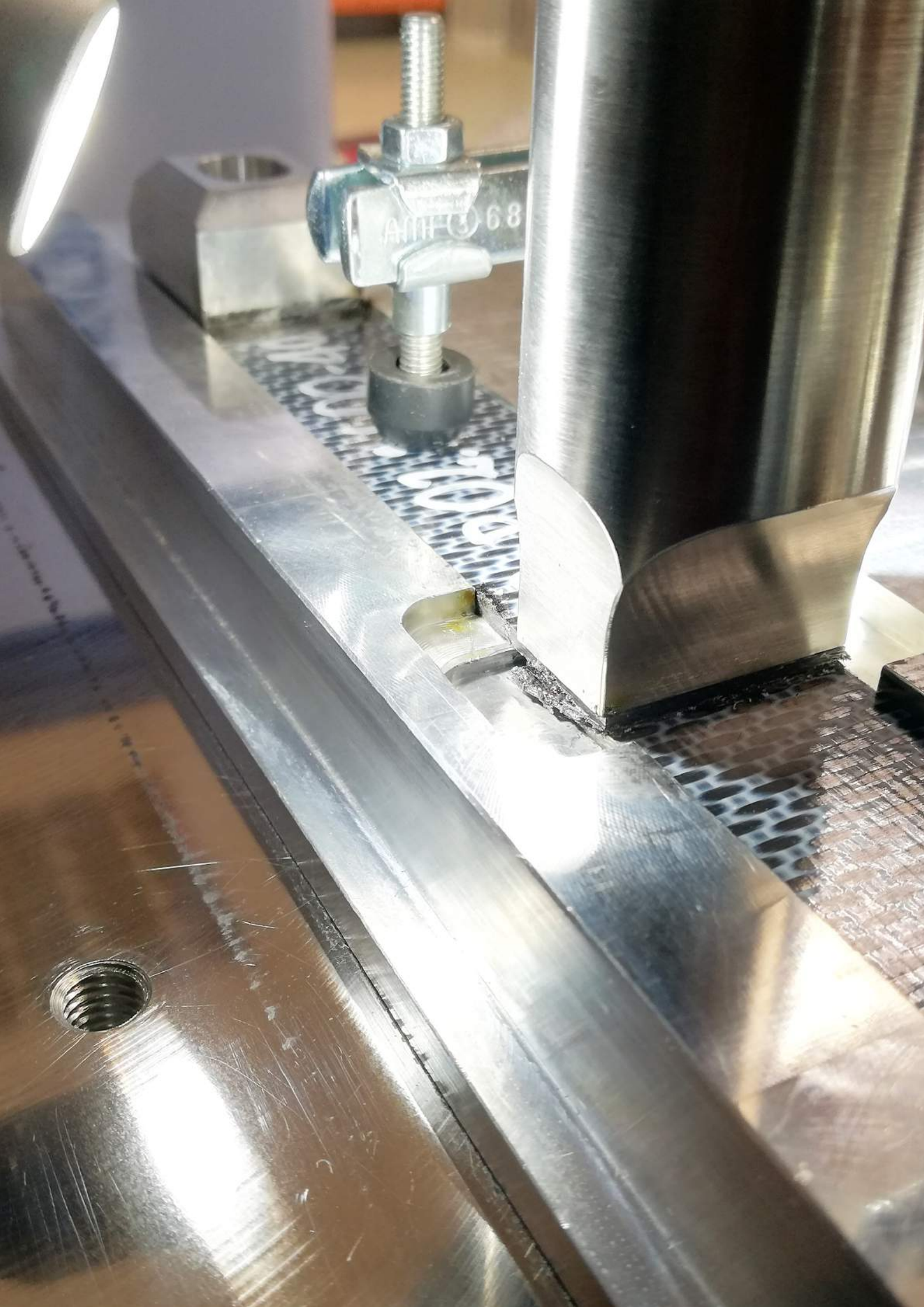
TECHNOLOGIES FOR THERMOFORMING PARTS

- Modeling of composite materials forming process using PAM COMPOSITES - PAM FORM software.
- Tooling design, modeling of flexible molding elements - silicone stamps using ABAQUS software.
- Manufacturing prototype composite parts in the thermoforming process on the press.

THERMOPLASTIC COMPOSITES JOINING

- Development of technology for thermoplastic composites resistance and ultrasonic welding process.
- Development of bonding technology, selection of adhesives and surface preparation methods.

Łukasiewicz Research Network -Institute of Aviation, has built a material database for the following materials PEEK TC 1200, PAEK TC 1225 and PPS TC 1100.

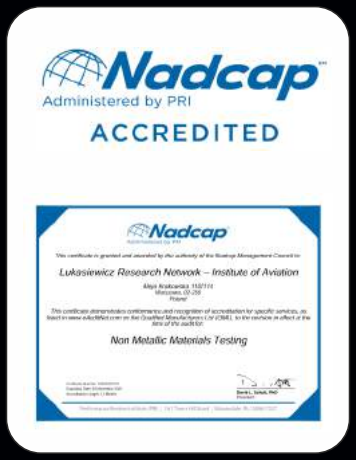


QUALIFICATION TESTS OF COMPOSITE MATERIALS

Łukasiewicz Research Network - Institute of Aviation has a high potential in the field of tests on composite materials. The Composite Testing Laboratory performs comprehensive tests of composite materials dedicated to aviation structures. Tests are carried out with the use of modern research equipment in accordance with the international standards. **The Composite Testing Laboratory has the PCA and NADCAP accreditation for non-metallic materials testing.**

