INTERNATIONAL CAE CONFERENCE

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THE ENGINEERING SIMULATION PATH TO DIGITAL TRANSFORMATION

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Comparison between Eulerian and MPS Methods for Numerical Simulation of Pelton turbine

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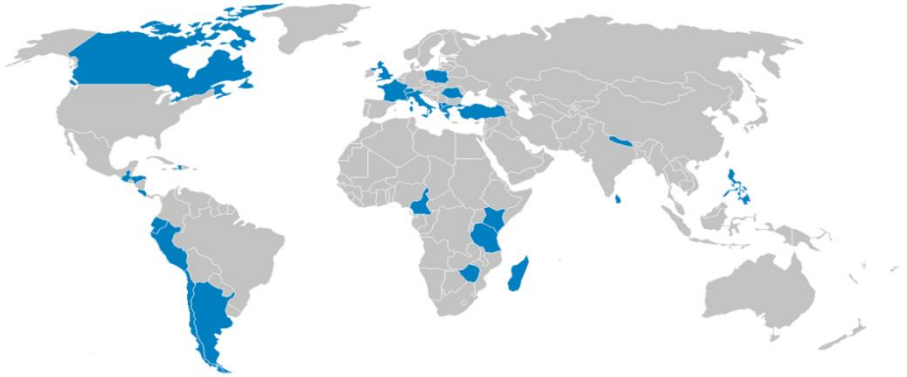
ZECO HYDROPOWER

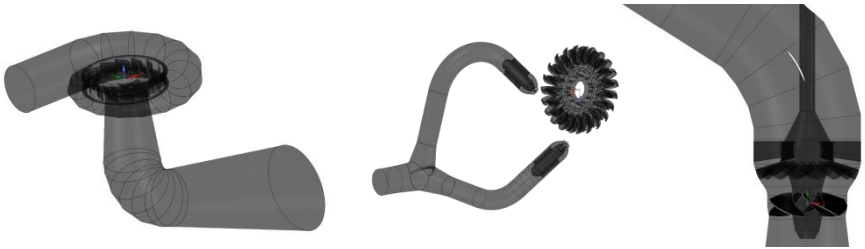
Agenda

- Company introduction: Zeco
- Pelton turbine description
- Eulerian state of art simulation procedure
- Moving Particle Simulation as a new approach
- Comparison of results
- Conclusions

Company presentation – ZECO

- ZECO has **more than 55 years of experience** in the hydropower market
- ZECO is **worldwide active** since 1985
- ZECO designs and manufactures hydro turbines and **water to wire** solutions

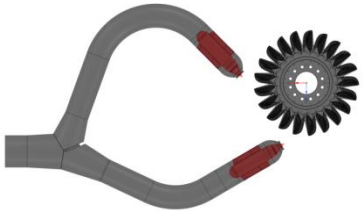




Pelton Turbines – Introduction

- Invented by Lester Allan Pelton in **1880**
- Improved by Abner W. Doble in **1895**
- It is still the best solution for **high head (> 100 m)**
- **ZECO** designs and manufactures Pelton turbines up to **20 MW**

