SELF-INDUCED INSTABILITIES OF THE SWIRLING FLOW IN HYDRAULIC TURBINES FAR FROM THE BEST EFFICIENCY REGIME

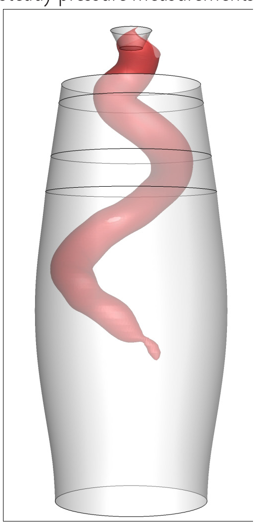
Goal of the project

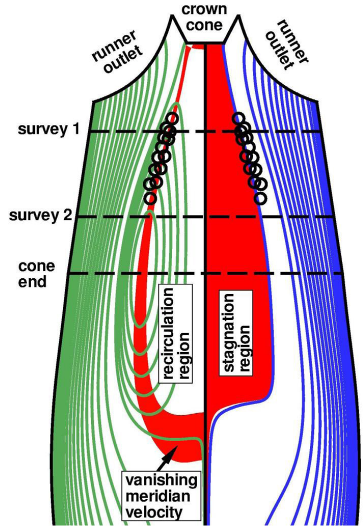
The project purpose is to develop an integrated methodology for a-priori quantitative assessment of the swirling flow unsteadiness in hydraulic turbines, thus providing the necessary tool for swirl optimization before actually designing the turbine runner. Such a methodology is required in order to answer the current requirements for modern turbines, which must operate safely within a large range of discharge values, quite often far from the best efficiency point.

Short description of the project

We develop mathematical models, numerical algorithms and computer codes for axisymmetric turbomachinery swirling flows including the axisymmetric vortex sheet developed downstream the runner at off-design operating regimes. Then, we analize the stability of the axisymmetric swirling flow with a central stagnant region bounded by a vortex sheet.

The scenario for axisymmetric vortex sheet instability and further development of a precessing helical vortex (vortex rope) is investigated by unsteady, three-dimensional, turbulent flow computations in real geometries of hydraulic turbine draft tube, in order to validate the main hypothesis adopted in the present study. Validation of the methodology for quantitative a-priori assessment of the unsteadiness level of the swirling flows issued from the hydraulic turbine runners when operating far from the best efficiency point will use experimental data obtained on a swirl apparatus, including both LDV and unsteady pressure measurements.





Main activities

Objective 1. Develop mathematical models, numerical algorithms and computer codes for axisymmetric turbomachinery swirling flows including the axisymmetric vortex sheet developed downstream the runner at off-design operating regimes.

Activity 1.1. Development of the mathematical model for 2D swirling flow, with stagnant region.

Activity 1.2. Implementation of the numerical algorithm and code development

The project develops a novel model to account for the swirling flow within the meridian cross-section of the turbine, which also solve the problem of singularity at the axis, currently dealt with by truncating the computational domain away from the axis. The vortex sheet originates from an inviscid separation on the runner crown, and evolves into the conical diffuser further downstream.

Project implemented by

Turbomachinery Hydrodynamics Division, Research Centre for Complex Fluid Systems Engineering, Politehnica University Timişoara

Implementation period

2013-2015

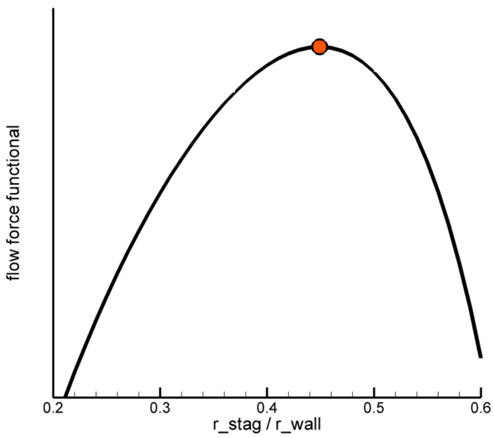
Results

Within the period sep.-dec. 2013 we validated a novel variational formulation for axisymmetric, steady swirling flows. While the functional for the Bragg-Hawthorne equation is minimized within the flow region, the new augmented functional which includes the contribution of the stagnant region is maximized with respect to the stagnant region extent.

From physical point of view, this corresponds to the minimization of the swirl number for the equilibrium configuration of the swirling flow, as expected. Our model considers that the stagnant region is bounded by a vortex sheet with a velocity jump but with continuous static pressure, as required for a fluid interface. A simple example for free swirl in a pipe shows that development of a central stagnant region avoids the axis singularity.

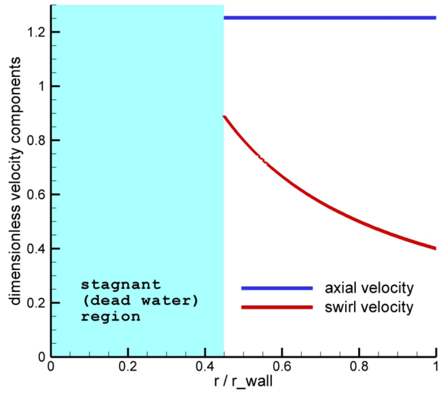
Applicability and transferability of the results

The basic research in turbine hydrodynamics was traditionally focused on improving efficiency of hydraulic-to-mechanic energy conversion at peak efficiency or in the neighborhood. However, the need to compensate in real time the wind-power fluctuations requires new approaches to safely increase the flexibility in operating hydraulic turbines. In particular, there is a need for methodologies to assess and minimize the flow instabilities and associated severe pressure fluctuations, and this project is developing the foundation to answer such demands through basic research developments.



Fields of interest

- Turbomachinery hydrodynamics, optimized design and flow control at off-design regimes
- Swirling flow hydrodynamics and instability
- Mathematical models and numerical algorithms for swirling flows
- Experimental investigation of swirling flows (Laser Doppler Velocimetry, unsteady pressure measurements)



Research centre

Research Centre for Complex Fluid Systems Engineering

Financed through/by

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Research team

Romeo SUSAN-RESIGA, PhD, Professor, project director
Sebastian MUNTEAN, PhD, Senior Researcher
Adrian STUPARU, Postdoctoral researcher
Alin BOSIOC, PhD, Postdoctoral researcher
Constantin TĂNASĂ, Postdoctoral researcher
Tiberiu CIOCAN, Doctoral student
Cosmin IGHIŞAN, Doctoral student

Contact information

Prof. Romeo SUSAN-RESIGA, PhD
Department of Mechanical Machines, Equipment and Transportation
Address: Bv. Mihai Viteazu, No.1, RO300222, Timisoara
Phone: (+40) 256 403 689
E-mail: romeo.resiga@upt.ro