Numerical investigation of the flow in a swirl generator, using OpenFOAM

Oscar Bergman

Outline

- Introduction
- Purpose and goal
- Experimental rig and measurements
- Numerical setup
- Results
- Conclusions
- Future work

Introduction

Purpose and goal

- Conduct steady-state and unsteady 3D simulations on a swirl generator.

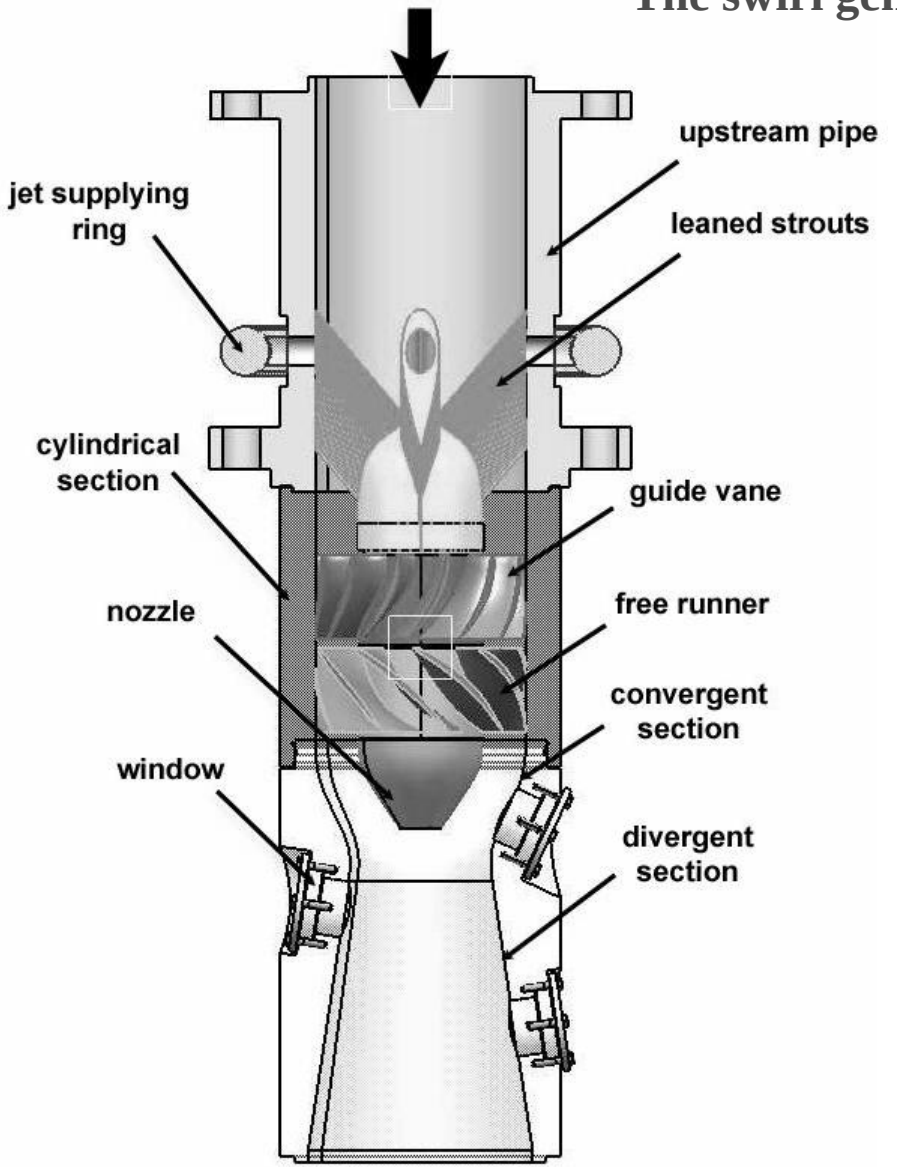
- Compare with measurements and theoretical design data from previous studies.

- Provide results for helping future studies in solving the problem with precessing vortex ropes in water turbines.

- Provide a tutorial of the case to the OpenFOAM community.