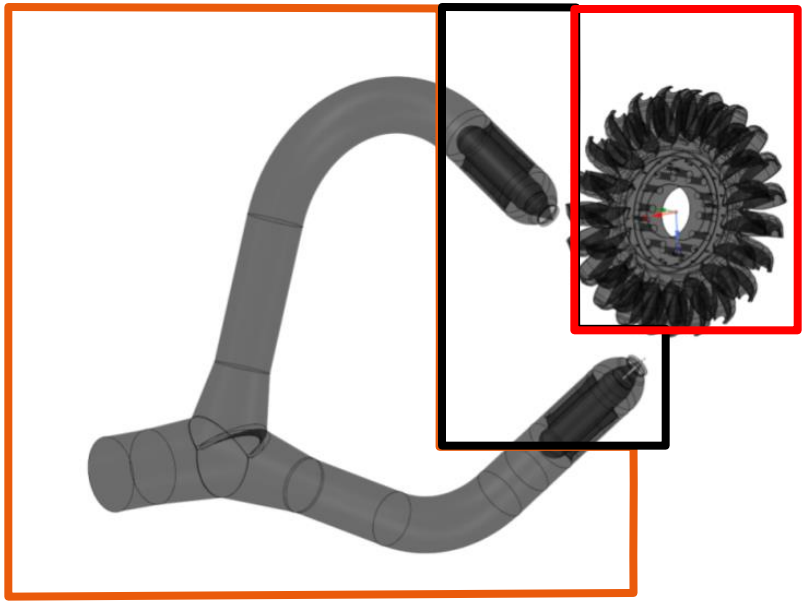
Manifold



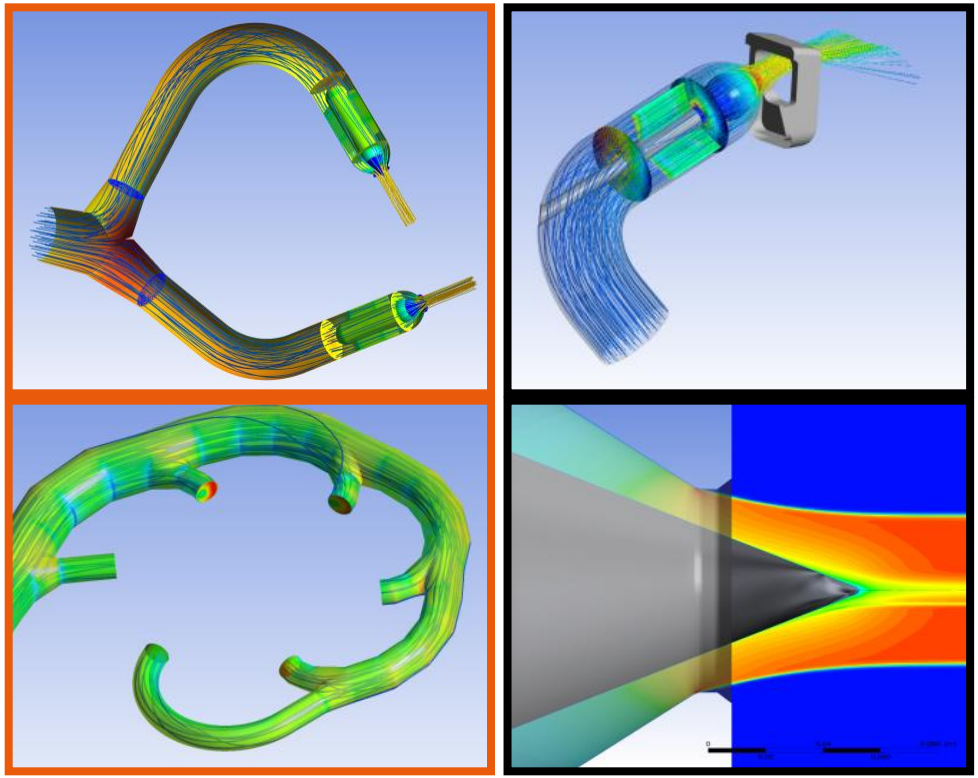
Nozzles

Runner

Pelton Turbines CFD – Eulerian state of the art

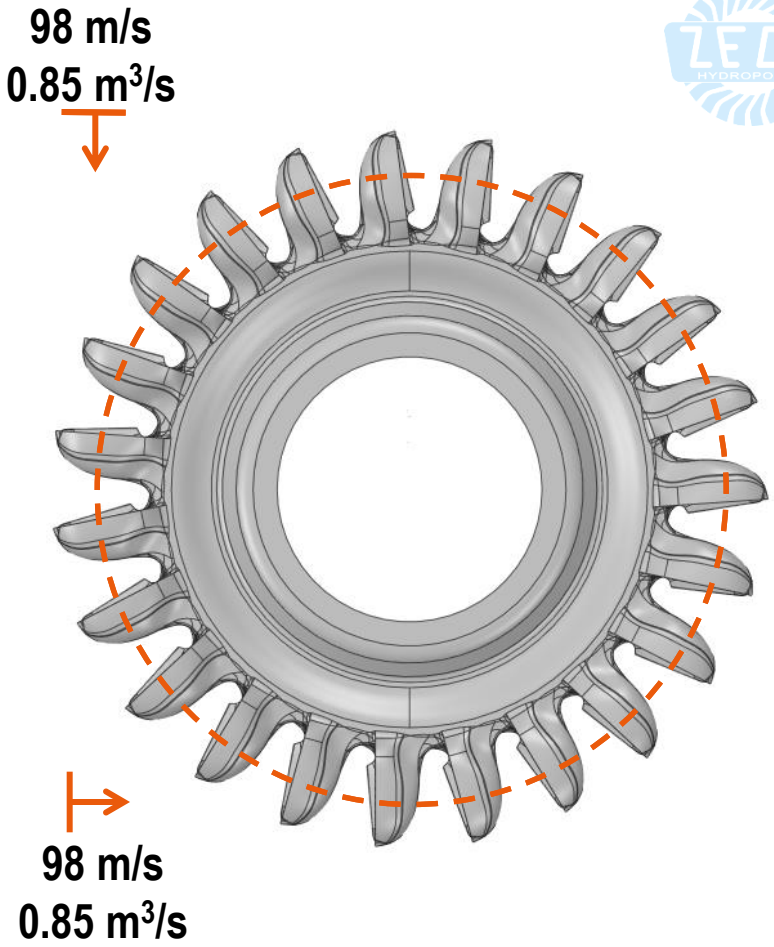


Manifold Nozzles Runner

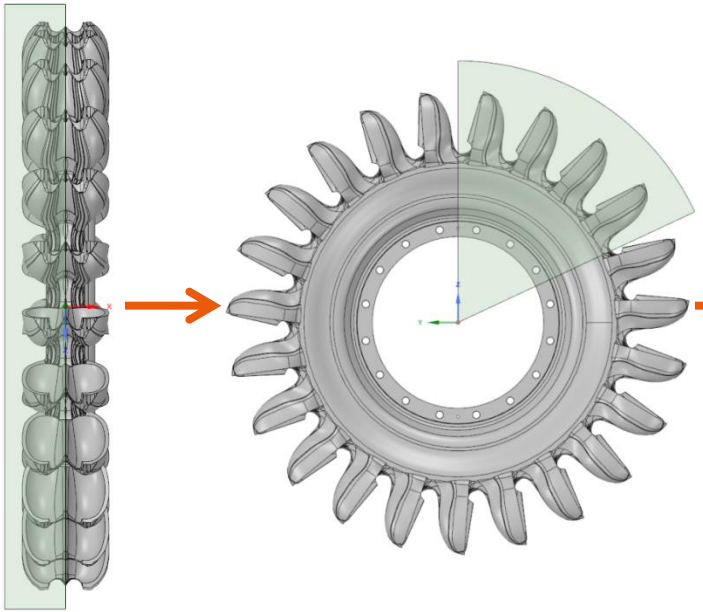


Benchmark information

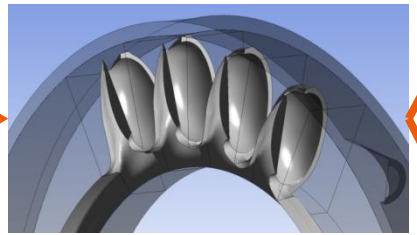
Jets Number (j)	2
Runner Diameter (D_1)	2150 mm
Buckets Number (B_N)	23
Head (H)	506 m
Jet Discharge (Q_j)	0.85 m^3/s
Total Discharge (Q)	1.7 m^3/s
Water Speed (v)	98 m/s
Runner Speed (N)	375 rpm
Max Power (P)	7.5 MW