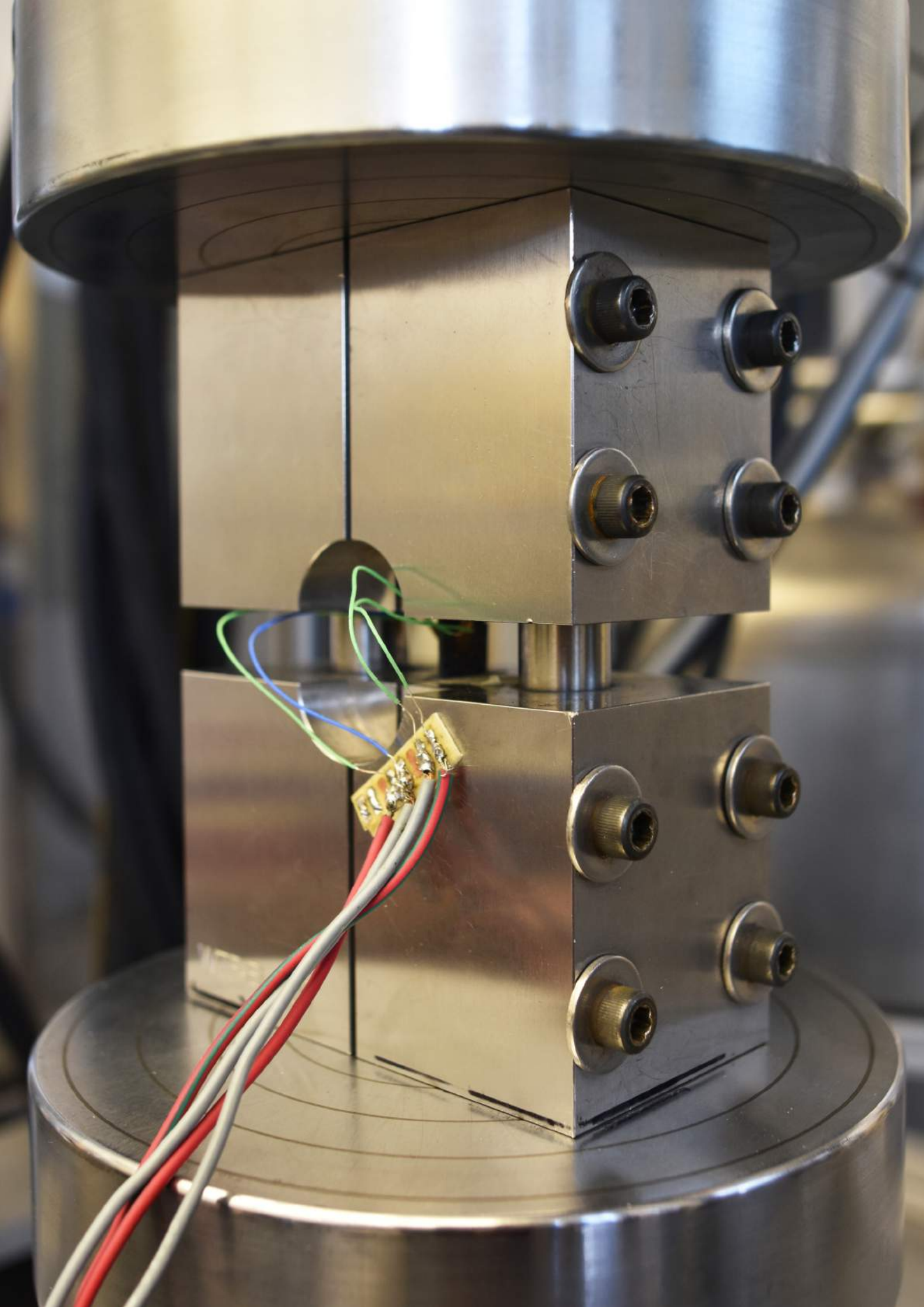
The scope of the Institute's offer includes the following services:

- Qualification tests of composite materials.
- Damage tolerance assessment.
- Static and fatigue tests, max load up to 250 kN.
- Tests in the temperature from -130 °C to 315 °C.
- Digital image correlation, use of strain gauges and extensometers.
- Research with the use of standardized fixtures and custom designed, directed to individual customers' needs.
- Impact resistance test; simulated energy range from 0.59 J to 1800 J.
- Thermal analysis: DMA, DSC, TGA, FTIR.
- Preparation of samples: cutting, grinding, drilling, tabbing conditioning.



LAMINA TESTS

Tension	ASTM 3039
Compression	ASTM D3410, ASTM D6641
Shear	ASTM D3518, ASTM D5379, ASTM D7078
Interlaminar shear	ASTM D2344
Three-point bending	ASTM D790
Mode I, Mode II and Mixed Mode Fracture Toughness	ASTM D5528, ASTM D6115; ASTM D7905; ASTM D6671



LAMINATE TESTS

Open Hole Compression	ASTM D6484
Open Hole Tensile	ASTM D5766
Compression After Impact	ASTM D7136, ASTM D7137

BOLTED JOINTS

Bearing Response	ASTM D5961
Pull-Through	ASTM D7332

ADHESIVE TESTS

Shear Test	ASTM D1002, ASTM D5656, ASTM D3528
Peel Resistance	ASTM D3167, ASTM D1781

CORE MATERIALS AND SANDWICH STRUCTURES

Compresion	ASTM C365
Core Shear	ASTM C393, ASTM C273
Flatwise Tensile	ASTM C297
Long Beam Flexure	ASTM D7249

