Key partner in Design Process Innovation

Cloud computing simulation for improvement of turbomachinery efficiency & renewable energy

M. Andreoli, A. Arcidiacono – EnginSoft S.p.A.
R. Bergamin – ZECO S.r.l

Outline

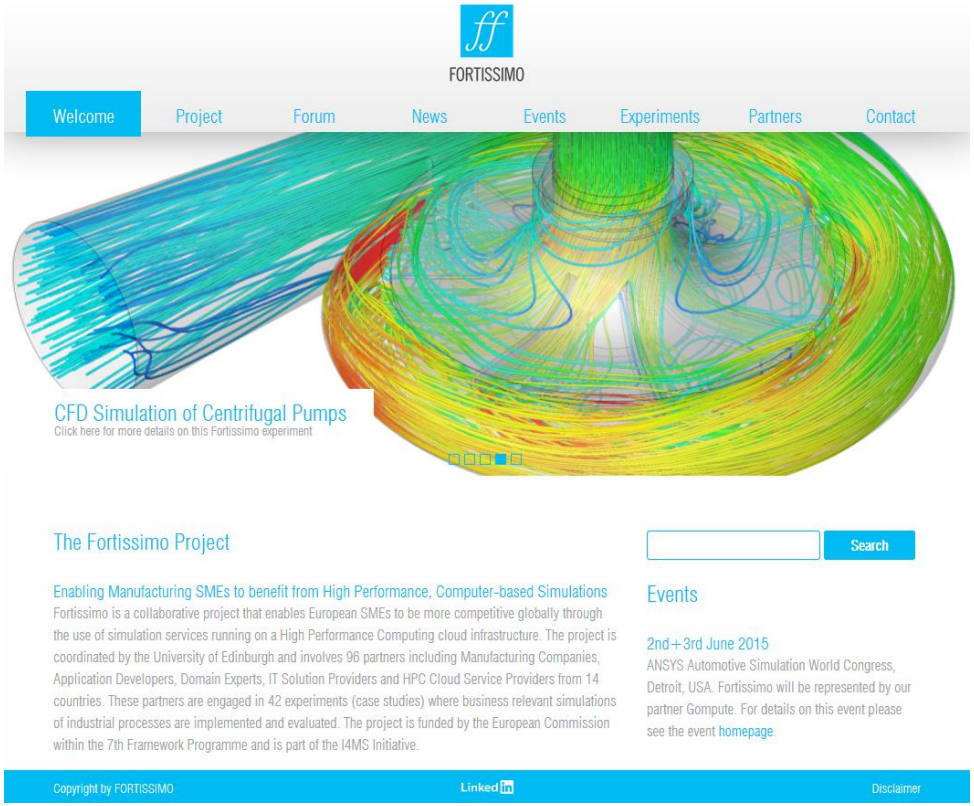
- Fortissimo project
- Partners
- Turbomachinery
  - *Centrifugal Pump*
- Renewable energy
  - *Hydro Power Turbine*

Fortissimo Project

- *Collaborative project that enables European SMEs to be more competitive globally through the use of simulation services running on a High Performance Computing cloud infrastructure*

- *96 partners*
- *14 countries*
- *42 experiments (case studies)*
- *Coordinator : University of Edinburgh*

- *More details:*
  - *http://www.fortissimo-project.eu/*



Project founded by EC within the 7th Framework Programme

Partners

- End User: SMEs
- Application Expert: EnginSoft
- HPC Expert: CINECA
- Software:
  - ANSYS WORKBENCH
  - ANSYS MESHING
  - ANSYS CFD
    - ANSYS BladeEditor/Turbogrid
    - ANSYS CFX
- HPC Provider: CINECA
- Host Centre: CINECA

EnginSoft – Who we are

- Italian channel partner (distributor) for ANSYS, Inc
- # employees
  - more than 120
  - ~80 engineers
- Offer:
  - About 30 years experience in CAE consultancy (more than 1000 projects)
  - CAE software training: CFD, FEM and EMG (ANSYS), optimization (modeFRONTIER)
  - Co-funded EU research projects (order of 10s)

