INSTITUTE OF THERMOMECHANICS ASCR

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The INSTITUTE of THERMOMECHANICS ASCR, v. v. i.

is a leading multidisciplinary research institute of the Academy of Sciences of the Czech Republic in the field of applied physics, with several branches across the country. The Institute cooperates intensively with domestic and foreign research institutions and universities of technology and natural sciences. One third of our research staff are young scientists under 35 years of age, primarily doctoral and postdoctoral students, to whom we provide opportunities for professional development in our research programmes. Although the Institute is focused primarily on basic research, it maintains extensive collaboration with large industrial companies as well as dynamic and technology-oriented SMBs.

The history of the Institute reaches back to 1953. The early research was focused on technical sciences and their applications in mechanical and power engineering industries. These two core specialisations have been central to our research up to the present day, though over the course of time the Institute's research scope has extended to new and perspective fields such as biomechanics, environmental engineering, mechatronics or electrical engineering. As a result, the Institute has acquired a largely interdisciplinary character.

Our researchers are members and chairs of international scientific organizations and they supervise doctoral students and train high-school talents under the country-wide educational projects. Our main building is the seat of several scientific societies.

The Institute has been the guarantor of cooperation between the Academy of Sciences of the Czech Republic and the Pardubice region in East Bohemia since 2009.

Do you want to collaborate or partner with us? Are you interested in our research? Would you like to visit the conferences and seminars organized by our Institute? Are you a student looking for a thesis topic or a research opportunity? Visit our website or our Facebook and YouTube pages for more information. You can also visit us to discuss how our knowledge and research can help your business. And our selected laboratories in Prague, Pilsen and Nový Knín are open to the general public during the annual Open Days held every autumn.

FLUIDS AND THERMAL SCIENCES RESEARCH

HIGH-SPEED AERODYNAMICS

The experimental research of high-speed flows in steam and gas turbines, compressors, ejectors and steam valves has almost 50 years of tradition in the Institute of Thermomechanics. Internal gas flows in models of flow machinery are studied in the wind tunnels in Nový Knín near Prague using the Mach-Zehnder interferometer and other optical and pneumatic methods.

Our key partner in aerodynamic research is Doosan Škoda Power. Our cooperation with the former ŠKODA Pilsen concern began in the 1960s and was formalized at the beginning of the 1970s with the signing of a contract for long-term cooperation. In the 1980s our scientists and their colleagues from Škoda were awarded a medal at the International Engineering Fair in Brno for the design of a 240-MW turbine for nuclear power plants.

Today our laboratories are equipped with several wind tunnels suited for different applications. The research continues in its rich tradition and focuses on modern power engineering applications.

Interferogram of air flow in a control valve, the fringes correspond to regions of the same density.

Colour schlieren image of the flow in the blade cascade of the last stage of a large steam turbine.

HEAT AND MASS TRANSFER

Our research of heat and mass transfer in gases and liquids is focused on the passive and active control of flows and thermal fields. Using an experimental approach we strive to discover new ways to intensify the transport of heat and mass during forced convection in wakes and impinging and synthetic jets. The results are useful in fluidics/microfluidics, the cooling of electronic components or gas turbine blades, improving the efficiency of mixing in chemical reactors or in external and internal aerodynamics.

Smoke visualization of a synthetic jet.

Coherent vortex lines in the shear layer and their breakdown, smoke visualization of submerged air jet.

Wake flow behind a cooled circular cylinder (Von Kármán vortex street).

NON-EQUILIBRIUM MULTIPHASE SYSTEMS

Changes of states of matter (or, more accurately, phase transitions) in nature and in engineering applications occur at a finite rate and under conditions that are more or less distant from the thermodynamic equilibrium (for example from the equilibrium boiling point). The non-equilibrium phase transitions include the formation (nucleation) of droplets in steam turbines and in the atmosphere, the nucleation of ice inside the droplets, the deposition of ice on the leading edges of airplane wings or the formation of cavitation bubbles in pumps and liquid turbines. Our research is focused on the measurement and modelling of these non-equilibrium phase transitions, on studying the properties of metastable liquids (e.g. supercooled liquid or supersaturated vapour) prior to the phase transition and on the characterisation of multiphase systems in sprays, aerosols and bubbles.

