Comparison of Numerical and Experimental Results of the Flow in the U9 Kaplan Turbine Model

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Aim of the present work

- Develop OpenFOAM as the future first choice for industrial CFD in water turbine applications (validate new implementations useful for Turbomachinery applications)

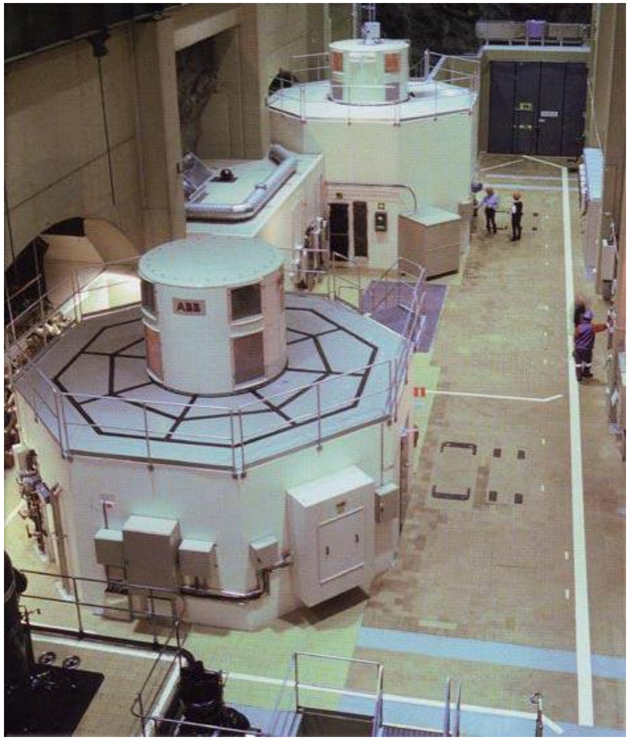
- Interact with the experimental project conducted by Berhanu Mulu and Pontus Jonsson in Luleå, Sweden, in order to improve the flow in the U9 model

OpenFOAM, a valid choice

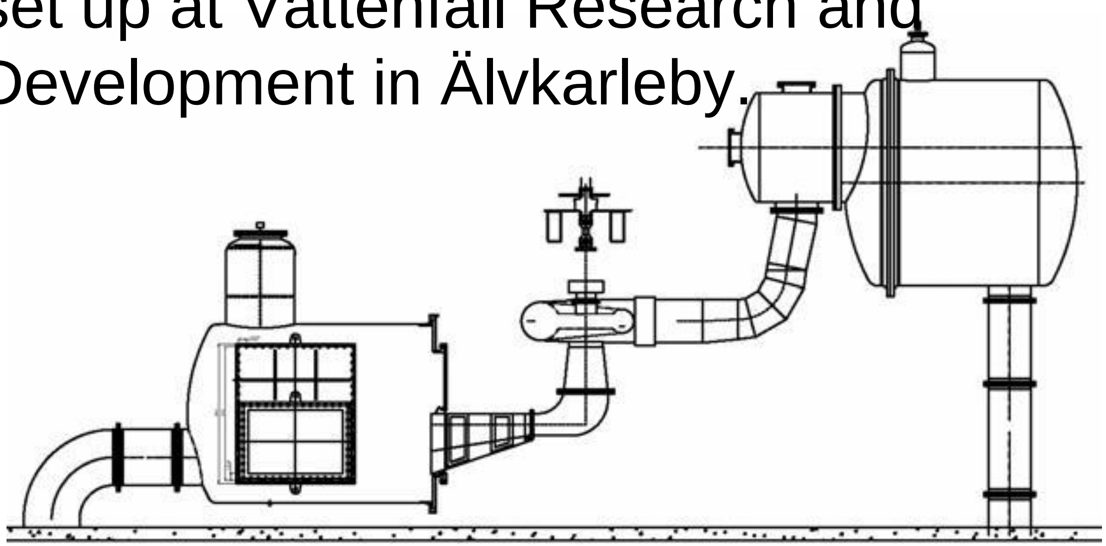
- OpenSource software (free access to the source code), no licence cost
- Large community of users, growing each year, and contributing to the growth of OpenFOAM
- Possibility of creating own solvers or applications from existing ones

The U9 project

- Prototype located in Porjus, consist in a Kaplan turbine.
- Designed to be able to perform detailed measurements on a real scale turbine/generator unit.
- 1:3.1 scale model of the U9 turbine is set up at Vattenfall Research and Development in Älvkarleby.



