

# Profile of the Czech Pilot Centre

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## 1 Introduction

In March 1993, after opening the ERCOFTAC Association to Central and East European countries, the Managing Board accepted the application of the Institute of Thermomechanics for the ERCOFTAC Corresponding membership. The contacts with the ERCOFTAC started after incorporating the research group working on transitional boundary layers into the EC COST Action F1 "Complex three-dimensional viscous flows". Since that time, this group joined the SIG10 Transition to collaborate in creation of the database of experimental data and in the development of closure models.

As the recognition of the contribution of the Institute in the field of Fluid Dynamics, the Czech Pilot Centre was established in the beginning of 2003 with the aim to coordinate international cooperation, exchange of knowledge and participation in the European research and educational projects. The Czech PC was founded with two academic members – Institute of Thermomechanics AS CR, Prague and Nuclear Research Institute, Řež. Two further academic members affiliated to ERCOFTAC during 2003 are the Czech Technical University, Faculty of Mechanical Engineering, Prague and the University of Technology, Faculty of Mechanical Engineering, Brno.

The primary aim of the PC is to support the engagement of the Czech research groups in the international research projects and to coordinate their activities in the ERCOFTAC, especially in Special Interest Groups. As well the PC stimulates collaborative programmes and research projects between academician research institutions and industrial partners.

## 2 Organizational structure

The seat of the Czech Pilot Centre is the Institute of Thermomechanics AS CR. The PC is headed by the coordinator and by the board formed by representatives of Czech ERCOFTAC members. Prof. Jaromír Příhoda is the coordinator for the first period of three years since the establishment of the PC and Dr. Tomáš Bodnár is the secretary. Prof. Karel Kozel and Prof. Jan Macek are members of the Scientific Programme Committee as representatives for research and for industry respectively. The WWW pages of the Centre can be found at the address: <http://www.it.cas.cz/~ercoftac/>.

The Czech Pilot Centre has currently four members from academician institutions: Institute of Thermomechanics AS CR Prague (contact person: Prof. Jaromír Příhoda); Nuclear Research Institute plc, Řež, Department of Thermal Hydraulic Analyses (contact person Dr. Jiří Macek), Czech Technical University in Prague, Faculty of Mechanical Engineering, Josef Božek Research Centre of Engine and Automotive Technology, Prague (contact person Prof. Jan Macek), and Brno University of Technology, Faculty of Mechanical Engineering, Brno (contact person Dr. Pavel Rudolf).

## 3 Research and other activities of ERCOFTAC members

### a) Institute of Thermomechanics, Academy of Sciences of the Czech Republic

The Institute of Thermomechanics deals with fundamental and applied research in applied physics with the aim to the mechanics of solid and fluid phases and their interactions. At present, the research is focused partly on following fields of applied physics - fluid dynamics, thermodynamics, dynamics of mechanical systems, solid mechanics, and material diagnostics, and partly to the solution of interdisciplinary problems, as fluid/body interactions, environmental aerodynamics, and biomechanics. In the field of fluid dynamics and thermo-dynamics, in particular following problems are solved:

- turbulent shear flows and turbulence and laminar/turbulent transition, flow separation including active control of some processes, fluid-body interaction;
- transonic flows in curved channels, especially in blade passages of turbine and compressor stages, secondary flows;
- mathematical modelling and numerical simulation of incompressible and compressible flows in internal, external, and environmental aerodynamics;
- instabilities and coherent structures in isothermal and non-isothermal shear flows (thermal plasma plume, free/confined jets, synthetic flows);
- atmospheric boundary layer over complicated terrain and urban area, modelling of processes connected with flow in atmosphere, dispersion and spreading of pollutants.

Simultaneously with solving of individual problems, experimental methods and measuring techniques as well as device and computer aided equipments are developed. Laboratories of the Institute are equipped with large experimental facilities and with necessary instrumentation.

The research activity is realized partly in the framework of the long-time research plan, and partly by solving of grant projects supported by the Czech Science Foundation and by the Grant Agency of the Academy of Sciences and by other providers – Ministry of Education (some international projects, e.g. COST), Ministry of Industry and Trade (applied research), and international projects supported from the EC budget (5th and 6th Framework Programme).

Further international cooperation is accomplished by force of exchange programmes and bilateral agreements on cooperation. On the basis of these agreements and personal contacts, the Institute collaborates with many foreign reputable institutions, as are e.g. Technical University Czestochowa, Meteorological Institute of Hamburg University, Technische Universiteit Eindhoven, National Taiwan University in

Taipei, Université de Toulon et du Var, von Karman Institute for Fluid Dynamics in Rhode-Saint-Genève, Finnish Meteorological Institute in Helsinki, Institute of Fluid-Flow Machinery of the Polish Academy of Sciences in Gdansk, Institute of Engineering Thermophysics of the Chinese Academy of Science in Beijing.

