18th International Conference
ENGINEERING MECHANICS 2012
Svratka, Czech Republic, May 14 – 17, 2012
pp. 326–327
Paper #57

# STRUCTURE OF FLOW FIELDS DOWNSTREAM OF TWO DIFFERENT SWIRL GENERATORS

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**Abstract:** *This paper discusses the comparison of the flow fields downstream of two different swirl generators. Both swirl generators are used to imitate the flow at the exit of the hydraulic turbine runner and study spatio-temporal behaviour of the swirling flow in the draft tube (i.e. outlet diffuser part of the hydraulic turbine), which undergoes breakdown into vortex rope. Unsteady CFD computations are carried out for identical Reynolds number. Resulting velocity and vorticity profiles are correlated with the structure of the vortex rope. Difference in excited pressure pulsations is illustrated on amplitude-frequency spectra of static wall pressure.*

**Keywords:** ***swirl generator, vortex rope, velocity profile, vorticity, pressure fluctuations.***

## 1. Introduction

Difficulty of the swirling flow investigation in scaled model of hydraulic turbine draft tube leads to idea of building up a simplified apparatus that best imitates the flow at the exit of the Francis turbine operated at partial discharge (Avelan et al., 2000, Ciocan et al., 2007, Susan-Resiga et al., 2009). The swirl generators have been developed at "Politehnica" University of Timisoara (SG-RO) (Susan-Resiga et al., 2008) as well as at V. Kaplan Dept. of Fluid Engineering, Brno University of Technology (SG-CZ) (Rudolf et al, 2011), see fig. 1.

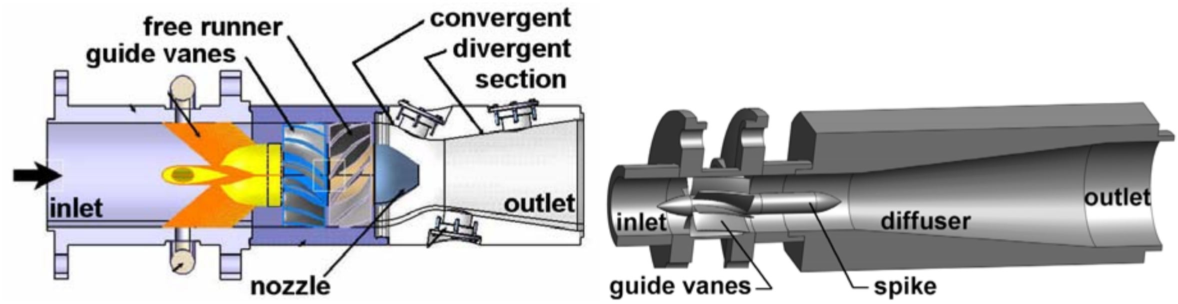


*Fig. 1: Experimental setup of SG-RO swirl generators on the left and SG-CZ on the right.*

Present comparison is based on numerical computation in commercial software ANSYS Fluent R13 using Reynolds Averaged Navier-Stokes equations. Both considered computational domains are downstream parts of swirl generator apparatuses, i.e. convergent divergent section in case of SG-RO and conical diffuser in case of SG-CZ. For better comparison of computed results, we employed RSM turbulence model with higher computational requirements but superior performance for highly swirling flow (Jawarneh et al., 2006, Susan-Resiga et al., 2010). Swirling flow generated by the swirl generator and further decelerated in the diffuser is very complex and time unstable. For result discussion the velocity and vorticity profiles as well as the pressure pulsations in four survey sections

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are extracted from unsteady calculation. Example of computed vortex ropes and time averaged backflow regions are shown in fig. 2 for both cases of swirl generators.

