The Department of Mechanical, Energy, Management and Transportation Engineering, DIME, University of Genoa



MicroNOx

Innovation for high efficiency multi-fuel ultra low NOx micro-gas turbine for distributed energy cogeneration

Presented by Pietro Zunino

Professor of Turbomachinery

University of Genoa (Italy)

DIME - Department of Mechanical, Energy, Management, and Transportation Engineering

Aerodynamics and Turbomachinery Laboratory

Activities



University of Genoa, Department of Mechanical, Energy, Management and Transportation Engineering: TURBINE



University of Leeds: COMBUSTOR



Ecòle Centrale de Lyon- Laboratoire de Mécanique des Fluides et d'Acoustique (LMFA): COMPRESSOR



Karlsruhe Institute of Technology: ADVANCED NUMERICAL SIMULATIONS AND RECUPERATOR



Institute of Fluid-Flow Machinery - Polish Academy of Sciences: TRANSONIC FLOWS



RSE - Ricerca sul Sistema Energetico: CERAMIC MATERIALS AND SYSTEM

Innovation for high efficiency multi-fuel ultra low NOx micro-gas turbine for distributed energy cogeneration

MicroNOx

Multidisciplinary optimization of turbine and compressor

Advanced time-dependent numerical simulations

Ceramic materials

High effectiveness recuperator

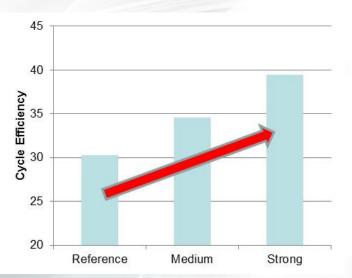
Multi-fuel ultra low NOx combustor

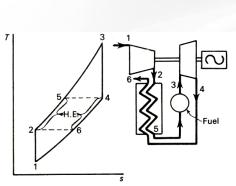
Cycle analysis

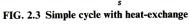


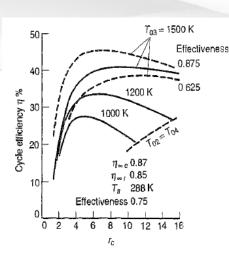
Cycle parameters sensitivity analysis – thermodynamic cycle code

Effect of three components optimisation: compressor + turbine + HX









Medium Optimisation:

Compr. Efficiency + 2 pt
Turbine Efficiency + 2 pt
HX effectiveness + 5 pt

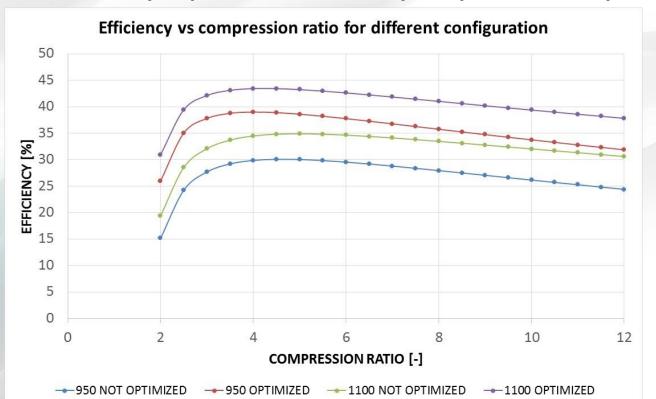
Strong Optimisation:

Compr. Efficiency + 4 pt
Turbine Efficiency + 4 pt
HX effectiveness + 10 pt

Cycle analysis



Cycle parameters sensitivity analysis – thermodynamic cycle code

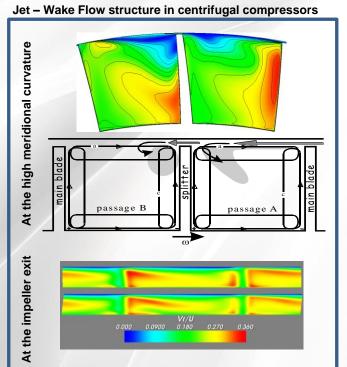


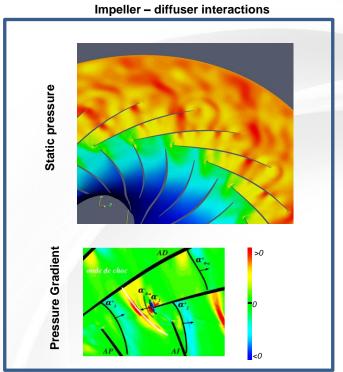
Original:	
Compr. Efficiency	0.80
Turbine Efficiency	0.86
HX pinch point	70 °C