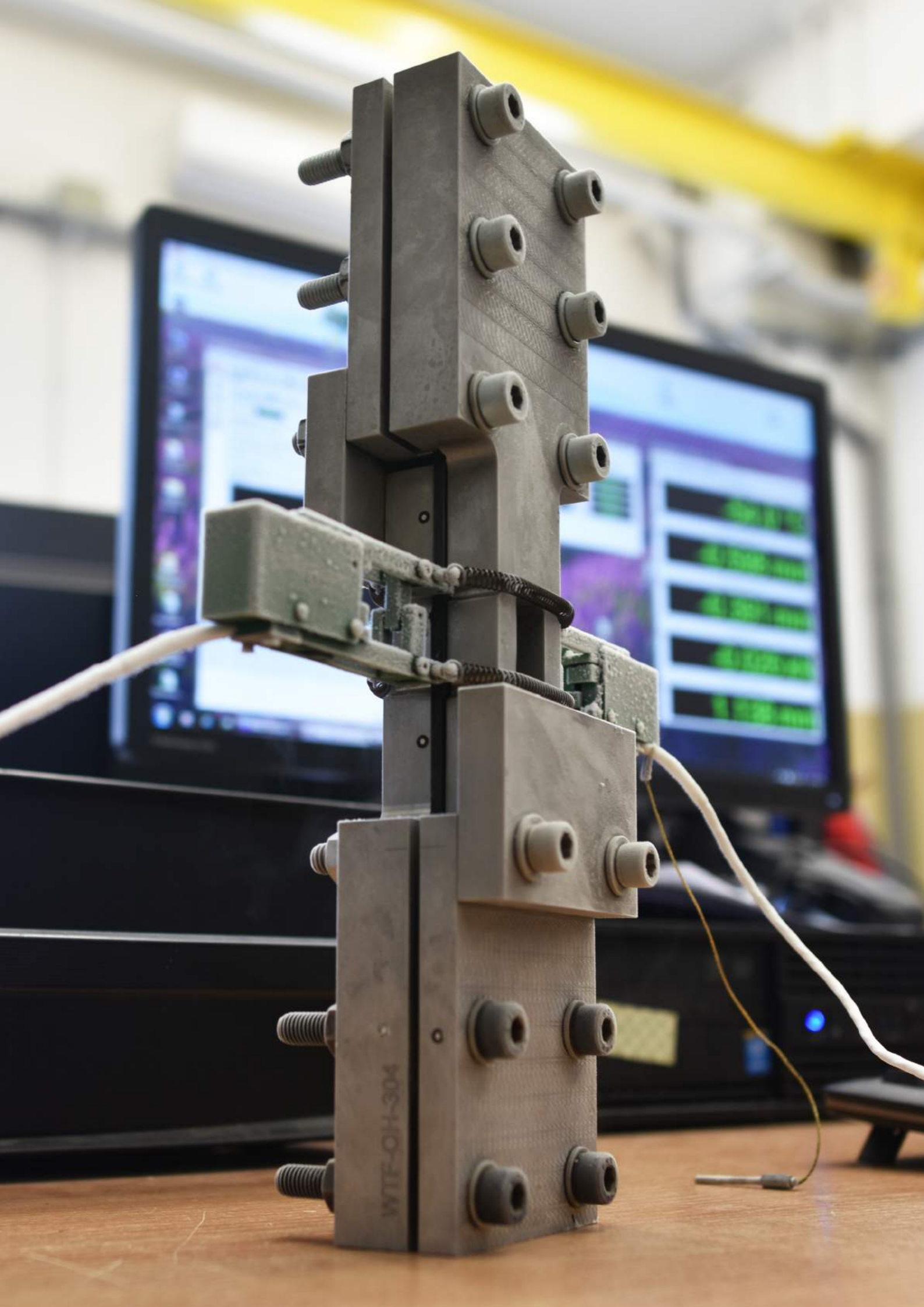
PHYSICO-CHEMICAL TESTS

Testing of uncured prepregs (gel time, resin flow, resin content)

Fiber volume	ASTM D3171
Glass transition temperature	ASTM E1640, ASTM D7028
Enthalpy of Fusion and Crystallization	ASTM D3418
Thermogravimetry	ASTM E1131

NON-DESTRUCTIVE TESTS, MICROSCOPIC ANALYSIS

Ultrasonic testing of laminates
Visual analysis
Microscopic measurement of porosity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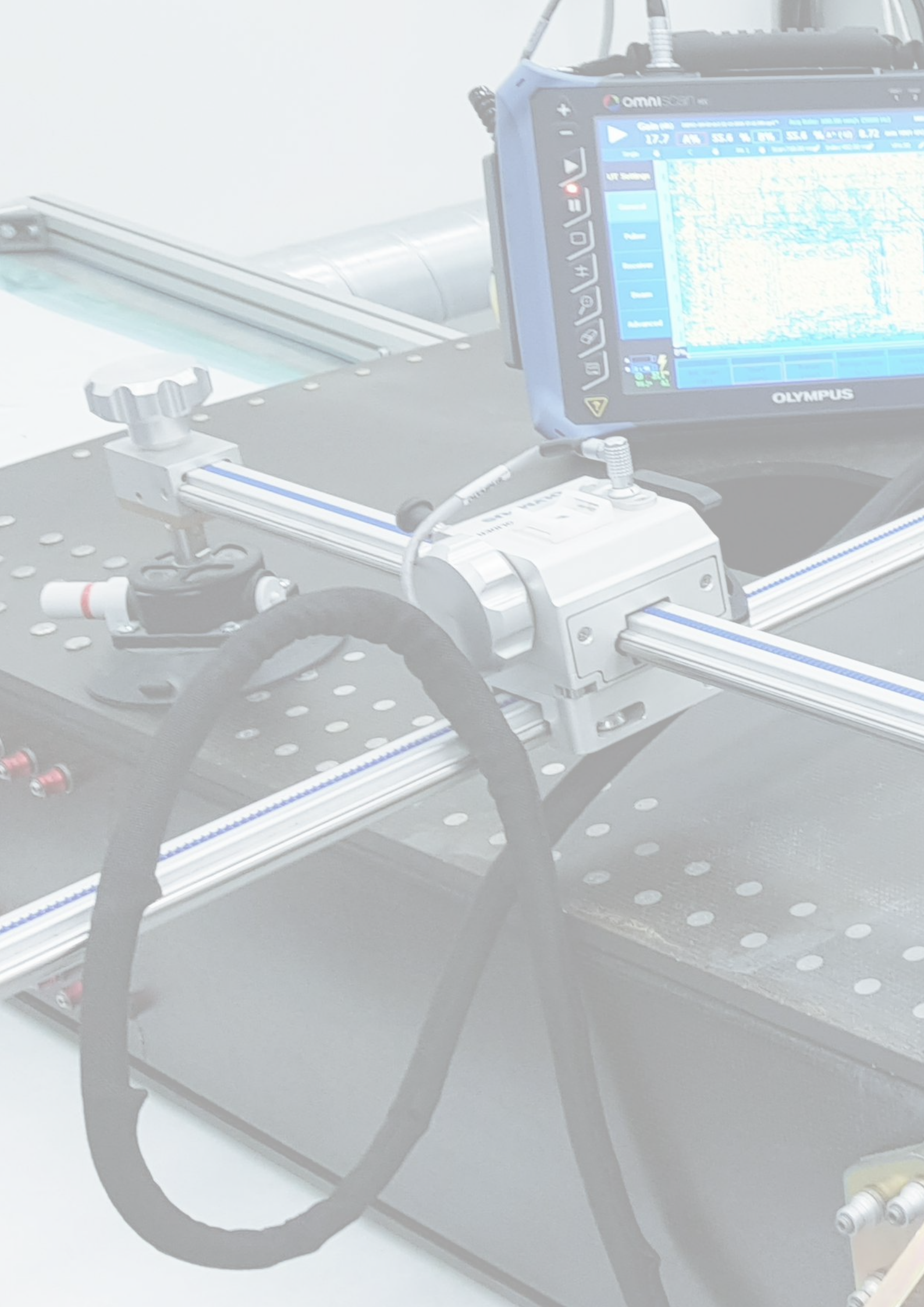

