A Swirl Generator Case Study for OpenFOAM

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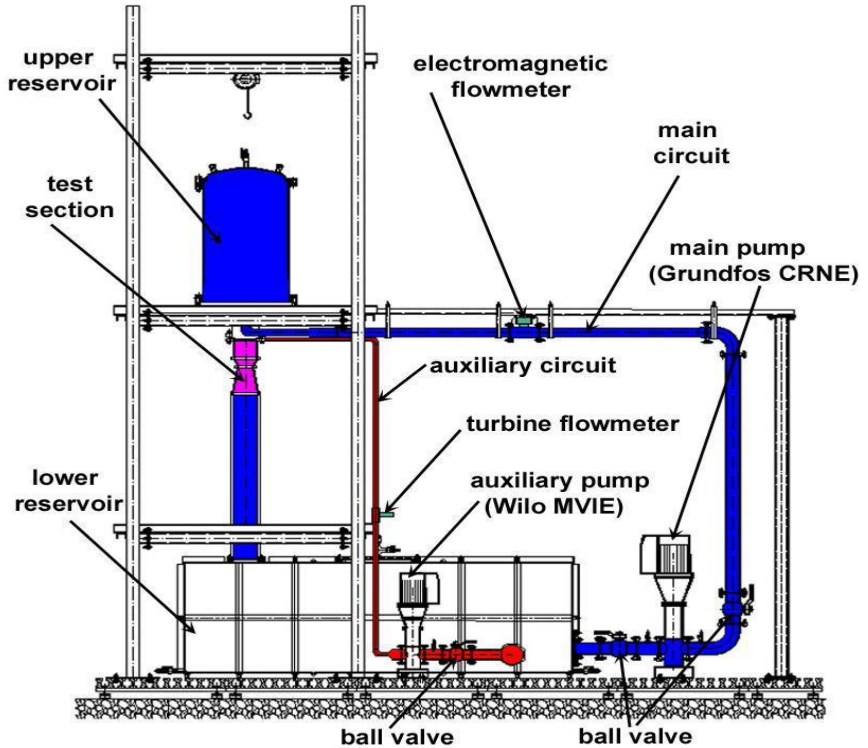
Aim of the Timisoara swirling flow test rig

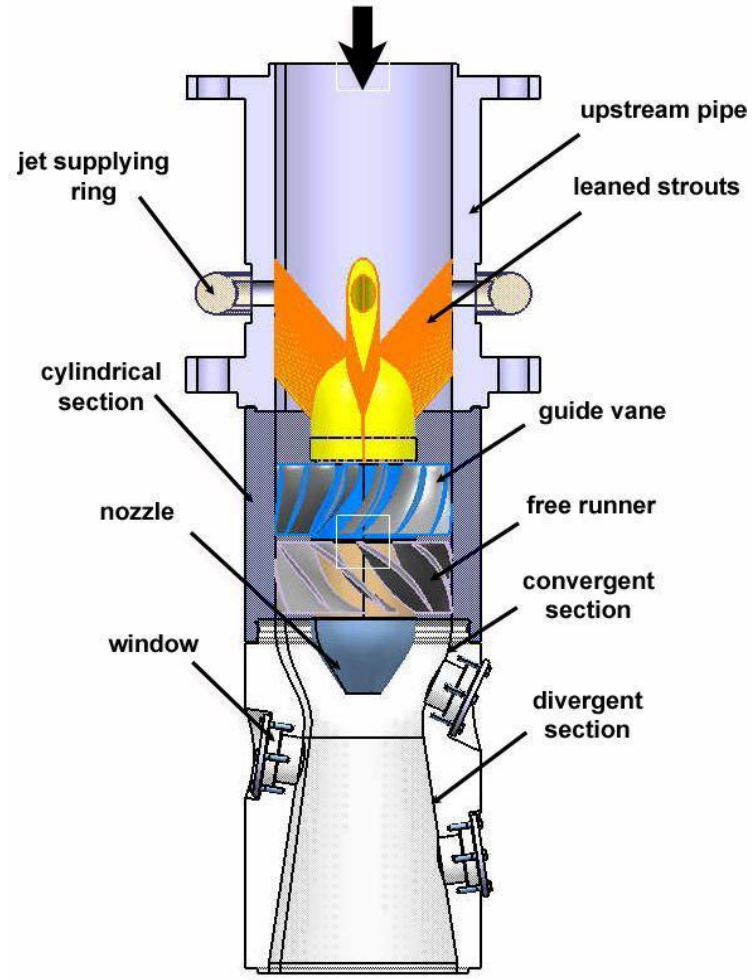
- Designed to create the flow features of a Francis turbine operating at part load