Optimised:	
Compr. Efficiency	0.84
Turbine Efficiency	0.90
HX pinch point	30 °C

Compressor design: internal flow analysis

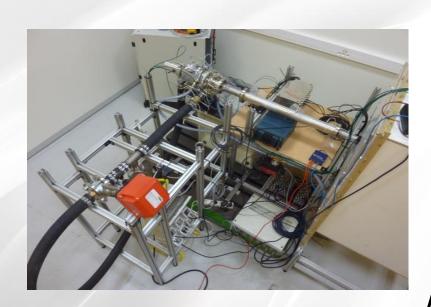






Compressor design: experimental validation

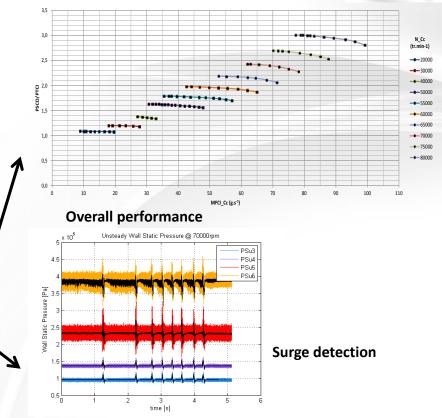




LMFA Test rig for small centrifugal compressors for

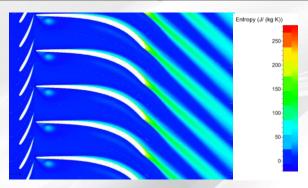
- Health monitoring
- Time-dependent mass flow measurement
- Fast pressure sensors
- PIV

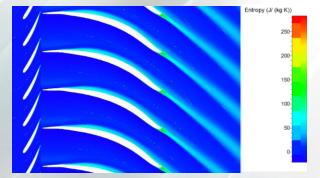




Turbine design: aeromechanical optimization results

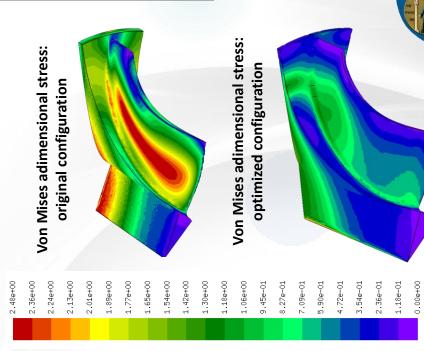
 $\sigma_{VM_ad} =$





Entropy: optimized configuration

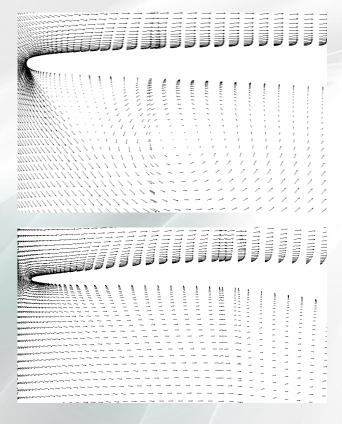
Reduction of viscous losses in the optimized configuration



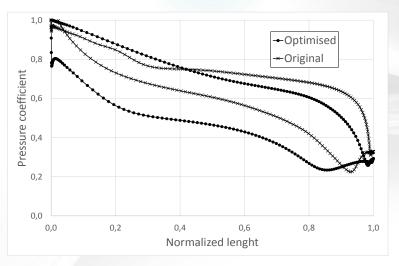
In the original configuration there is a high stress mainly due to the lean angle of the blade. Optimised configuration shows lower level of stress and stress peak is concentrated in the fillet radius, where local plastic strains are allowed.