Besides the fundamental research, the Institute takes part in solving of projects with application character in co-operation with research institutes and with factories, e.g. with the SIGMA Research and Development Institute Lutín, the Aeronautical Research and Test Institute in Praha-Letňany, company ŠKODA Power in Plzeň.

#### **b) Czech Technical University in Prague Faculty of Mechanical Engineering**

*Department of Automotive and Aerospace Engineering – Josef Božek Research Centre of Engine and Automotive Engineering*

The Research Centre has been established as a part of the Czech Technical University using the support of the Ministry of Education for years 2000-2004 and 2005-2009. The Centre provides research and development of spark ignition and diesel engines in the field of thermodynamics, aerodynamics, turbocharging, emissions, motor management, engine dynamics and structural strength applied to the design optimisation. The Centre collaborates in engine aerothermodynamics with VW AG, John Deere, Renault, Mercedes Benz Engineering, and many Czech Companies (ŠKODA Auto, ČKD MOTORY – large bore diesel and NG engine manufacturer, TEDOM – NG co-generation units, turbocharger manufacturers, etc.).

The Centre is an official partner Gamma Technologies, Inc. in applications of GT Suite/GT Power simulation codes for 1-D unsteady compressible flows of gases and liquids and Q-D models of a cylinder. It uses FLUENT, Star CD and FIRE CFD commercial codes together with CHEMKIN package for engine internal aerodynamics/thermodynamics simulations, included into bigger models via domain approach and transfer of boundary conditions or using regression representation of detailed model results (e.g., in chemical problems). This qualified use of commercial software is possible due to the Centre's own activities in creation in-house CFD codes, like AMEM (3-D moveable grid, turbulent reacting flow simulation) and AMEM-Spray (up to now 2.5-D, Euler/Euler unique model of two phase evaporating rare spray, which can be coupled in the future to Euler/Euler dense spray simulation), CYCLE (Q-D engine and turbocharger thermodynamics) or RADTUR (1-D quasi-steady flow in a radial centripetal turbine). The Centre uses PIV and IPI technologies enhanced by endoscopy for experiments of internal engine flows in the real scale.

The Centre takes part in several European integrated projects of the 6th Framework Programme (NICE, GREEN Heavy Duty Engine, applied as a participant for IP Roads2HyCOM and New TREC in Marie Curie programme). It was successful in some simulation and experimental tasks concerning engine combustion and emission simulations (especially using natural gas), turbocharging and engine/vehicle control.

*Department of Technical Mathematics*

Besides teaching in bachelor's, graduate and doctoral study programmes, the Department of Technical Mathematics deals mainly with problems of numeri-

cal mathematics, especially with qualitative properties of numerical solutions PDE describing flow problems (finite difference, finite volume, and finite element methods), and with qualitative properties of Navier-Stokes equations for compressible and incompressible flows. Numerical simulations are concentrated on solution of various physical and engineering problems of fluid dynamics. CFD methods based on modern numerical schemes of FVM and FEM are applied for solution of incompressible turbulent flows in mechanical engineering and biomechanics, internal and external transonic flows in power engineering and aeronautics, and problems of atmospheric boundary layer. All numerical simulations are carried out using in-house developed numerical codes. Turbulence modelling is based on various models including algebraic models, one-equation Spalart-Allmaras model, two-equation models as  $k-\epsilon$  and  $k-\omega$  Menter models as well on explicit algebraic Reynolds stress model.

The long-time cooperation with the Institute of Thermomechanics resulted in the establishment of the common research group dealing with modelling of turbulent flows in turbomachinery. Further, the Department collaborates with many academician and industrial institutions, e.g. with Aeronautical Research and Test Institute Praha, University of Technology Brno, ŠKODA Power Plzeň, PBS Velká Bíteš in the Czech Republic and VKI Brussels, Univ. Gent, TU Dresden, Univ. Toulon, Univ. Barcelona abroad.

The research is supported by Grant Agencies in the Czech Republic (grant projects) and by the Ministry of Education (long-time research plans, research centres) and by the Ministry of Industry and Trade (applied research). The CFD group takes part as well in several projects of the 5<sup>th</sup> Framework Programme EU, as COST projects (COST 715, COST 732) and Thematic Networks (QNET-CFD).