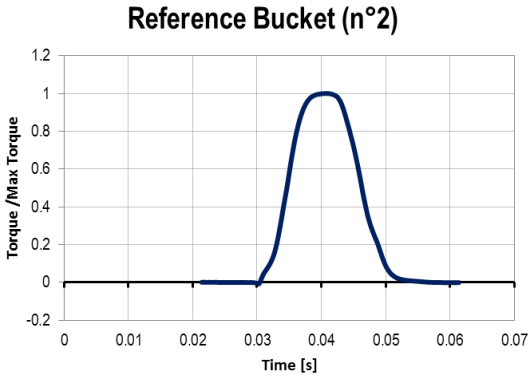


Model setup: Eulerian Workflow



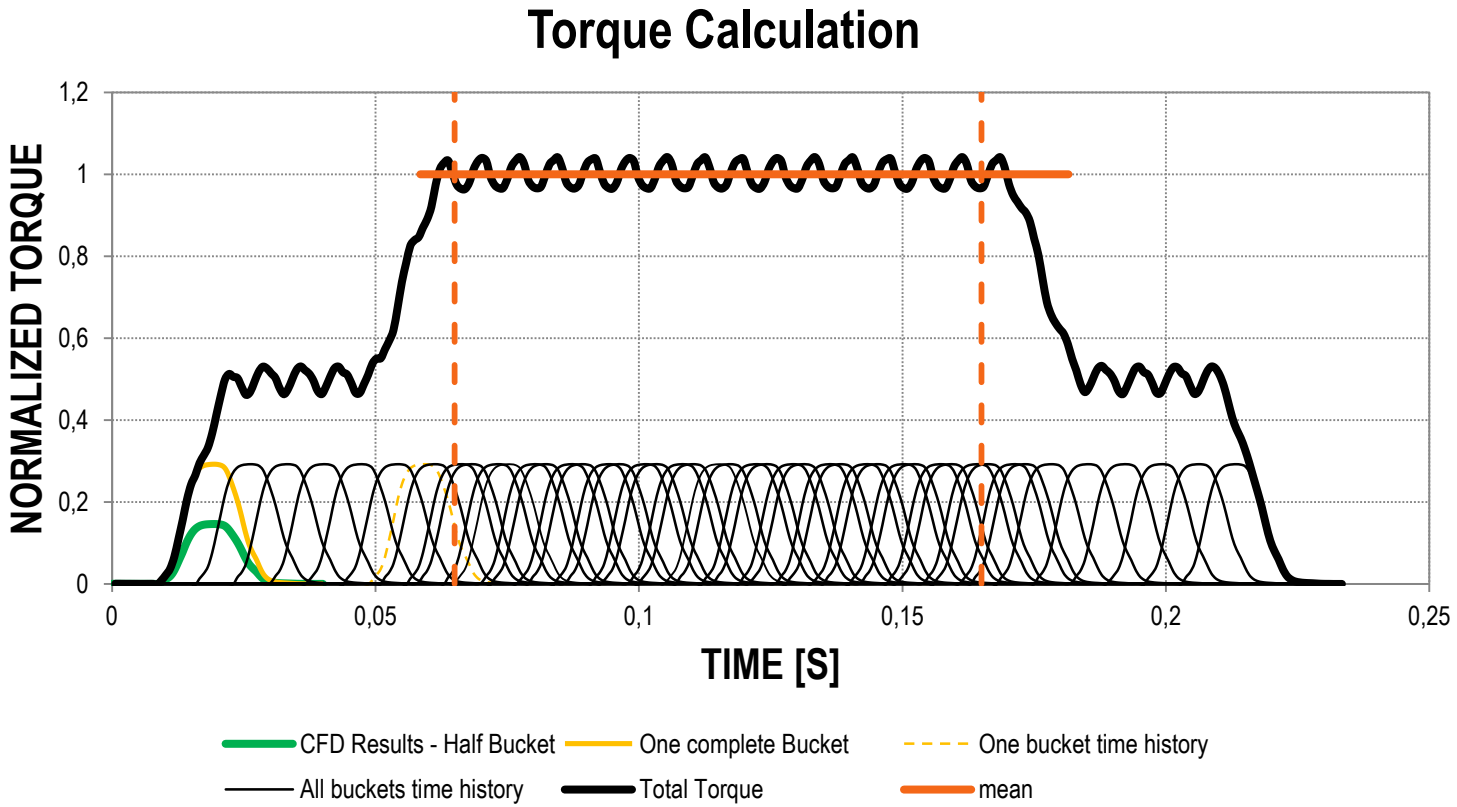
~16 milion element mesh
~3 days of simulation



