Optimisation of Hydraulic Draft Tubes through CFD and Machine Learning

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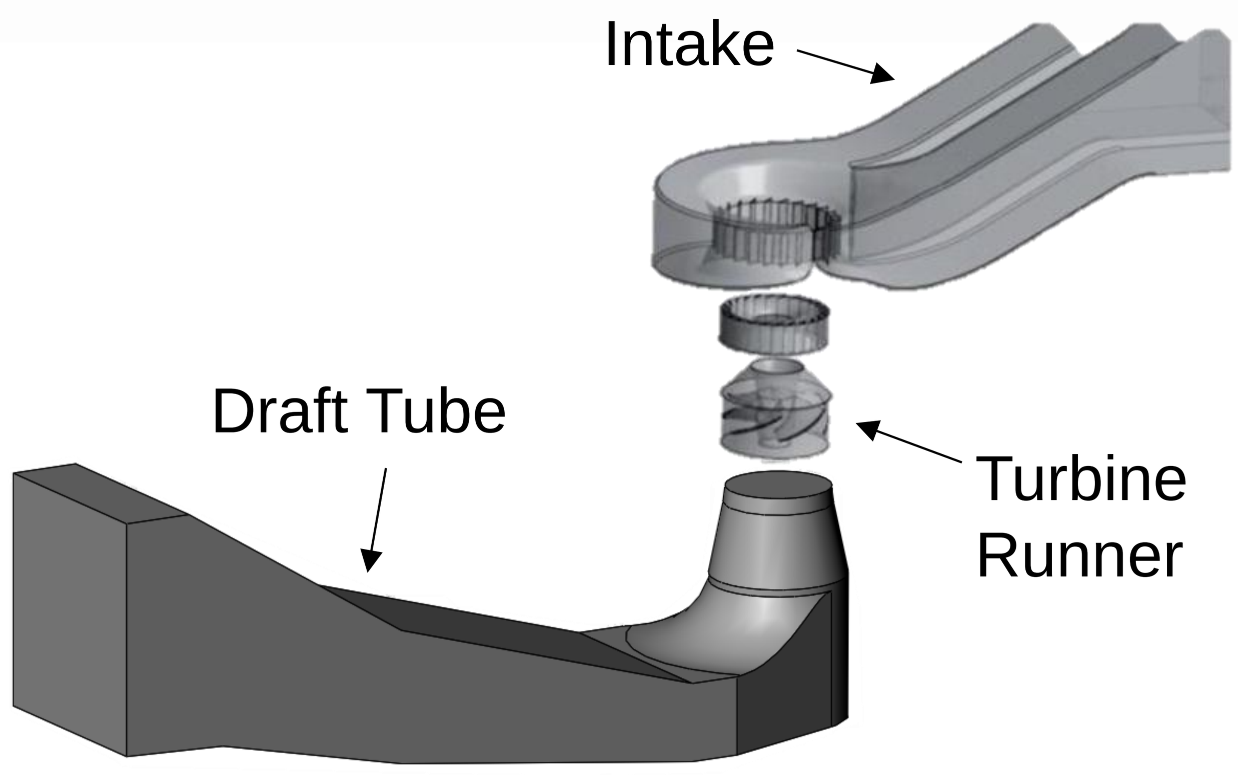


Figure 1: CAD model of Hölleforsen draft tube and representative prior components [1].

Introduction

Draft tubes are conduits between the turbine exit and tail race for hydropower plants. They are designed to reduce flow velocity and increase static pressure within the turbine, improving energy extraction and thus turbine performance.

An optimiser was developed to find an optimal design for the diffuser of the Hölleforsen draft tube, using the pressure recovery factor between the inlet and outlet of the draft tube as the objective function.

Experimental

Validation Data

3D printed 1:220 scale models were tested to provide practical data on models, identified by the optimiser, that were simulated by CFD.

