THE SZEWALSKI
INSTITUTE OF FLUID-FLOW MACHINERY
POLISH ACADEMY OF SCIENCES

MAIN RESEARCH AREAS:
- ENERGY CONVERSION IN FLOWS
- SMALL-SCALE DISTRIBUTED COGENERATION
- POWER AND FUEL PRODUCTION BASED ON RENEWABLE ENERGY SOURCES
- MECHANICS OF MATERIALS AND MACHINES
- ROTOR DYNAMICS MODELLING
- AERODYNAMICS & AVIATION
- LASER & PLASMA APPLICATIONS
- NANOMATERIALS
Main scientific task of the Institute is concentrated on energy conversion in flows and constitutes the fundamental research in the Institute. Over the last few years we have changed our scientific policy and have started to build a new scientific specialization viz. - small-scale distributed power engineering based on renewable energy sources, especially home cogeneration power plants.

The Institute has been a coordinator of a few European projects in the frame of FP6, FP7 and recently in Horizon 2020. Also a leader of work packages in over a dozen European projects and in a few NATO projects. Institute is the coordinator of the largest and most important polish consortium in the area of eco-energy, Baltic Eco-energy Cluster (BKEE).

The Institute was awarded the „Green Phoenix”, prize for the activity in a field of eco-energy, as well as „Quality of the year award in 2010, 2013” in category of research projects and honoured with “Diamonds of Forbes” and “Business’s Gazelle” awards in 2014.

The IFFM is a state funded research institute but is open to other sources of funding like application to European and Polish research grants and industrial projects. The Institute is fully compliant with the new European energy regulations.

**Motto of the Institute: Combination of basic and applied research**

We focus on high efficiency of distributed heat & power cogeneration to stimulate the high-tech/modern technology in polish industry. We work on new problems connected with micro-turbines, boilers, conversion of biogas, solar and wind energy. Every second researcher, working at the Institute, acquires one industrial project each year which is the highest indicator for industrial projects among all institutes under the PASci.

**Disciplines represented at the Institute:**
- energy conversion in flows
- distributed small scale heat & power generation based on renewable energy sources
- Combined Heat and Power (CHP) technology, energy storage, wind and water turbines and plus energy technologies for private buildings
- photovoltaics
- diagnostics of steam turbines
- machine mechanics (computer analysis, vibrations, rotor dynamics, model–based diagnostics, expert systems)
- high-temperature gasification and gas/syngas cogeneration
- aerodynamics and aviation, new materials, condition monitoring and smart structures
- plasma and laser engineering
- nanomaterials
- small scale hydropower plants
The activities of the Centre of Hydrodynamics involve both the fundamental research of fluid–flow phenomena, including numerical modelling and experimental studies, as well as design and diagnostics of hydraulic machinery.

The areas of interest include:
- mathematical modelling of turbulent flow phenomena, especially in dispersed and reactive flows,
- thermomechanics of flow and heat transfer in porous media,
- particle methods for two–phase flows with interfaces,
- flow path analysis and design of water turbines,
- analysis of transients in pipeline systems and control valves.

Department of Multiphase Flow
- turbulent dispersed flows
- stochastic Lagrangian approaches
- flows with interfaces
- smoothed particle hydrodynamics
- LBM for porous media
- reactive flows modelling

Contact person:
Jacek Pozorski, D.Sc., Ph.D., Eng.
Head of the Centre
jacek.pozorski@imp.gda.pl

Department of Hydropower
- small capacity water turbines
- flow path analysis and design
- field and laboratory measurements
- hydraulic machinery performance tests
- transients in pipelines and valves

Contact person:
Adam Adamkowski, D.Sc., Ph.D., Eng.
adam.adamkowski@imp.gda.pl

Department of Cavitation
- cavitation diagnostics
- cavitation erosion
- wear processes modelling
- hydropower development trends

Contact person:
Janusz Steller, Ph.D.
janusz.steller@imp.gda.pl

Department of Electrohydrodynamics
- EHD phenomena and processes
- experiments in multiphase flows
- flows in microscale systems
- aerosol charging
- electrospraying, electrospinning
- dust removal from flue gases

Contact person:
Anatol Jaworek, Prof., D.Sc., Ph.D., Eng.
anatol.jaworek@imp.gda.pl
Applications include:
- design and technical analyses of hydraulic machinery and equipment,
- development of counter-measures against unwanted flow phenomena and their effects,
- production of nanothin films, nanofibrous materials and hydrophobic self-cleaning coatings.