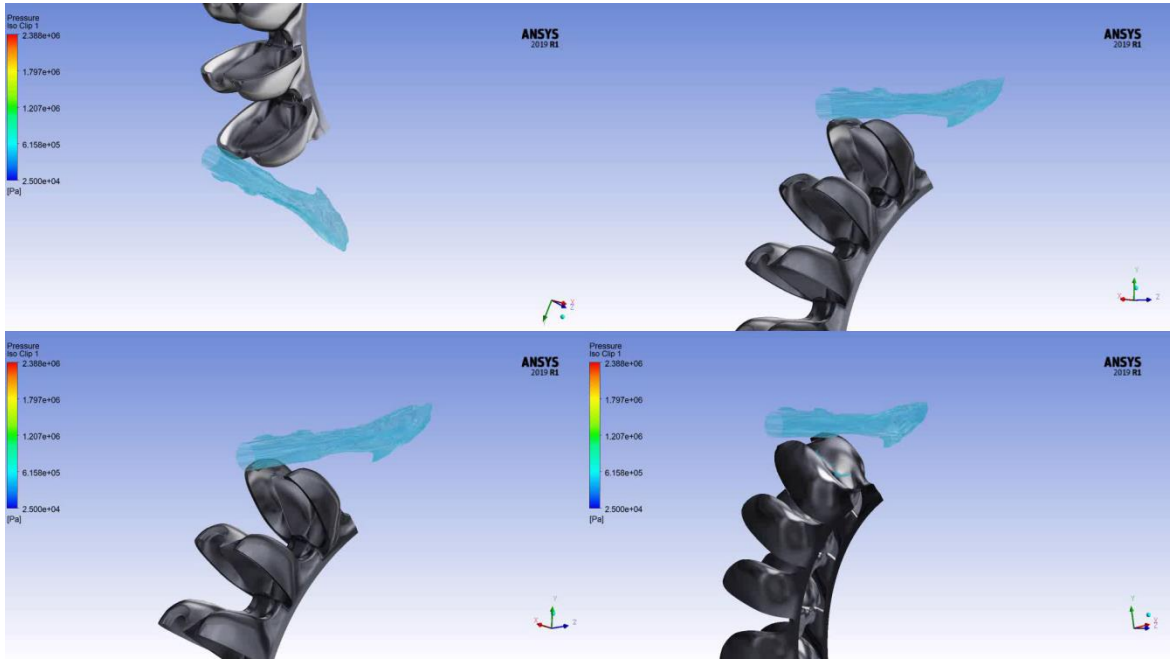


Prediction of the torque of
1 jet for one half-bucket

Torque evaluation: Eulerian Results



Visualizing the results: Eulerian results



*Reconstruction

Runner – Eulerian open issues

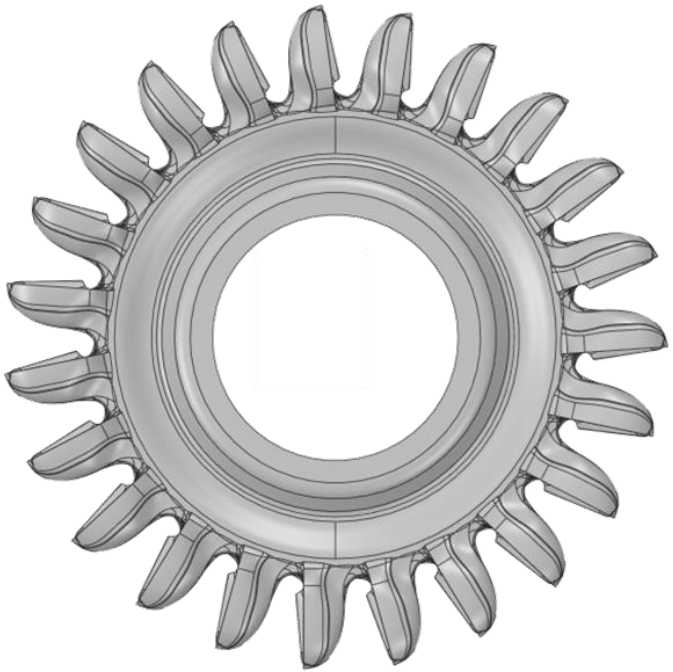
- Jet – jet interaction (**multi jet** analysis)
- **Case – jet** interaction
- **Computational** limits:
  - Transient simulation
  - Complex geometry – mesh quality
  - Complex free-surface flow and length scales
  - Multiphase simulation

For these reasons, Zeco wanted to investigate the simulation with **Moving Particle Simulation (MPS)** methodology