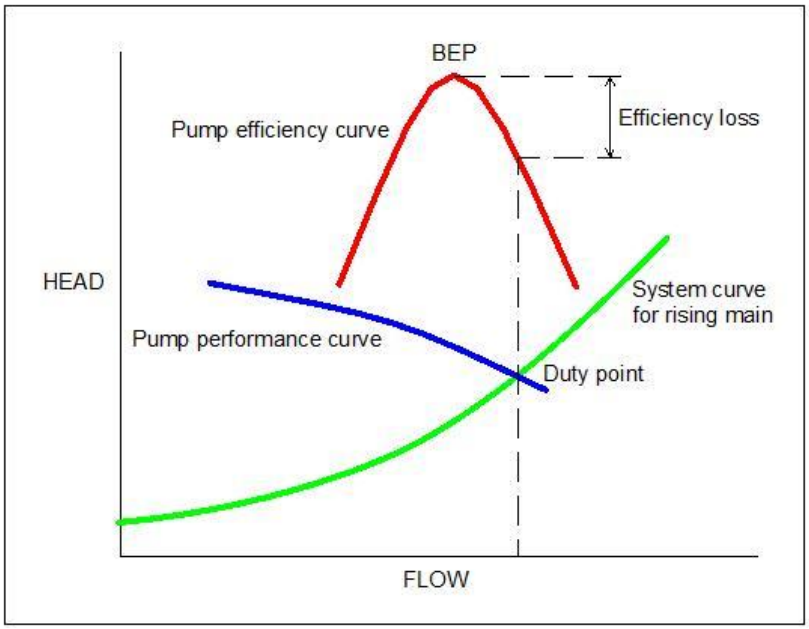
TURBOMACHINERY

Business Relevance – Market

- Selected device: centrifugal pump
- Why? Because they are widely used in many industrial applications, from oil&gas to power generation, from automotive to water treatment → good potential interest

Business Relevance – Market

- Today, the pump designer from a typical SME has to cope with 2 key points:
  - competitive market sale target
  - strict energy efficiency regulations
- The designer is driven to “raise the bar” and he knows that a few % points often make the difference in a sale scenario.
- Hence an accurate prediction tool coupled to a computing system easily accessible, like Cloud computing, will allow SMEs to gain a competitive edge.



Business Relevance – Market: CFD

- Pumps may be required to operate over a wide flow range, so a reliable prediction of characteristic curves (performance and efficiency) is essential for designers.

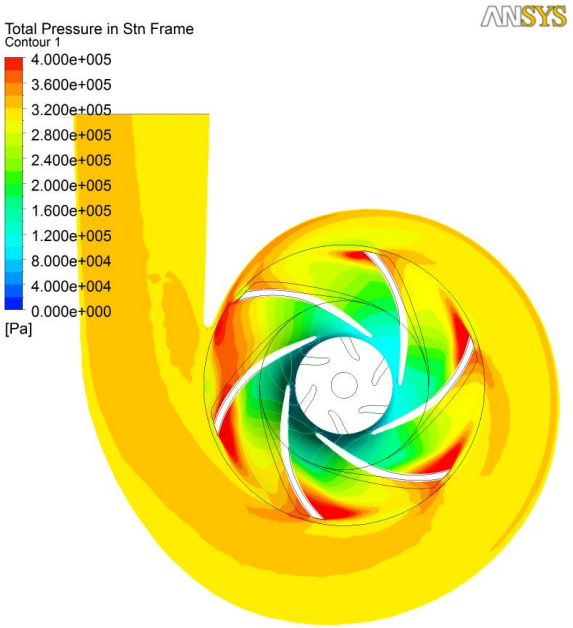
- Unfortunately, all theoretical methods and experimental tests are unable to gain insight of performance.

- In these terms, Computational Fluid Dynamics (CFD) becomes an important and common tool for pump designers.

Business Relevance – Why CFD

- Many tasks can numerically be solved much faster and cheaper than by means of experiments and, most important, the complex internal flows in water pump can be accurately predicted.

- As a result of these factors, CFD is now an established industrial design tool, helping to reduce time to market and improve processes throughout the engineering world.



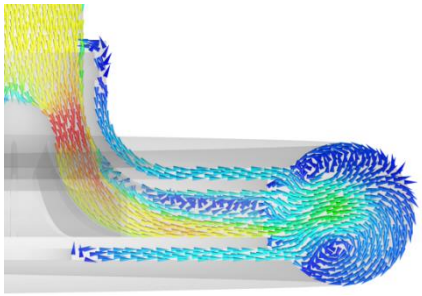
Business Relevance – Why CFD

- Numerical simulation of centrifugal pumps is not easy due to some difficulties:
  - complex geometry
  - unsteadiness
  - turbulence
  - secondary flows
  - separation
  - boundary layer
  - etc.