The Polish Hydropower Conference is organised each year as a national discussion forum on hydropower related scientific, technical, economic and administrative problems.

The Workshop on Multiphase Flows is held biannually to bring together the recognised authorities and young scientists from the fields of chemical and process engineering, fluid mechanics, thermodynamics, heat and power.

Offer for industrial partners

**Hydroelectricity sector:** expertise in methods for hydraulic machinery design and solutions for hydropower plants operation
- determination and optimisation of water turbine and pump performance characteristics,
- diagnostic techniques to assess condition of hydraulic machinery and equipment, performance tests and diagnostics of water turbines and pumps (under field and/or laboratory conditions),
- documentation of replacements and upgrading of water turbine runners,
- expert opinions and consultations, supervision of third party services and deliveries,
- documentation and supervision of tubular turbine manufacture,
- conceptual design of small hydropower plants, design of small hydraulic turbines,
- analysis and evaluation of the penstock strength,
- erosion resistance tests in cavitation and hydro-abrasive facilities,
- laboratory investigation of static and dynamic characteristics of check and control valves.

**Power engineering sector:** novel dry and wet methods of flue or exhaust gas cleaning from submicron and nanoparticles (PM2.5/PM1)
- The dry method uses fine particle electrostatic agglomeration in electrical discharges in alternating electric fields for removing them by conventional electrostatic precipitator. The method is aimed at removing fine mineral and heavy metal particles (incl. Hg) from coal or biomass fired boilers in power industry with collection efficiency >95%.
- The wet method utilises electrostatic deposition of particles charged in electrical discharge onto oppositely charged droplets. The collection efficiency of this method is higher than 95% in the submicron range. The wet method also allows the removal of sulphur oxide from the gas with efficiency higher than 90%. The method is aimed at removing soot nanoparticles from Diesel engine exhaust.
The Centre of Flow and Combustion

deals with problems of aerodynamics, fluid mechanics, thermodynamics of energy systems and combustion. Activity of the research groups is connected with modelling flows in airplanes, helicopters and aircraft engines. A significant part of the work is related to the heat and power plants efficiency and analysis of steam and gas turbines. The Centre also conducts research in the area of renewable energy for the small heat and power cogeneration units, biomass and municipal waste gasification systems.

The aerodynamics group

has an expertise in experimental and numerical investigations of subsonic and supersonic flows in the channels, turbomachinery or external aerodynamics configurations.

The area of expertise of the group covers both basic and applied research, including:

- shock wave boundary layer interaction,
- flow control methods countereacting boundary layer separation,
- secondary flows and vortical structures analysis in the channel flow,
- aerodynamic and aero-acoustic analysis of external flows,
- cooling of gas turbine internal channel, blades and end-walls,
- numerical investigations of flow structure in rotating machinery:
  - turbomachinery (gas turbine, axial and radial compressor),
  - wind turbine,
  - helicopter rotor.

Measurements in the low and high speed wind tunnels:

- pressure and temperature measurements,
- Flow Visualization and density distribution measurements (Schlieren, Mach–Zehnder interferometer, flow structure on the wall),
- velocity fluctuation measurements: Constant Temperature Anemometry – Hot wire probes,
- Laser Doppler Anemometry – 3D LDA,
- Particle Image Velocimetry – 3D PIV,
- Pressure and Temperature Sensitive Paints – PSP and TSP.
The combustion group

has wide experience in experimental research and CFD modeling of heat and flow processes in small and medium scale energy generation systems with strong emphasis on thermo-chemical conversion of solid organics into useful liquid and gaseous products.

In general, our interest focuses on utilization of biomass, waste and RDF.

The areas of expertise include:

- enhancement of energy conversion in multiscale thermodynamics,
- mass, momentum and thermal-FSI,
- problems of pyrolysis, gasification and combustion,
- chemical analyses of substrates and products,
- design and optimization of energy system devices (gasifiers, pyrolysis reactors, boilers, syngas cleaning installations),
- theoretical and numerical analysis of heat and mass transport in porous/granular materials in reactive flows,
- numerical computations of thermal characteristics of heat exchangers (ANSYS Fluent, in-house codes),
- development of CFD codes for simulation of thermo-chemical conversion processes.

We perform research for many branches of industry, including refinery, pharmacy, food, environmental protection, as well as for widely understood sector of processing, distribution and use of various products.