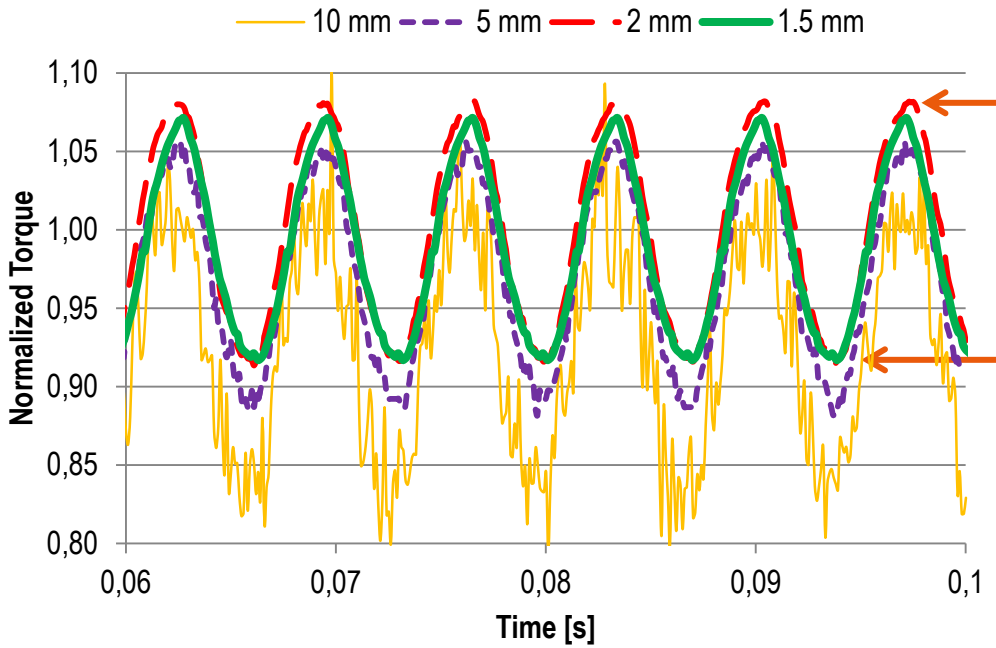
Conventional (Eulerian) CFD → **MPS**

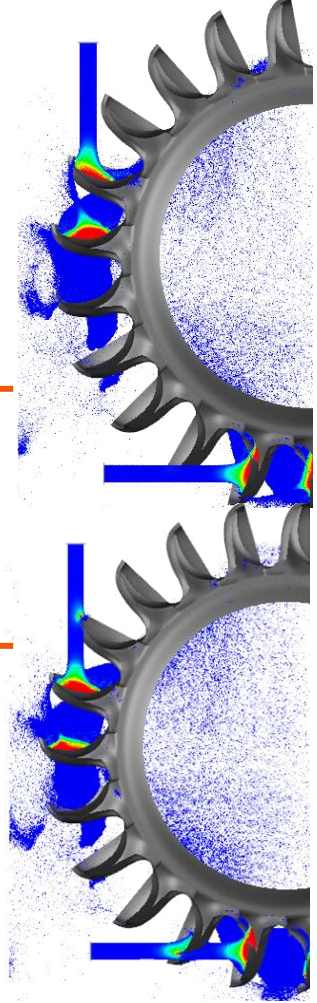
MPS: model and simulation setup

- The geometry of the turbine is imported into Particleworks **without modifying or simplifying** the CAD provided by Zeco.
- Since the **mesh-generation step is not required**, the simulation can start after setting up the boundary conditions and the numerical settings.
- Moreover, Particleworks easily solves for the **entire domain** taking advantage from the **GPU**-accelerated solver.