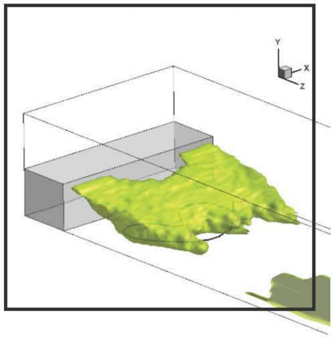
THERMOPHYSICAL PROPERTIES OF LIQUIDS

Density, viscosity, surface tension and other thermophysical properties of liquids serve as the input parameters for the design of power engineering and chemical devices and for the modelling of geophysical and biological processes. We carry out very precise measurements of thermophysical properties of liquids and use the obtained experimental data and the laws of physics to develop mathematical models of the properties. We measure relations between pressure, volume and temperature for environmentally friendly refrigerants and new ionic liquids using the constant-volume method and a vibrating tube. Tensiometric methods and the method of capillary elevation help us to determine the surface tension of the substances.

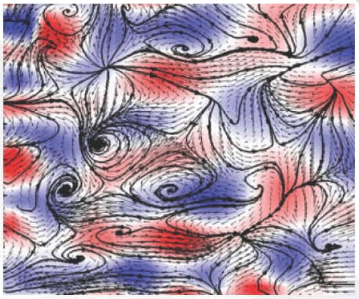
A significant part of our research of multiphase systems and the thermophysical properties of liquids is motivated by the priorities of the International Association for the Properties of Water and Steam (IAPWS), whose national committee is headquartered from the Institute of Thermomechanics ASCR.

TURBULENT FLOWS

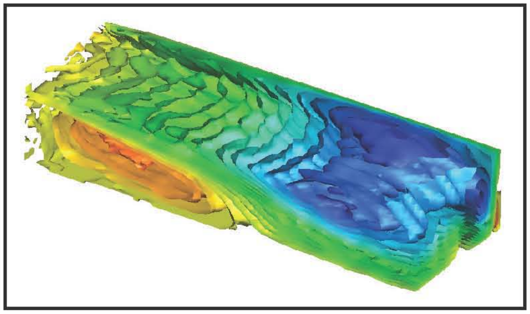
Despite the recent advances in experimental and computational techniques the fundamentals of turbulent flows continue to puzzle scientists, being arguably the last unsolved problem of classical physics. We concentrate on the experimental and numerical modelling of turbulent flows and the transition to turbulence in 3D geometries, measuring the velocity fields and turbulent flow characteristics and studying fluid-solid interactions. Our results are applied in the aerodynamic optimisation of flow past bodies (e.g. aircraft or automobiles) or flow machinery (turbines and compressors).



Isosurfaces of the vertical component of the time-averaged mean velocity downstream of a step in a narrow channel. Kidney-shaped impact object at the channel bottom.



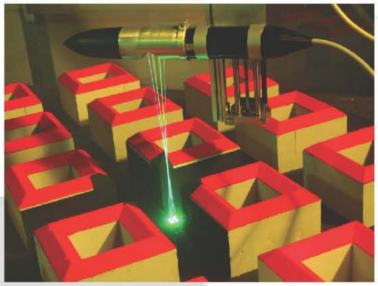
Turbulent flow of air in a rectangular-cross-section channel. Energy dynamic mode characterizing velocity field fluctuations.



