Sperimentazione e Ottimizzazione Avanzata Applicate a Progettazione e Sviluppo di Turbomacchine

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Test Rigs and Resources for Numerical Analyses

- Close Rig for Centrifugal Pumps
- Open Rig for Axial Pump
- Open Rig for Centrifugal Pump
- Open Rig for Francis and Kaplan Turbine
- Open Rig for Pelton Turbine
- Micro Pump Test Lab
- Low Velocity Wind Tunnel
- 3 Test Rigs for Fan

- Cluster of about 120 CPU with an average clock of 2.67GHz
Research Activities on Turbomachineries

- Pump and Hydro Turbines
- Micro Pumps
- Fan
- Wind Turbine
- Gas Turbine
- Transonic Compressors
- Turboshift
Multi-objective Optimization Algorithms

Principal Investigators: Ardizzon G. Benini E.

Decision Variables

\[ \mathbf{X} = (x_1, x_2, \ldots, x_n) \]

Mathematical Model

\[ \mathbf{F}(\mathbf{X}) = (f_1, f_2, \ldots, f_m) \]

Optimization Algorithm

Response Surface

\[ \widehat{\mathbf{F}}(\mathbf{X}) = (\widehat{f}_1, \widehat{f}_2, \ldots, \widehat{f}_m) \]

Pareto Optimal Solutions

\[ \mathbf{X}^* = (x^*_1, x^*_2, \ldots, x^*_n) \]

Response surface types available:

- Parametric models;
- Nonparametric models;
- Artificial Neural Networks;
- Multivariate splines;
- Radial basis functions;
- Support vector regression;
- Regression Kriging;
- Moving Least Squares;
- …

Algorithms types available:

- Non Linear;
- Geometric;
- Dynamic;
- GA;
- PSO;
- Hybrid;
- Neural-Network-Based;
- Stochastic;
- …
Principal Investigators: Ardizzon G. Pavesi G.
Optimization of the cavitating behaviour and of the performance and size reduction in cellular/multistage pump design

Principal Investigator: Ardizzon G.
Micro Pumps
Performance Optimization

Principal Investigator: Pavesi G.

Applications:
- Biomedical
- Micro cooling

Turbomachinery and Energy System Group
Prof. G. Pavesi | Sperimentazione e Ottimizzazione Avanzata Applicate a Progettazione e Sviluppo di Turbomacchine
Giornata di studio sulle Turbomacchine - Bergamo, 15 Luglio 2016
Micro Pumps
Performance Optimization/ Blood Volume Damaged Reduction

Principal Investigator: Pavesi G.
Hydro Turbine
Optimization of the Pelton Bucket Geometry

Optimization of the Pelton bucket geometry by hybrid Eulerian-Lagrangian numerical approach

Variable-speed Pelton turbine

Principal Investigator: Pavesi G.
The use of a variable-speed system led to an increase of the plant’s average efficiency of about 11% that can be translated into an extra 300 MWh production each year.

- Commissioning tests have been carried out in a 12 months period
- Results showed correspondence with the data obtained by experimental trials

Principal Investigator: Pavesi G.
1. **Describing** the formation of clouds

2. **Understanding** the dynamic behavior of clouds and its consequences
   - collapse, impact

3. **Predicting** the surface stress by collapsing clouds and bubbles
   - material damage

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Principal Investigator: Pavesi G.
Principal Investigator: Pavesi G.

- Influence Scale/rpm Effects
- New Standardized Design Criteria
- Strict Control of Cavitation
Principal Investigator: Pavesi G.
Hydro Pump/Turbine Storage
Load Reduction Scenario

Principal Investigators: Pavesi G. Cavazzini G.

Turbine

Unstable operating zone

- Stable points
- Turbine brake
- Runaway

Pump

Legend

Hump Region

Legend

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Fan
Energy Consumption
Noise Reduction

Principal Investigator: Pavesi G.