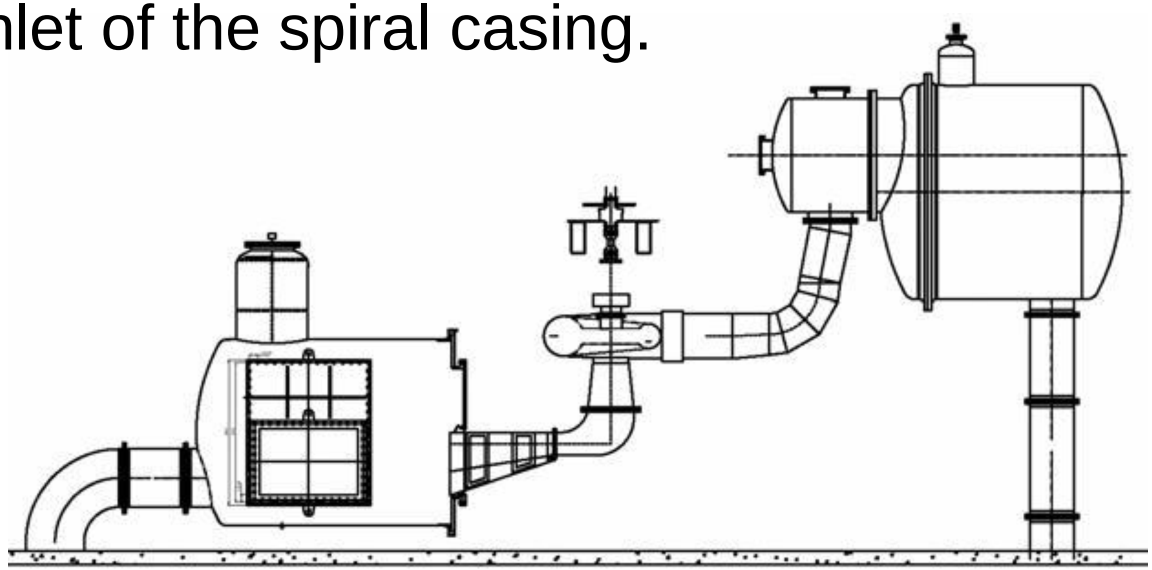
U9 unit, Porjus, Sweden



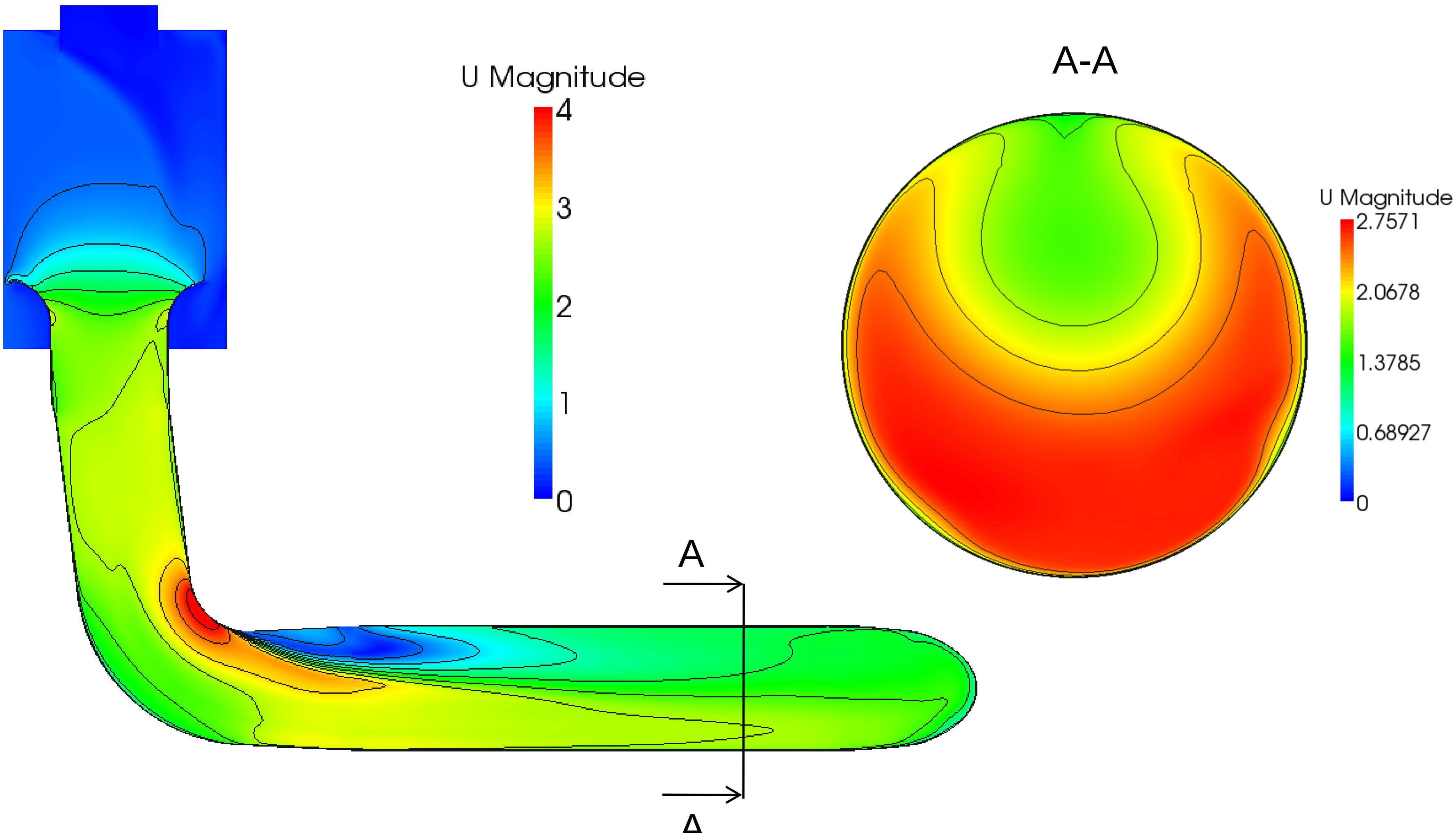
U9 scale model, Älvkarleby, Sweden

Goals of the U9 project

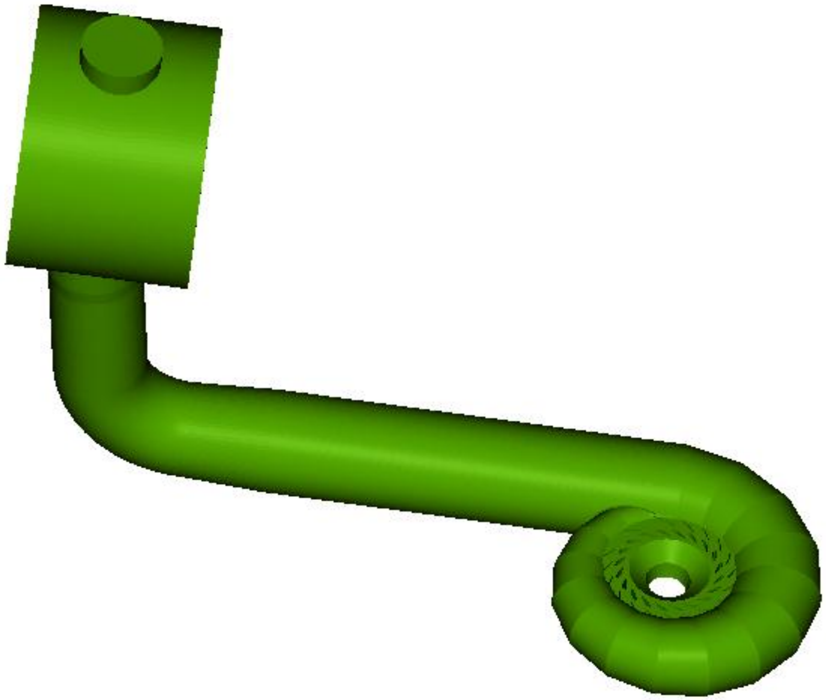
- Create a detailed measurements database that can be used to validate future numerical simulations. Berhanu Mulu and Pontus Jonsson (Luleå, Sweden) are responsible of this side of the project.