Turbine design: aeromechanical optimization results





Velocity vector for original (top) and optimized configuration (bottom)



Pressure coefficient diagram for original and optimized configuration at midspan

In the optimised case the optimisation tool increases the tangential component of the absolute velocity at the rotor, thus minimizing the incidence angle at the impeller leading edge. This re-establish a right incidence condition to the impeller as well as by the absence of recirculating flow region

Turbine design: aeromechanic optimization results



	Original	Optimised
$\dot{m}\left[kg/s ight]$	0.907	0.769
$\eta_{t-t}\left[- ight]$	0.872	0.927
Power [kW]	250.24	246.17
U/C _o	0.655	0.651
Stress usage factor [–]	2.54	0.98
Resonance 4EO	Yes	No
Resonance NPF	Yes	No

Stress usage factor =	$\sigma_{Von\ Mises}$
Stress usage factor =	$\sigma_{allowable}(T)$

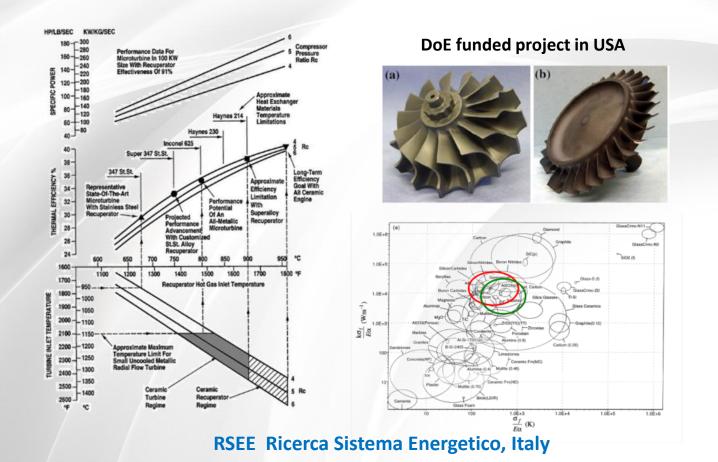
Allowable stresses have been calculated according to metal temperature in each impeller location

Multidisciplinary optimization enabled to achieve the following goals:

- high efficiency (92.7%); no separated flow regions;
- Von Mises stress field below the allowable limits, defined as a function of temperature;
- free from resonance behaviour of the impeller, in the speed operating regime, for the sources of excitation considered.

Studies on materials and coatings for a ceramic





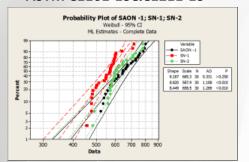
Studies on materials and coatings for a ceramic



RSE facilities&expertise



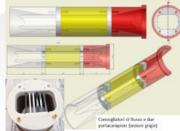
RT an HT 4 point bending test ASTM C1161-13&C1211-13





Thermal shock ASTM C1525-04



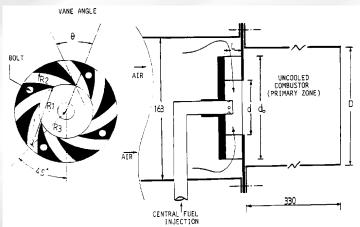


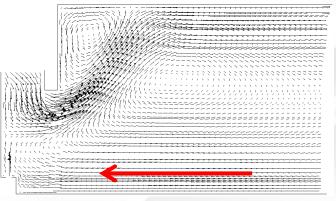
Burner rig with tunable steam content up to 1400°C

Combustor design



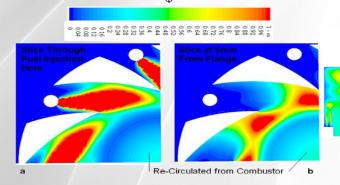






Central reverse flow gives high internal EGR for low NOx and good flame stability

Fuel mixing in the radial passage



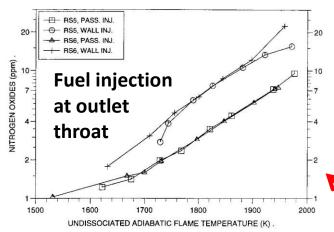
Turbulent kinetic energy



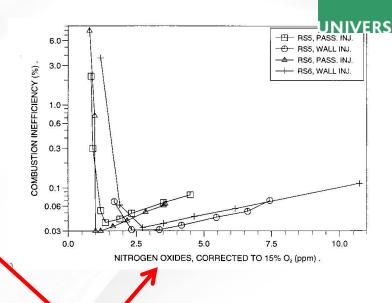
Concentrated shear layer turbulence for good fuel and air mixing

