**5th International Workshop on**
Cavitation and Dynamic Problems in Hydraulic Machinery,
September 8-11, 2013, Lausanne, Switzerland

# Numerical Investigations of the Dynamics of the Full Load Vortex Rope in a Francis Turbine

**Olivier Braun[1], Adrien Taruffi[1], Nicolas Ruchonnet[1], Andres Müller[2] and François Avellan[2]**

[1]Andritz Hydro, R&D, Engineering Methods, Hardstrasse 319, 8021 Zürich, Switzerland.
olivier.braun@andritz.com
[2]EPFL Laboratory for Hydraulic Machines, Av. de Cour 33 Bis, 1007 Lausanne, Switzerland.
andres.mueller@epfl.ch, francois.avellan@epfl.ch

**Abstract**

The draft tube vortex rope occurring in Francis Turbines at full load is a potential cause of severe system instabilities, limiting the operating range of concerned hydro power plants. Studies focusing on physical mechanisms [1], methods for stability assessment based on numerical flow simulation [2, 3], studies on simplified configurations [4] and detailed numerical simulations [5] have been published. The pulsations of the rope volume being the core element of the system instability, the size and shape and dynamic evolution of the vortex rope predicted by numerical methods are essential in the validation of these methods. More experimental results [6, 7] of the study case underlying former numerical simulations [3], allow a review of these cases with improved boundary conditions, based on measurements instead of assumptions. On the other hand, the completed experimental database provides more validation cases to better understand the shortcomings of the numerical simulation techniques and identify the potential for improvement of predication capabilities. Advances in computational resources and optimization of the numerical parameters have allowed completing the range of comparisons of numerical versus experimental results close to the onset of instability. Results are compared in terms of the globally unsteady behavior as well as local pressure and velocity measurements at different locations in the draft tube.

**Keywords**: Full load, Surge, Stability, Multiphase, Cavitation, Vortex rope.

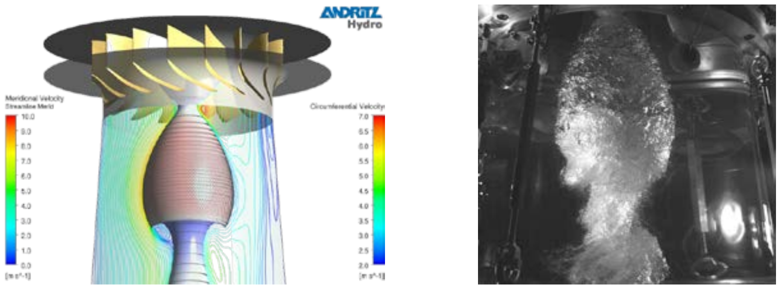


**Fig. 1 –** Comparison of predicted vortex rope shape versus High Speed Visualization.

## References

[1] Chen, C., Nicolet, C., Yonezawa, K., Farhat, M., Avellan, F. and Tsujimoto, Y., 2008, “One dimensional analysis of full load draft tube surge”, Journal of Fluid Engineering, No. 130, pp. 041106-1 - 041106-6

[2] Alligné, S., Maruzewski, P., Dinh, T., Wang, B., Fedorov, A., Iosfin, J. and Avellan, F., 2010, “Prediction of a Francis turbine prototype full load instability from investigations on a reduced scale model”, 25th IAHR Symposium on hydraulic Machinery and Systems, Timisoara, Romania

[3] Dörfler, P., Keller, M. and Braun, O., 2010, “Francis full-load surge mechanism identified by unsteady 2-phase CFD”, 25th IAHR Symposium on hydraulic Machinery and Systems, Timisoara, Romania.

[4] Yonezawa, K., Konishi, D., Miyagawa, K., Avellan, F., Dörfler, P. and Tsujimoto, Y., 2012, “Cavitation Surge in a Small Model Test Facility Simulating a Hydraulic Power Plant”, Proceedings of the 8th International Symposium on Cavitation, August 14-16, 2012, Singapore

[5] Chirkov, D., Avdyushenko A.,Panov, L., Bannikov, D. ,Cherny, S., Skorospelov, S. and Pylev, I., “CFD simulation of pressure and discharge surge in Francis turbine at off-design conditions”, 26th IAHR Symposium on hydraulic Machinery and Systems, Beijing, China

[6] Müller, A., Bullani, A., Dreyer, M., Roth, S., Favrel, A., Landry, C. and Avellan, F., “Interaction of a Pulsating Vortex Rope with the Local Velocity Field in a Francis Turbine Draft Tube”, 26th IAHR Symposium on hydraulic Machinery and Systems, Beijing, China

[7] Müller, A., Dreyer, M.; Andreini, N. and Avellan, F., “Draft tube discharge fluctuation during self-sustained pressure surge: fluorescent particle image velocimetry in two-phase flow”, Experiments in Fluids, 2013