- Investigate the impact on the flow of the curved pipe at the inlet of the spiral casing.

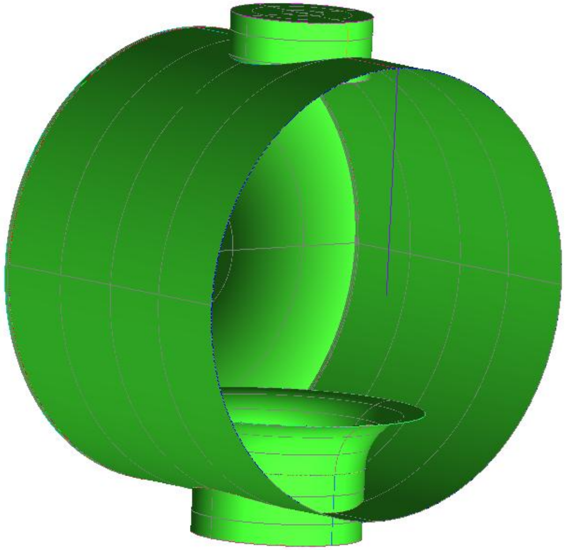


Goals of the project: impact of the curve pipe at the inlet on the flow



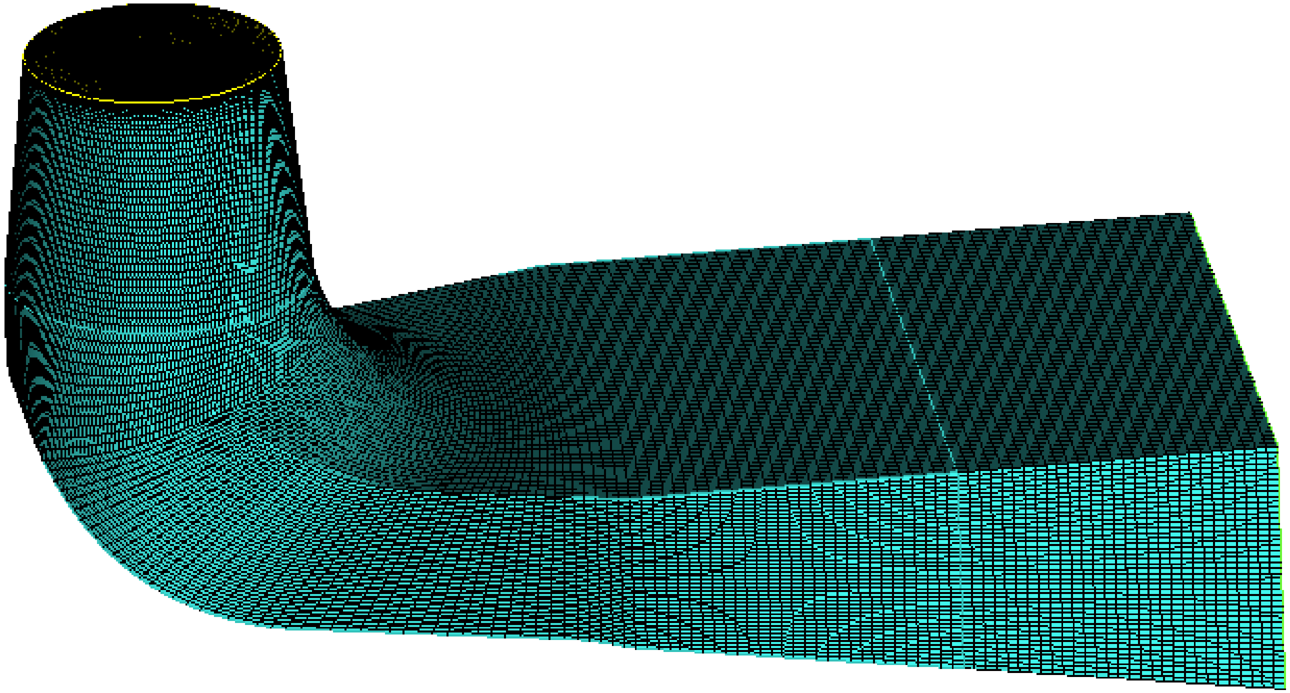
Porjus U9 computaional domain: spiral casing and inlet tank