The scope of services offered includes, but is not limited to:

- development of analytical methods,
- sampling of fuels, bio-fuels, bio-components, water, sludge and soils,
- gas composition analysis,
- elemental composition analysis,
- testing of fuel properties.

If needed, we are able to provide service on measurements of selected parameters, e.g. temperature, pressure, flow rate, gas composition analysis, in industrial large-scale systems.
The Centre of Plasma and Laser Engineering is focused mainly on plasma and laser investigations and their applications in practice. It is worth noting that the research on lasers has been carried out in the Centre since mid-sixties of the last century, i.e. it has started only several years after the first laser invention.

Processes of materials synthesis and nano-structuration using interaction of the coherent photon beams (lasers) are investigated. The research aims on production of scalable, functionalized nanomaterials and development of the dedicated technologies for industrial (photovoltaics, photocatalysis) and also ultra-sensitive biosensing applications.

Moreover, activities such as the laser surface cleaning and complex, non-invasive analysis of historical materials and also 3D-object scanning are performed for the Cultural Heritage sector in collaboration with museums and conservator’s enterprises.

The Photophysics group carries research on new materials mainly for the sector of renewable energies.

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The research on electrical-discharge based plasma processing of gaseous pollutants has been carried out in the Centre since 1990.

The staff of the Centre have had experience in the non-thermal plasmas acquired over two decades of investigations and diagnostics of various kinds of low-pressure discharges (DC and pulsed glow discharges, DC and pulsed corona discharges, microwave discharges).

The acquired expertise in the fundamentals of various gas discharges has been recently employed practically by the Centre for gaseous pollutant abatement using electrical-discharge based plasmas at atmospheric pressure.

Present topics are:

- production of hydrogen from gaseous and liquid hydrocarbons, including biomethane and bioethanol, using microwave plasma at atmospheric pressure,
- microwave plasma processing of highly-concentrated (tens of %) hydrocarbons and their chlorinated and fluorinated derivatives by microwave torch discharges with the purpose of destruction of hazardous compounds,
- submicron dust removal from flue gases using advanced electrostatic precipitators,
- electrohydrodynamic pumps allowing to avoid using mechanical fans,
- plasma actuators for aviation (studied extensively in the frame of European project PlasmAero) and wind turbines.

Due to the experience acquired and the existing equipment, the Centre can offer services and cooperation in the following fields:

- plasma destruction of Freon® and organic solvents,
- hydrogen production from gaseous and liquid fuels using microwave plasma,
- surface modification using non-thermal plasma,
- job-shop for micromachining of materials using nano- and femtosecond lasers,
- Laser Direct Imaging,
- plasma actuators for aeronautics and wind turbines,
- flow diagnostics using PIV as 2D, 3D, Time Resolved or Volumetric,
- laser surface cleaning,
- non-contact digital 3D laser scanning for the purpose of reconstruction, virtual presentations, reverse engineering, etc.,
- non-invasive material analyses (XRF, LIBS, UF, NIR) of e.g. metal alloys, glass, ceramics, pigments, minerals and cultural heritage objects,
- new materials (nanomaterials and thin films, including metal [eg. Au, Ag, Pt] and metal oxides [eg. SnO₂, TiO₂] nanoparticles in the range of 5–20 nm) for PV and energy storage systems, including supercapacitors as well as their characterization,
- dye-sensitized solar-cell integration and their characterization,
- PVT system-integration (PV modules with cooling set-up),
- monitoring system for PV large scale farms,
- biogas technologies, mainly related to biowaste, including municipal waste and sewage sludge,
- diagnostics of internal combustion engines,
- laser systems development for medical and industrial applications,
- modelling of plasma wall interactions, including ion thruster systems.
The Mechanics of Intelligent Structures Department specializes in various Non-Destructive Testing and Structural Health Monitoring methods, vibration control, damage assessment, structural dynamics, smart materials and structures, composite structures, fracture mechanics, working in these fields both theoretically and experimentally. The studies concentrate on the use of guided elastic waves, the spectral finite elements, the fibre optic sensors and sensing as well as other smart and multifunctional materials.

Our offer includes measurements using:

- THz spectrometry.
- 3D Scanning Doppler Laser Vibrometer.
- Vibrothermography.
- Static–dynamic testing machine.
- Impedance analyzer.
- FBG strain sensors.