Experimental rig

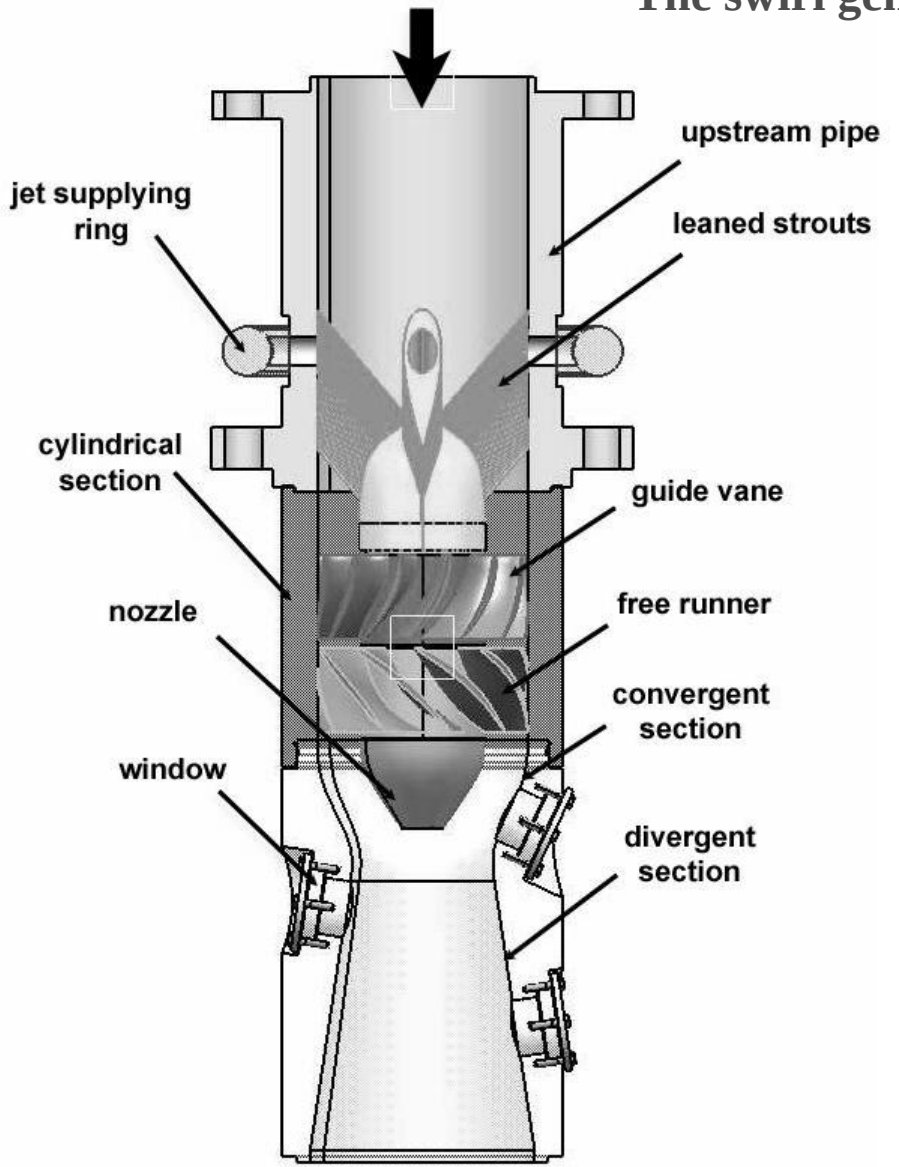
The swirl generator



Experimental rig

- Strout
  - Holds up the nozzle

The swirl generator

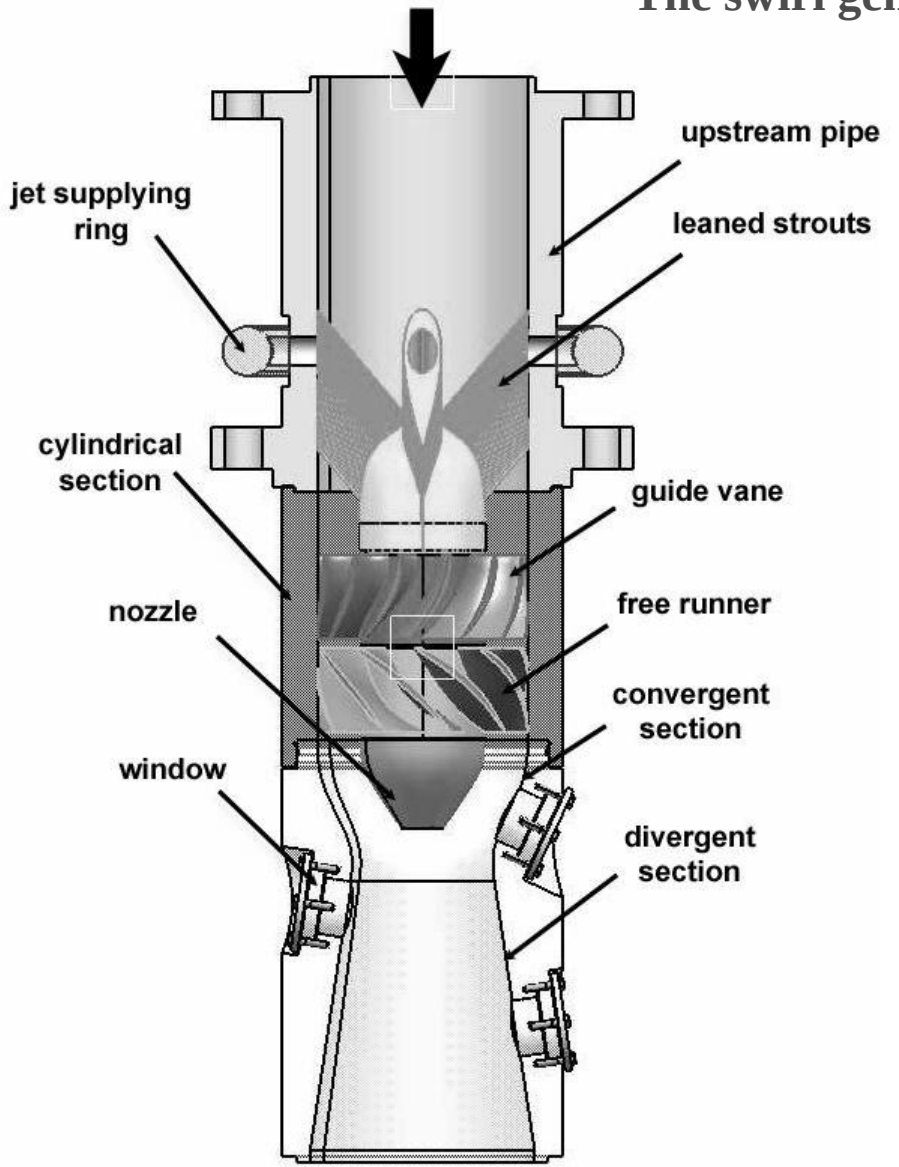


Experimental rig

- Strout
- Guide vanes

  - creates a swirling profile

The swirl generator

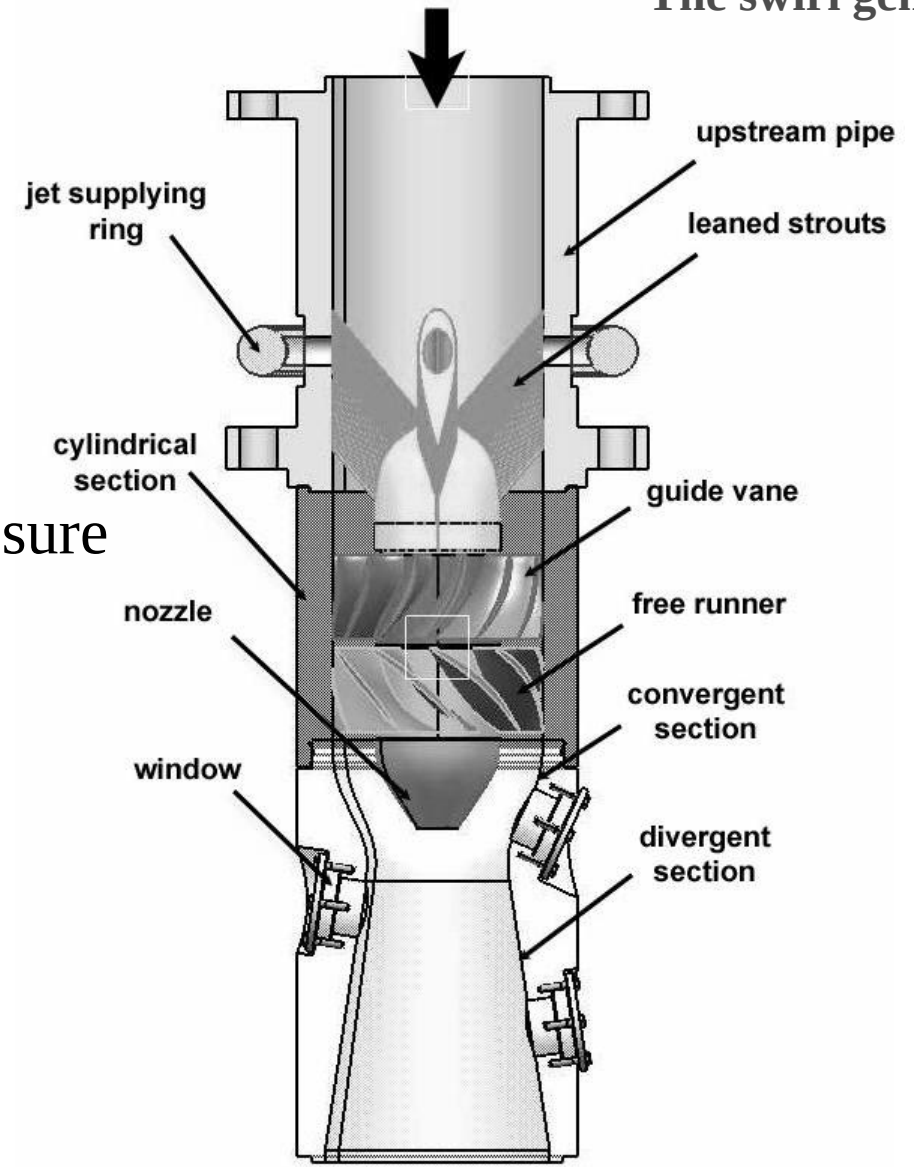


The swirl generator

Experimental rig

- Strout
- Guide vanes
- Free runner

  - redistributes the total pressure
  - rotates freely

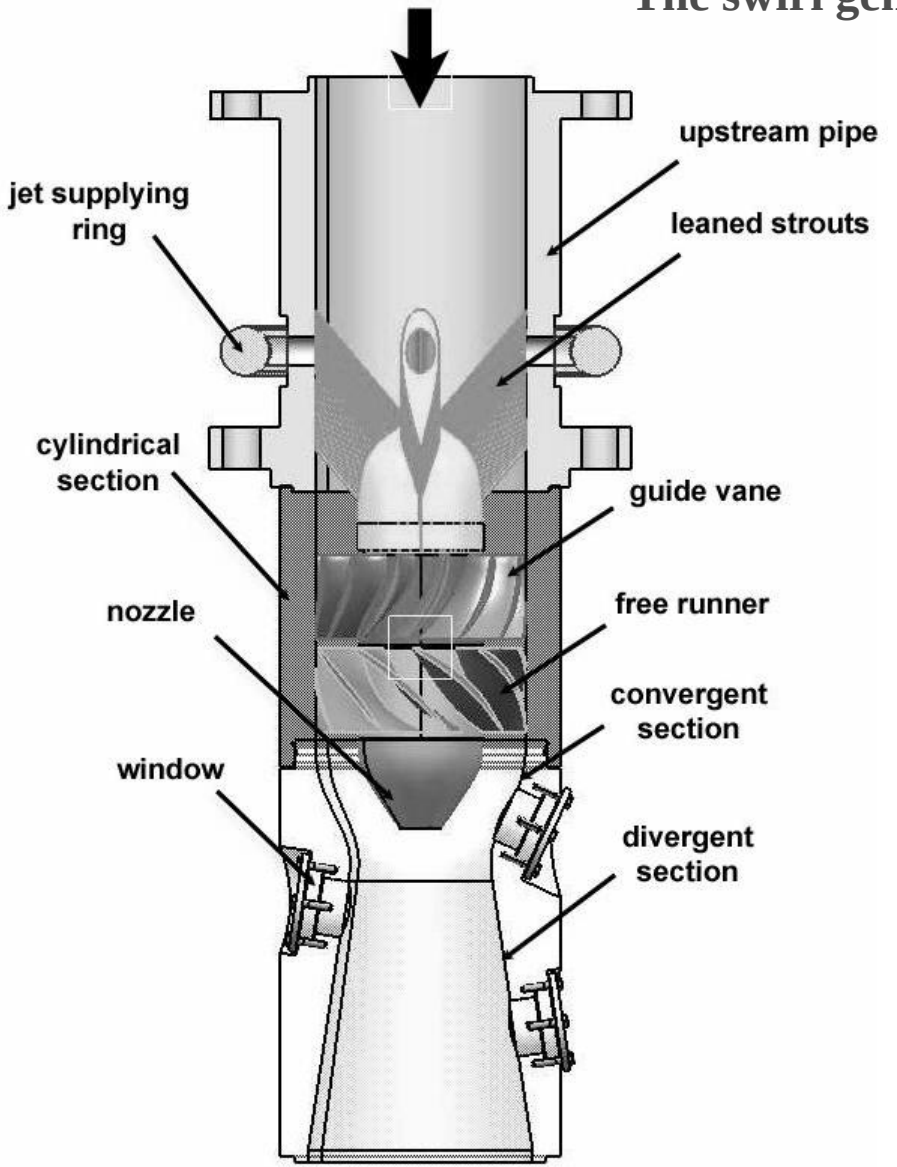


Experimental rig

- Strout
- Guide vanes
- Free runner
- Draft tube