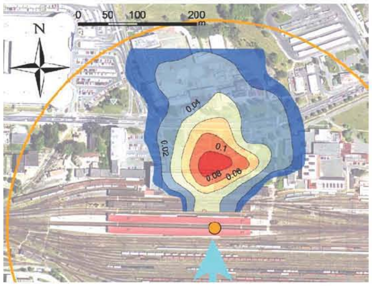
Channel flow; the isosurfaces of the component of the time-averaged mean velocity normal to the channel bottom characterize the space topology of the flow field.

ENVIRONMENTAL AERODYNAMICS

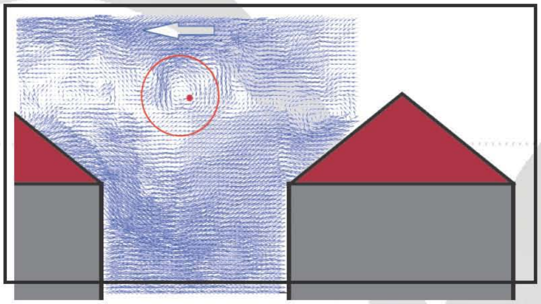
The atmospheric dispersion of emissions and dangerous substances from local and area sources or road traffic or during chemical accidents or terrorist attacks affects a society's health, safety and quality of life. Simulating atmospheric pollution and studying the interaction between urban areas and atmospheric flow helps us to improve our environment and brings benefits to all of us. The results of our studies have been used to build more accurate city evacuation plans in, for example, Prague and Pardubice. We use the physical and mathematical modelling of flow and diffusion in the atmospheric boundary layer, various flow visualization techniques and measurements of flow velocities in a specialized wind tunnel in the Aerodynamic laboratory in Nový Knín.



Detection of turbulence in a model of an urban area using LDA (Laser-Doppler Anemometry).



Simulation of chlorine dispersion over Pardubice train station, concentration 10 m above ground level.

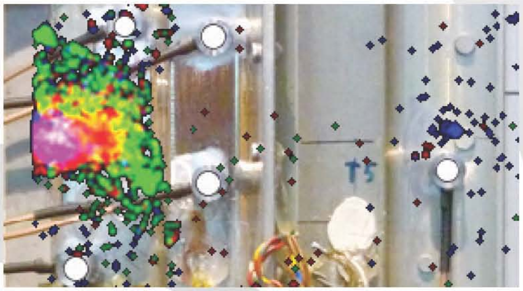


Particle Image Velocimetry (PIV) analysis of turbulent flow within street canyon in atmospheric boundary layer.

RESEARCH OF SOLIDS AND MECHANICAL SYSTEMS

DIAGNOSTICS OF MATERIALS AND STRUCTURES

The reliability and safety of aircraft, nuclear power plants, chemical plants, civil structures, pipelines, storage tanks and certain machines require the periodic health monitoring. Our methods of nondestructive testing (NDT) and evaluation of defects are based on the propagation of elastic waves in solids. We use advanced signal analysis (e.g. time reversal mirrors) and data processing (e.g. artificial neural networks). With the use of acoustic emission and nonlinear ultrasonic spectroscopy and other methods we are able to localize material defects, evaluate the damage caused by the loading, fatigue, corrosion or wear of structural parts and predict their lifetime. The methods can be used to predict building failures and detect leakages of gases and liquids from pressurized vessels and tubes. Ultrasonic methods can be used in medical diagnostics of the properties of human skin and their changes due to mechanical loading or UV radiation.



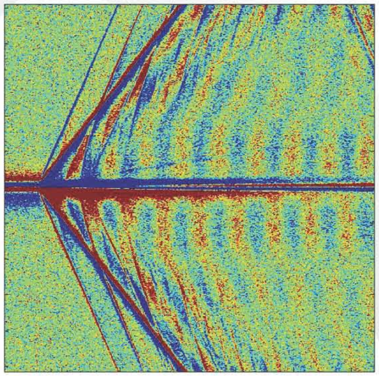
Acoustic emission sources and zones with cracks detected by nonlinear ultrasonic spectroscopy with time reversal mirrors during the fatigue test of an aircraft wing flange.

