Computational Fluid Dynamics simulations: a tool in the successful refurbishment of a Kaplan turbine

Sylvain Tridon, Xavier Cornut, Laurent Tomas
SHF - Enhancing Hydropower plants
Grenoble, April 9-11, 2014
Computational Fluid Dynamics simulations

Usual process

1. Identification in the hydraulic portfolio of design featuring close characteristics
2. Shape Optimization: hydraulic and mechanical aspects
3. CFD calculations
4. Model tests (manufacturing of the model, tests)
5. Manufacturing, Installation and commissioning of the prototype
6. Site tests

Standard process, mandatory for complex requirements
Computational Fluid Dynamics simulations

Process applied to Lopet project

1. Identification in the hydraulic portfolio of design featuring close characteristics
2. Slight modifications of the shape
3. CFD calculations
4. Manufacturing, Installation and commissioning of the prototype
5. Site tests

Shorter process, ideal for Retrofit projects
Computational Fluid Dynamics simulations

Lopet HPP – Existing data

- Turbine max. output: 24.36 MW
- Minimum Head: 15.5 m
- Rated Head: 18 m
- Maximum Head: 18.5 m
- Synchronous speed: 136.36 rpm
- Runner diameter: 4.665 m
- Runner axis level: 211.20 m
- Min. Tail Water Lvl - Full Load: 217.3 m
Computational Fluid Dynamics simulations

Reference runner

1. Main hydro players have large portfolio of hydraulic profiles, coming from new and retrofit projects supplied since decades and from specific R&D developments

2. Taking into account:
   - Efficiency
   - The operating points of the project on the hill chart
   - Cavitation limits
   - Runaway speed
   - Power saturation

➢ Identification of the right “Reference Design” to meet the guarantee

Large hydraulic portfolio is mandatory
Computational Fluid Dynamics simulations

Design modification

• Required modifications due to mechanical constraints have to be identified and to be assessed:
  − Lopet case – modification 1: slight increasing of the blade thickness
  − Lopet case – modification 2: increase the geometrical ratio between the hub diameter and the diameter of the runner

• Modifications for hydraulic purposes are assessed by using CFD as a comparative tool: new design losses vs. reference design losses.

Experience is mandatory
Computational Fluid Dynamics simulations

CFD analysis

The adopted CFD analysis strategy is to compute the performances and then to compare both designs:

1. Runner computations are performed for the REFERENCE design and for the new LOPET design with similar conditions in terms of computations (mesh, boundary conditions...).

2. Then hydraulic losses are quantified as well as the cavitation behaviour for both designs to check and justify that the expected performances will be achieved on site.

Know-how in state-of-the-art numerical simulations is mandatory
Computational Fluid Dynamics simulations

CFD analysis – Computation Methodology

• The CFD computations concern only the runner and the distributor.

• The embedded parts behaviour and their “head losses” impact are issued from Alstom’s know how.
  - Example: a similar draft tube was qualified by model test

Know How on previous designs and Experience are mandatory
Computational Fluid Dynamics simulations

CFD analysis – Runner computation

• Comparison of results:

Velocity vectors at FL for reference and new LOPET runners.

Comparison between CFD and forecasted hillchart (for peak efficiency set up to 100%) vs Q11 for prototype

The new runner design has slightly less head losses than the reference
Computational Fluid Dynamics simulations

CFD analysis – Cavitation Behaviour

“Adjusted pressure” is defined in order to transpose computed pressure levels to the prototype

No impact on the blade profile with regards to cavitation phenomena
Site tests

- Method used: Winter Kennedy
- Standard: IEC41
- High precision measurement devices
- Test campaign: June 2013
- The Site tests confirm:
  - The maximum power of 29 MW is reached with this new design (+19%)
  - The shape of the performance curve perfectly matches expected hill chart
  - Good match between theoretical cam and measured on-site cam (only slight adjustment required)
Conclusions

• Model test is often seen as a mandatory step to validate runner design. The LOPET project shows on a real case study that an alternative process is possible in applying a rigorous method based on:
  – Large hydraulic portfolio
  – CFD computation
  – Know How
  – Site tests campaign

• Such a method is a real alternative to standard development with a model test and allows:
  – significant cost reduction
  – several weeks time reduction

Any project with objectives close to reference designs of hydraulic portfolio is eligible for such an approach