  - plexiglass walls
  - windows for LDV measurements

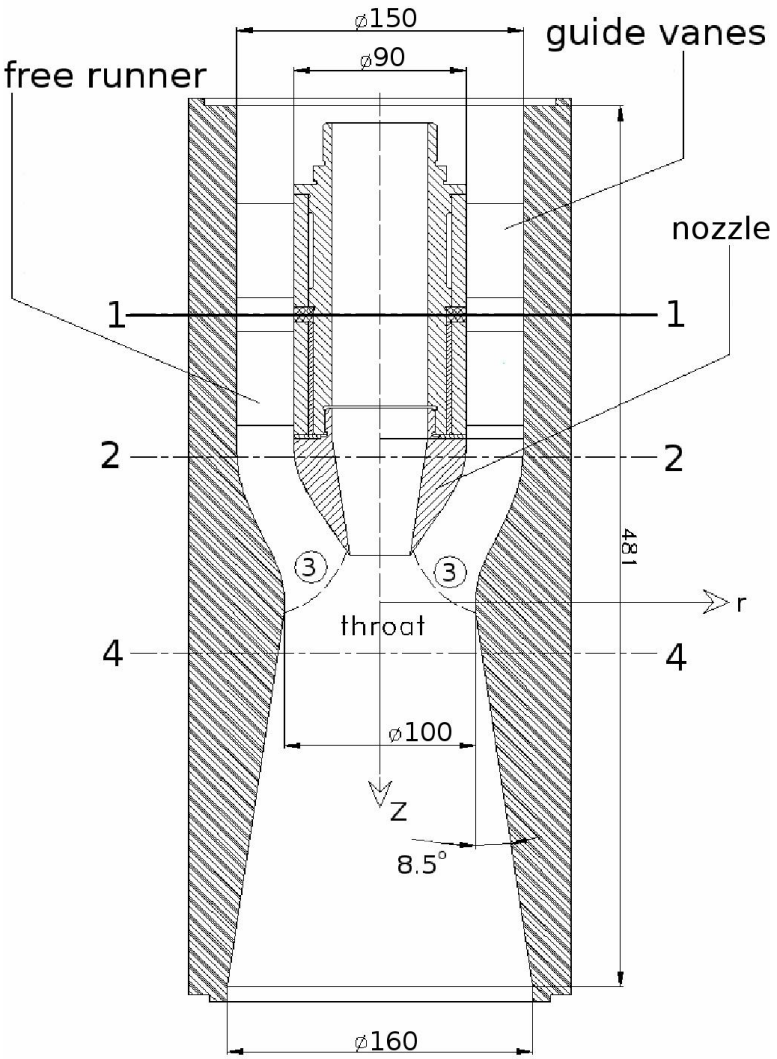
The swirl generator



Experimental rig

- Strout
- Guide vanes
- Free runner
- Draft tube

- Theoretical design profile
  - Cross-section 1 & 2



Measurements

- Total volume flow: 30 l/s

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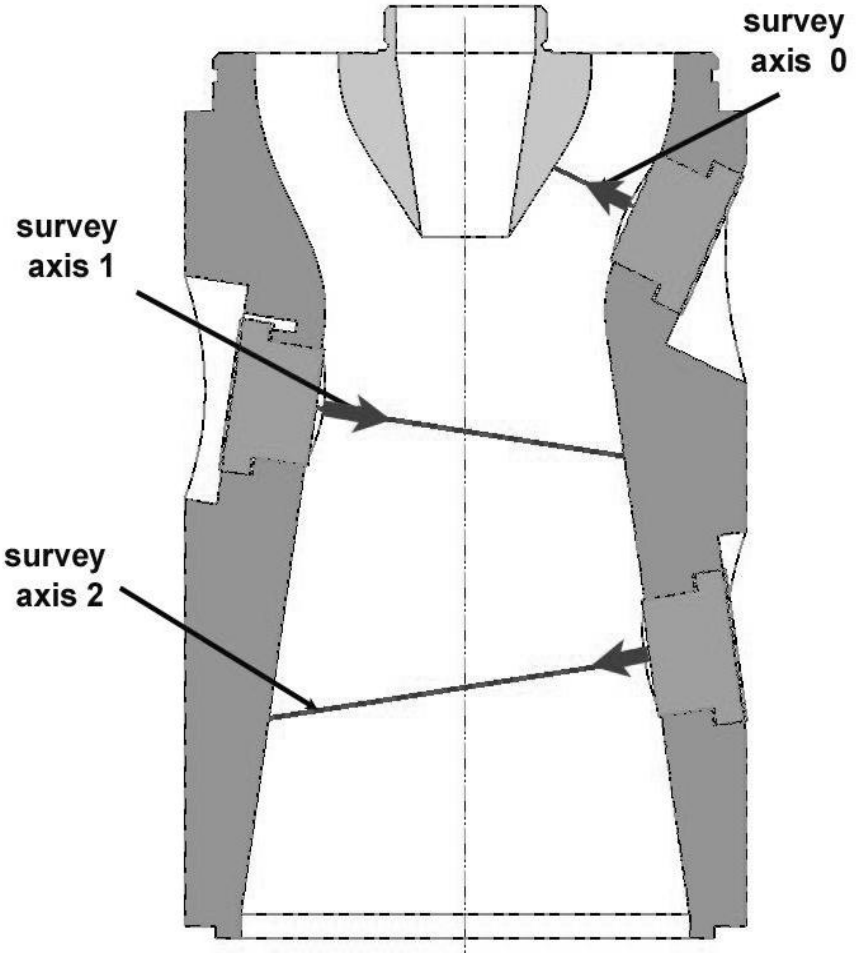
- Laser Doppler Velocimetry

  - measuring the meridional and tangential velocities



Measurements

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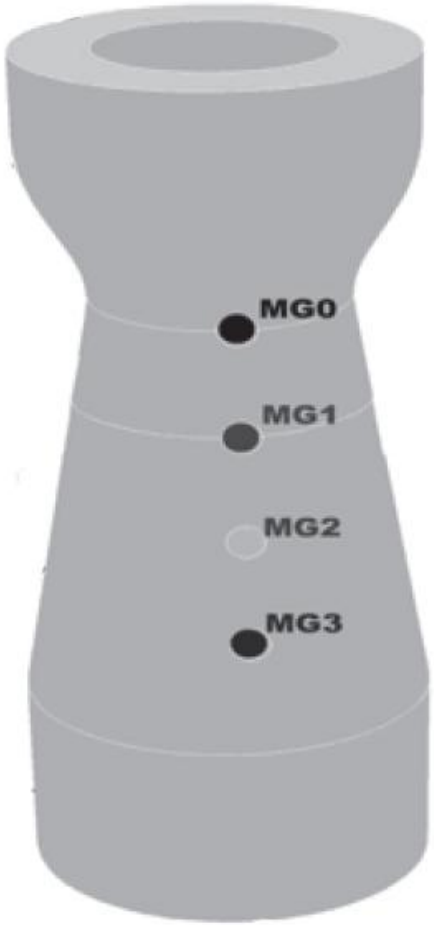