We also conduct measurements of changes during the thermal aging of materials after their cyclic thermal loading (e.g. the aging of the polymer insulation of electric cables) or nanoindentation measurements of changes in hardness and the ratio of elastic and plastic deformations of materials. We can also evaluate gradual changes of mechanical properties and the behaviour of materials under low-cycle and high-cycle fatigue loading with combined tension and compression or even torsion.

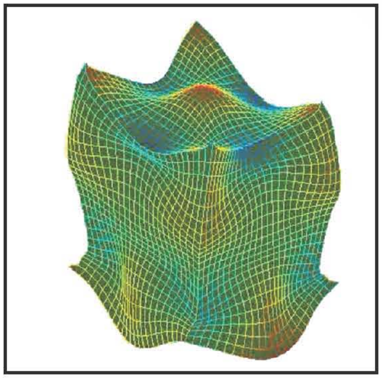
ELASTIC AND THERMOMECHANIC PROPERTIES OF MATERIALS AND THIN LAYERS

Studying elastic and thermomechanic properties of solids and thin layers helps us to better understand modern functional materials such as ferromagnetic and ferroelectric materials, fibre composites, ceramics, shape-memory alloys and thermal spray coatings. To measure the elastic properties of materials we use Resonance Ultrasound Spectroscopy (RUS), which was developed in our laboratories. Using other methods, including laser ultrasound methods, the ultrasonic pulse-echo method, scanning acoustic microscopy and the surface acoustic wave method, we measure and characterize the elastic properties of materials, we measure the plane elasticity of thin coatings and surface layers (such as plasma coatings), the elastic anisotropy of extremely fine-grained materials and the mechanical properties and temperature changes in solids in-situ during their loading and we characterize phase transitions in solids.

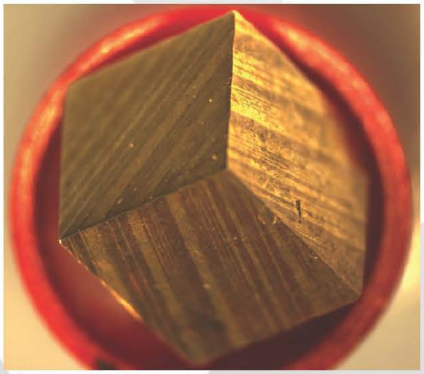
RESEARCH OF SOLIDS AND MECHANICAL SYSTEMS



Propagation of elastic wave in silicon wafer over time.



Eigenmode of 3D vibration of prismatic body (measurement by RUS; Resonance Ultrasound Spectroscopy).

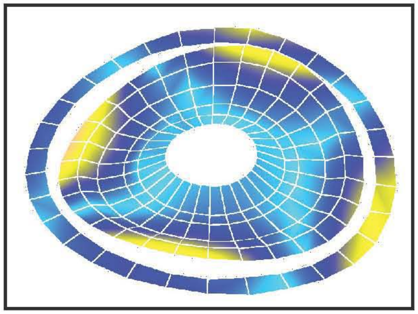


Sample of the Cu-Al-Ni smart alloy for RUS measurements.

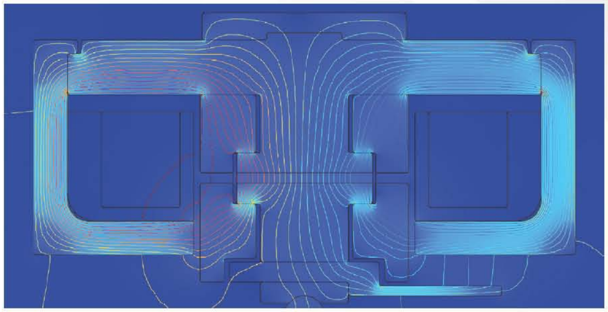
VIBRODIAGNOSTICS AND ROTOR DYNAMICS

The contactless analysis of the vibrations, state and potential damage of complex mechanical systems during operations enables the advanced planning of maintenance shutdowns. The system developed in our Institute measures the motion, vibrations and loading of rotating mechanical parts (such as turbine and compressor blades). The system is installed in several power stations in the Czech Republic, where it has helped to achieve significant savings in maintenance.