OLYMPUS

NON-DESTRUCTIVE TESTING AND QUALITY CONTROL PROCESSES

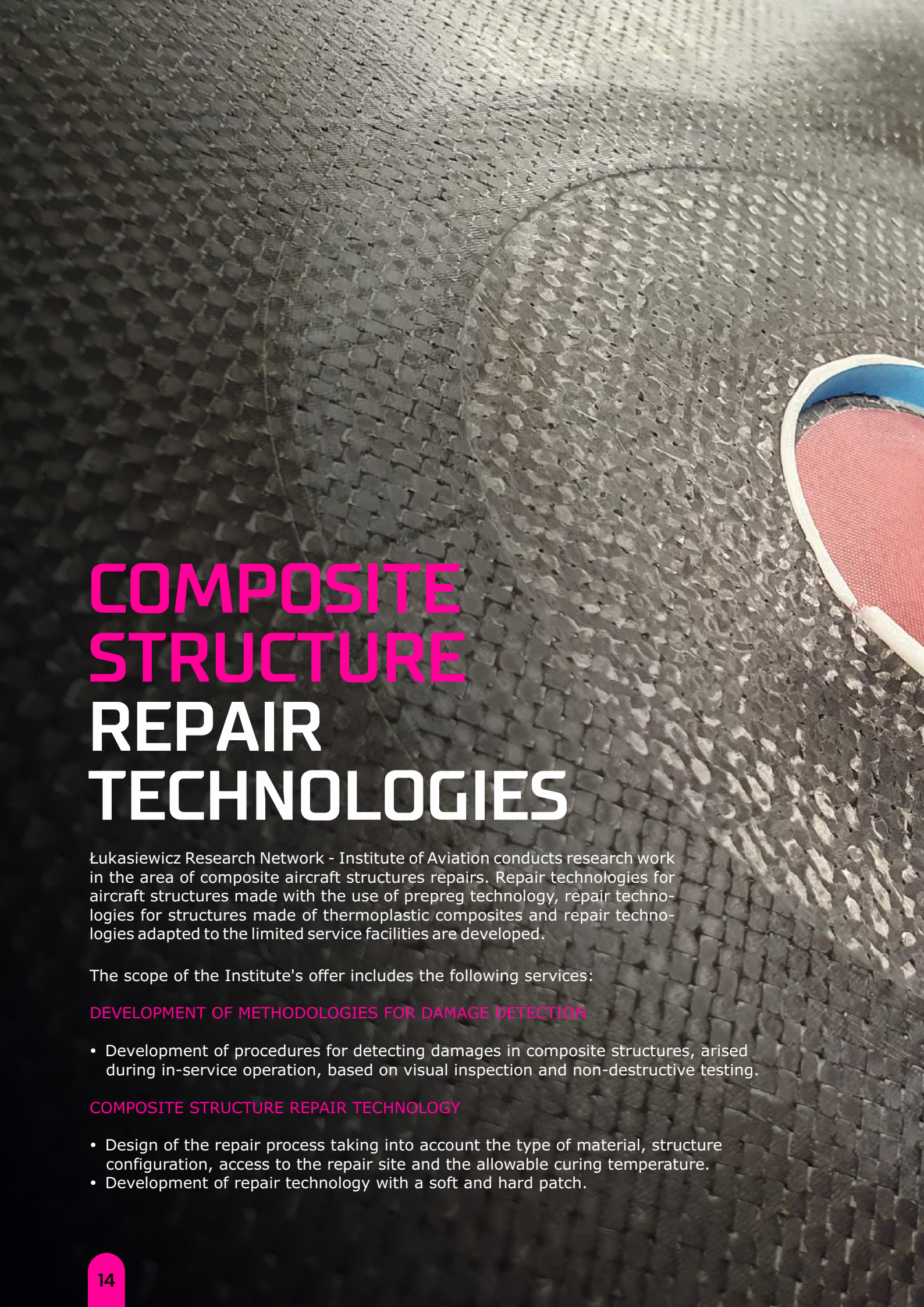
All manufacturing works are subject to quality control. The quality control process includes document and material control, process control and product control. The scope of quality control each time is adjusted to part and technology.

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

- Ultrasonic examination of composite structures using the conventional phased array (C-scan) technique.
- Low-frequency examination of composite structures by bond testing (C-scan), tap testing (woodpecker, hammer).
- Thermographic examination of composite structures (active thermography).
- Visual inspection of composite structures.
- Comprehensive development of methodologies for non-destructive testing of composite structures.
- Designing calibration plates.
- Detection of defects such as: delamination, cracks, porosity, foreign objects.

DEVELOPMENT OF COMPREHENSIVE QUALITY CONTROL PROCESSES FOR COMPOSITE STRUCTURES.

- Defining procedures for recording the production process and quality control activities for each stage of production of composite aerospace structures.
- Defining the scope of destructive tests - witness samples.
- Control of tooling and structures geometry with a 3D laser scanner.



COMPOSITE STRUCTURE REPAIR TECHNOLOGIES

Łukasiewicz Research Network - Institute of Aviation conducts research work in the area of composite aircraft structures repairs. Repair technologies for aircraft structures made with the use of prepreg technology, repair technologies for structures made of thermoplastic composites and repair technologies adapted to the limited service facilities are developed.

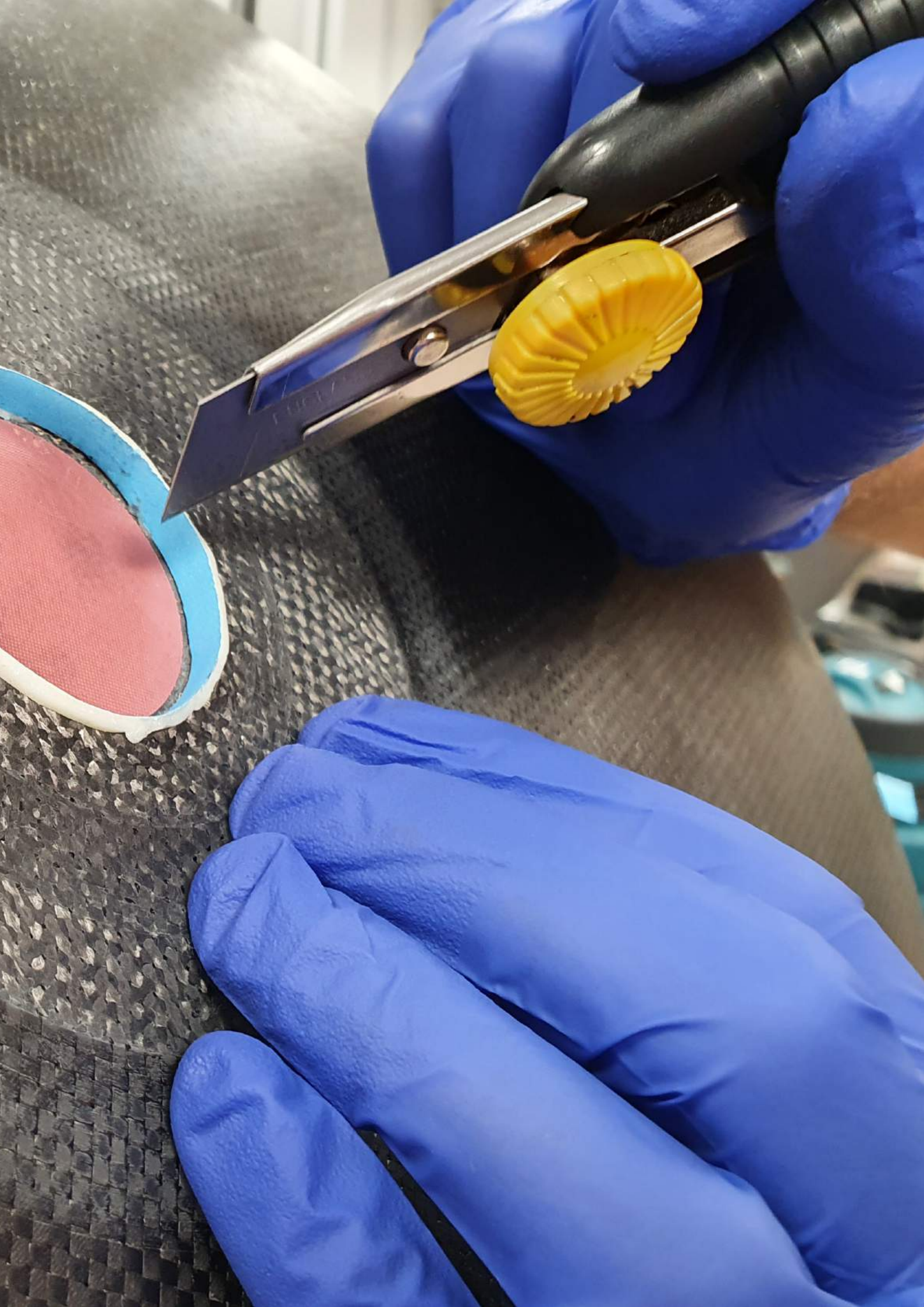
The scope of the Institute's offer includes the following services:

DEVELOPMENT OF METHODOLOGIES FOR DAMAGE DETECTION

- Development of procedures for detecting damages in composite structures, arised during in-service operation, based on visual inspection and non-destructive testing.