- Laser Doppler Velocimetry
- Pressure transducers

  - measuring the static pressure at the wall

Numerical setup

- The grid
  - 2.3 million hexahedral cells
  - Coupled parts by General Grid interfaces (GGI)

Numerical setup

- The grid
- Solvers
  - For steady-state:
    - » SIMPLE pressure corrector
    - » Rotation through different frames of reference

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  - For steady-state:
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  - For unsteady:
    - » PISO pressure corrector
    - » Real rotation with a sliding grid at the interface

Numerical setup

- The grid
- Solvers

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    - » SIMPLE pressure corrector
    - » Rotation through different frames of reference
  - For unsteady:
    - » PISO pressure corrector
    - » Real rotation with a sliding grid at the interface

Turbulence model: standard k-ε model with wall-functions

Numerical setup

- The grid
- Solvers
- Boundary conditions

  - Velocities and turbulence: Homogenous Neumann at outlet
  - Pressure: Zero mean pressure at outlet and homogenous Neumann at all other boundaries

Numerical setup

- The grid
- Solvers
- Boundary conditions
- Convection scheme
  - 1st order upwind at startup
  - 2nd order linear upwind when stable

Unsteady results

- Rotational speeds
  - 870 rpm (runner rotates freely)
  - 920 rpm (runner rotates freely according to fluent simulations)
  - 890 rpm (linearly interpolated)

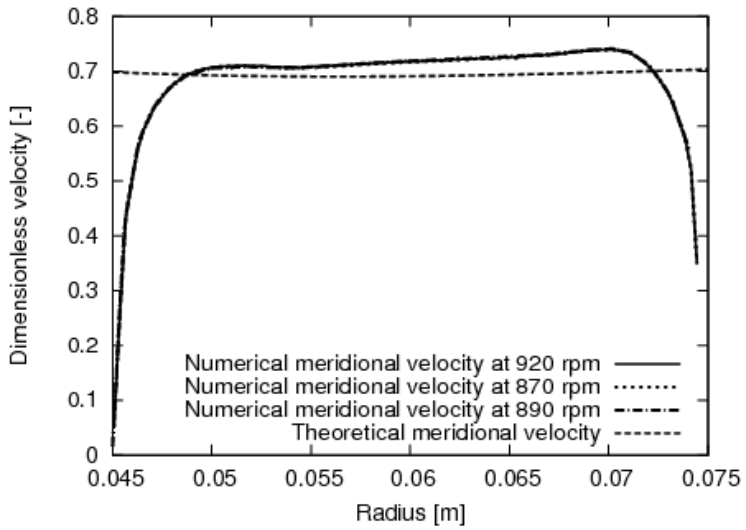
Unsteady results

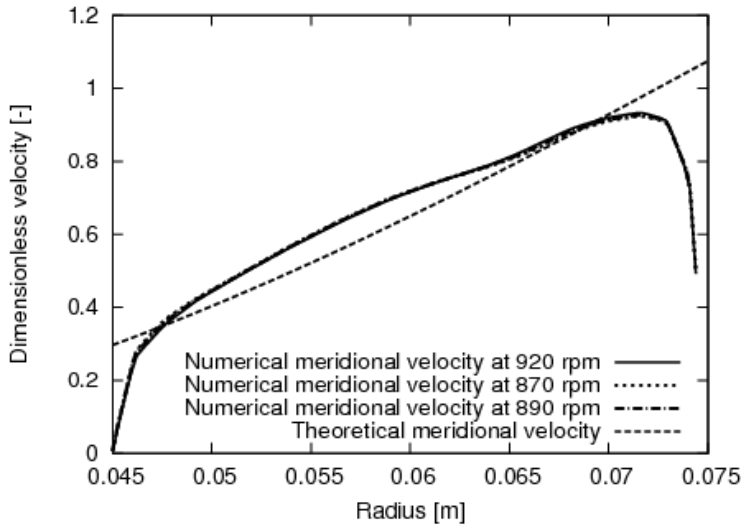
- Rotational speeds
- Initial boundary condition
  - Results from the steady-state simulations