Main achievements in recent years:

- Polish Patent entitled "Method and device for damage localisation in structural elements" (ref. no. P 386233).
- Honours, awards and prizes such as START and KOLUMB scholarship (Foundation of Polish Science), Prof. O.C. Zienkiewicz’s medal, INNODOKTORANT scholarship (Pomorskie Voivodeship).
- National and international projects and grants founded by, among others POIG, EC FP6, EC FP7, NCBiR, NCN (Maestro, Harmonia, Sonata), FNP, NATO, Boeing Co.
The Centre of Mechanics of Machines specializes in dynamic performance tests, bearing systems, and technical diagnostics of turbomachinery. Both research works to achieve scientific objectives and works for industry focusing on finding a solution to specific technical problems are regularly conducted here. In these activities, we use laboratory facilities, composed of three independent laboratories (Micro CHP Power Plant Laboratory, Machine Vibrodiagnostics Laboratory, Rapid Prototyping Laboratory) as well as own and commercial CAD/CAE software.

Main research directions carried out in the Department are:
- experimental studies of rotating machinery,
- modeling and simulation analysis of real systems, model-based diagnostics,
- design, optimization, and construction of fluid-flow machine prototypes.

Our offer includes:
- dynamic state assessment and diagnostics of machines,
- design of fluid-flow machinery and complete power devices,
- choosing and optimization of bearing systems,
- experimental and computational modal analysis,
- measurements of temperature distribution with thermal imaging camera,
- rotor balancing and shaft alignment, noise level measurements,
- rapid prototyping (3D prints).

Main achievements in recent years:
- design, construction, and bringing into operation of the country's first CHP domestic power plant, with ORC technology, biomass-fired,
- construction and startup of several variants of steam microturbines,
- construction and startup of several original test rigs, used mainly for testing of turbo-machinery and subassemblies of small CHP power plant,
- numerical model of high-speed foil bearing and its experimental verification.

The Turbine Dynamics and Diagnostics Department specializes in dynamic performance tests, bearing systems, and technical diagnostics of turbomachinery. Both research works to achieve scientific objectives and works for industry focusing on finding a solution to specific technical problems are regularly conducted here. In these activities, we use laboratory facilities, composed of three independent laboratories (Micro CHP Power Plant Laboratory, Machine Vibrodiagnostics Laboratory, Rapid Prototyping Laboratory) as well as own and commercial CAD/CAE software.

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- experimental studies of rotating machinery,
- modeling and simulation analysis of real systems, model-based diagnostics,
- design, optimization, and construction of fluid-flow machine prototypes.

The Aeroelastic Department specializes in aeroelastic and structure calculations of blades, bladed discs, and several bladed-discs-shaft system of the steam and gas turbine, non-intrusive measurements of rotating blades.

Main research carried out in the Department include:
- structure calculations – static analysis, and free and forced vibration of turbine blades and bladed discs and thermoelastic calculations of turbine (rotor and casings) during run-up and run-down,
- stress and natural frequencies of several bladed discs on the shaft,
- 2D and 3D Flutter calculation of the rotor blades and 3D unsteady forces of the stage with vibrating and rotating rotor blades in the subsonic, transonic, and supersonic inviscid and viscous flow,
- the diagnostic system to measure the rotor blade vibration amplitude and frequencies using the tip-timing and tip-clearance method,
- the neural algorithm for prediction of the temperature and stress in rotor of the steam turbine during run-up and run-down.

The industry offer:
- the tip-timing diagnostic system to measure the rotor blade vibration,
- the numerical in-house codes to calculate the rotor blade flutter and unsteady forces acting on rotor blade with taking into account the blade vibration,
- the numerical codes to calculate the temperature and stress in components of the steam turbines using neural algorithms.

The achievements:
- non-intrusive new algorithm to measure the rotor blade vibration in last stage steam turbine,
- analysis of unsteady forces acting on rotor blades in all stages of compressor with taking into account the blade vibration and for non-symmetrical engine inlet as result of the bird impact,
- analysis of the temperature and stress in components of steam turbines using neural network.
The main interests of the Centre of Heat and Power Engineering are problems of thermomechanics of fluid-flow machinery and cogeneration of heat and power.

The investigations include both fundamental research of energy conversion in heat and fluid flow as well as applied research related to diagnostics, design, experimental and numerical analysis, also retrofit of turbines, combustion engines, heat exchangers and other heat and power generating devices.

Works carried out at the Centre combine theoretical, numerical and experimental investigations.