- Create a detailed measurement database to understand and better control the precessing vortex rope in the draft tube

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

Experimental setup

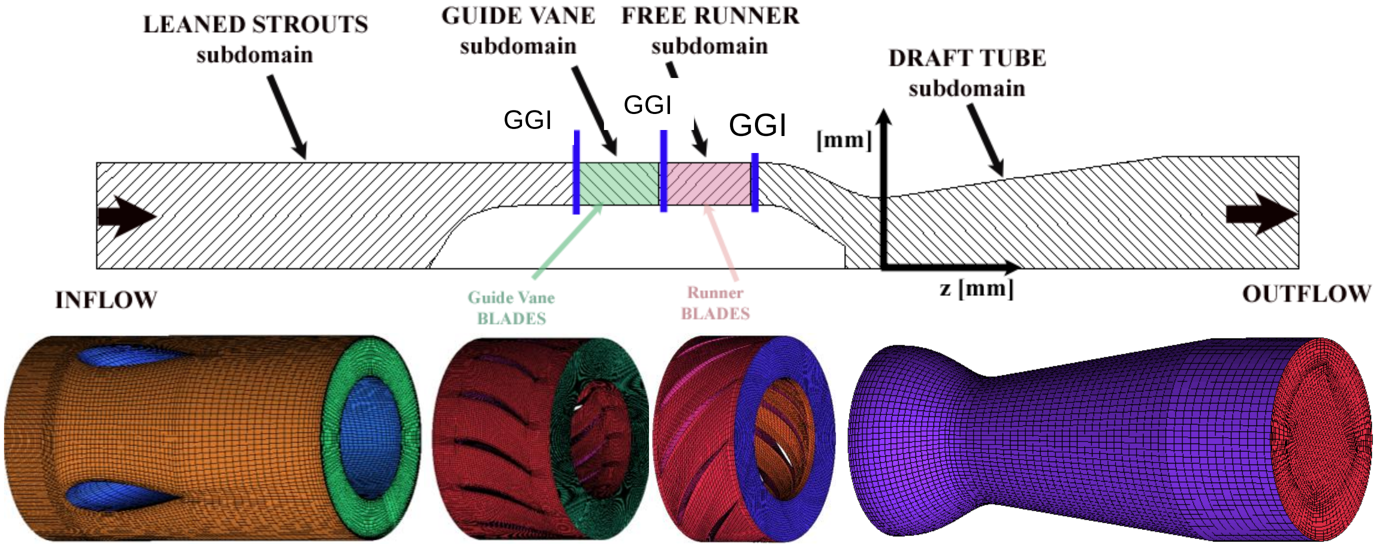




- Four leaned strouts
- 13 guide vanes
- Free runner with 10 blades
- Convergent divergent draft tube
- Free spinning runner (torque=0), omega=870 rpm