Design profiles

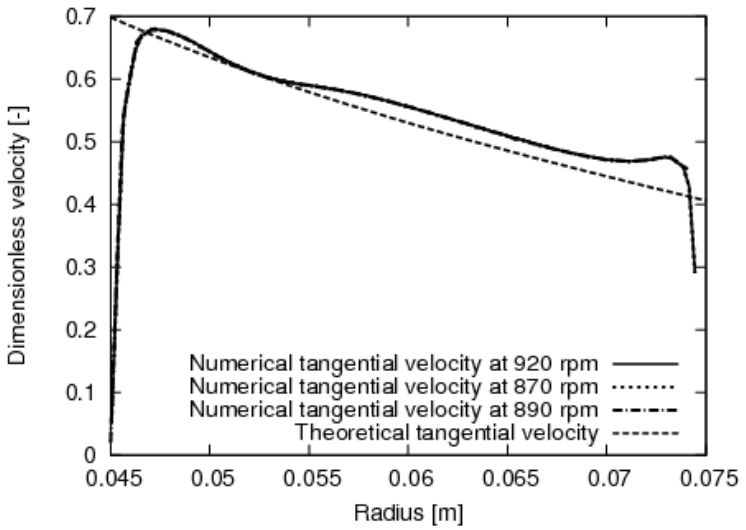
Unsteady results

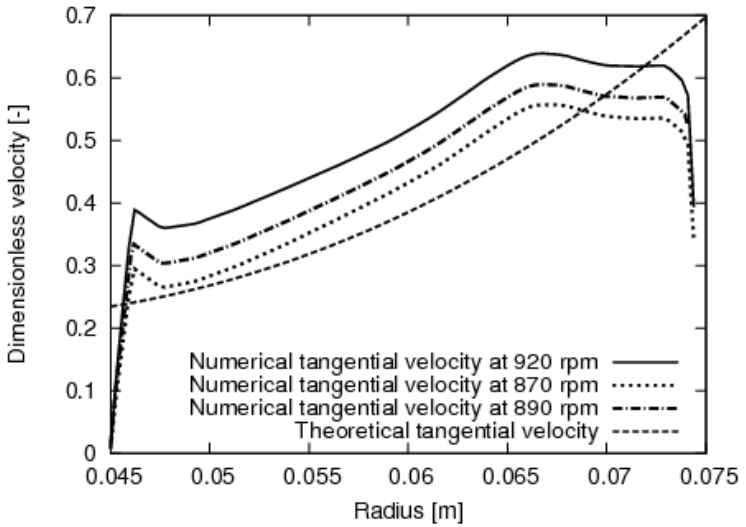
Meridional velocity



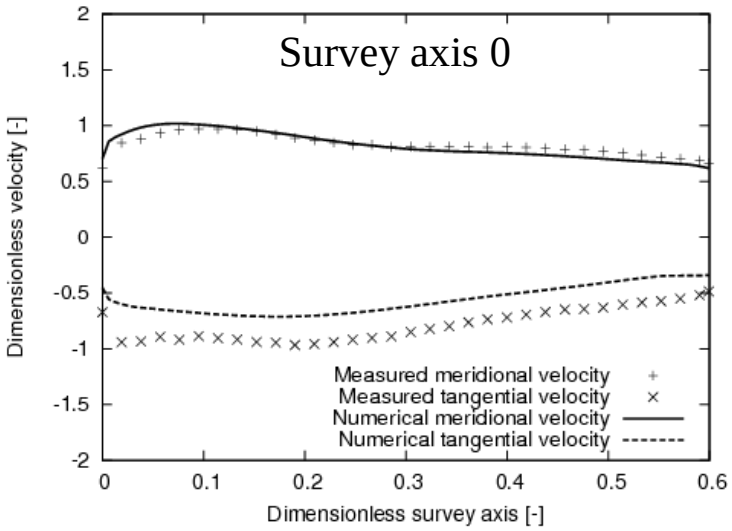


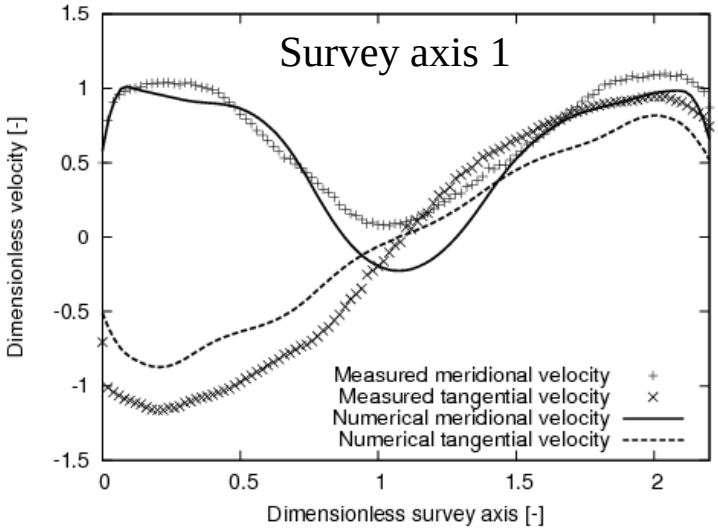
Tangential velocity

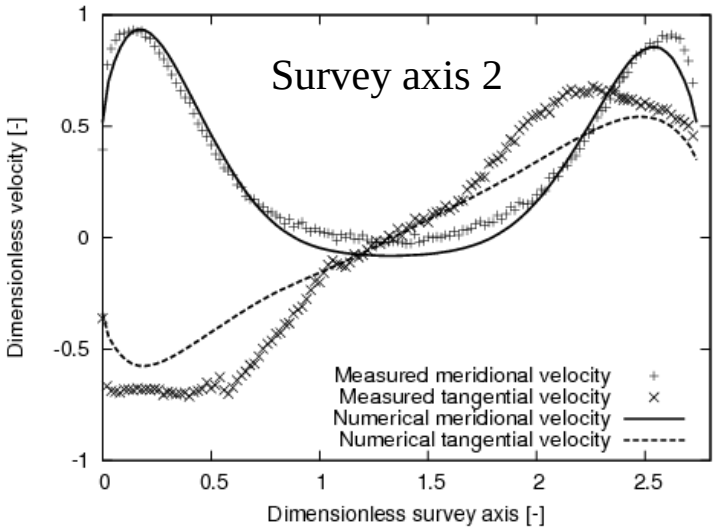


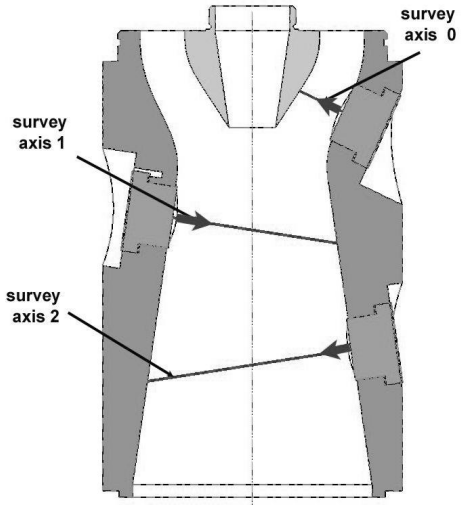


Comparison with LDV at 870 rpm

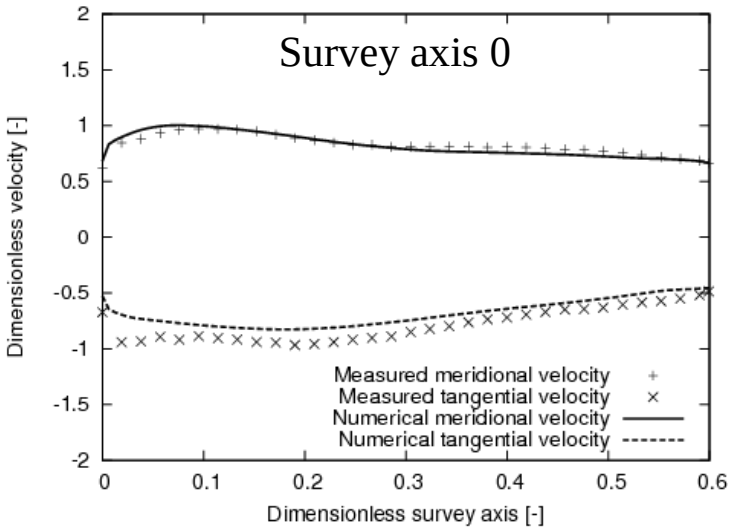