- In terms of application of CFD, these aspects require *high fidelity CFD models*, or, in other words, very fine computational grids and transient analysis.

Business Relevance – Why CFD

- Low fidelity CFD tools are available on the market, but they are suitable just for a rough sizing of the turbomachinery.
- However, due to the high competitive world-wide market, high fidelity solutions *are necessary* to take into account:
  - secondary flows → responsible of 5% to 20% efficiency reduction respect to simple low fidelity analysis



  - transient analysis → high fidelity solution are 2-5% more accurate in terms of efficiency respect to simple low fidelity analysis
- NB: current regulations requires at least 75% efficiency at BEP

Business Relevance – An example

- Industry: oil&gas
  - Requirements from customer:
    - 100 centrifugal pumps installation
    - Minimum efficiency: 80% (regulations and customer consumption target)
- SME: develop a new design for the pump through 2 different approaches:
  - Low fidelity CFD analysis
    - Such target cannot be reached with a simplified steady state analysis
    - Many key details (unsteady behaviour, turbulence, secondary flows, etc.) are not modelled

    → SME is NOT able to satisfy customer's requirements! **ENTRANCE BARRIER**
  - High fidelity CFD analysis
    - All the fluid flow details can be captured → thanks to this deep knowledge the designer can reach better and better performance for his design

    → SME is able to satisfy customer's requirements!

Business Relevance – An example

- How much do these approaches cost?
  - Low fidelity
    - Low CPU time (1x)
    - Low licenses cost (1x)
  - High fidelity
    - High CPU time (~10x)
    - Higher licenses cost (at least 2x)

- *High fidelity vs. low fidelity: difference between a SME leader on the market or out of the market*

Business Relevance – Why HPC

- The high fidelity approach, which call for a scale-up of computer resources, is quite prohibitive for a typical Italian SMEs scenario, where EnginSoft operates:
  - a quite large number of simulations is required to verify the performance of each design
  - each simulation runs for ~160h, operating on 16 parallel threads on EnginSoft systems
  - typical SMEs installations do not comprises more than a single solver license with 8 parallel threads, and this license cannot be blocked for a long period of time

Business Relevance – Why HPC

- Why CLOUD HPC computing:
  - Design process implies uneven computing loads needs, with peaks where local cluster may be insufficient followed by periods where it could remain underutilized
  - Once the setup is done the workflow is easily customizable for optimization parameter sweeps

Business Relevance – SME

	Low-Fidelity (local)	High-fidelity (local)	High-fidelity (HPC Cloud)
Type of infrastructure	Workstation	Small cluster	Large cluster
Type of simulation	Steady state	Transient	Transient
# cores	≤ 8	8-32	≥ 32
# of licenses	1 HPC pack	1 / 2 HPC packs	≥ 2 HPC pack
CPU time required	2-3 days	2-3 weeks	≤ 1 week
Costs	Local workstation: 5k€ Licenses: 20k€	Hardware: small cluster 100k€ Maintenance: 40k€/y Licenses: 40k€	Pay-per-use CPU hour + licenses

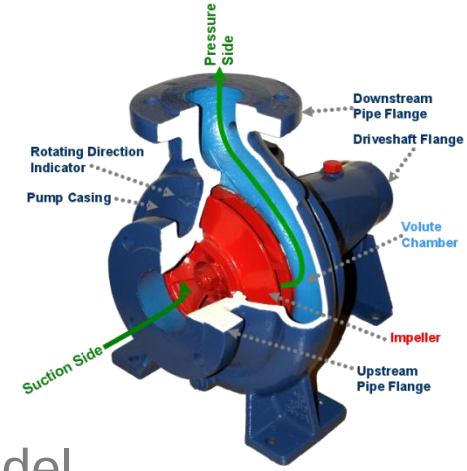
Business Relevance – SME

- So the aim of the Fortissimo HPC Cloud solution is to provide an *extremely attractive solution* in terms of business and technological perspective for any SME which can hardly deal with high fidelity calculations by its own efforts.