University of Leeds, UK

Combustor design







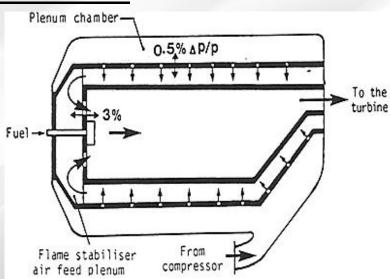
Lowest NOx in the literature for both circular and rectangular cross section radial passages of constant area with vane passage fuel injection.

Addition of an outlet duct can increase mixing and reduce NOx, but the same can be achieved with an outlet shroud

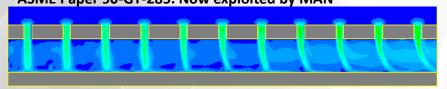
University of Leeds, UK

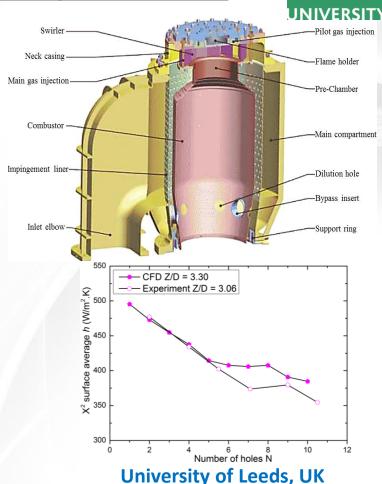
Combustor design: Regenerative Cooling of Low NOx

Combustors



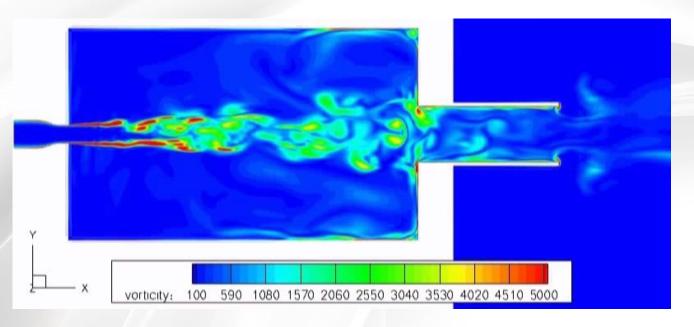
Abdul Husain, R.A.A. and Andrews, G.E. (1990).
Full Coverage Impingement Heat Transfer at High Temp.
ASME Paper 90-GT-285. Now exploited by MAN