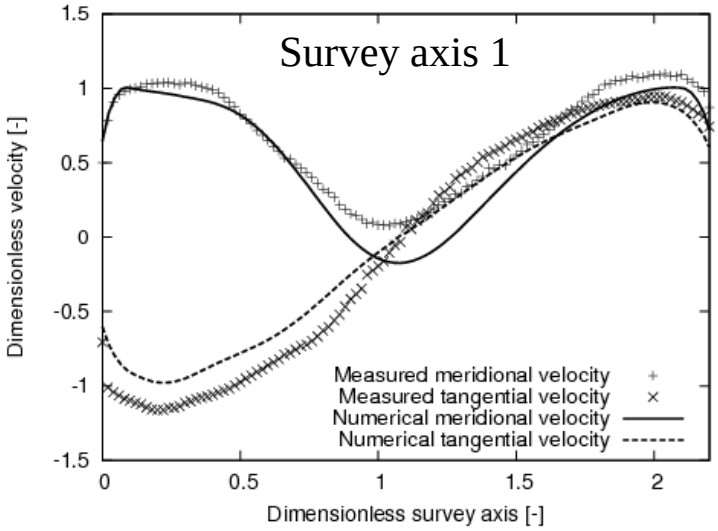


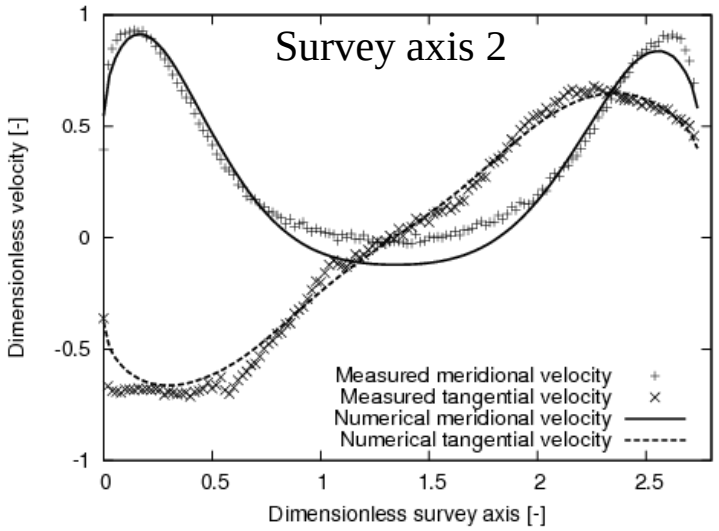


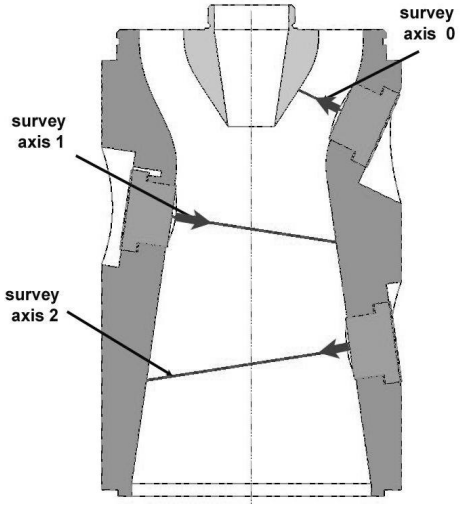


Comparison with LDV at 920 rpm

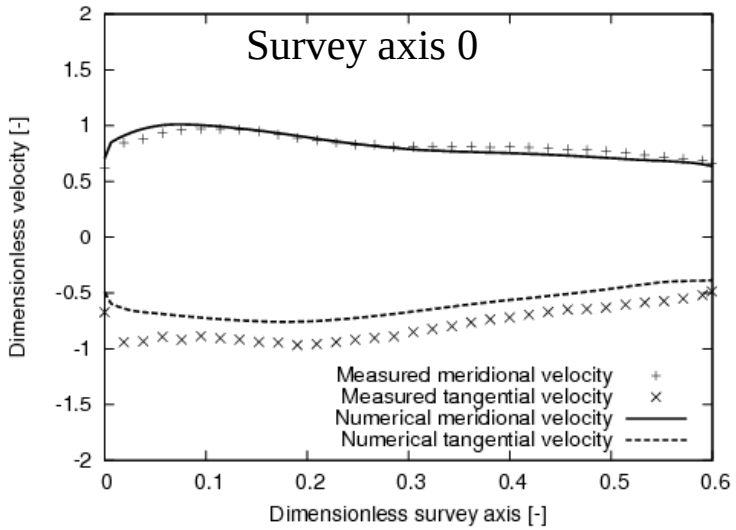


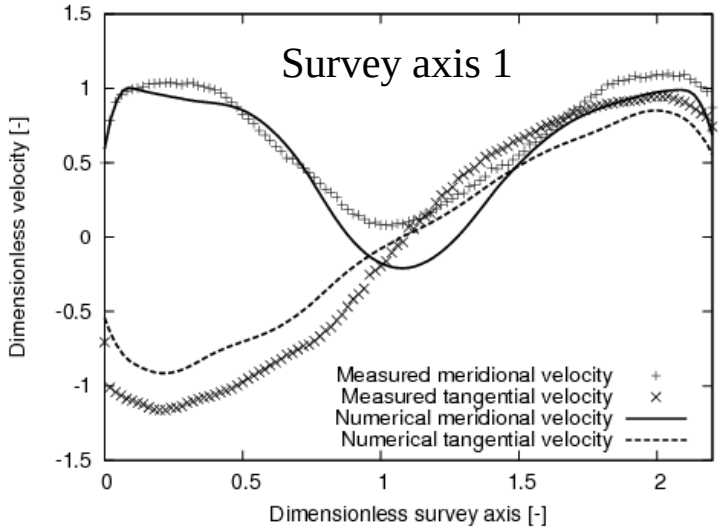


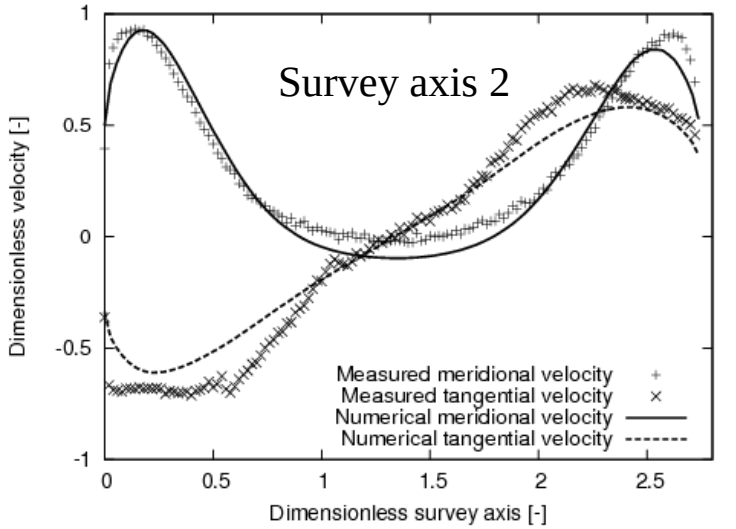


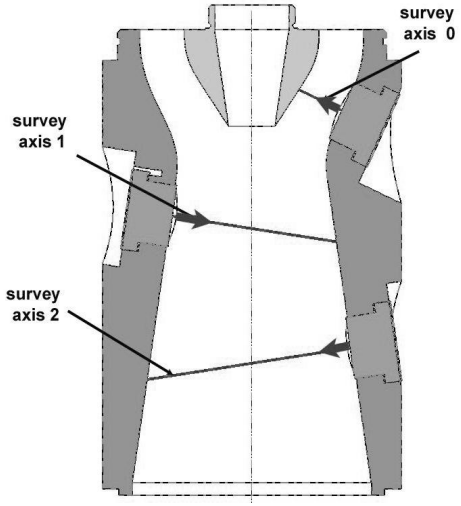


Comparison with LDV at 890 rpm