Particlesize sensitivity analysis



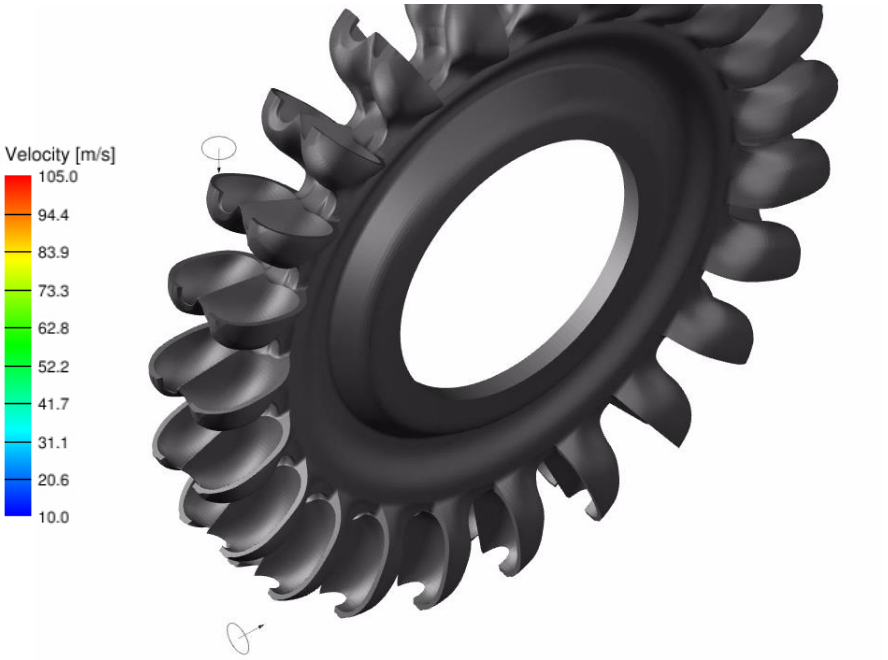


Visualizing the results: MPS

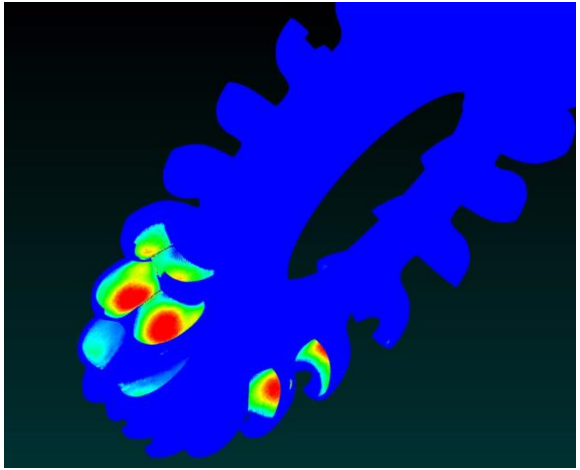
Visualization of the velocity

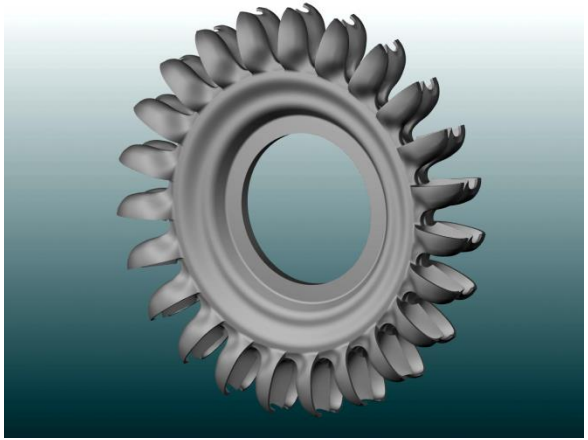
Visualization of the pressure

No reconstruction needed



Results: Mapping of pressure and surface rendering

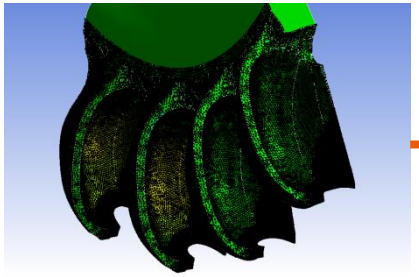


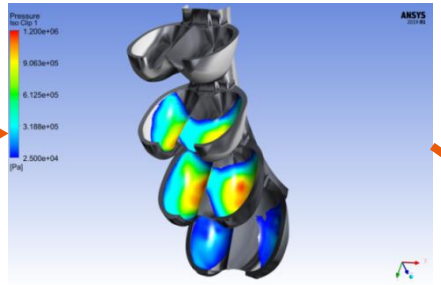


FEM study: comparison CFD (Eulerian)/MPS