The vibrodiagnostics of rotating machines and vibroacoustics also help to study the vibrations of railway wheels, bearings, shafts, brakes, rolling mills, crushers and other machines. These techniques have a broad application – e.g. they can help to suppress the noise generated by railway or tramway traffic, which has an adverse effect on the quality of life and the environment. We are helping one of the largest manufacturers of railway wheels in Europe to develop technology for the optimum damping of railway wheels. We also measure the dynamic characteristics of rubber materials and develop models of vibrations and interactions of non-linear dynamic systems. And last but not least, we also study the influence of the new types of bearings, such as magnetic bearings and bearings with magnetorheological dampers, on the rotor dynamics.



Vibration eigenmode of a rubber-damped railway wheel.

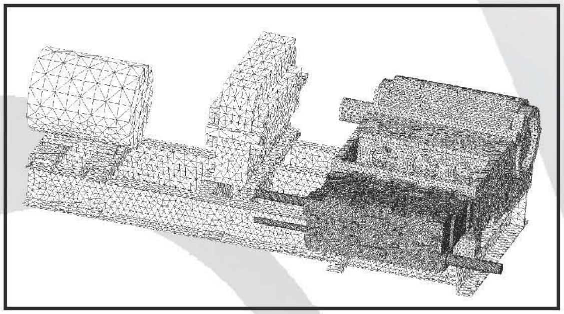


Distribution of the magnetic flux density in the body of the magnetorheological squeeze film damper.

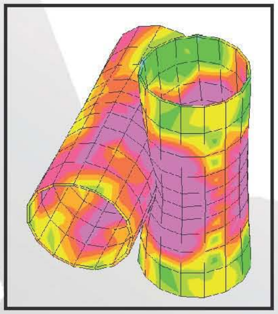
COMPUTATIONAL MECHANICS OF SOLIDS AND MECHANICAL SYSTEMS

In our institute we develop, implement and test numerical and analytical methods for continuum mechanics. Our main interest lies in linear and non-linear static and dynamic problems, thermomechanical problems, stress wave propagation, problems of the contact and impact of deformable bodies and the development of constitutive equations for solids. We also develop a FEM-based (Finite Element Method) computational PMD (Package for Machine Design) system, which has received the certificate of the State Office for Nuclear Safety.

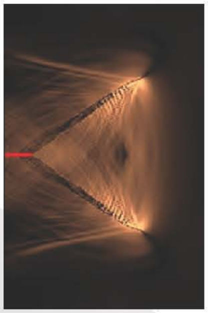
We put a vast effort into studying material defects, crack-growth mechanisms and crack propagation in crystalline materials using molecular dynamic (MD) simulations and multi-scale methods. We also collaborate on the calculation of electron structures and total energies of non-periodic systems using FEM and pseudopotential methods.



Example of FEM-based mesh for the mechanical analysis of a complex structure.