COMPOSITE STRUCTURE REPAIR TECHNOLOGY

- Design of the repair process taking into account the type of material, structure configuration, access to the repair site and the allowable curing temperature.
- Development of repair technology with a soft and hard patch.



TRAINING AND SEMINARS

Łukasiewicz Research Network - Institute of Aviation organizes specialized training in the field of composite technologies. Training programs are prepared in agreement with the representatives of certifying organizations. The trainees participate in the training program using modern research and technology facilities.

"COMPOSITE SAFETY" AND "CERTIFICATION MEETING"

As a part of cooperation with certification organizations, Łukasiewicz Research Network - Instituteof Aviation organizes seminars on contemporary aspects of certification and safety of composite aircraft structures.

Meetings are organized in cooperation with:

- Civil Aviation Authority (CAA).
- Federal Aviation Administration (FAA).
- European Union Agency for Aviation Safety (EASA).
- National Institute for Aviation Research (NIAR).

„COMPOSITES HANDS-ON TRAINING”

Basic training in the field of composite technologies directed to design and stress engineers and technical personnel. Training program agreed with aircraft certification organizations.

- Manufacturing of composites.
- Bonded and mechanical joints.
- Basic repairs of composite structures.
- Material testing.

„REPAIR OF COMPOSITE STRUCTURE TRAINING”

Training for engineers designing repairs and for personnel of maintenance organizations. People trained under the supervision of trainers perform a number of repairs of composite structures in various technologies, using professional tools and equipment for repairs.

- The theory of repair of composite structures.
- Advanced repair techniques for composite structures.

Contact: CCTtrainings@ilot.lukasiewicz.gov.pl

SELECTED PROJECTS

DEVELOPMENT OF THE TECHNOLOGY FOR THE MANUFACTURE OF THE WING BOX OF THE ILX-34 NORMAL CATEGORY AIRCRAFT

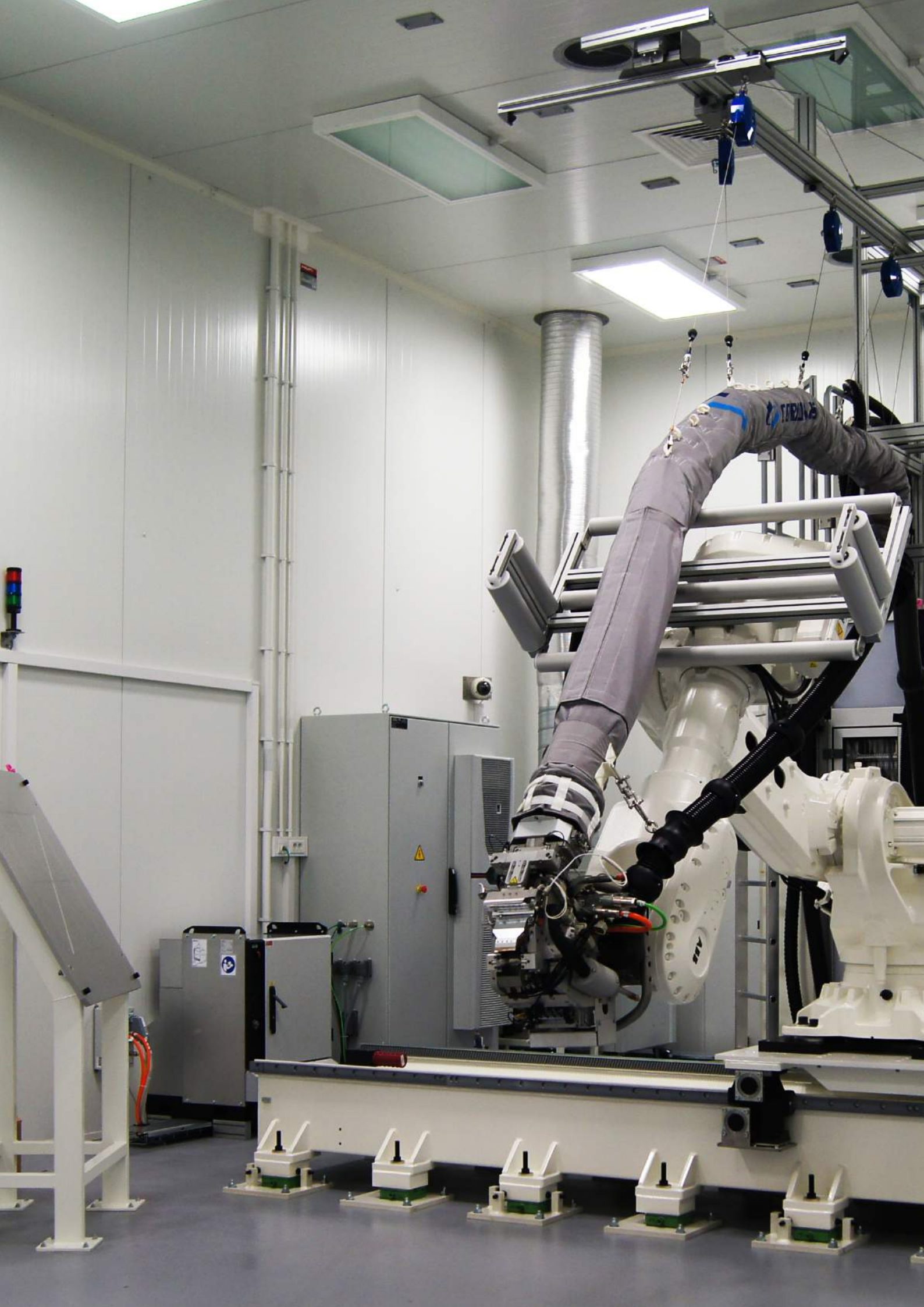
The aim of the project was to develop a design methodology and technology for manufacturing a composite wing box for the ILX-34 normal category aircraft with a take-off weight of 4,740 kg.