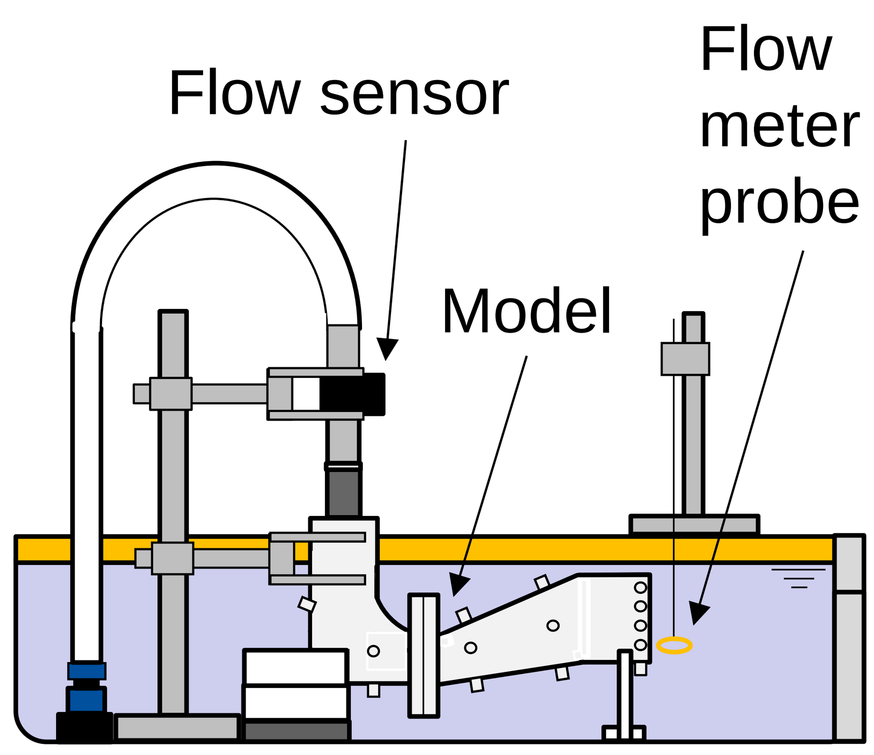


Figure 2: Diagram of experimental setup to measure flow properties.

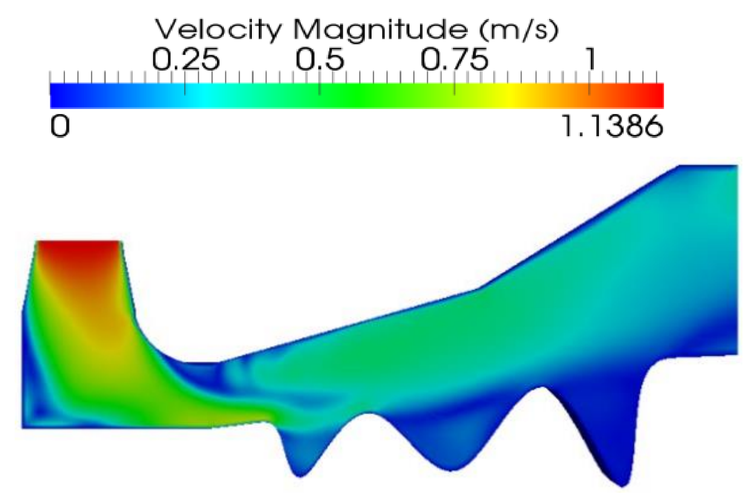


Figure 3: High curvature geometry used for validation of simulations.

CFD

Evaluating Solutions

Develop *automatic*, *robust* and *accurate* CFD models able to dynamically simulate a range of parameterised designs using OpenFOAM.

Optimisation

Intelligent Sampling

Efficient global optimiser developed through the implementation of Bayesian learning.
The diffuser was optimised by manipulating its 2D profile using Catmull splines.