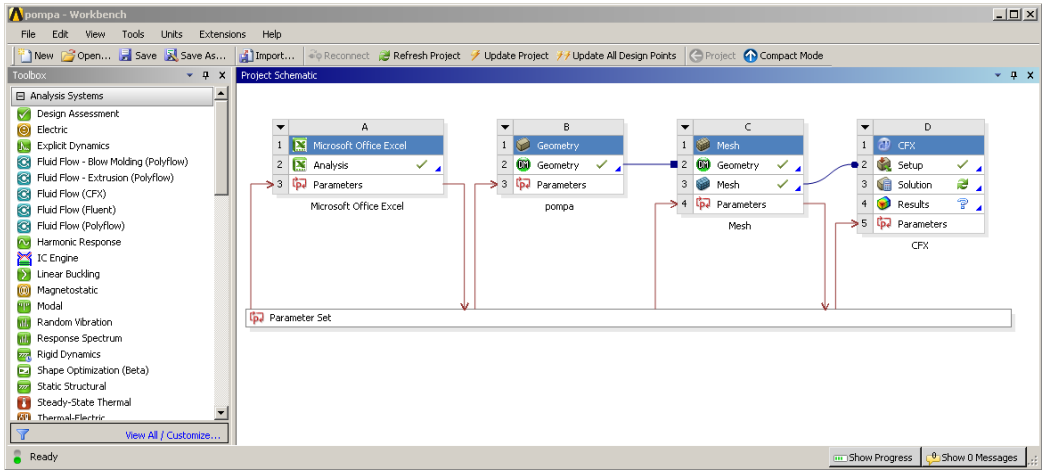
- EnginSoft and CINECA cooperate to develop a solution that provide to SMEs:
  - a tool able to improve their products
  - a better performance per core
  - a much improved parallelism

Achievements

- Collection of user requirements for a typical turbo-machinery (centrifugal pump)
  - geometry definition
  - operating conditions

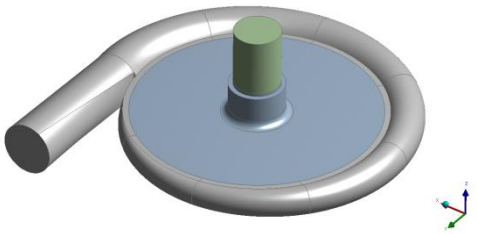


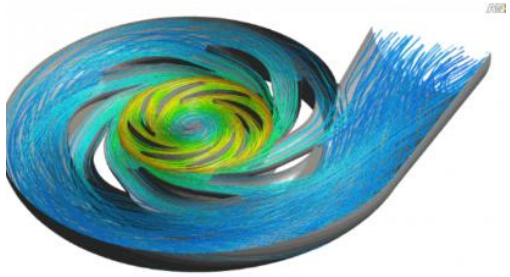
- Parametric definition of the CFD model



Achievements

- Implementation of the simulation process (completely automated pre-processing, solution and post-processing) on HPC infrastructure





- Tests show a good scalability of CFD simulations, up to 60K elements per core (~80% efficiency) → this means that with a high fidelity approach, design time can be reduced significantly!