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Giornata di studio sulle Turbomacchine - Bergamo, 15 Luglio 2016
Horizontal Axis Wind Turbine
Coupled Aerodynamic-Structural Wind Turbine Blade Optimization

Principal Investigator: Ernesto Benini
Group: Andrea Dal Monte, Stefano De Betta, Gabriele Bedon, Hagar Elarga

Objectives: Maximize Annual Energy Production (AEP), Maximize rotor stiffness, Maximum aeroelastic response under lateral flow and wind gusts.

Methodology: in-house Multi-objective surrogate-assisted optimization algorithm + validated aero-codes (BEM and/or CFD) + FEM structural codes

Achievements: Composite layup optimized along with chord/twist distribution (Pareto solutions); Optimal rotor configuration for unsteady gusts
Vertical Axis Wind Turbine
Aerodynamic-Structural VAWT Turbine Blade Optimization

Principal Investigator:
Ernesto Benini
Group: Andrea Dal Monte, Stefano De Betta, Gabriele Bedon, Hagar Elarga

Objectives: Maximize rotor total torque and maximize rotor upwind torque

Methodology: 2D URANS + FEM

Achievements: New profile named “WUP 1615” characterized by a peak power coefficient value 8% higher than the baseline configuration (patent pending).
Vertical Axis Wind Turbine
Self Starting Turbine

Principal Investigator: Pavesi G.

- Urban and Sub-Urban Area:
  - Low Visual Impact
  - Low Noise < 30 dB
  - Power < 3 kW

![Graph showing performance characteristics of a wind turbine](image-url)
Gas Turbine (LPT)
Multi-criteria turbine cascade optimization

Principal Investigator: Ernesto Benini (EU Clean Sky “iTURB”, Topic Leader: GE-Avio)
Group: Lorenzo Dalmas, Francesco Pellegrino, G. A. Misté

Objectives: Assess best strategies for LPT optimization including efficiency, weight, acoustics, structural objectives

Methodology: Gradient-based vs. population-based vs. DOE+surrogates algorithms and quasi 3-D code

Achievements: Best strategy for preliminary to detailed multi-criteria optimization
Transonic Compressor
Transonic compressors optimization

Principal Investigator: Ernesto Benini
Group: Francesco De Vanna, Roberto Riollo, Giovanni Venturelli

Objectives: Maximize rotor efficiency, pressure ratio and stall margin

Methodology: in-house Multi-objective surrogate-assisted optimization algorithm + validated aero-codes

Achievements: -1.5% reduction in total pressure losses, +8% in pressure ratio, +4% in stall margin
Turboshaft

Multi-objective optimization of turboshaft air intakes and exhausts

Principal Investigator: Ernesto Benini
Group: Andrea Garavello, Rita Ponza (EU Clean Sky “TilTOp”, Topic Leader: AgustaWestland)

Objectives: Maximize Intake/exhaust pressure ratio, minimize flow distortions

Methodology: in-house Multi-objective surrogate-assisted optimization algorithm + validated aero-codes

Achievements: -2.1% reduction in fuel consumption in cruise, -1.5% in hover (experimental). Tests conducted at RUAG wind Tunnel (CH).
INDUSTRIAL FANS DESIGN:

i) High-efficiency tube-axial fans

ii) Cross-flow fans

Massimo MASI ¹ et al. ²

University of Padova

¹ Department of Management and Engineering
² Department of Industrial Engineering
MASI et al.

i) High-efficiency tube-axial fans

- From experimental testing & validated CFD models
  ➔ Operation of actual non free-vortex bladings [1]
From basic theory for swept fan rotors:


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i) High-efficiency tube-axial fans
• From experimental analysis of cross-flow fans:

**Optimal design under casing constraints [6]**


Research on Turbomachinery

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Bergamo 15 luglio 2016 - Giornata di studio sulle Turbomacchine: «I gruppi di ricerca delle Università Italiane incontrano le imprese»
Design of turbines for ORC applications

Aim: predicting the design and efficiency of axial/radial turbines operating with any kind of organic fluid.

Fig. 1. Model's flowchart: dotted arrows indicate updates for guess values.

Fig. 5. Schematic representation of turbine stage meridional channel.
Inclusion of turbine efficiency maps in a design optimization tool of ORC systems

Max ORC system efficiency (black point) is generally obtained at non-max efficiency of the turbine

References: