FOREWORD

Dear Attendee,

The Royal Military Academy is a federal university embedded within the Belgian Defence and is among other things responsible for the graduate and post-graduate education of a major part of its officers. Research plays an important role in supporting the educational program. Therefore the Academy is pleased to welcome you on its campus.

It is the intention of the organizers to promote NCTAM 2012 as a meeting place where scientists and engineers from several communities can meet to discuss current research topics related to mechanics. As a national congress, NCTAM 2012 offers young researchers a first experience as well the opportunity to meet accomplished researchers. It is also the place to foster links at national level, exchange knowledge and dress up the map of national research teams with their respective skills.

This year’s 9th National Congress is in line with the tradition initiated in 1987. The scope covers all major aspects of mechanics, ranging from theoretical, methodological and scientific developments to a large variety of application areas. Relevant topics for the symposium program include:

- Applied Thermodynamics
- Biomechanics
- Computational Methods
- Damage
- Education Engineering
- Experimental Techniques
- Fluid mechanics
- Heat transfer and Thermal Analysis
- Kinematics and Dynamics
- Machine Design
- Manufacturing Engineering and Production Systems
- Rheology
- Mechatronics and Robotics
- Solid Mechanics
- Structural Mechanics
- Theoretical Mechanics
- Vibration, Noise and Waves

I take this opportunity to thank both the scientific and local organizing committee for all the work done during the preparation and execution of this congress.

Also the support of the National Committee for Theoretical and Applied Mechanics is greatly acknowledged.

On behalf of the organizing and scientific committees I wish you a pleasant and fruitful congress,

Walter BOSSCHAERTS
Conference Chairman
UNSTEADY THREE-DIMENSIONAL FLOWS IN HIGH-SPEED COMPRESSORS: 20 YEARS OF UNIVERSITY/INDUSTRY PARTNERSHIP

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Understanding of complex unsteady flows and aerodynamic instabilities in turbomachinery justifies coordinated projects between the scientific and industrial communities. This partnership led to develop two test rigs of strong power for the studies of the aerodynamics in high-speed compressors. These compressors, hosted at the Fluid Mechanics and Acoustic Laboratory (LMFA) at Ecole Centrale de Lyon, are rare tools for experimental studies. The main themes of the present lecture are (i) about the unsteadiness associated with blade-row interactions with a time-average effect on compressor performance and (ii) about the surge inception.

The lecture presents some results of a research program on transonic centrifugal compressors of high-pressure rate ($\approx 9$) used in helicopter engines. This program has been undertaken for twenty years within a cooperative framework between LMFA, Turbomeca and ONERA. During this work, both experimental and numerical approaches were successfully used and proved to be very complementary. On one hand, numerical simulations allow detailed investigations for a reasonable cost but their predictive capacity for very complex flows remains questionable. On the other hand, experiments are very useful to validate numerical models and to provide reliable data but induce high costs. Moreover, experiments are up to now the only confident approach for investigating instabilities and transient phenomena.

The centrifugal compressors were mounted on the 1MW test rig equipped with steady sensors (temperature, pressure, and vibration measurements) dedicated to health monitoring and overall performance measuring. Laser anemometry measurements were performed to obtain velocity fields. Unsteady pressure measurements were carried out during stable operation as well as during unstable operation when the compressors came into surge.

The computations were performed with the elsA software developed at ONERA. The elsA CFD code solves the RANS equations associated with the two equations ($k-l$) turbulence model using a cell-centered approach on multi-block structured grids. The steady-state simulations used a mixing plane method for the flow communication between the blade rows. In the inter-blade plane, conservative flow quantities are circumferentially averaged but their radial variations are preserved. The unsteady simulations were performed using a phase-lagged approach assuming that the unsteady effects are only due to the rotation, which excludes external unsteady causes.

In order to assess the effects of unsteadiness on performance, the time-averaged figures of merit (efficiency/loss and pressure rise) calculated from the experiments, the unsteady simulations and the steady-state simulations are compared. The shift in performance due to the steady-state approach is quantified through a detailed analysis of the time-dependent local flow structures. This study led to link the overall performance to local flow behaviour. At low mass flow rate, the flow phenomena that limit the stable operating range of modern centrifugal compressor stages with vaned diffusers are detailed together with the flow mechanisms which trigger the surge. Finally, the prospect of enhancing the operability range by implementing control techniques is discussed.
ENGINEERING A LOW NOₓ HYDROGEN FUELLED GAS TURBINE

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A lot of research effort is spent worldwide in order to reduce the environmental impact of the transportation and power generation sector. To minimize the environmental pollution the role of hydrogen fuelled gas turbines is intensively discussed in several research scenarios, like the IGCC-technology or the application of hydrogen as large scale storage for renewable energy sources. The adaptation of the applied gas turbine combustion chamber technology and control technology is mandatory for a stable and secure low NOₓ operation of a hydrogen fuelled gas turbine.

Against the background to evolve a secure and low NOₓ combustion of hydrogen the micromix burning principle is developed since years. This combustion principle is based on cross-flow mixing of air and gaseous hydrogen and burns in multiple miniaturized diffusiontype flames. The two advantages of this principle is the inherent safety against flash back and the low NOₓ-emissions due to a very short residence time of reactants in the flame region of the micro-flames.

The intention of the current scientific research work at Aachen University of Applied Sciences is to improve the operational behavior of low NOₓ hydrogen fuelled gas turbines. This included the experimental characterization and further improvement of the micromix combustion principle, the design of a combustion chamber scalable for industrial gas turbine applications and the improvement of the gas turbine’s control and metering technology.

The experimental characterization of the micromix combustion investigates the impact of several geometrical key parameter influencing the formation of NOₓ-emissions.

The improved combustion chamber design concept includes the experiences gained during the experimental characterization and covers the industrial needs regarding scalability and manufacturability.

In order to demonstrate gas turbine integration effects and safe engine control in a hydrogen-fuelled gas turbine a test bench with an Auxiliary Power Unit GTCP 36-300 is used. A new hydraulic fuel metering unit has been designed and implemented. The hydrogen-fuelled gas turbine as well as the hydrogen metering unit are controlled by a standard industrial engine controller, modified for the hydrogen operation. The combination of the micromix combustion principle and of the optimized control and metering technology allows a stable, secure and low NOₓ hydrogen-fuelled gas turbine operation.
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