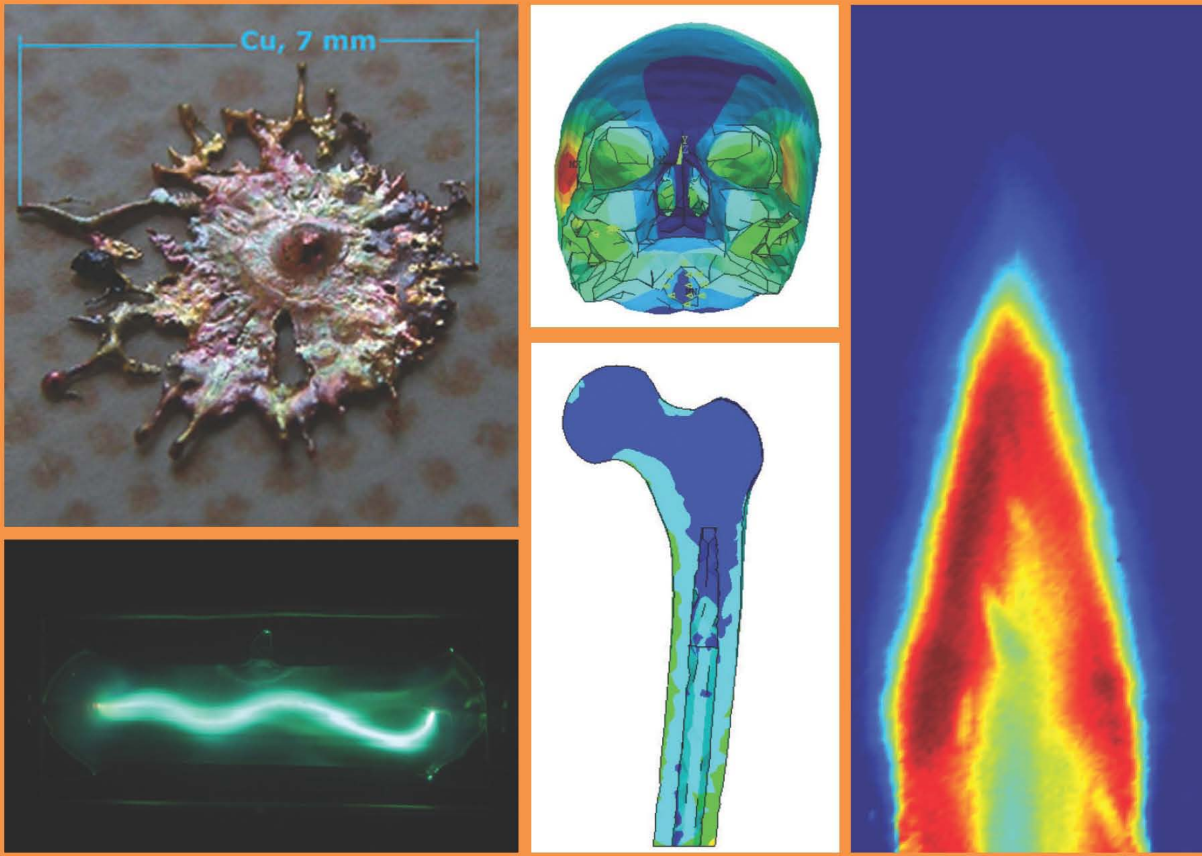


Snapshot of a stress state of two thin-walled tubes at impact.



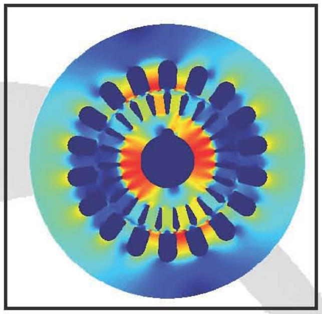
Molecular dynamics simulation of transonic propagation of crystal defect in the BCC phase of iron with shock waves.