For numerical investigations we use a number of in-house heat, flow and structure solvers as well as a number of commercial packages. Experimental investigations are made in our well equipped laboratory base at the Institute of Fluid-Flow Machinery and from 2015 at the new subsidiary - Research Centre at Jabłonna.

Besides statutory activities our employees take part and coordinate a number of research projects, including a national strategic programme entitled

The team of our employees, headed by Director Prof. Kiciński, was granted a first-rank award of Prime Minister for a scientific-technical achievement „New Technologies for Small-Scale Distributed Energy Systems in Autonomous Energy Centres“.

The scope of work includes a technical and economic analysis of a model energy centre with a fuel diversity. The whole heat and power system (of electric power up to 10 MWe and heating power up to 25 MWt) consists of four modules: biomass-fed ORC and steam turbine cycle, natural gas combustion piston engine and coal boiler. The elaborated system enables high-efficiency cogeneration according to the local demand for heat.

Investigations within the field of gas, steam and ORC turbines concentrate on: multidisciplinary optimization of turbine blading systems, partial admission turbines, adaptive control in LP turbines, problems of turbine startup as well as Tesla-type bladeless turbines.

The Centre cooperates with industrial partners for whom we offer:

- design and analysis of dedicated poligeneration systems,
- diagnostics, numerical analysis, design and modernisation of flow systems for steam, ORC and gas turbines,
- measurement of thermal and flow processes in industrial devices,
- design and diagnostics of heat pumps, cold production systems and heat storage tanks with phase transformation materials,
- measurements of gas flows in the electrostatic precipitators.
This Research Centre is intended to be a laboratory base in which the Institute of Fluid-Flow Machinery of the Polish Academy of Sciences will carry out research investigations and cooperate with other centres of the Polish Academy of Sciences, universities, R & D entities as well as with the leading companies of the energy sector.

The research on solar, wind and biomass energy as well as on integration of these types of energy with micro-cogeneration plants conducted in the Centre will enable design of modern technologies for energy–plus houses and other technologies in order to carry out the national and EU policies on distributed energy generation and reduction of CO₂ emissions.

- These technologies will facilitate future implementations and enable profitable operation of different companies and small spin–off enterprises in the Renewable Energy Sources (RES) market.
- The Centre will also be an excellent exchange platform in the field of small-scale eco–energetics for research institutions and industry as well as an important training and education centre for the region and the country.

Polish Academy of Sciences Research Centre
Energy Conversion and Renewable Resources in Jabłonna

Main Beneficiaries:
- local government authorities,
- small but innovative spin–off enterprises,
- big industrial companies of the energy sector, among others: KGHM Polska Miedź SA, Tauron Polska Energia SA, Energa SA,
- other entities interested in modern technologies.
Centre's objectives:
The Centre is designed as a research and technological facility for the Mazowieckie Voivodeship and the northwest part of Poland, with a view to creating the so-called “Autonomous Energetic Regions” aiming to assure energetic safety. One of the main objectives of the Centre is to conduct research on new sources of renewable energy and on its conversion.

Research interests of the Centre:
- new technologies of energy and heat production,
- cogeneration of energy obtained from different sources,
- methods of heat storage and waste heat utilisation,
- standardisation of measurement methods in distributed energy generation,
- certification methods for equipment used in renewable energy generation,
- rationalisation of energy consumption and implementation of smart-grid systems for intelligent houses and “Autonomous Energetic Regions”
- integration of different energy production technologies (solar cells, wind turbines, biomass boilers, heat pumps, fuel cells) in small community-scale power plants.

MOTTO OF THE CENTRE:
Micro Plus-Energy Technologies for houses and public buildings

What the Centre should offer:
- Research Centre
- Commercial research (Field tests)
- Education and promotion
- Research and development
- Prosumer energy trading
- Shows, conferences
- Local Smart Grid Applications for “cloud computing”
- New solutions for energy storage
- Cheap, hybrid mini/micro CHP power plants
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Fiszer 14, 80-231 Gdańsk, Poland

Secretary
phone: +48 58 6995110, fax: +48 58 3416144
e-mail: imp@imp.gda.pl

Director of the Institute
Prof. Jan Kiciński, D.Sc., Ph.D., Corresponding Member of PASci
office: +48 58 3416071, e-mail: jan.kicinski@imp.gda.pl

Deputy Director for Scientific Issues
Prof. Piotr Doerffer, D.Sc., Ph.D.
phone: +48 58 6995202, e-mail: piotr.doerffer@imp.gda.pl

www.imp.gda.pl