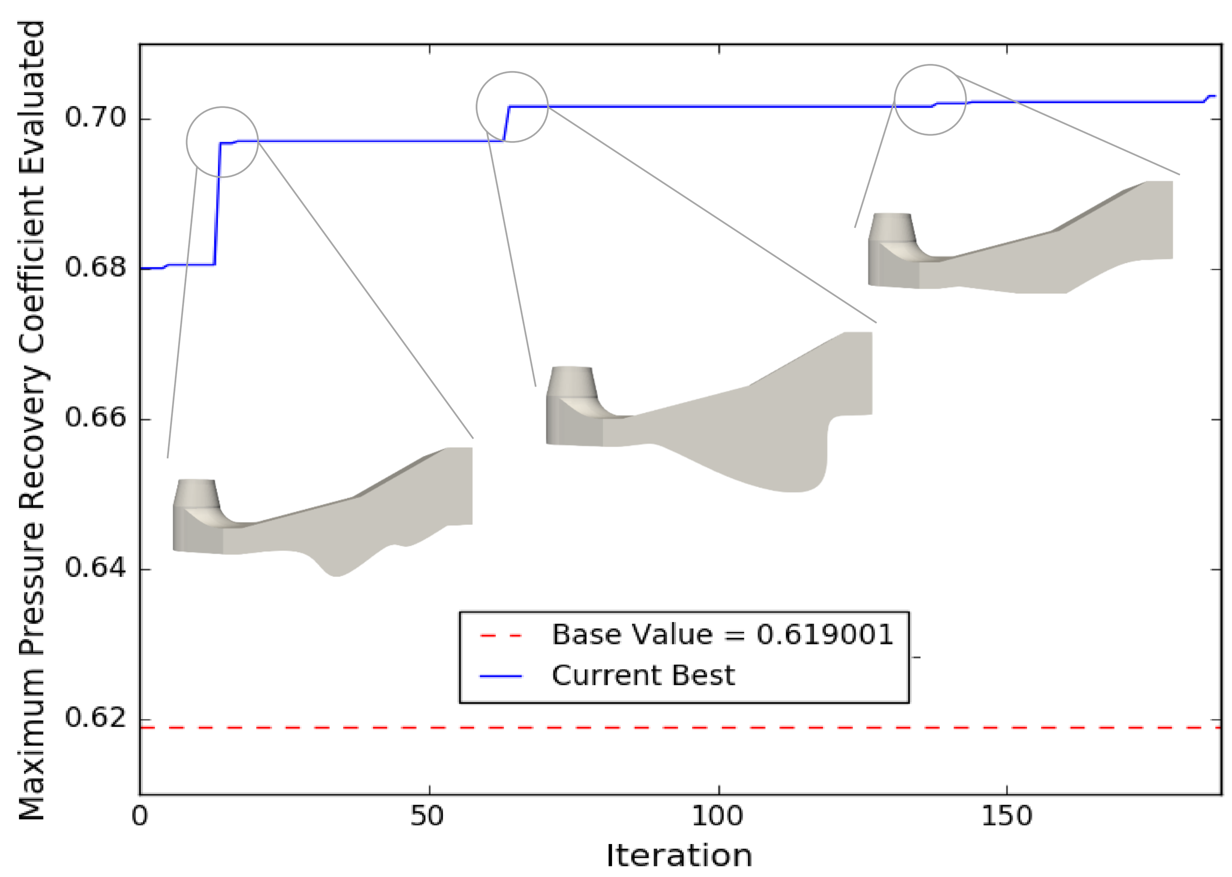


Figure 4: Maximum pressure recovery coefficient evaluated and the intermediate solutions.

Results

Pressure recovery factor difference between original and optimised geometry show a 14% improvement in the CFD and 7% in the experimental. Final optimised design is shown in Figure 5.

Pressure Recovery Factor (C_p)	Experimental Mean	CFD
Original Geometry	0.608	0.617
Optimised Geometry	0.655	0.706

Table 1: Pressure recovery factors between inlet and outlet of original and optimised draft tubes.

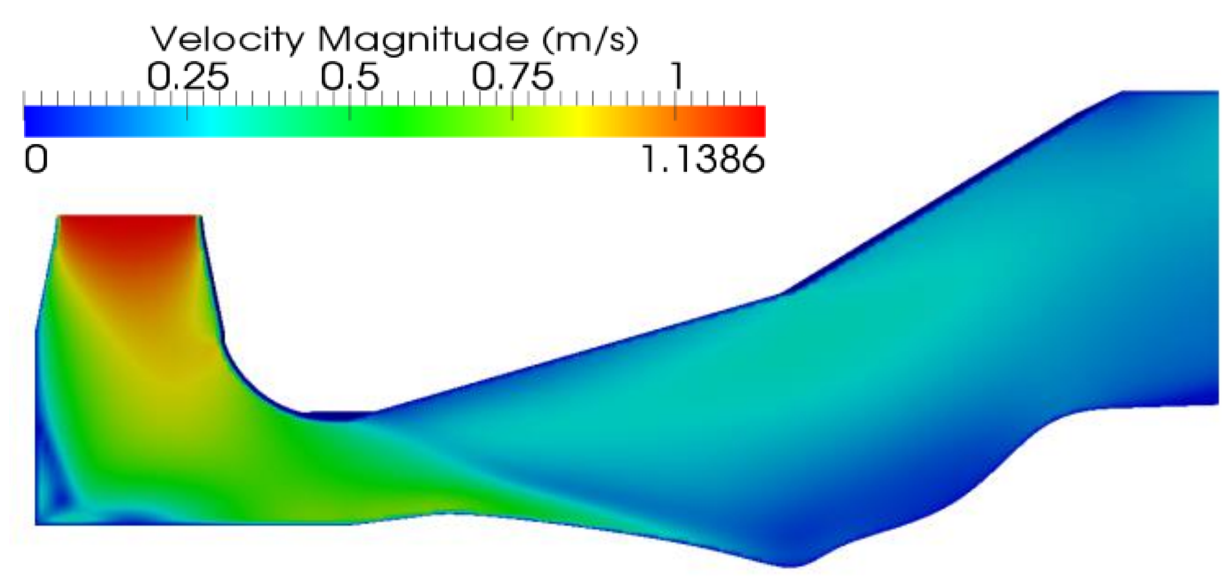
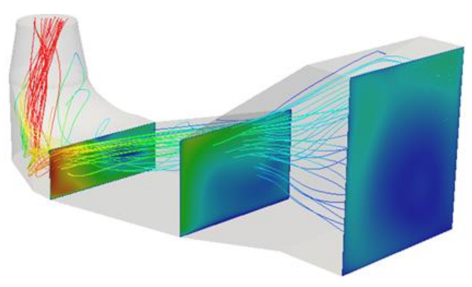


Figure 5: Final optimised geometry with simulated velocity field.

Further work



- Incorporate a swirl inlet condition to represent industrial operation.
- Implement Bayesian optimisation with gradient information to reduce the optimisation time.
- Fully parameterised geometry using Catmull-Clark subdivision surface - optimising the entire geometry.

References

[1] J.-M. Gagnon, V. Aeschlimann, S. Houde, F. Flemming, S. Coulson and C. Deschenes, "Experimental Investigation of Draft Tube Inlet Velocity Field of a Propeller Turbine," Journal of Fluids Engineering, vol. 134, no. 10, 2012.

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