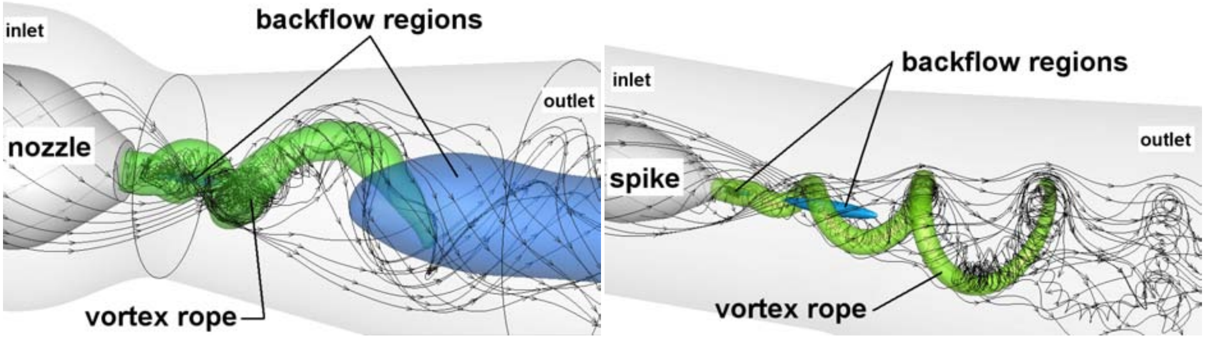


*Fig. 2: Vortex rope and time averaged backflow regions, SG-RO on the left and SG-CZ on the right.*

## 2. Conclusions

Different shape of vortex rope, generated by each swirl generator, corresponds with different value of swirl number. SG-RO with higher swirl number than SG-CZ composes swirling flow with more massive vortex rope. Vortex rope has larger width and forms into shape with higher ascend of helix. This shape is similar to the vortex rope appearing in Francis turbine draft tube (FLINDT project) during operation on 70%$Q_{BEP}$ and was main designed parameter of SG-RO. On the other hand, vortex rope generated by SG-CZ is thinner and forms into shape with lower ascend of the helix. In comparison with the vortex ropes computed in paper Rudolf 2009 for inlet boundary conditions derived by Susan-Resiga et al., 2006, the vortex rope generated by SG-CZ is very similar one to the vortex rope corresponding with the turbine operation on 90%$Q_{BEP}$. Results show strong coupling between axial and circumferential velocity profiles and its influence on vortex rope shape. The circumferential velocity component appears as the factor with largest influence on vortex rope formation.

## Acknowledgement

Czech Science Foundation is gratefully acknowledged for support of the research under project No. 101/09/1715 "Cavitating vortical structures induced by rotating liquid". This project is supported by junior research grant number FSI-J-12-21/1698 provided by Brno University of Technology. The Timisoara swirl generator test case and associated experimental data was supported by the Romanian Agency CNCSIS – UEFISCSU, Exploratory Research Project PN II - IDEI 799/2008.

## References

Avellan, F. (2000) Flow Investigation in a Francis Draft Tube: The FLINDT Project, in: *Proceedings of the 20th IAHR Symposium on Hydraulic Machinery and Systems*, Charlotte, USA, Paper DES-11.

Ciocan, G. D., Iliescu, M. S., Vu, T. C., Nennemann, B., Avellan, F. (2007) Experimental study and numerical simulation of the FLINDT draft tube rotating vortex, *Journal of Fluids Engineering*, Vol. 129, pp.146–158.

*Hydrodynamics,* Stuttgart, Germany, June 12-15.

Jawarneh, A. M., Vatistas, G. H. (2006) Reynolds Stress Model in the Prediction of Confined Turbulent Swirling Flows, in: *ASME Journal of Fluid Engineering,* Vol. 128, p.p.1377-1382.

Rudolf, P. (2009) Connection between inlet velocity field and diffuser flow instability, in: *Applied and Computational Mechanics,* Vol. 3, No. 1, pp. 177 - 184

Rudolf, P., Hudec, M., Zubík, P., Štefan, D. (2011) Experimental measurement and numerical modeling of cavitating flow in converging-diverging nozzle, in: *Proceedings of the International Conference Experimental Fluid Mechanics 2011*, pp.423-431, Jíčín, Czech Republic.

Susan-Resiga, R. F., Ciocan, G. D., Anton, I., Avellan, F. (2006) Analysis of the swirling flow downstream of a Francis turbine runner. *Journal of Fluid Engineering,* Vol. 128, pp.177-189.

Susan-Resiga, R. F., Muntean, S., Tanasa, C., Bosioc, A. (2008) Hydrodynamic Design and Analysis of a Swirling Flow Generator, in: *Proceedings of the 4th German – Romanian Workshop on Turbomachinery Hydrodynamics* (GRoWTH), June 12-15, 2008, Stuttgart, Germany.

Susan-Resiga, R. F., Muntean, S., Stein, P., Avellan, F. (2009) Axisymmetric swirling flow simulation of the draft tube vortex in Francis turbines at partial discharge, in: *Int. J. Fluid Mach. Sys.* 2, pp.295–302.