#### **c) Nuclear Research Institute pcl, Řež Nuclear Power and Safety Division Thermal-Hydraulic Analyses Department**

The mission of the Institute is research and development in the field of nuclear technologies (research and services for nuclear power plants aimed at their efficient operation), as well as in the radioactive waste management. Results are also applied in the other, non-nuclear industries, aiming especially at application of the developed computation procedures, analyses and information systems in such industries where risk is involved, implementation of the developed chemical technologies, protection of the environment, and disposal of toxic wastes.

The Nuclear Power and Safety Division provides primarily research and development in the field of nuclear power plants safety and other non-radioactive domains as e.g. power engineering, chemical industry and environmental protection. As well, the division provides expertises and services for operators of the nuclear power plants in the Czech Republic and abroad. The Division has necessary experimental facilities, including zero-power LR-0 reactor, computer centre, as well as an extensive complex of SW tools.

Research activities of the Department of Thermal-Hydraulic Analyses are focused on the utilisation of computer codes from thermal-hydraulics and neutron kinetics area, including 3D and CHF computer codes; development of new methods for evaluation of nuclear power plants safety, including "best-estimate" approach and uncertainty assessment, development of new models for plants computations; computer codes

verification against experimental data, and transfer of the results to a nuclear power plant. As concrete applications, verification of emergency operation procedures thermal-hydraulic analyses related to PTS conditions, analyses of accidents at low power and shutdown conditions, and analyses of flow using CFD computer codes can be mentioned.

Research projects are supported by the Czech Science Foundation, by the Ministry of Industry and Trade, and by State Office for Nuclear Safety. All departments take part in a number of international projects (5<sup>th</sup> and 6<sup>th</sup> Frame Programme EC, in particular EURATOM) and are generally involved in a wide international co-operation (especially in the frame of the OECD).

**d) University of Technology, Brno**  
**Faculty of Mechanical Engineering**  
*Institute of Power Engineering*

Two departments of the Institute of Power Engineering are focused on study of fluid flow and combustion: the *Viktor Kaplan Department of Fluid Engineering* and the *Department of Thermodynamics and Environmental Engineering*.

Research activities of the Dept. of Fluid Engineering are concentrated on flow not only in hydraulic machines (water turbines and pumps), but also in various applications including jetting technologies, waste water treatment devices (multiphase flows), and biomechanics of cardiovascular system. The Department has a long tradition dating back to invention of Kaplan turbine in 1910 in Brno. Particular success, meaning return to these traditions, was achieved with the design of a new type of hydraulic turbine - swirl turbine - suitable for low heads up to 3 meters which was recently developed and patented. First prototypes have already been manufactured and put in operation, while research has been going on aiming on further increase of efficiency and specific speed.

The Department of Fluids Engineering has a strong orientation towards cooperation with industry and provides research and development services to almost all companies producing hydraulic machines and equipment in the Czech Republic. The theoretical research comprises study of flow instabilities (study of vortex rope in draft tubes of hydraulic turbines), flows with moving boundaries (artificial heart) and fluid structure interactions. The commercial software (FLUENT, FIDAP) as well as in-house codes for flows with moving boundaries are used for simulations. The Department disposes of heavy laboratory for testing hydraulic machines and laboratories of fluid structure interaction and biomechanics. Cooperation on European level was established within projects of SurgeNet (5<sup>th</sup> Framework Programme), Socrates/Erasmus and in cooperation with industrial companies (Germany, Austria).

Research activities at the Dept. of Thermodynamics and Environmental Engineering are focused on problems of industrial and residential ventilation, ducting and heat exchangers, fuel injectors and spraying systems, special exhaust system (reinforced or Aaberg exhaust system), dispersion of pollutants in city micro-scale (vehicular tunnels, street canyons, intersections, etc), as well as on use of solar energy for HVAC systems (double skin facade, solar air collectors, solar chimney) and on research of high efficiency recuperators for microturbines and of continuous casting. The research is supported by exper-

imental (LDA, PDA, Mach-Zehnder interferometer) and computational (work stations, computer cluster, various CFD codes) equipment. International cooperation of this department is established within grant projects of EU (5<sup>th</sup> Framework Programme, COST, EUREKA).

## 4 Activity of the PC

The members of the Centre are actively engaged in particular in following topics:

- internal and external aerodynamics, especially compressible flow in blade cascades;
- turbulent shear flows and transition to turbulence;
- multiphase flows;
- combustion in internal combustion engines;
- environmental aerodynamics;
- hydraulics.

