Flexibility of Hydraulic Turbines

A Parametric Design Tool

HydroFlex

Intro

If hydropower shall fit in the energy mix of tomorrow, with ever increasing elements of highly intermittent energy sources such as solar and wind, **new turbine designs** must be developed to operate with very **high flexibility** and at **higher efficiency.** In HydroFlex WP3 Task 3.2, the ANSYS software package will be used to develop a **multi-parametric design tool** for automatic optimization of a design that shall meet these requirements. This work is lead by EDRMedeso.

The design tool consists of:

1. Matlab code for initial design with corresponding geometry files.
2. Computational Fluid Dynamics (CFD) simulations in **ANSYS CFX**.
3. Finite Element analysis (FEA) in **ANSYS Mechanical**.

The parametric design tool will be built around the system simulation and **design optimization tool** called **ANSYS OptiSLang**, utilizing the multi-parametric modeling capabilities of **ANSYS Workbench**.

The Matlab design code exports geometry files for ANSYS. **Exact same geometry** will be used by the CFD and FE analyses **in the optimization loop.**

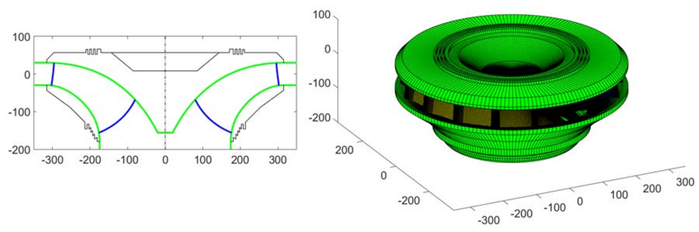

Figure: Example design from Matlab Design code **TurboPARAMETRIC**

Computational Fluid Dynamics (CFD) module

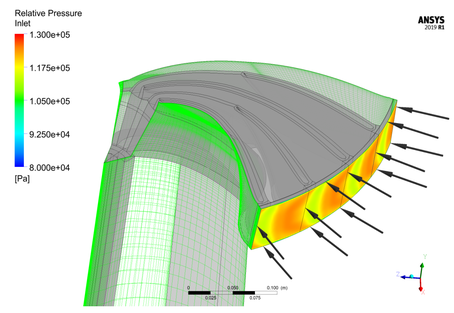

Figure: Harmonic Analysis (HA) setup in ANSYS CFX

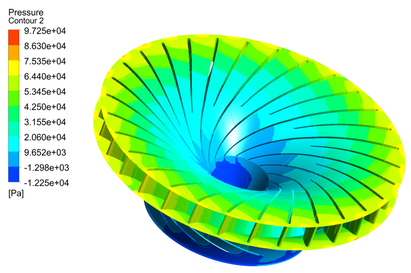

Figure: Runner pressure from HA simulation

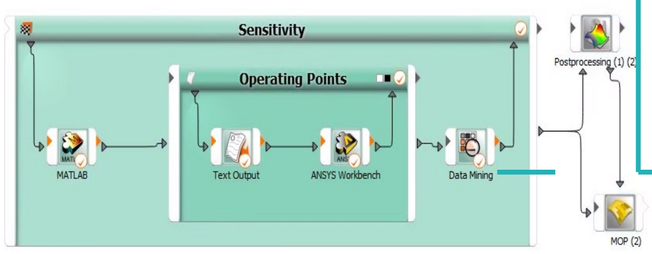

Figure: OptiSLang workflow for CFD module alone

Intial Turbine Design Matlab design code *TurboPARAMETRIC* exports curve files for :

- ANSYS Turbogrid (CFD)

- ANSYS SpaceClaim (FEA)

Optimization loop

- Automatic cyclic geometry generation
- Automatic mesh
- Automatic CFD setup for simulation (Harmonic Analysis)

CFD pressure

Automatic post-processing:

- Hill charts
- Efficiency

-> output parameters for optimaziation loop

Structural Integrity

- Automatic cyclic geometry generation
- Automatic mesh
- Automatic Acoustic analysis set up