Combustor design: Simple Helmholtz resonator with LES



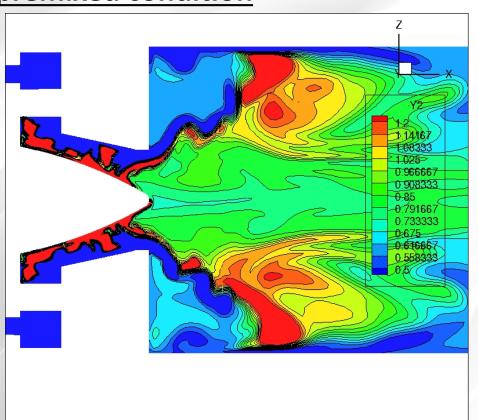


Computational time: 100 h using 64 processors for 4.5*10⁶ control volumes

Karlsruhe Institute of Technology, Germany

Combustor design: calculation with non perfectly premixed condition



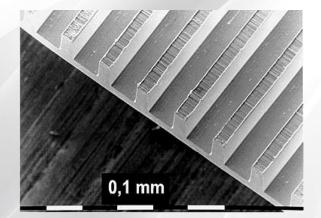


Large Eddy Simulation

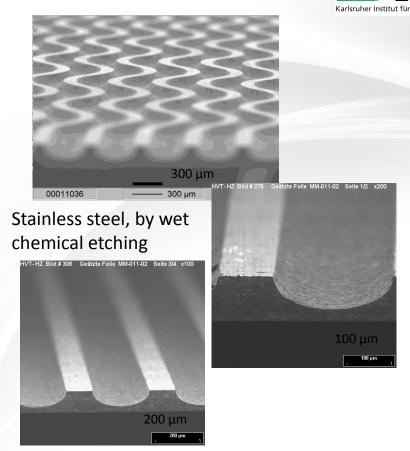
Equivalence ratio in the symmetry plane

Manufacturing of Miniaturized Equipment

Mechanical Micromachining



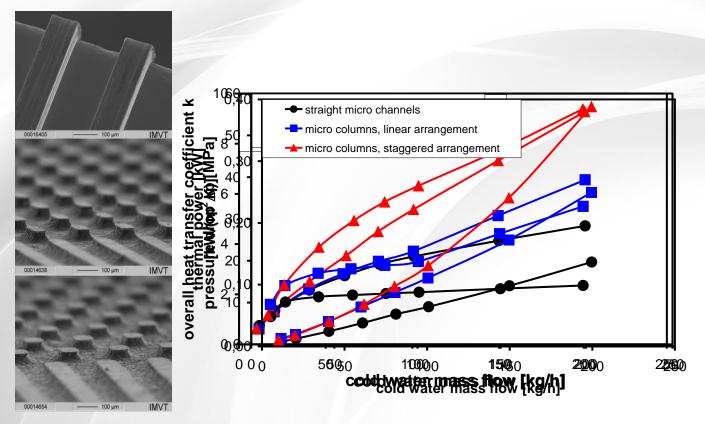
Copper, by micro-milling



Microstructure Heat Transfer Devices

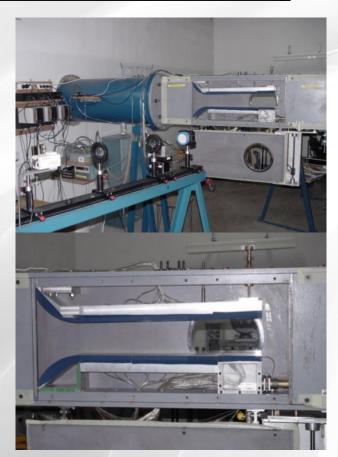
Micro Heat Exchangers with different geometries integrated





, Karlsruhe Institute of Technology, Germany

Transonic flows test rig



Experimental tools

Test Section:

1800mm x 350mm x 100mm

Vacuum Tanks: 120 m3

Pump Unit: 2300 + 700 m3/h Evacuation time: 5, 20, 35 min

Blow down time (100mm 12 100mm throat:)~20 sec.

Drying Unit: silica gel, layer of 1 m height, 2.5 m diameter; 70 kW heating

system (end temp. 150°C). Measurement Equipment:

Pressure: -digital barometer DRUCK,

- pressure transducers KULITE and DRUCK
- intelligent pressure scanners PSI System

9010, 4 x 16 channels,

- computer controlled pneumatic probe
- PSP Pressure Sensitive Paint Optics:
- Schlieren system, SPECLE method
- Mach-Zehnder interferometer,
- CCD technology for picture registration
- PIV system of DANTEC.



Combustion Laboratory Facilities and Expertise

The DIME Combustion Laboratory is intended to perform a whole range and high quality analysis of gas turbine

combustors

- RIG-500 Test rig for combustive flow designed for full LPP burners

- √ 200 kW Electrical Air Pre-Heater
- √ 440 kW Gas fuelled Pre-Heater
- ✓ Mass Flow Rate up to 2 kg/s (atmospheric condition)
- ✓ Inlet Air Temperature up to 700 K
- ✓ Optical Access to the Flame Area
- √ Variable Length Test Section
- ✓ Maximum Operating Pressure 6 bar





The rig is typically operated using natural gas, but even non-conventional gas mixtures, such as Hydrogen Rich Syngas Low-BTU gases, Biogas may be tested

It is fully equipped with cooled pressure transducers, IR thermo camera, thermocouples, spectrophotometer and combustion instability optical detector PIV, LDA, PDA, LIF Instrum.