Most of ERCOFTAC activities are accomplished by the research groups of the Institute of Thermomechanics AS CR and the Faculty of Mechanical Engineering CTU in Prague. These research groups participated in the 5th FP Thematic Network project TRANSPRETURB "Implementation and Further Application of Refined Transition Prediction Methods for Turbomachinery and Other Aerodynamics Flows" (No.ERBICT20-CT98-0005) and project QNET "A Thematic Network for Quality and Trust in the Industrial Application of CFD" (No.GIRT-CT-2000-05003). During solution of these projects, two test cases were elaborated and included into ERCOFTAC databases – test case T3A+ "Bypass transition on a flat plate" and test case TA6-12 "Steam turbine rotor cascade". These activities are going on in the framework of the SIG10 Transition. Further, environmental problems are studied by the research groups of the Institute of Thermomechanics and Faculty of Mechanical Engineering CTU in Prague in the framework of COST projects COST 715 "Urban meteorology applied to air-pollution problems" and COST 723 "The role of the upper troposphere and lower stratosphere in global change".

A very close cooperation is especially with Polish ERCOFTAC members – the Institute of Thermal Machinery, University of Technology in Czestochowa, and the Institute of Fluid-Flow Machinery, Polish Academy of Sciences in Gdansk. Several Polish – Czech joint research projects were solved and proposed since 2000. These projects are focused on experimental and numerical investigation of transitional boundary layers and turbulent diffusion in internal and environmental flows (Czestochowa) and on investigation of bypass transition and turbulent flows in internal and external aerodynamics (Gdansk).

Since its establishment in the year 2003, the Centre started to be a co-organizer of annual scientific events taking place in the Institute – the conference "Topical Problems of Fluid Mechanics" (organized since 1994 in February) and the colloquium "Fluid Dynamics" (organized since 1992 in October). The aim of these meetings is to bring together experts in theoretical, numerical and experimental fluid dynamics and present latest result of grant projects supported by the Czech Science Foundation and by other providers in the Czech Republic and abroad. As well,

a space is given to doctoral students to present their results. These events are regularly attended by experts not only from academic institutions and universities but from industry as well. Recently, meetings are particularly focused on following topics:

- experimental investigation of shear flows especially effects of transition, wall curvature, vortex structures and flow separation;
- numerical simulation of turbulent shear flows including RANS models, direct and large-eddy simulation;
- applications in the internal and external aerodynamics, environmental aerodynamics and in other fields of mechanical and civil engineering, biomechanics;
- experimental methods and measuring techniques, new experimental facilities and devices.

The Winterschool on "Environmental and Industrial CFD Simulations" was organized at the Institute of Thermomechanics in Prague in February 23-27, 2004 together with the conference on "Topical Problems of Fluid Mechanics". The aim of the Winterschool was to bring together people interested in CFD simulations of environmental and industrial problems and to offer the latest state of the art in theoretical and applied CFD to doctoral students on one hand, and to establish and reinforce the contacts between young specialists from different European countries on the other hand. Eleven lectures were presented altogether and 40 participants from 6 European countries prepared more than twenty posters. The scope of the course covered mathematical background for solution of Navier-Stokes equations including their theoretical analyses and qualitative properties of its solution, numerical techniques from classical finite-difference method to advanced finite-volume and finite-element methods. Further, physical features of turbulent shear flows and various turbulence models used for their solution in environmental and industrial applications were presented. Presented applications covered particularly internal and external transonic flows, free-surface flows and atmospheric boundary layer flows.

The Czech Pilot Centre participated in the ERCOFTAC Spring Course and Conference on "Numerical Simulation of Complex and Multiphase Flows" organised by Université du Sud, Toulon-Var in Porquerolles, France, in April 18-22, 2005. Besides activities during the preparation of the course, two lectures were presented and Czech participants of the course prepared and presented 10 posters covering the numerical simulation of incompressible and compressible flows in the internal aerodynamics (especially in turbomachinery) and in the environmental aerodynamics.

The Institute of Thermomechanics organized together with VUB Brussels the 7th QNET-CFD Meeting in May 28, 2003 and the 3rd QNET-CFD Workshop in May 29-30, 2003 in Prague. The meeting of the ERCOFTAC Managing Board, the Scientific Programme Committee and the Industrial Advisory Committee was held on October 21-22, 2004 in the Institute of Thermomechanics in Prague.

## 5 Future activities

The Pilot Centre intends to support permanently the participation of Czech research groups in international scientific cooperation and in research projects

granted by EU. Further, it will organize scientific events and endorse the exchange of researchers and doctoral students with foreign partners. Finally, the PC will support proposals of common research projects with the aim to recruit new ERCOFTAC members, especially from industry.

## 6 Contact address

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