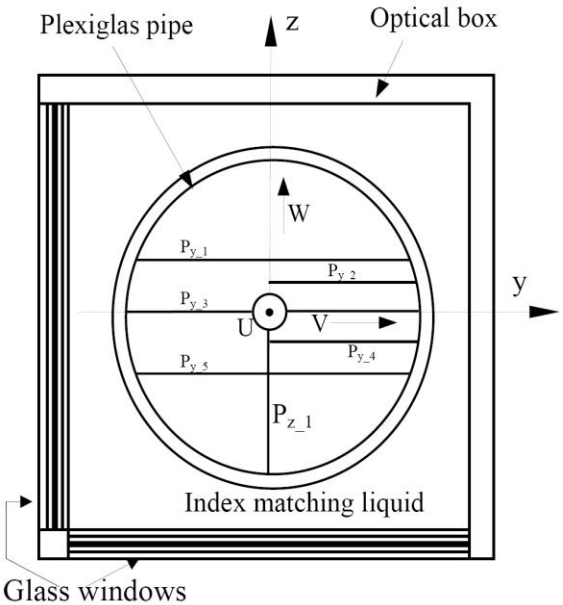
- U9 spiral casing: mesh of 5 millions cell, block structured hexaedral, realized with ICEM-HEXA.
- Y+ value between 50-100.

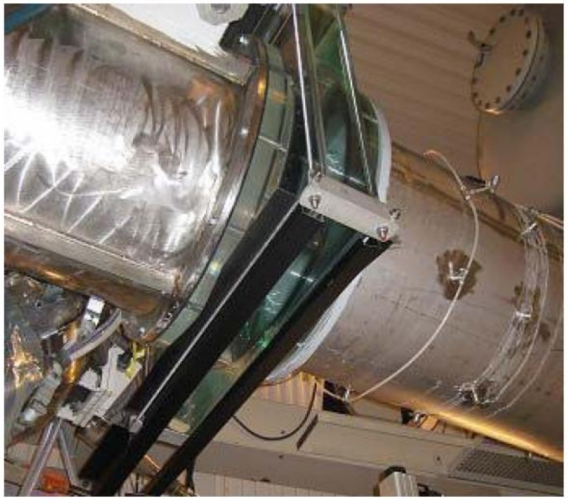
Porjus U9 computational domain: draft tube



- U9 draft tube: mesh of 1 million cell, block structured hexaedral, realized with ICEM-HEXA.
- Y+ value between 50-100.

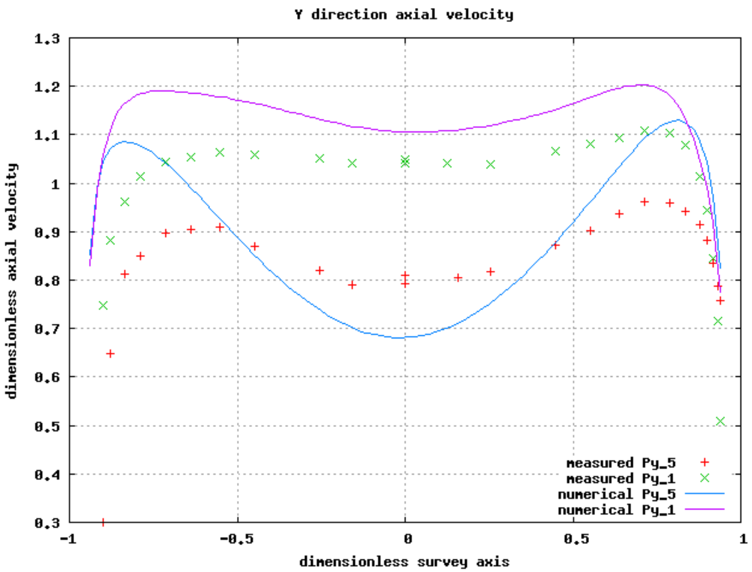
Inlet comparison with experimental measurements