As part of the work, the most stressed part of the wing's structure - the central part of the wing box - was designed, manufactured and tested. This project was aimed at validation of stress analysis methods and the technology of manufacturing a composite wing with a sandwich structure. A combination of the technology of a robotic system for laying composite tapes and out of autoclave prepregs was used to create the structure, which allowed to obtain high quality structure at acceptable production costs. Thermoforming technologies for thermoplastic composites were used to produce secondary structures parts. The demonstrator was sub-jected to comprehensive fatigue tests, taking into account damage tolerance and repair.

DESIGN AND DEVELOPMENT OF TECHNOLOGY FOR THE CONSTRUCTION OF MAIN ROTOR BLADES FOR THE ILX-27 HELICOPTER

The aim of the project was to develop main rotor blades for the ILX-27 unmanned helicopter with a take-off weight of 1100 kg. As part of the project, a design methodology and low-cost manufacturing technology based on out of autoclave pre-impregnates with carbon reinforcement were developed. The spar of the blade was made of S-2 type reinforced glass roving.

The research and development phase of the project was based the building block approach, including material tests, elements tests and full scale rotor blades dynamic test. The designed rotor blades have been aerodynamically optimized. The prototype blades were tested on a test stand. Over speed tests, drag polar measure-ments and endurance tests were carried out as part of the research program.

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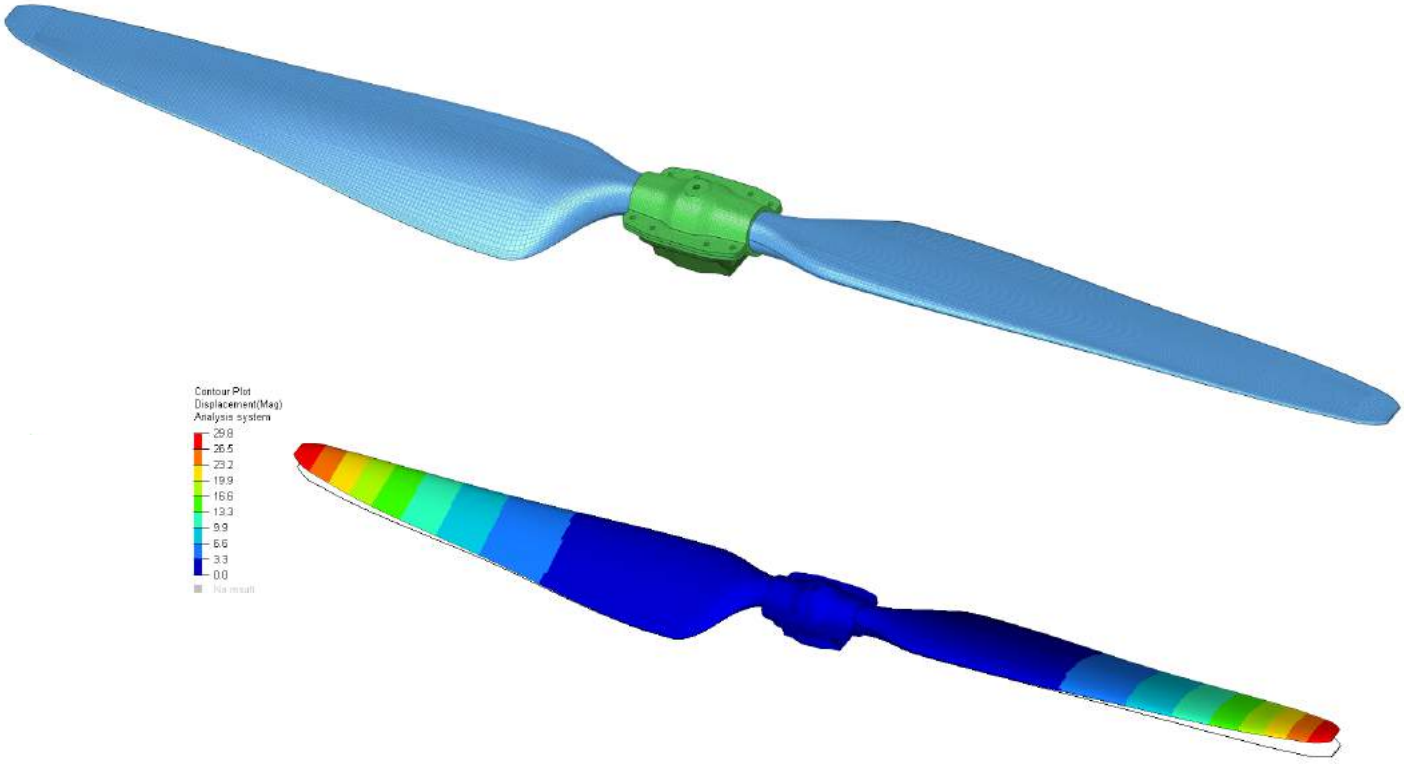
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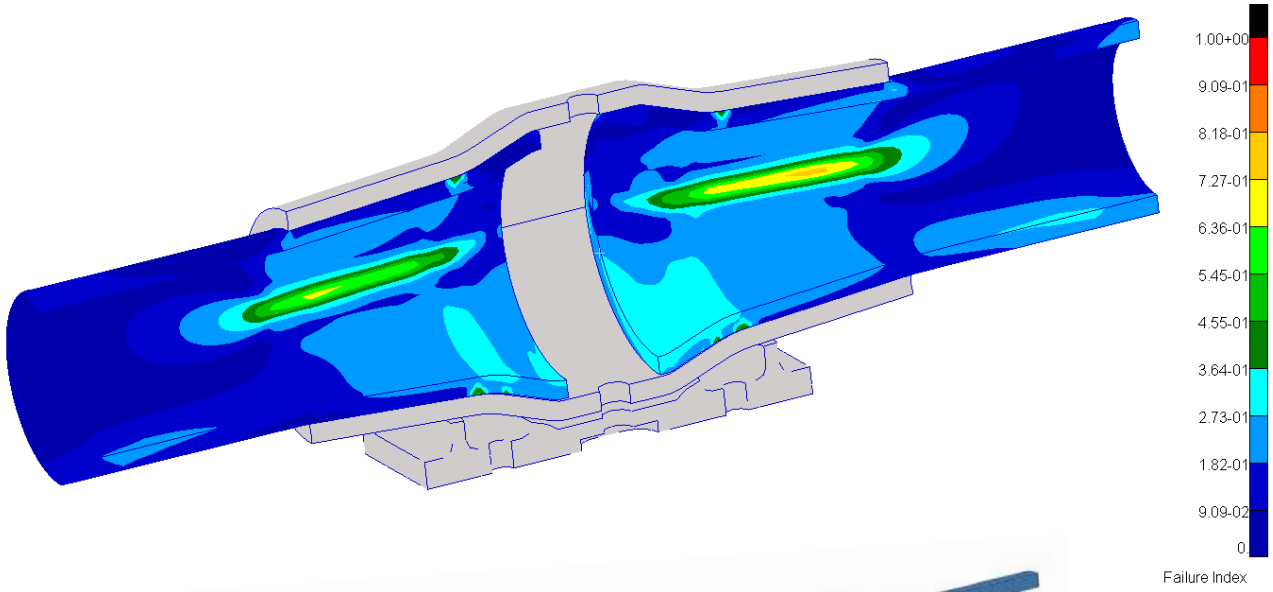
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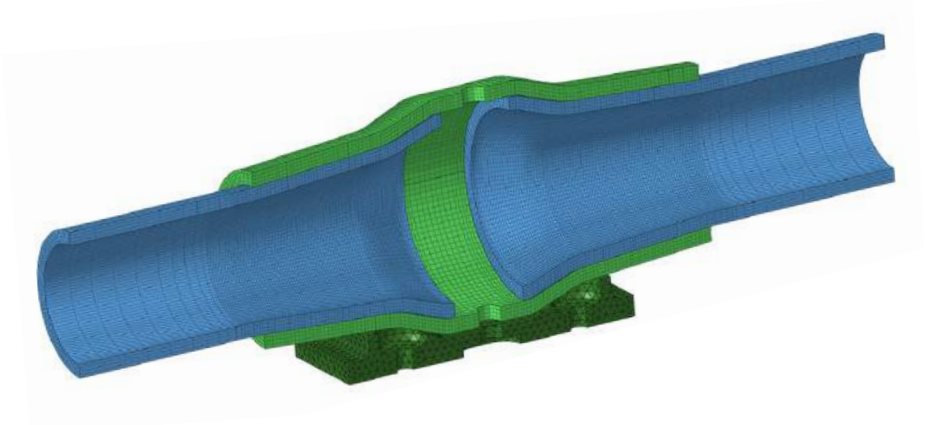