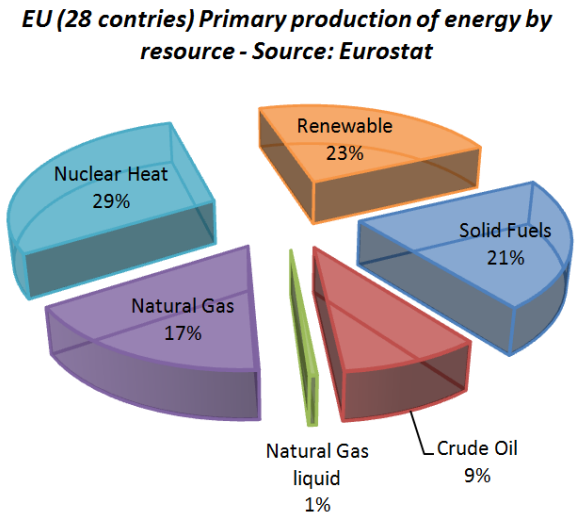
Successes and Impact

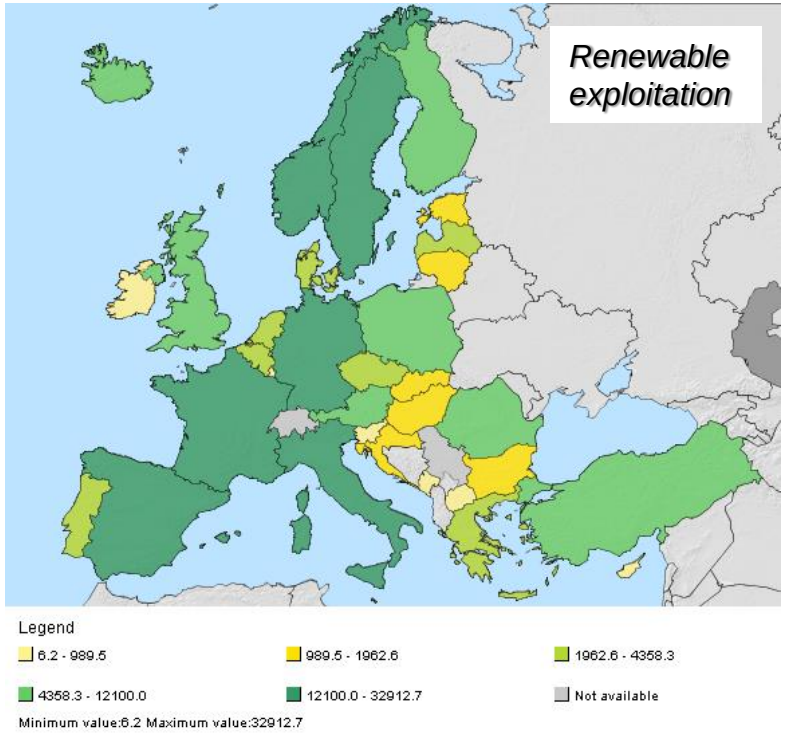
- Turbomachinery SMEs
  - ability on the Italian territory to access cost-effective HPC service
- EnginSoft
  - ability to offer its engineering competence in CFD applied to turbomachinery for the design of competitive products with high fidelity data → “ask to expert”
- CINECA
  - feedback on requirements for the Fortissimo Infrastructure
  - success story for promoting the project
  - business opportunity

RENEWABLE ENERGY

Business Relevance

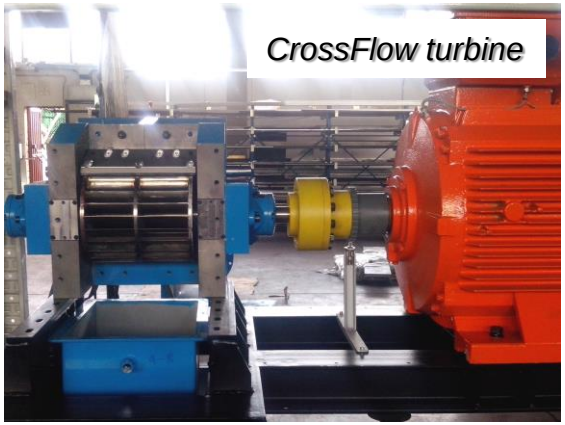
- Renewable energy plays a crucial role in reducing greenhouse gas emissions and other form of pollution
- Emerging markets in their industrialization path are increasing the energy demand





Business Relevance – Market

- Diversification of energy supply → Hydro power
- Why? In emerging markets new hydro plants or refurbishing old plants by means of new more efficient turbines and generators



SME – ZECO S.r.l.

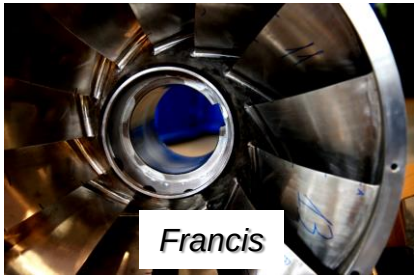
- SME specialized in the construction of **turbines** for *hydroelectric power plants*
- From design to manufacturing process control
- Installation and after sales service

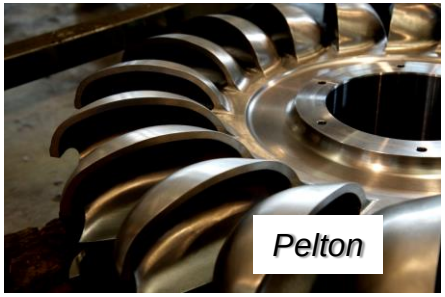
- More details:
  - www.zeco.it
  - *Riccardo Bergamin*
    - riccardo.bergamin@zeco.it

Business Relevance – Turbines

- Nowadays, the turbine designer has to validate the plant performance in order to be competitive in the market, satisfying strict energy efficiency regulations