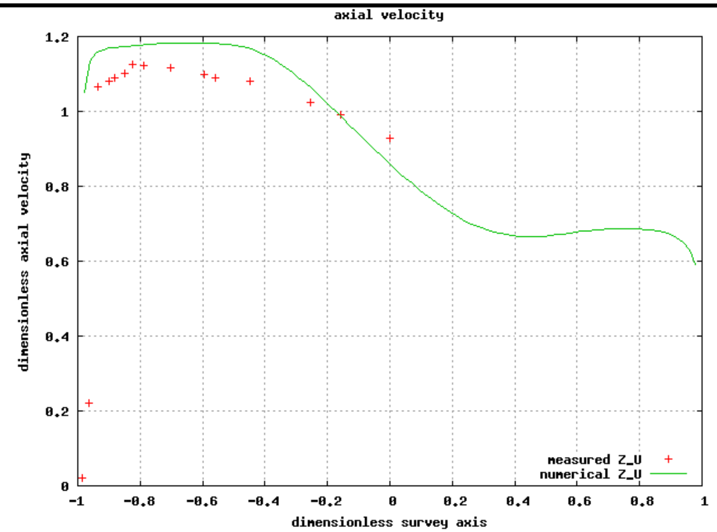


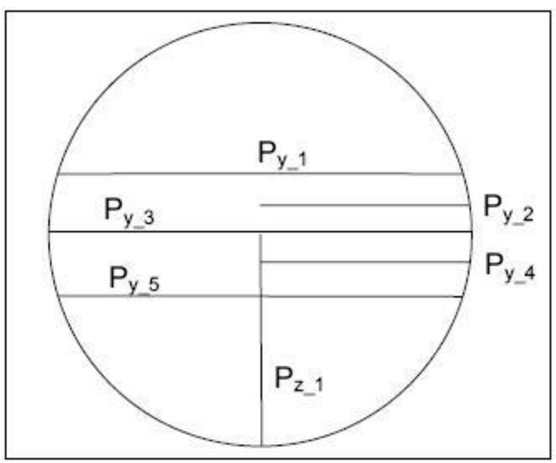


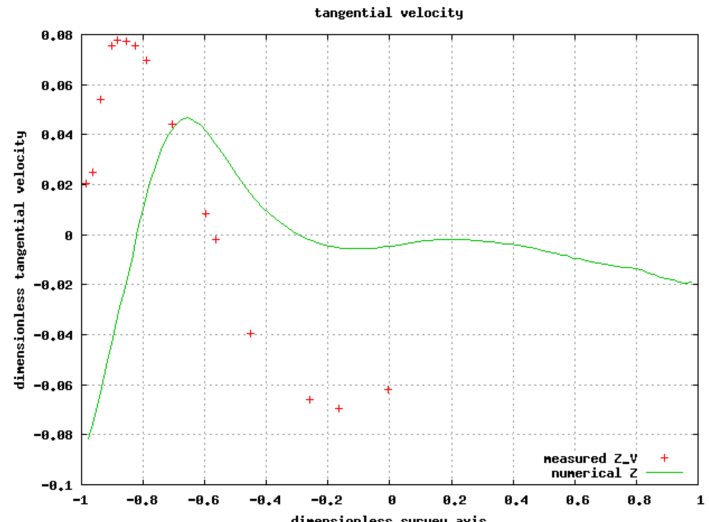
- At the inlet of the spiral casing, velocity profiles measured with LDA technique at 5 horizontal profiles(Py 1-5), and 1 vertical (Pz).
- Results presented in dimesionless form using R_{inlet}=0.316m, and $v_{Bulk}=Q/A_{inlet}$ Q=0.71 $m.s^{-1}$
- Comparison between experimental and numerical results are shown for the best efficiency point, Q=0.71 m/s, and alpha=26° (angle of the guide vanes)