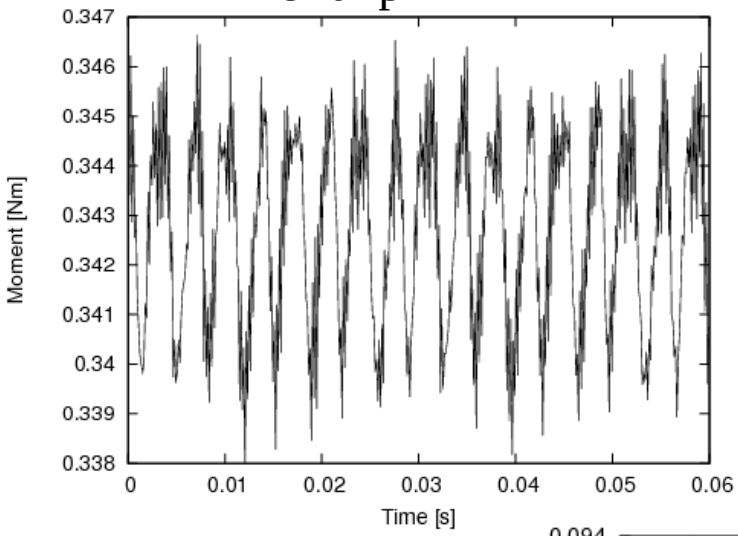




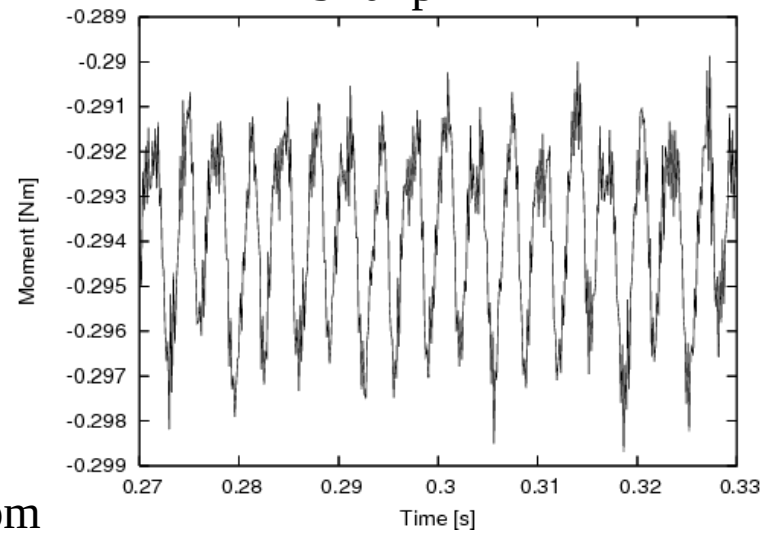


Moment acting on the runner

870 rpm



920 rpm



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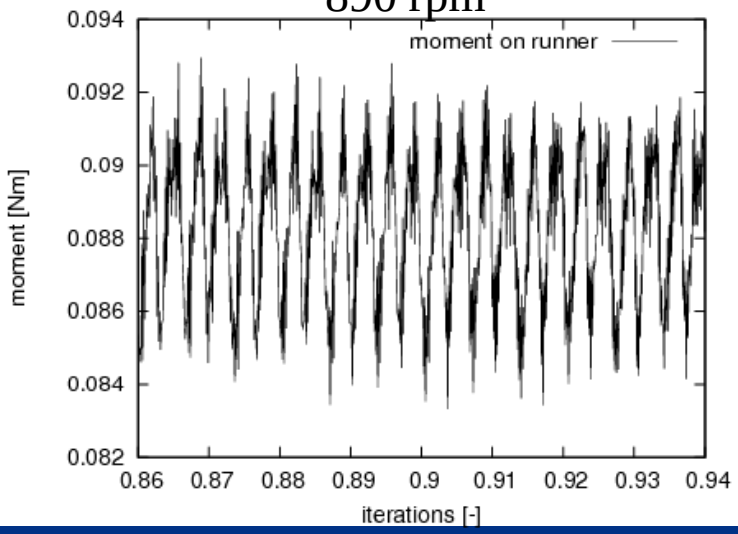
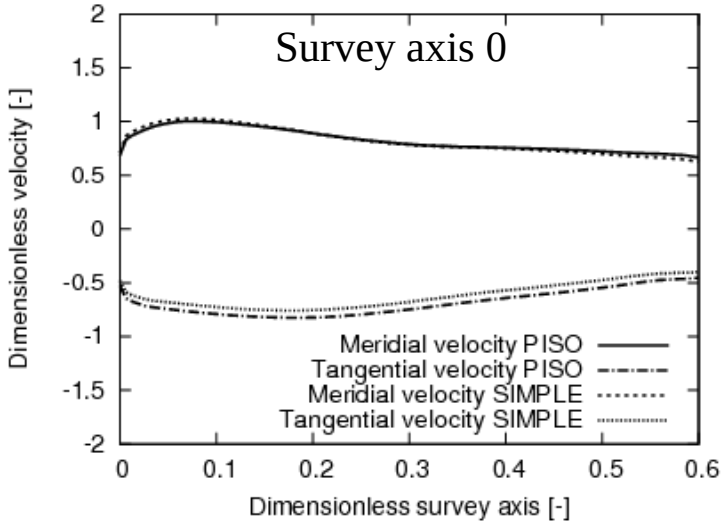
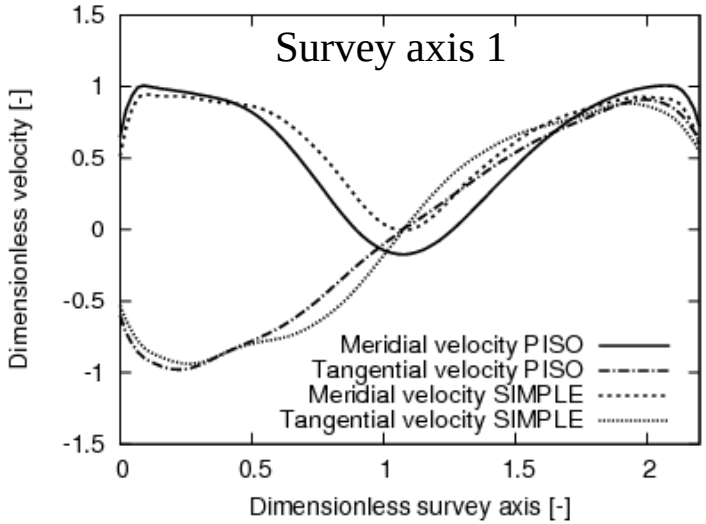
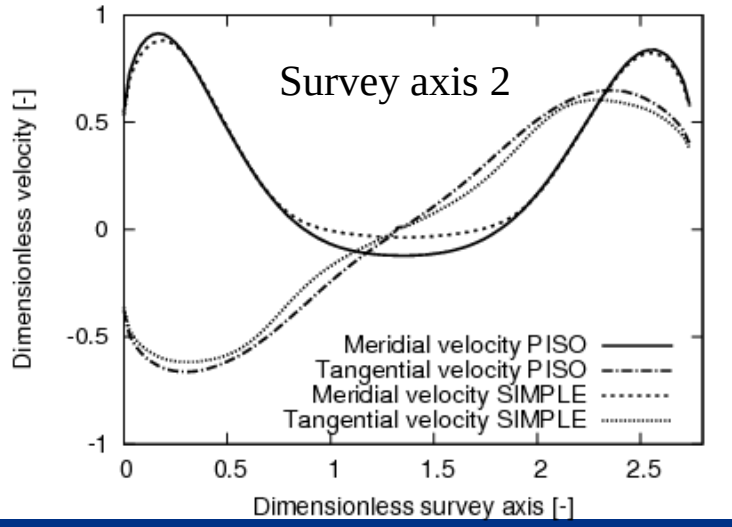
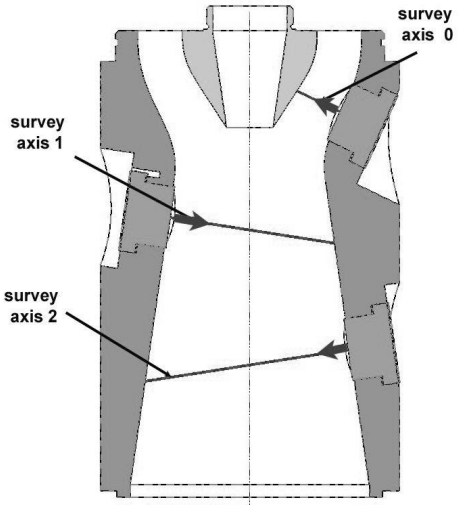