Automatic post-processing for structural integrity checks

-> output parameters for optimization loop

Optimization loop

Finite Element Analysis (FEA) module

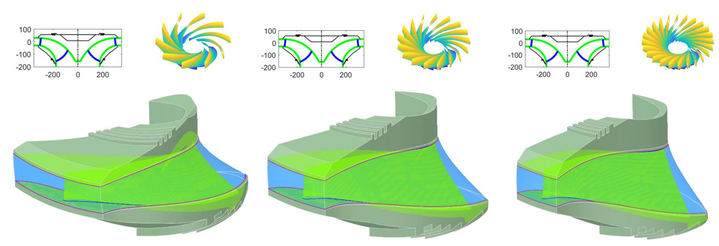

Figure: Examples of generated geometry for 10, 17 and 24 blades (left to right)

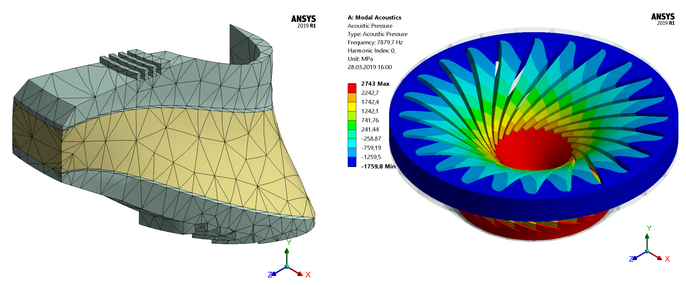

Figure: Example of mesh and expanded result with cyclic symmetry

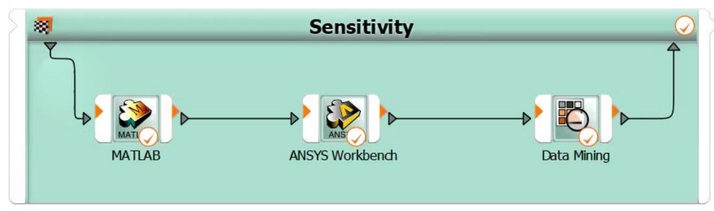

Figure: OptiSLang workflow for FEA module alone

The first version of the parametric design tool consists of separate systems for CFD and FEA. The final version will see a single analysis system combining CFD and FEA by using load from CFD calculation, that:

- performs variable speed design simulations for optimizing the turbine efficiency based on flow simulations
- adjusts the structural strength of the runner blades to allow for high ramping rates and many start/stops.

Multi-parametric setup in ANSYS OptiSLang includes a top level optimization loop set to fine tune the design based on certain optimization criteria.

- Typical criteria may be highest possible efficiency and thinnest possible blades.
- Turbine parts to be optimized include the stay vane, guide vane and runner as well as an innovative guide vane system located in the draft tube.

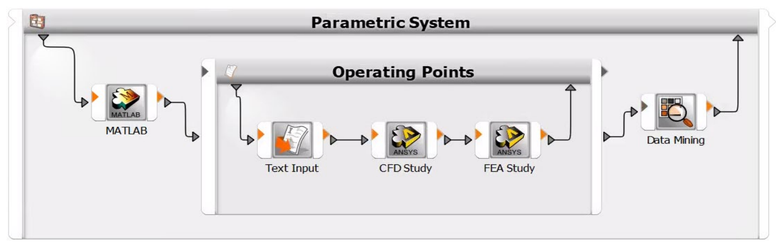

Figure: Preliminary suggestion of workflow combining CFD and FEA

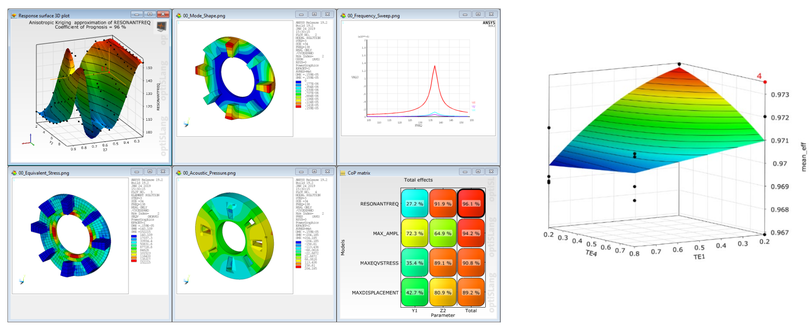

Figure: Example of typical sensitivity analysis result for OptiSLang

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