Inlet comparison with experimental measurements





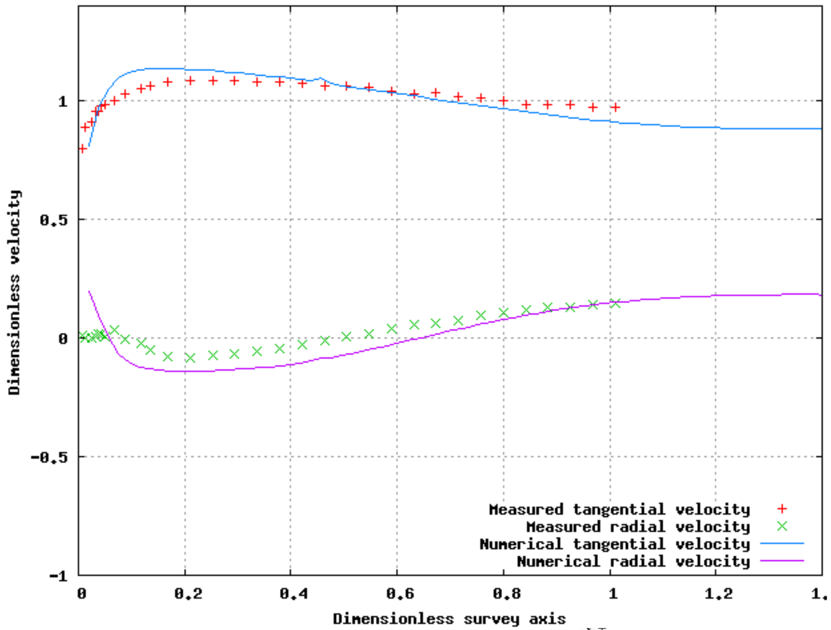


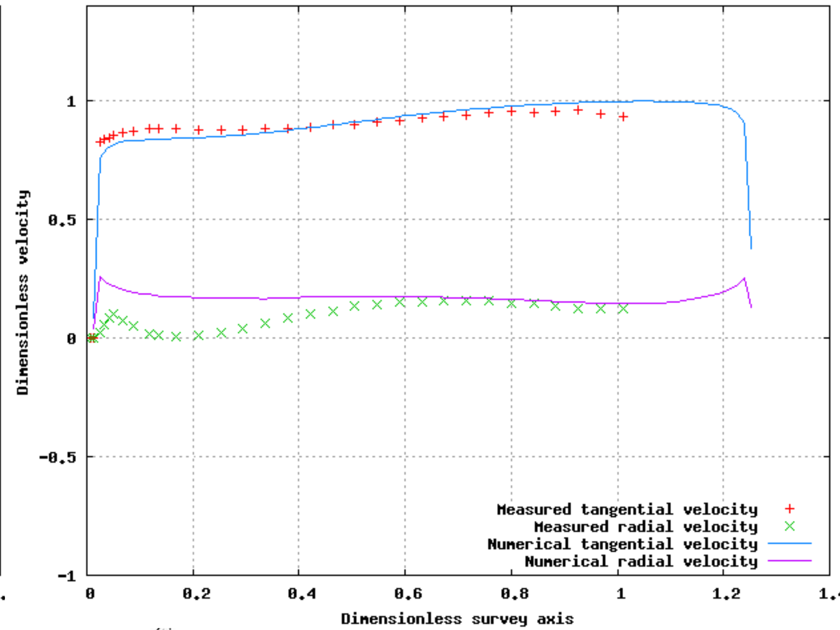


Inlet comparison with experimental measurements

- Similar behaviour between experimental and numerical results.
- Difference between numerical and experimental prediction of the flow can be due to the turbulence model and measurements error due to the curvature of the pipe.
- k-ε model does not solve accurately the flow features in a bend, need to aim at DES or LES model for better accuracy.

Spiral casing comparison with experimental measurements





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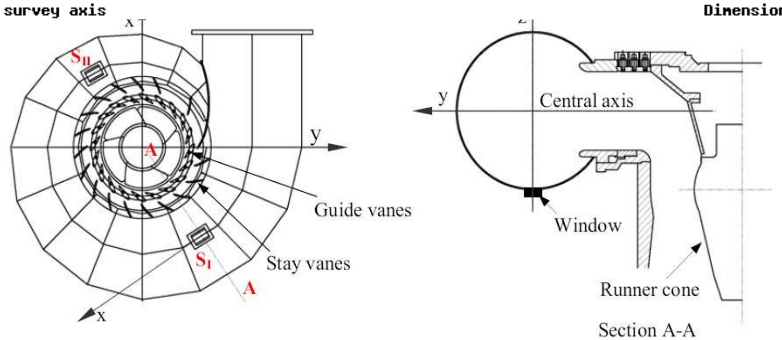

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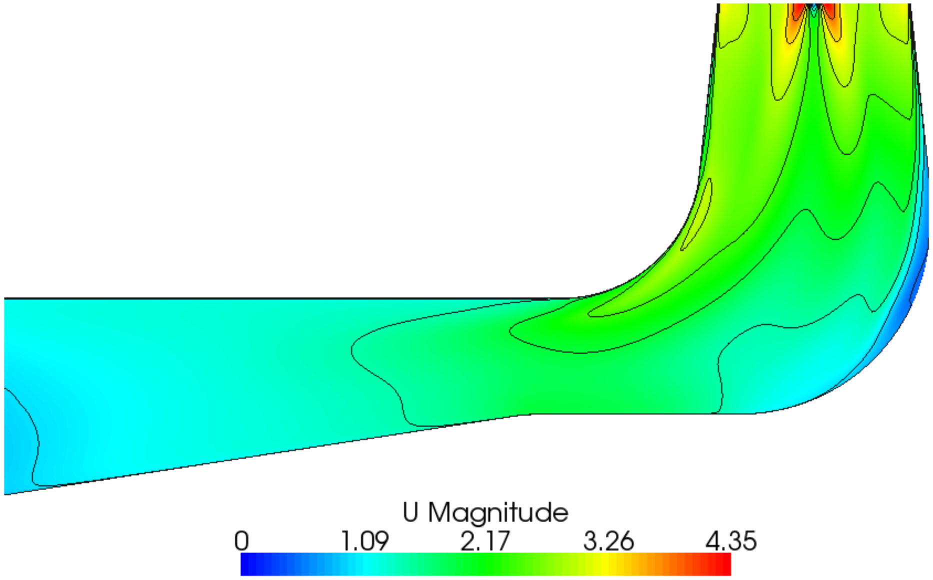
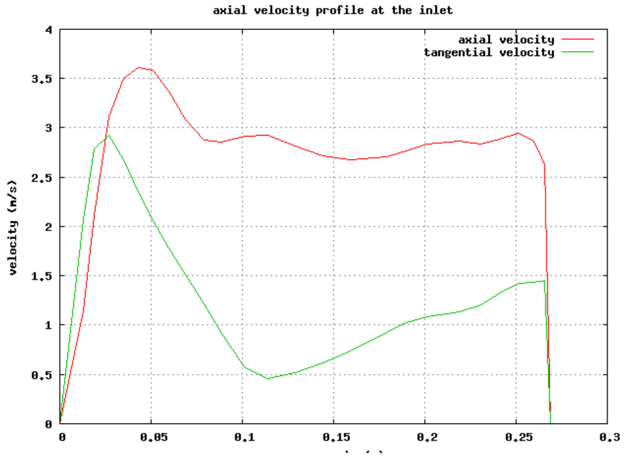
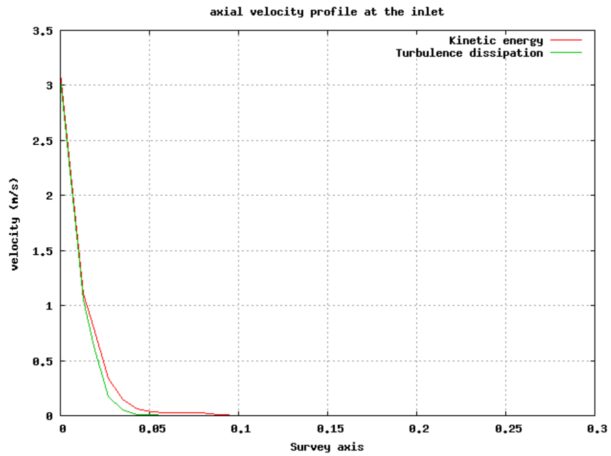
- Reference point is at the wall for both windows.