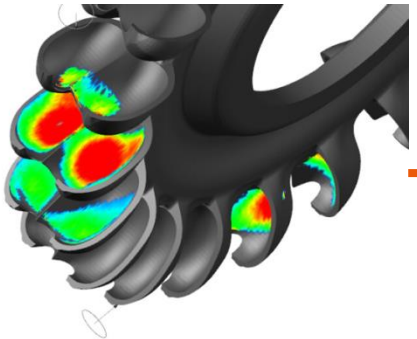
Eulerian CFD

Complex data reconstruction and remapping due to symmetry of CFD model



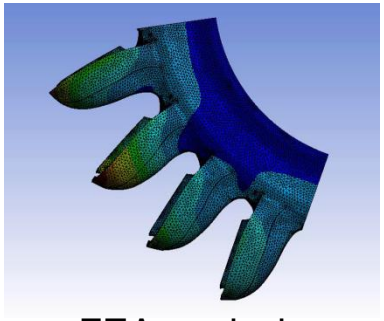


MPS



Direct data transfer

ANSYS® Workbench

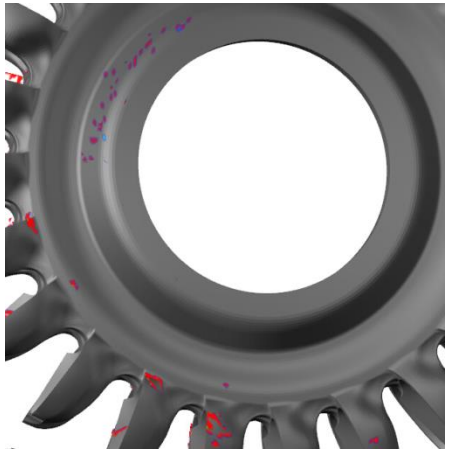


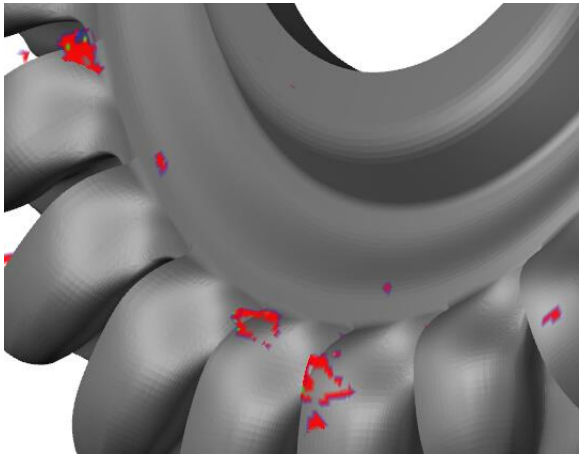
FEA analysis

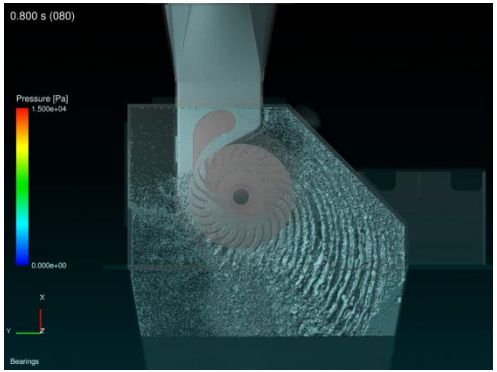
Advantages of whole-turbine simulation

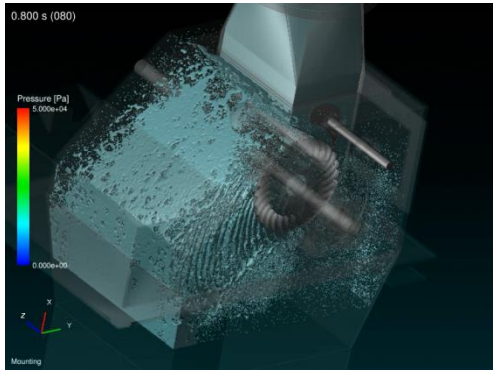
Further possibilities enabled by MPS:

- **Long range** jet-jet and jet-turbine interactions (water interacting with turbine in red on the left)
- **Casing** influence on the working efficiency of the turbine



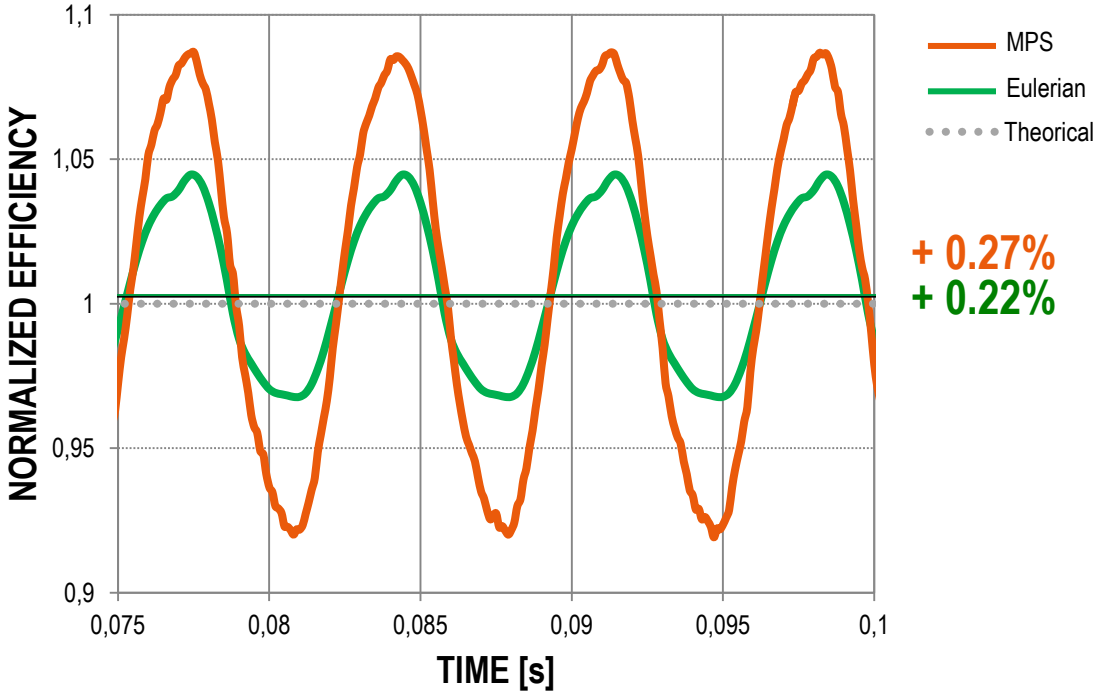






Results: comparison CFD (Eulerian)/MPS

- The predicted efficiency is comparable for both the Eulerian and MPS approaches.
- In the field, for Pelton turbines in particular, these simulation results are very insightful.



Results: comparison CFD (Eulerian)/MPS

	CFX	PARTICLEWORKS
Pre / Post Processing	3 working days / 4h	2 h / 1 h
Simulation time	70 h	2 h
Simulated rotation (angle)	138°	225°
Geometry	4 half buckets	Complete turbine
Complete runner (multi jet, casing) simulation	Not feasible	Possible
Mesh elements/particles	16M	4M
Hardware	12 CPU Intel Xeon X5650@2.67 GHz 96 GB RAM	1 GPU + 1 CPU NVIDIA V100
Calculated vs model efficiency (absolute)	+0.22%	+0.27%

Conclusions

- Eulerian CFD and MPS are compared for the simulation of Pelton turbines, both in terms of **complexity of model definition and accuracy** of the results.
- Eulerian CFD is the standard approach for the simulation of **manifolds** and **nozzles**.
- In the design phase of the runner, the **MPS method is simpler and faster** to use, for the efficiency prediction, for FEA evaluation of the runner and for the study of the complete turbine system (jet-runner and jet-casing interaction)
- Several design configurations or operating conditions can be simulated **in one day**, using MPS.

Thanks for your attention!

ZECO HYDROPOWER