DEVELOPMENT OF DESIGN METHODOLOGY AND TECHNOLOGY FOR THE PRODUCTION OF MULTI-ROTOR PROPELLERS

As part of the work, the design methodology and manufactoring technology of propellers for a multi-rotor with a take-off weight of 450 kg were developed.

The multi-rotor propeller was designed as a combination of two composite blades connected with an aluminum hub. The blade structure consists of a spar with an upper and lower coverings bonded to it. The space between the covers is filled with the foam. The blade skins and the spar are made of carbon fabrics and tapes.

Linear and nonlinear models were used in the strength analyzes. Typical for the designed structures, aerodynamic and dynamic loads resulting from the loads occurring during the operation of the structure were assumed.

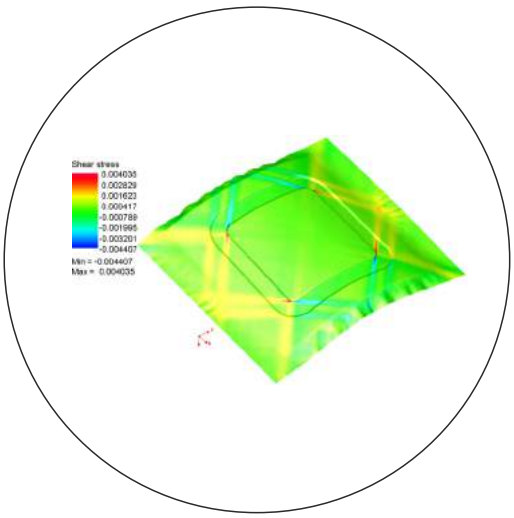
During the design of the structure, a number of analyzes were performed taking into account:

- Analysis of propeller vibration, taking into account preload caused by centrifugal force.
- Analysis of the joint between the blade and the hub.
- Analysis of the strength of the blade elements, including: spar, top and bottom skins, filling elements (foam) and adhesive.
- Analysis of static and fatigue strength of the hub.
- Analysis of the strength of bolted connections.

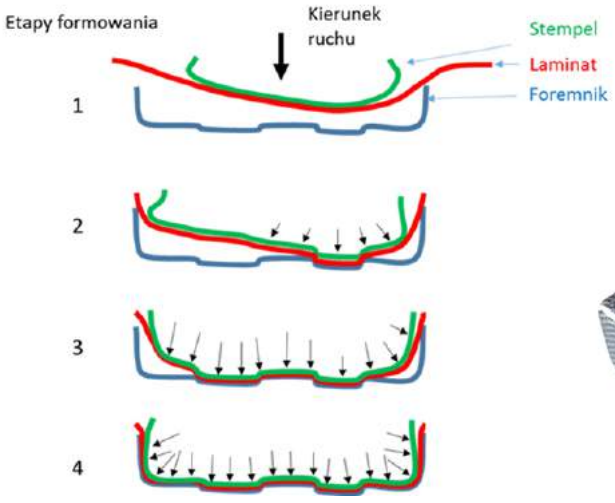
COST-EFFECTIVE TECHNOLOGIES OF THERMOPLASTIC COMPOSITES FOR AEROSPACE PARTS

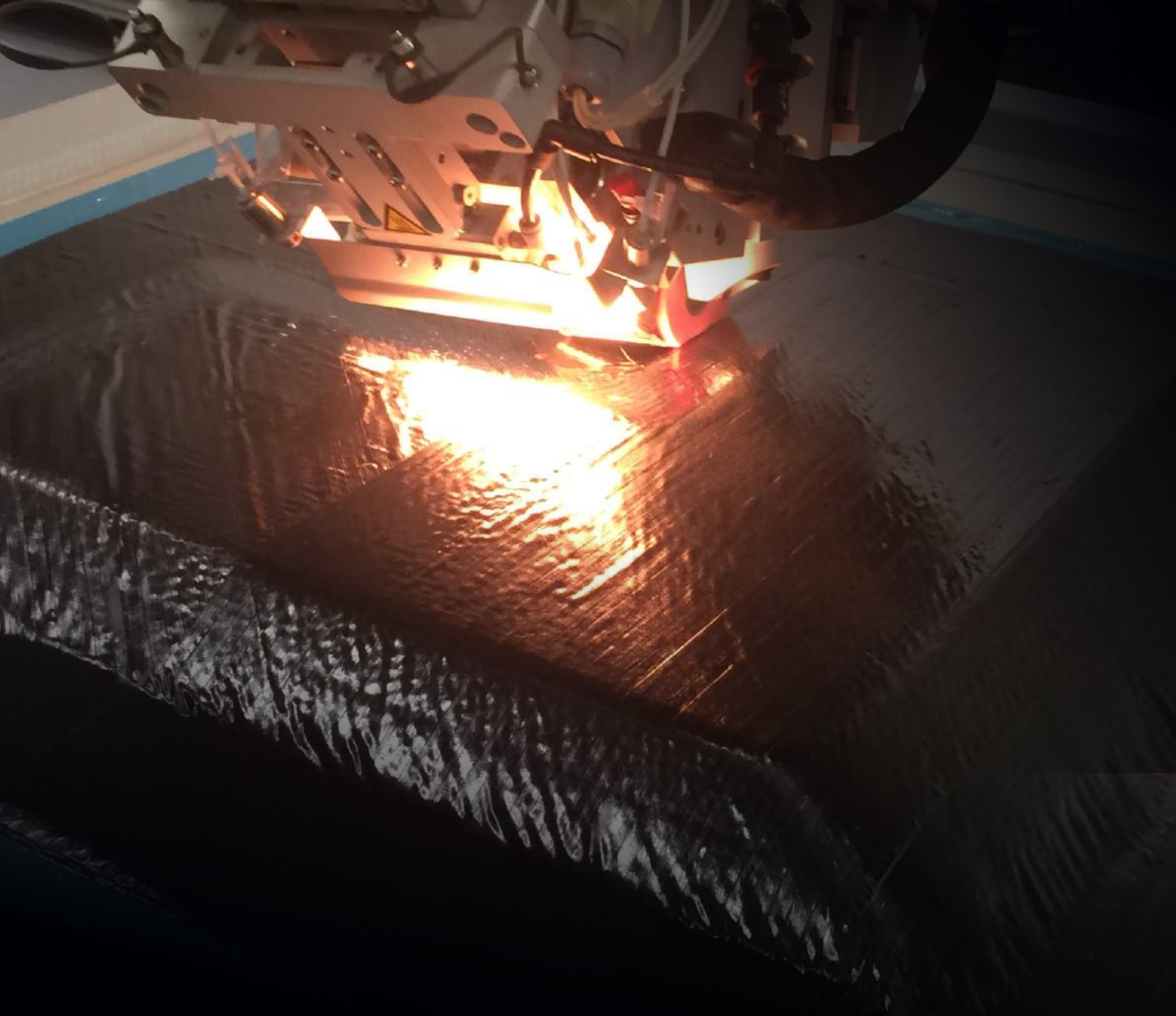
The aim of the project was to develop a technology for the production of secondary aircraft structures based on the thermoforming process of thermoplastic composites.