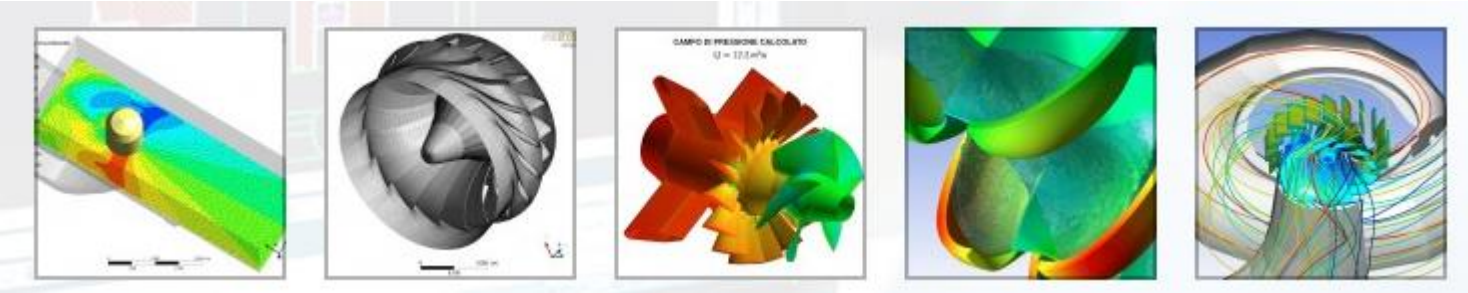
- Hydraulic Efficiency
- Cavitation
- Free surface flow
- Turbulence
- Blade loading
- Transient phenomena





Business Relevance – Why CFD

- Virtual prototyping allows:
  - Prevent undesirable behaviour
  - Evaluate peculiar aspects of the installations
  - Save money and time
  - Collect information on the cost-benefit balance between alternatives
- As a result of these factors, CFD is now an established industrial design tool



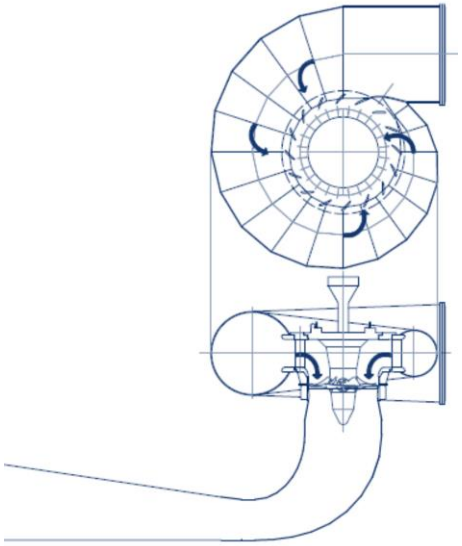
Business Relevance – Why HPC

- High fidelity simulations are required for an accurate evaluation of the performance
- Tenths of design options must be tested for the same project in order to evaluate the different installation possibilities and then compete with the best efficient and cost-saving solutions

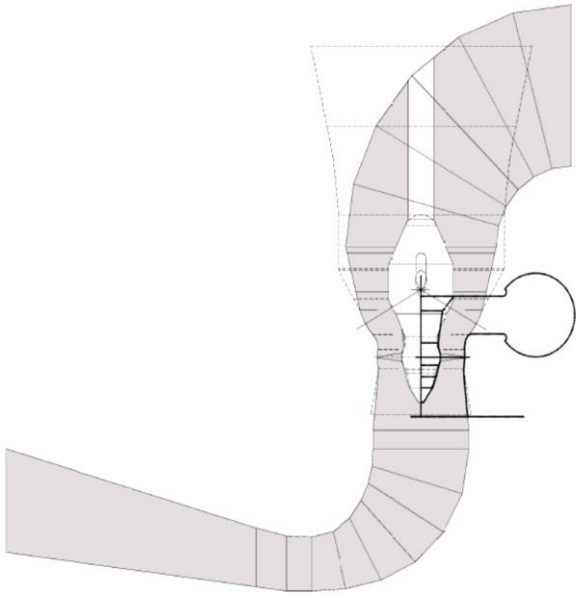
- The high fidelity approach is usually quite prohibitive for a typical Italian SMEs scenario where
  - a quite large number of simulations is required to verify the performance of each design
  - each simulation runs for a long run time (almost ~300h), operating on 8 parallel threads on Zeco systems
  - typical SMEs installations do not comprises more than a single solver license with 8 parallel threads, and this license cannot be blocked for a long period of time

Achievements

- Collection of user requirements for a typical turbine
- Definition of a new layout
  - **Kaplan hydro turbine with axial flow distributor**
    - geometry definition
    - operating conditions
    - comparison with a standard radial distribution



Typical Layout (radial)

