von Karman Institute for Fluid Dynamics

T U R B O M A C H I N E R Y & P R O P U L S I O N

Project Subjects for Graduation Theses 2014-2015

The TURBOMACHINERY AND PROPULSION Department has facilities for research on the flow in turbomachine components such as compressors, pumps and turbines. Fast response instrumentation and data acquisition systems are available. The theoretical effort concentrates on the calculation of the flow and performance prediction schemes for turbomachinery components.
Several Graduation projects are proposed in each of the following areas:

1. INTERNAL COOLING IN GAS TURBINES

The increased performance of gas turbines calls for higher turbine entry temperatures and higher aerodynamic loadings. Important areas of investigation include the development of efficient internal cooling schemes, the investigation of the flow- and temperature fields, and the development of dedicated instrumentation chains for pressure and temperature measurements.

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2. TURBINE AERO-THERMODYNAMICS

The main research activities in the domain of turbine aerodynamics are related to unsteady wake flow characteristics, wake-blade and shock-blade interferences and the aero-thermodynamics of cooled turbine blades. Progress in the understanding of these complex flow problems depends on the use and/or the development of advanced measurement and testing techniques such as fast response pressure and temperature probes, thin film gauges, data transmission systems and optical methods e.g., Laser Doppler Velocimetry, Particle Image Displacement Velocimetry, holographic interferometry and ultrafast flow visualisation. Students eager to learn and use advanced data acquisition and data processing techniques are welcome to participate in this advanced research.
The use of Computational Fluid Dynamics also plays an important role in the understanding of turbomachinery flow field at different levels. Multistage configurations are analysed with 1D codes, unsteady aspects of the flow field in a stage with quasi-3D or 3D Euler codes and detailed steady aero-thermal flow fields with 3D Navier-Stokes stage calculations.

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3. GAS TURBINE CYCLE ANALYSIS
Supervisor :

This project is related to the analysis and optimization of gas turbine cycles used in subsonic and high-speed propulsion. Performance of the individual components are considered together with the internal heat transfer on steady and transient operation.

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4. AXIAL COMPRESSOR AERODYNAMICS AND STABILITY

Over the past 30 years there has been a continuous research concerning possible benefits of casing treatments for improving axial compressor performance at off-design conditions. This problem has gained recently new interest with the trend to increased blade and stage loading to reduce costs and weight of the engine.
It is proposed to investigate new engine designs, with higher bypass ratios but with reduced weight in order to gain on propulsive efficiency and hence save on fuel burn. It is also proposed to investigate new engine architectures, like geared turbofans or contra-rotating turbofan engines, which would enable substantial noise reductions by lowering the fan speed. All these objectives result in higher stage loadings and require aerodynamic designs which go beyond classical know-how.

Current projects are of both experimental and numerical nature :

- Accurate measurements of the performance of the compressor, its stability margin, including the determination of efficiency by different methods / comparison with CFD.
- Development of accurate temperature probes for efficiency measurements
- Development of entropy probes
- Detailed fast response measurements with unsteady pressure probes (single- and multi-hole pressure probes), comparison with single- and X-hot wires, measurements of inlet turbulence. Comparison with CFD.
- Stall detection probes and investigation stall inception mechanisms.
- Parametric study and numerical optimization of casing treatment configurations.
- Numerical optimization of the 3D aerodynamic design of the compressor stage (lean, sweep, platform contouring).

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5. ADVANCED INSTRUMENTATION TECHNIQUES FOR TURBOMACHINES

Experimental techniques to measure the highly unsteady and three-dimensional flow field in turbomachines have tremendously improved over the last decades. Still higher temperature instrumentation is required, with smaller probe sizes, and better frequency response.
Current projects include :

- Development of fast response directional and static pressure probes.
- Assessment of unsteady errors on measurements (in an axial compressor for example), comparison with CFD.
- Determination of frequency response of a probe system by shock tube tests, development of a fast opening mechanism to determine the frequency response of slower systems.
- Experiments with an infinite line pressure probe used for remote pressure measurements in high temperature environments. Comparison to theoretical predictions.
- Development of ultra-high temperature (2000K) cooled fast response pressure probes.
- Development of high temperature (800K) miniature uncooled fast response pressure probes
- Assessment of turbulence measurements with fast response pressure probes

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6. DESIGN OPTIMIZATION OF TURBOMACHINERY COMPONENTS

This numerical work focuses on automated design optimization techniques to assist the designer in improving the performance of typical turbomachinery components such as axial and radial compressors and turbines in the virtual design environment based on Computer Aided Engineering (CAE) tools. Projects in this field target to improve existing industrial designs in a multidisciplinary context. The successful candidate will explore the paradigm of optimization techniques using a hands-on application while improving the optimization algorithm. The real challenge is to improve aero-performance of components while still satisfying structural integrity including stress and vibration analysis. The multidisciplinary context of this project requires candidates to work with different CFD and CSM codes.

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A E R O N A U T I C S / A E R O S P A C E

Project Subjects for Graduation Theses 2014-2015

The AERONAUTICS/AEROSPACE Department is involved in a variety of research projects with both experimental and numerical aspects. Experimental facilities cover the entire speed range of aerial vehicles from low to hypersonic speed and are equipped with modern instrumentation and data acquisition systems. Numerical projects are concerned with the development of new physical models (e.g. for reacting flows, turbulence, plasma's) and advanced numerical algorithms for solving fluid flow (higher order schemes, solvers, grid generation).
Graduation projects are proposed in the following areas:

1. AEROTHERMODYNAMICS OF RENTRY VEHICLES IN PERFECT GAS TEST FACILITIES

Development of hypersonic vehicles for future access to space or civil transport applications requires improved knowledge of shock-wave boundary layer interactions and transition to turbulence in the hypersonic regime. Experimental and numerical investigations of these phenomena are currently being conducted in the framework of ESA programmes (e.g. EXPERT program for in-flight testing and validation with simulation and ground testing). For the experiments, two VKI facilities are being used : Longshot, which is a free-piston tunnel that produces high Reynolds and Mach number flows of short duration and H3, which produces Mach 6 flow for a range of Reynolds numbers. Topics of current interest include : control surface simulation, heat flux and pressure distribution measurements, instrumentation development, aerodynamic coefficients determination, and facility flow characterization.

1.1 Simulation of Mach 14 Longshot facility

The Longshot is a facility designed to produce a flow for a very short time but at high Mach number and high Reynolds number. This facility can be operated with nitrogen or carbon dioxide.

The purpose of this project is to study the behavior of the piston during all the phase of compression. When the piston is released, it reaches very high speed and a shock appears in front of it. This shock is reflected at the end of the tube before to impact the piston. After several reflections, the pressure can reach up to 4000 bar and the piston stops at the end of the tube.
Tools are now available for 1D modelisation of the behavior of the piston. This new program has first to be adapted to the Longshot configuration. The final objective is to be able to define new conditions with nitrogen, carbon dioxide or other gases. A correct modelisation can also be used to improve the capability of the tunnel by increasing the Reynolds number or the enthalpy. This new tool gives the possibility to investigate the use of the tunnel with air in order to obtain more real gas effects…
The project consists mainly in programming the new code. Existing experimental data will be used for comparison. Participation to new measurements can eventually be included.

This project requires capabilities in numerical modelling, aerodynamics and thermodynamics.