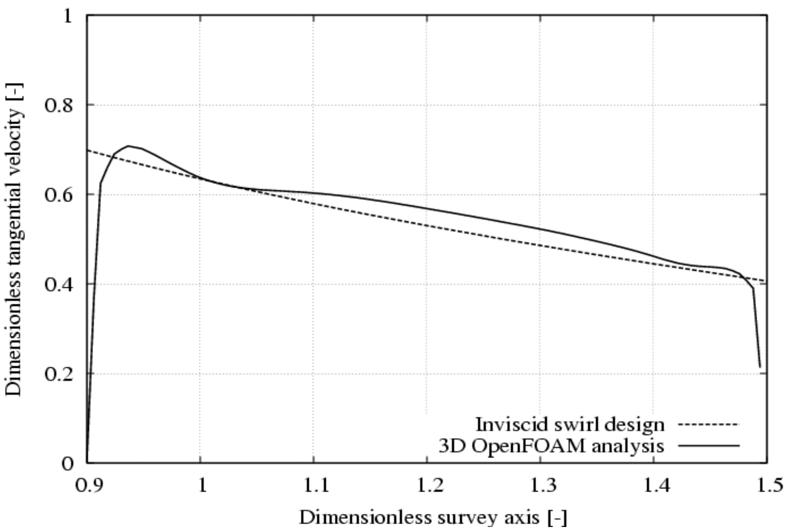
Computational domain and OpenFoam setup

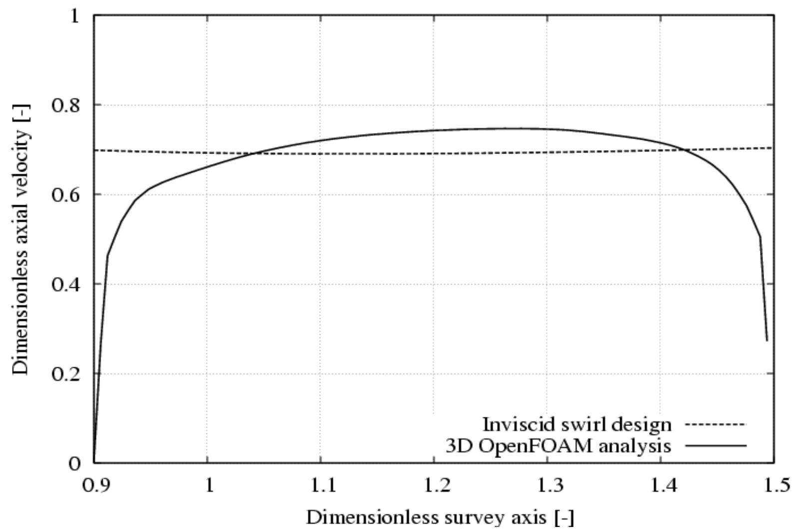
- 2.8 Millions cell, Hexaedral mesh
- Boundary condition at the inlet: plug-flow with nominal discharge 30 l/s
- Omega = 890 rpm (for which the runner spins freely in OpenFOAM)
- Unsteady simulation using k-ε turbulence model

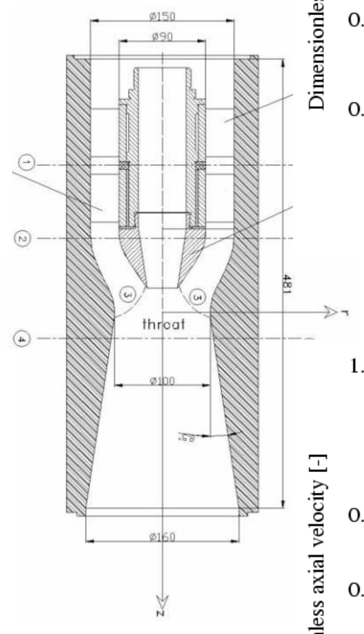


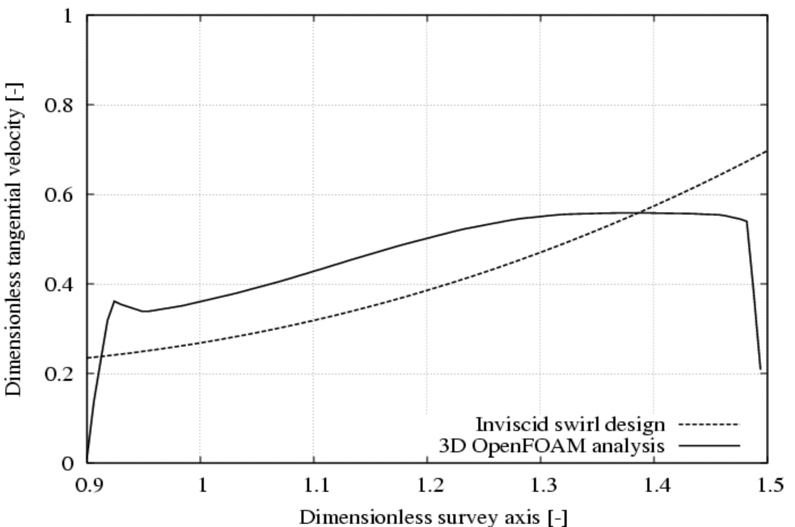
Comparison between designed and computed velocity profiles