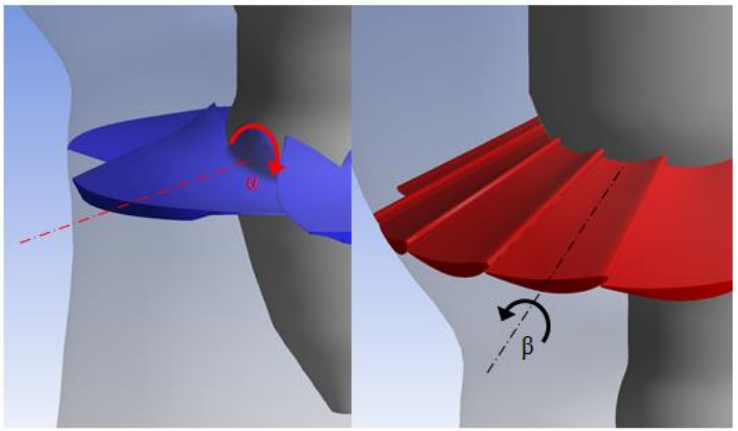


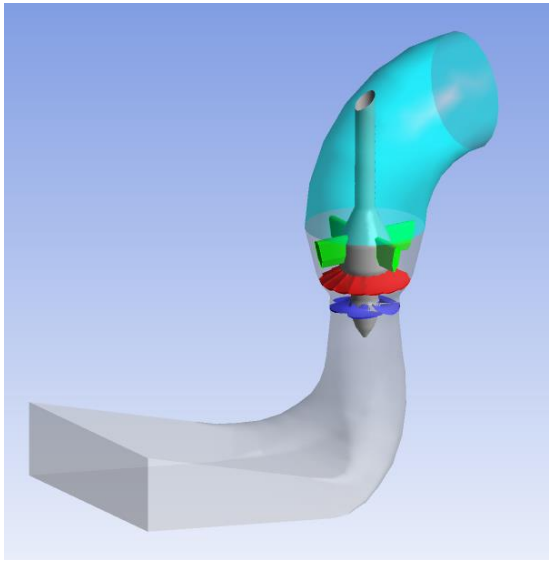
New Layout (axial)

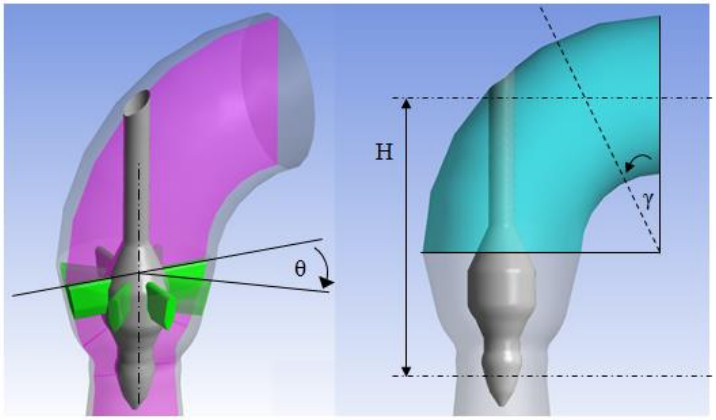
Achievements

- Parametric definition of the CFD model

Parameter name	Symbol	Units
Rotor angle	α	degree
Stator angle	β	degree
Distributor blade position	θ	degree
Distributor inlet angle	γ	degree
Distributor inlet height	H	m