As part of the completed works, a structure was designed, a manufacturing process was developed and a technology demonstrator in the form of the inspection doors was produced. One of the newest carbon fiber-reinforced thermoplastic pre-impregnates available on the commercial market, TC 1225 5HS, was used as the material for the door elements. The process of pressing thermoplastic composites was modeled using the Pam-Form software. The door elements were joined together using the bonding process and non-adhesive joining techniques (welding). The strength of the obtained join has been verified by the laboratory tests.



In the project of forming composite ribs, it was necessary, in addition to modeling the pressing process, to develop and verify the model of a silicone stamp. The aim of this part of the work was to design the shape of a silicone punch that will deform according to the predicted sequence to ensure the possibility of composite forming in the area of the vertical walls of the element. Silicone has been described with a hyper-flexible material model, the properties of which have been determined based on experimental research. The modeling process was carried out using the ABAQUS software.





DEVELOPMENT OF TECHNOLOGIES BASED ON AUTOMATED FIBER PLACEMENT

Robotic laying of composite tapes.
Sandwich structures laid with the AFP robot:

As part of the work, an automation method of manual process of manufacturing sandwich composite panels with honeycomb core was developed. The robot automatically lays composite tapes on a very delicate substrate, which is a honeycomb. Proper work with the process parameters and the robot's movement strategy allowed to lay the material of appropriate quality without introducing damage to the substrate. A heavy machine carries out an extremely subtle process.

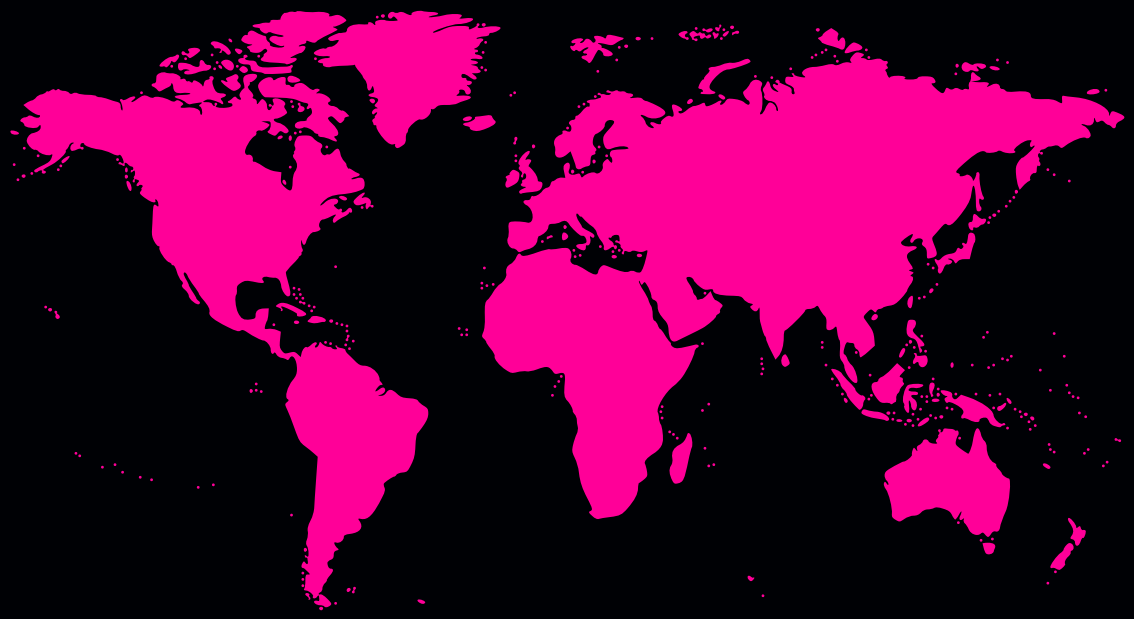
Processing of next-generation composite materials:

Thanks to the AFP robot, it is possible to process thermoplastic composites, quickly lay prepregs, as well as lay dry carbon fibers, the finished multilayer packages of which are saturated with resin. The complete reinforcement can be placed on almost any shape with an accuracy not found in manual technologies. Full control over the amount and direction of the fibers in the composite enables the use of a cost-effective supersaturation process by resin infusion.

COOPERATION

Łukasiewicz Research Network - Institute of Aviation provides testing services in the field of composite materials and develops new manufacturing technologies for the aviation, space and related industries. It also carries out research activities through participation in international project consortia, in which both scientific and research entities as well as private enterprises can participate. The Institute is a partner of many recognized institutions from the aviation industry, together with which it carries out research and development projects and works, or conducts scientific cooperation.

FEDERAL AVIATION AUTHORITY	**EUROPEAN UNION AVIATION SAFETY AGENCY**
NATIONAL INSTITUTE FOR AVIATION RESEARCH – WICHITA STATE UNIVERSITY	**CIVIL AVIATION AUTHORITY**
MIDDLE RIVER AIRCRAFT SYSTEMS	**PZL MIELEC A LOCKHEED MARTIN COMPANY**
ASELAN	



CONTACT

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