Section 1

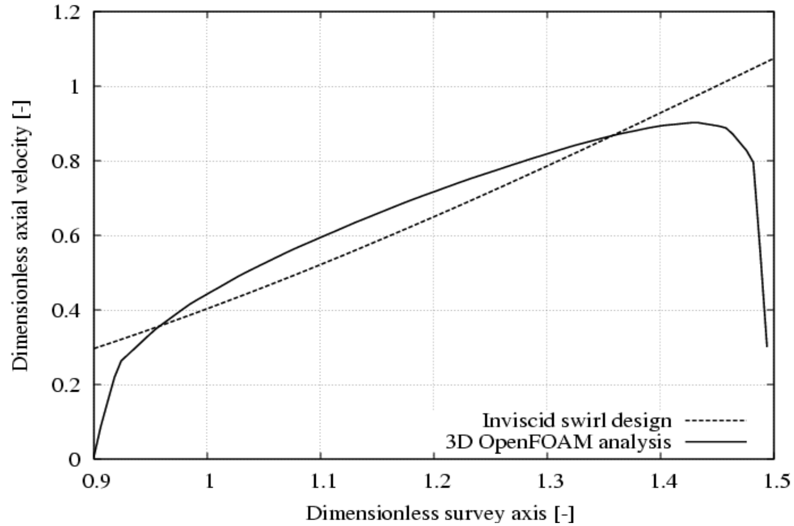








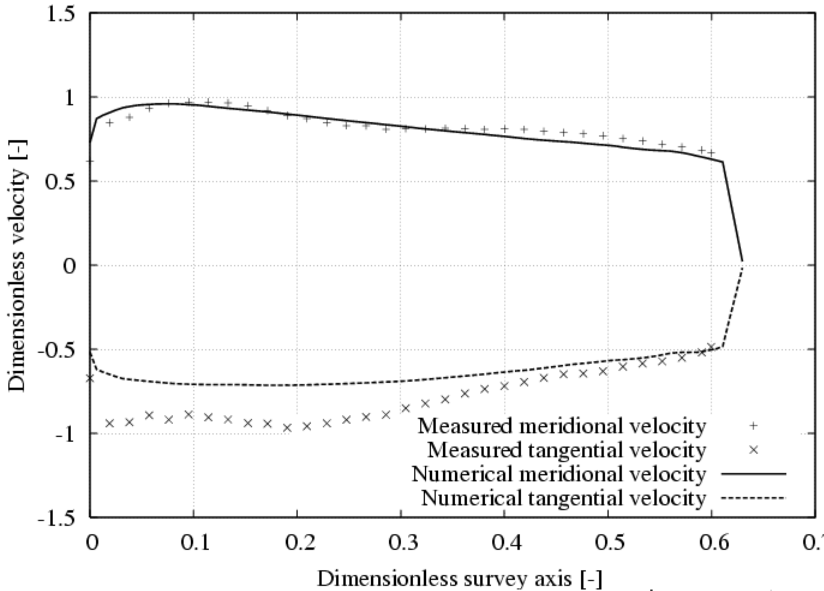
Section 2



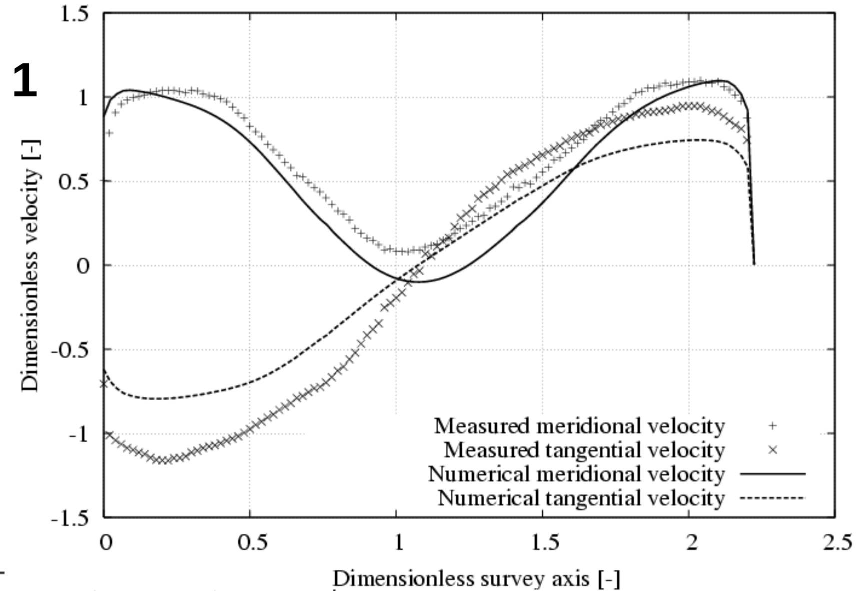
Comparison between designed and computed velocity profiles

- The numerical results obtained with OpenFOAM are in good agreement with the designed profile
- At section 2, although the axial velocity follows the intended profile rather well, the tangential velocity can not reach the intended value near the shroud
- Probable error in the estimation of the rotational velocity of the runner.