ELECTRICAL ENGINEERING AND INTERDISCIPLINARY RESEARCH



ELECTRIC DRIVES AND POWER ELECTRONICS

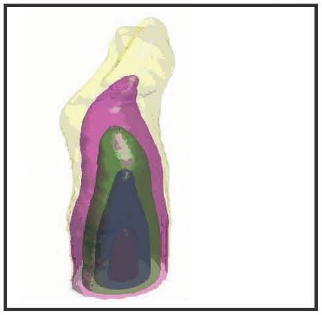
The current challenges of power engineering, such as power quality and the stability of the power grid with a large ratio of renewable energy sources, place new demands on electrical engineering research. In our laboratories we focus on the research of electric drives, electric rotating machines and power electronics and on other electromechanical conversions. The results of our research can be applied, for example, in the design of electric generators for wind and hydro power plants. We study the circuit structure of solid-state power converters and the mutual interaction of power inverters, machines and the power grid and develop advanced control and diagnostic algorithms for inverters. In collaboration with ČKD Elektrotechnika we are developing AC drives fed from multi-level, high-voltage inverters for demanding industrial applications. The design of a power inverter for a new-generation drive for mining equipment, developed as a joint effort of ČKD Elektrotechnika and our Institute, was awarded the GOLDEN AMPER award at the international AMPER 2011 trade fair. We are a competence centre of the European Centre for Power Electronics.



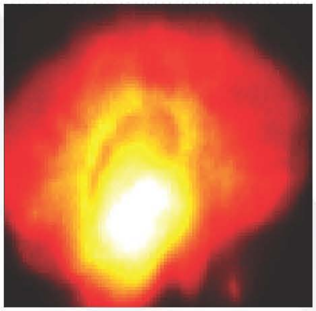
Numerical model of a magnetic field in an induction machine.

ELECTROPHYSICS AND COUPLED PROBLEMS IN ELECTRICAL ENGINEERING

Complex phenomena in electrical engineering require insight into other fields such as electrophysics or electrical power engineering. We use experimental techniques to study dynamic phenomena in electric arcs and thermal plasma jets, which are used in plasma coating, metal cutting or waste disposal technologies. We also develop novel numerical methods for coupled problems in heavy-current and electrical power engineering. These methods are applied in the electromagnetic processing of solid and molten metals, electromagnetic stirring and melting, the pumping of molten metals, hot pressing, thermoelasticity and in the development of electromagnetic actuators (devices converting electrical to mechanical energy).



3D tomographical reconstruction of turbulent thermal plasma jet.



Microphotography of molten hafnium pool at cathode tip of plasmatron cutter. Different colours denote different temperatures of the molten hafnium.

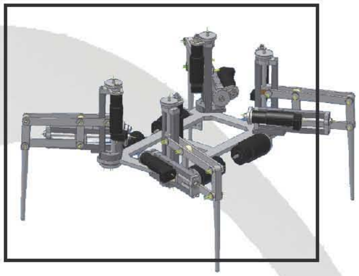
INTERDISCIPLINARY RESEARCH

A significant part of our research is highly interdisciplinary. Our fields of interest include biomechanics, biophysics, mechatronics, robotics or fluid-structure interaction.

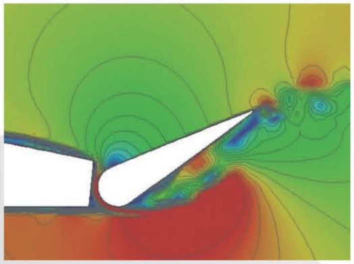
Our biomechanical and biophysical research finds applications in medicine or dermatology. We model changes in bone tissue under dynamic loading, the flow of cerebrospinal fluid or the flow of liquids in elastic tubes (e.g. blood flow through the heart and the bloodstream). We search for the optimum lubrication of hip-joint endoprotheses and study the biomechanics of the human voice or the biophysics of cardiac cells.

Our joint centre with the Brno University of Technology develops methods of Artificial Intelligence (AI) in engineering. These methods are tested and applied in mechatronic and robotic systems of our own design.

We develop theoretical models of interaction between fluid flows and deformable bodies. We are interested mostly in the vibration characteristics and stability limits of aero-hydroelastic systems, mainly the aeroelasticity of airfoils.


Four-legged walking robot for walking gait self-generation verification.


In vivo destroyed ceramic total hip joint endoprothesis.


Numerical simulation of flow around airfoil flutter.

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