Draft tube comparison with experimental measurements



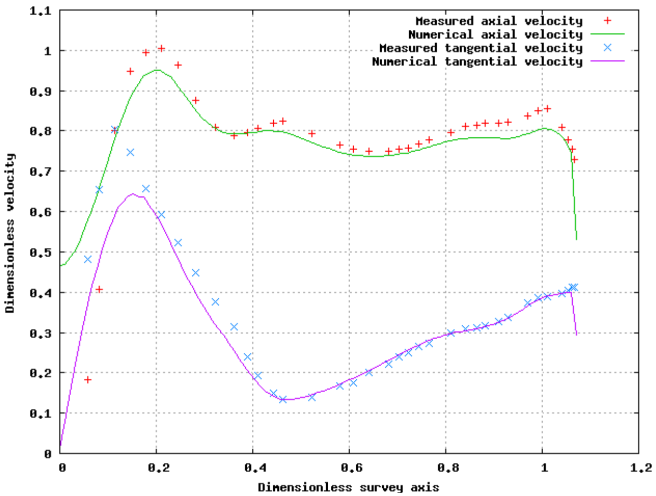




- The reference point is located on the centerline.
- Axi-symmetric profile is taken at the inlet from experimental data provided by Berhanu Mulu.

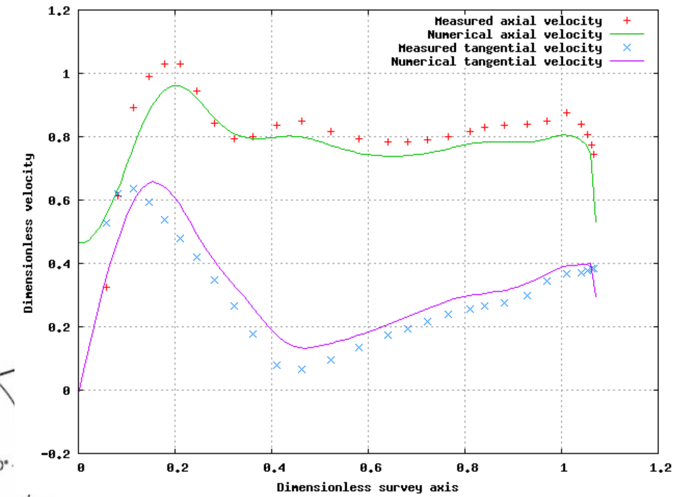
Inlet boundary conditions

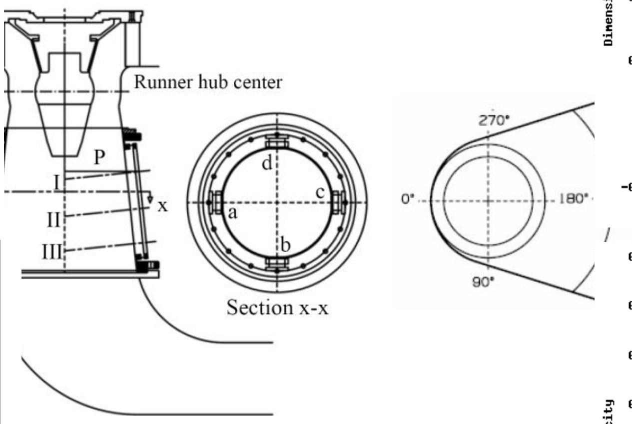
Draft tube comparison with experimental measurements