Comparison between experimental and computed velocity profiles

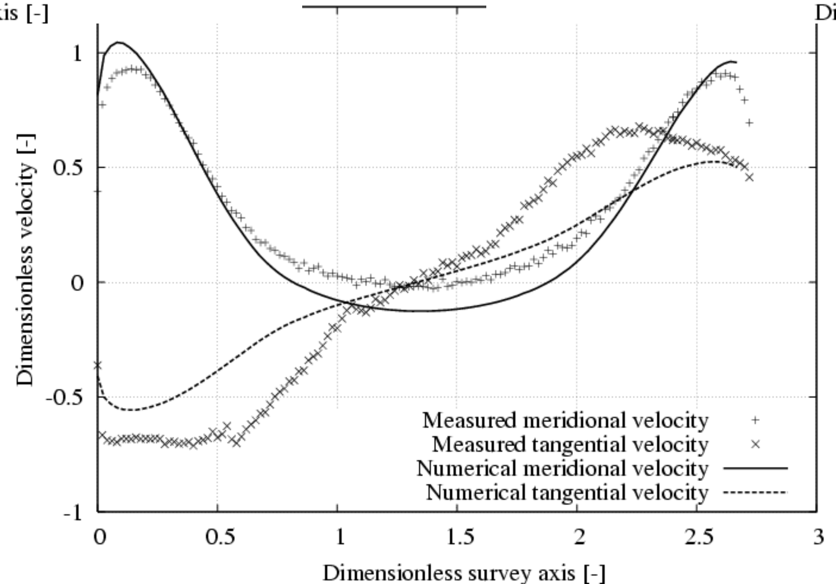


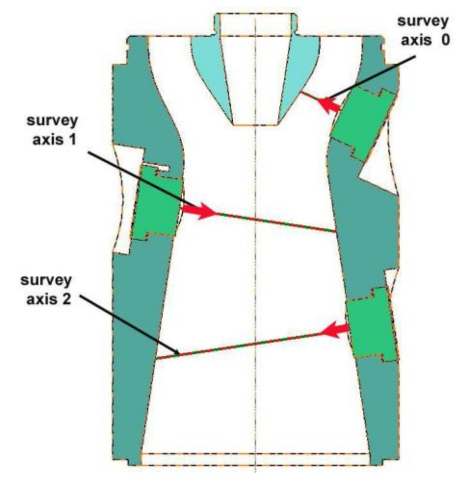
Axis 1



Axis 0

Axis 2



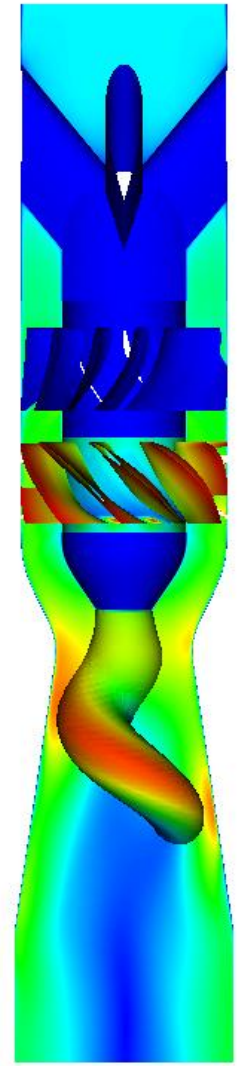


Comparison between experimental and computed velocity profiles

- Computed tangential velocity is a bit under predicted. This is probably due to an underestimation of the runner speed.

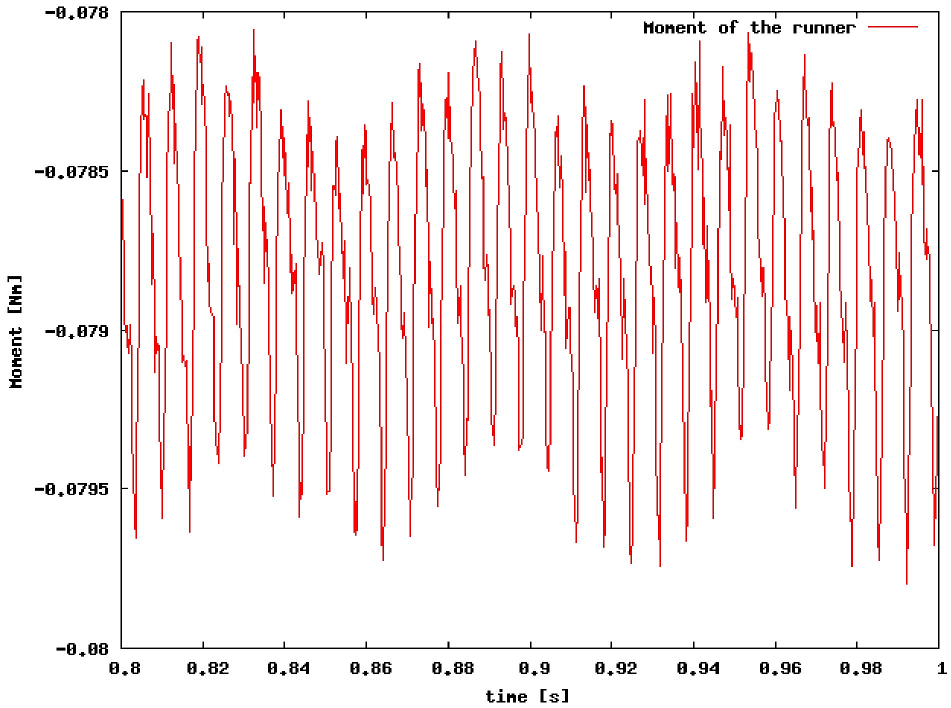
- The numerical set-up used in this simulation consists in a first-order scheme for the convection terms. Better prediction should be achieved using a second-order scheme.

Visualisation of the vortex rope.



Torque analysis

- The measured rotational velocity of the runner while achieving a zero torque is Ω=870 rpm, and in OpenFOAM was estimated to be Ω=890 rpm
- Two main frequencies are visible: the rotating vortex rope (low frequency), and the rotor-stator interaction (high frequency).



Conclusion

- The velocity profiles predicted by OpenFOAM are accurate, and in good agreement with experimental LDV measurements and designed velocity profiles.

- The tangential velocity is under estimated, probably due to the inaccuracy of the first-order scheme for the convection terms, and to the rotation speed of the runner.

Future work

- Find the accurate runner speed for which in OpenFOAM the runner spins freely
- Investigate different turbulence models to better predict the unsteadiness of the flow
- Pressure analysis and frequency analysis should as well be realized

Acknowledgements

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Thank you for your attention!