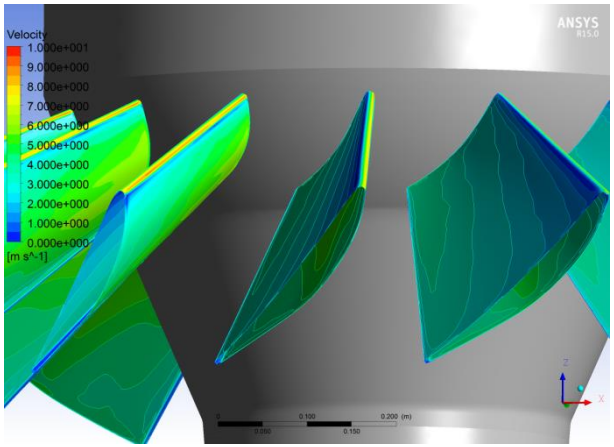


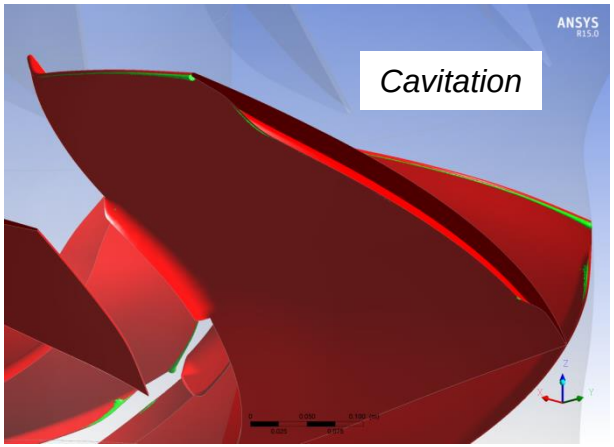


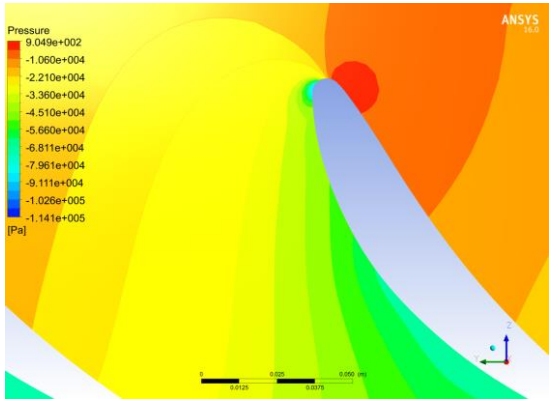


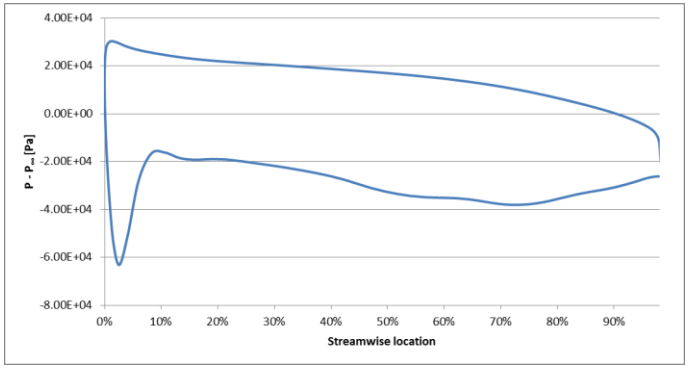
Achievements

- Implementation of the simulation process (completely automated pre-processing, solution and post-processing) on HPC infrastructure





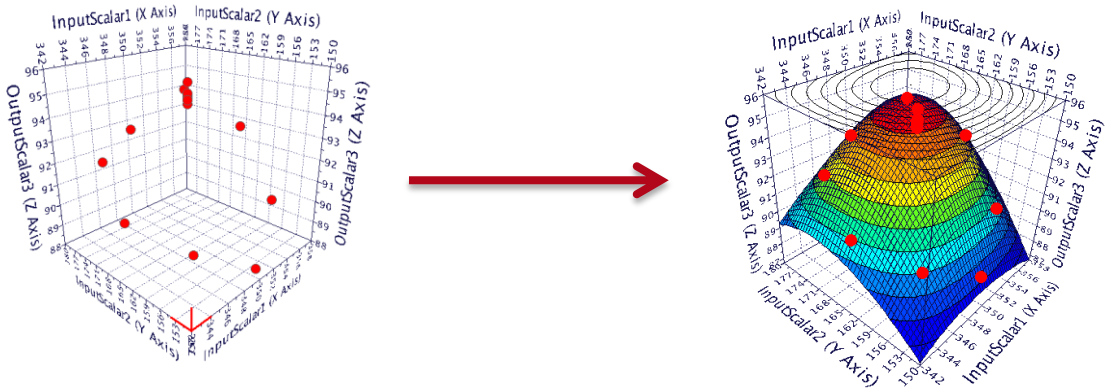




Work in progress

- Definition of the Design of Experiment (DOE)
- Evaluation of the scalability of CFD simulations

- Relation between input & output variables
  - Response Surface Methodology
  - Identification of the best design and/or Pareto Front



Future Impacts

- ZECO S.r.l.
  - ability to access cost-effective HPC service for the optimization/development of new turbines
- EnginSoft
  - ability to offer its engineering competence in CFD applied to turbomachinery for the design of competitive products with high fidelity data → “ask to expert”
- CINECA
  - feedback on requirements for the Fortissimo Infrastructure
  - success story for promoting the project
  - business opportunity

THANK YOU FOR YOUR ATTENTION!