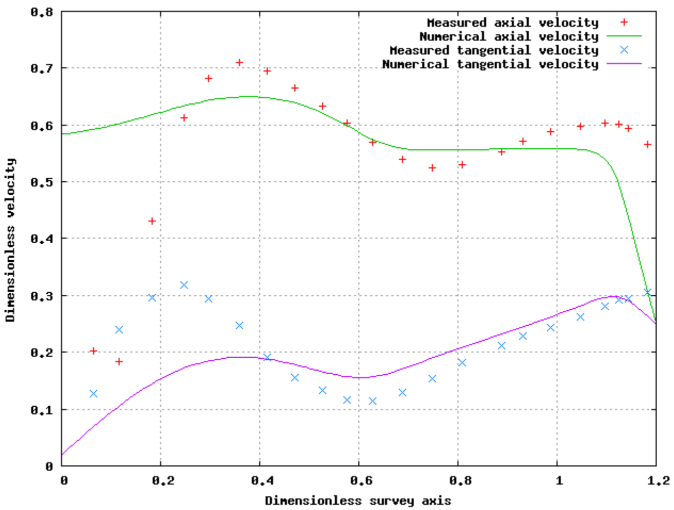


P1_a

P1_c







P3_a

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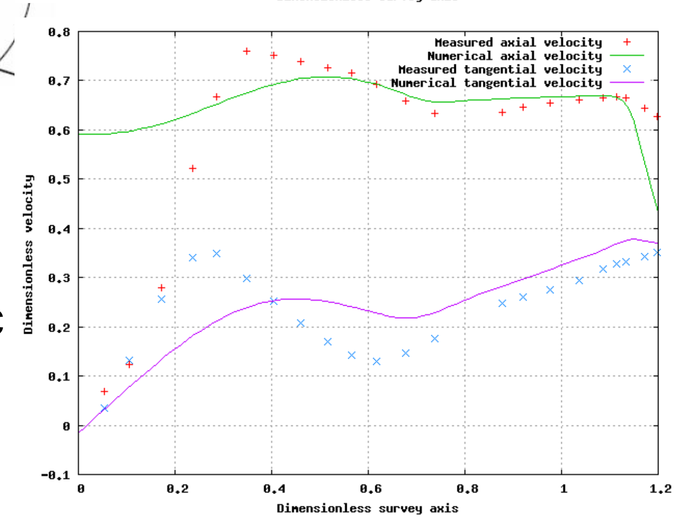


Draft tube comparison with experimental measurements

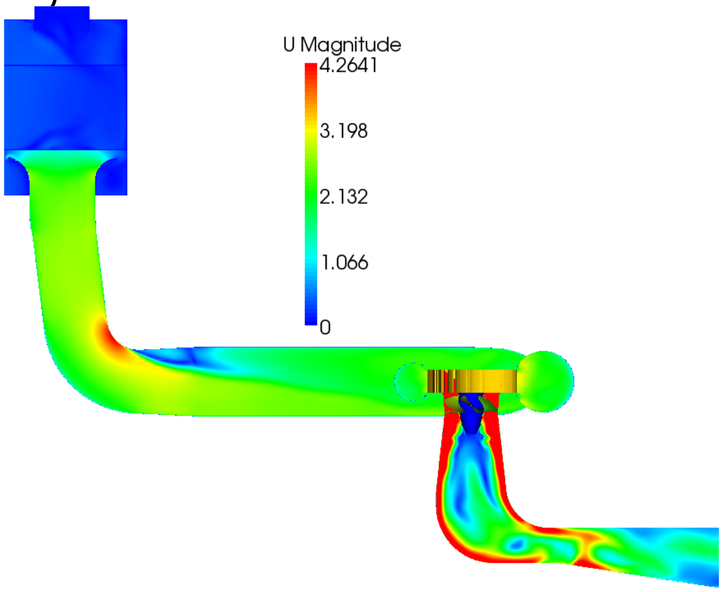
- Inlet boundary condition needs to include the unsteadiness of the wakes to predict accurately the flow in the draft tube

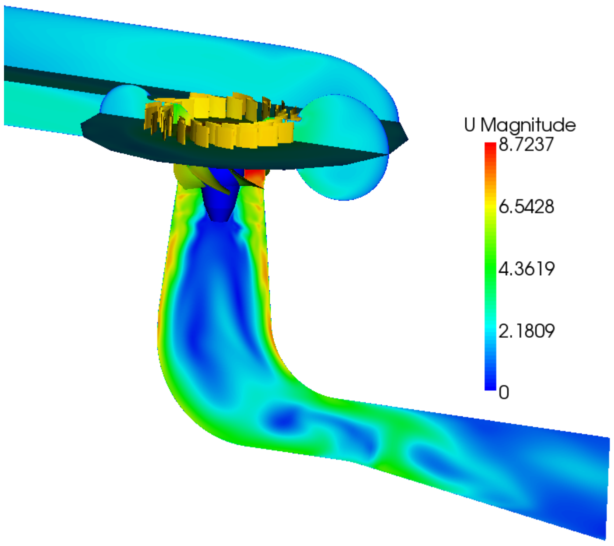
- Radial velocity must be included to get a good approximation of the flow

- Ultimately, unsteady simulation of the U9 runner coupled with the draft tube should predict accurately the turbulence flow features.

Future work

- Detailed investigations of appropriate boundary conditions for the U9 spiral casing.
- Turbulence model analysis to predict the flow more accurately. DES / LES should be investigated.
- Unsteady simulations of the whole U9 domain is ongoing work, the results need to be analysed.





Acknowledgements

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Thank you for your attention!