SIMPLE based solver vs. PISO based solver

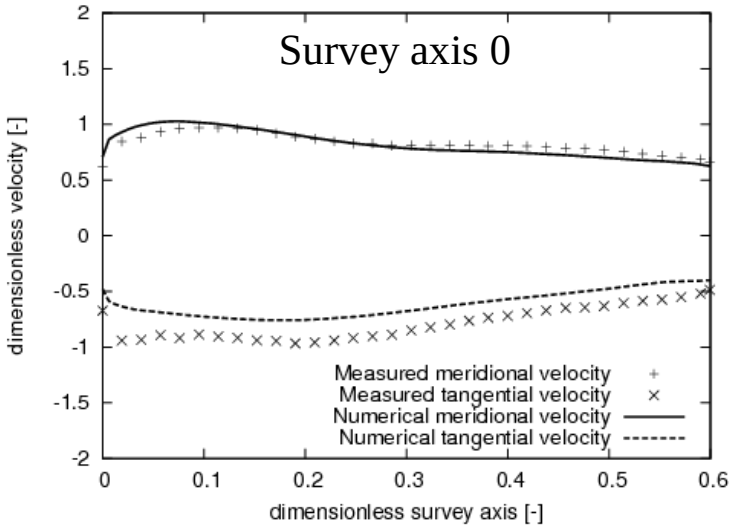


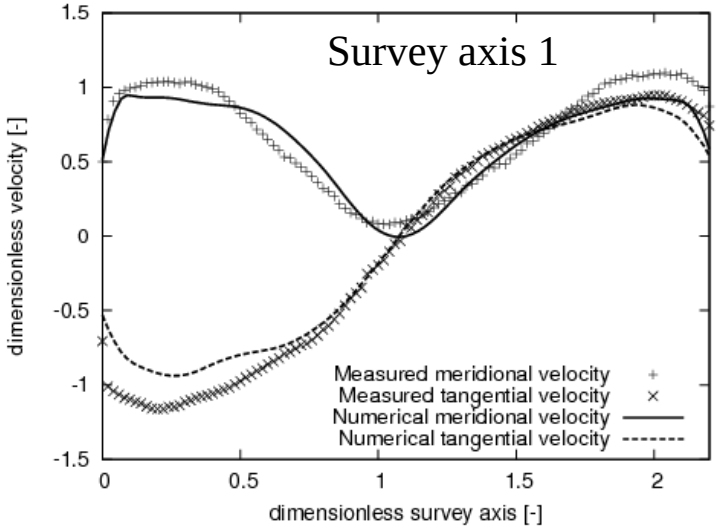


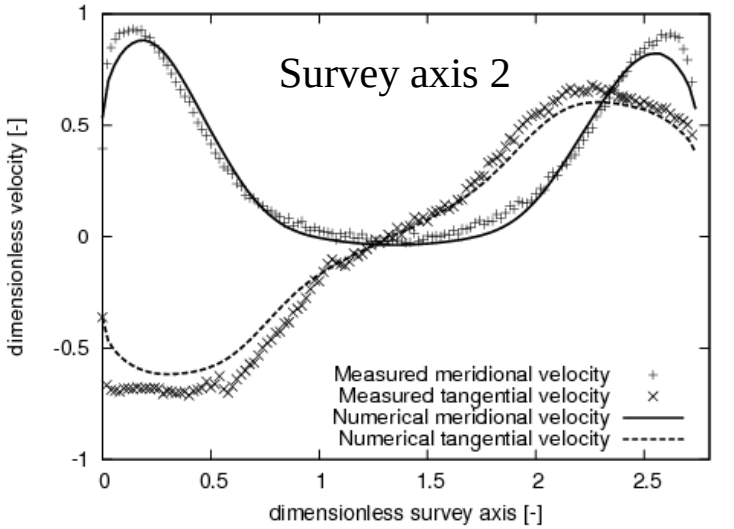


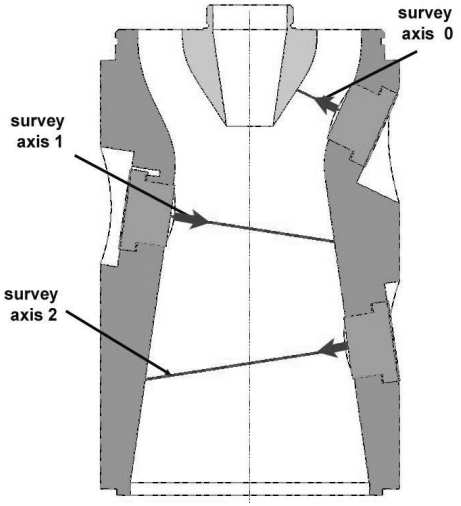


SIMPLE based solver compared to measurements



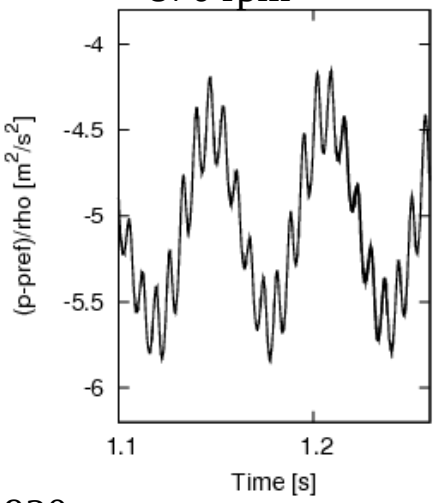




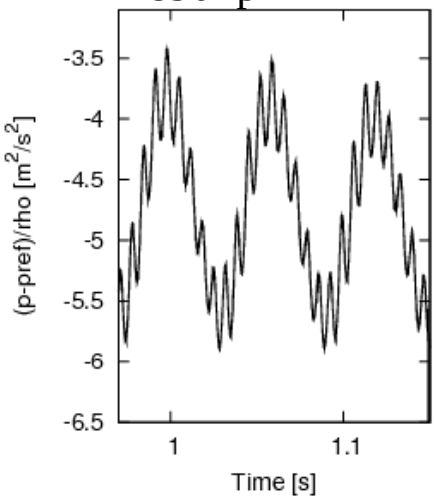


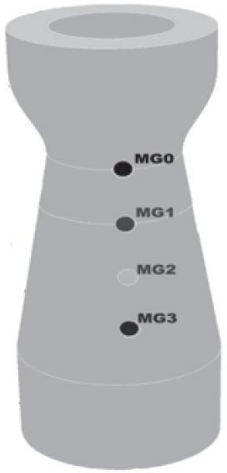
Pressure at MG0 (at the throat of the draft tube)

870 rpm

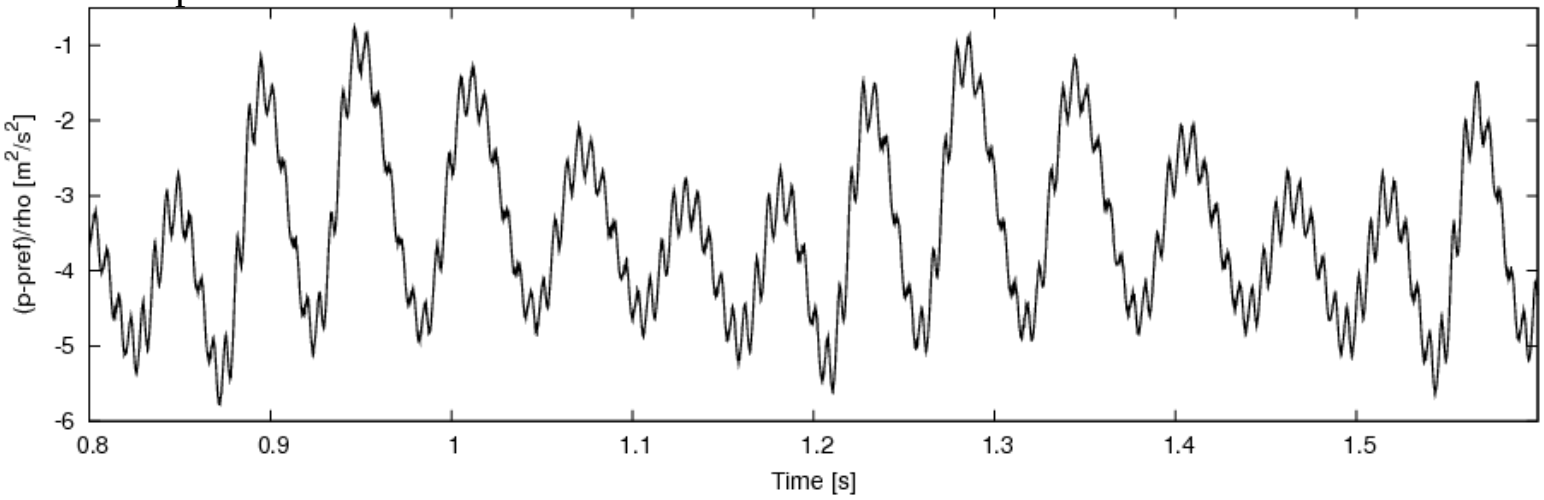


890 rpm

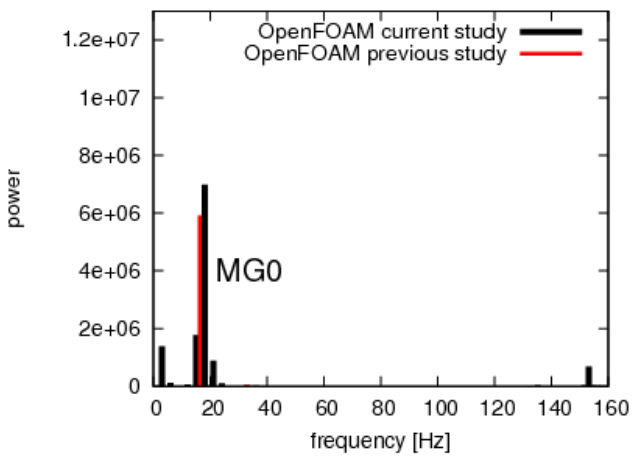


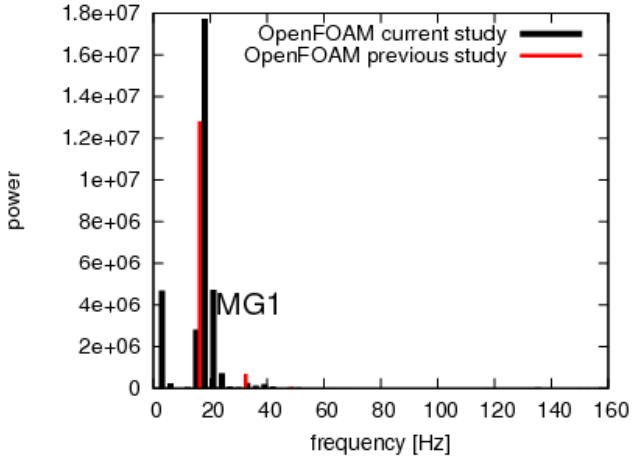


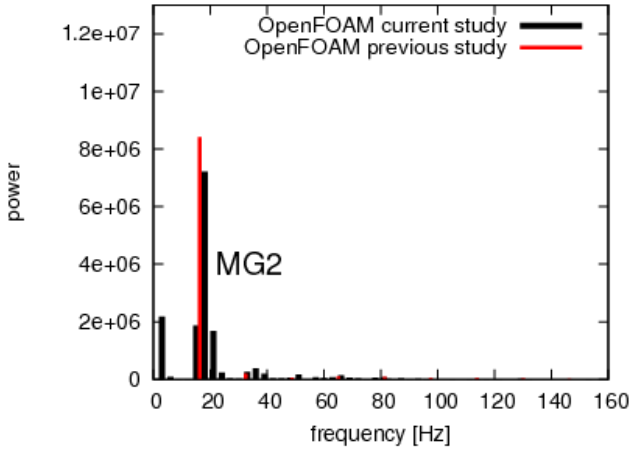
920 rpm

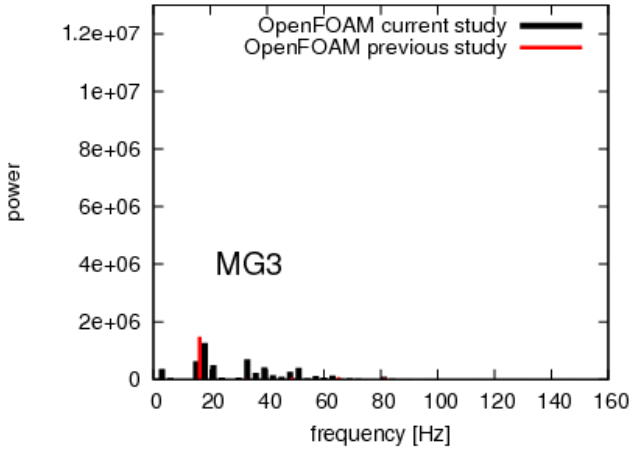


Fourier analysis of results from 920 rpm

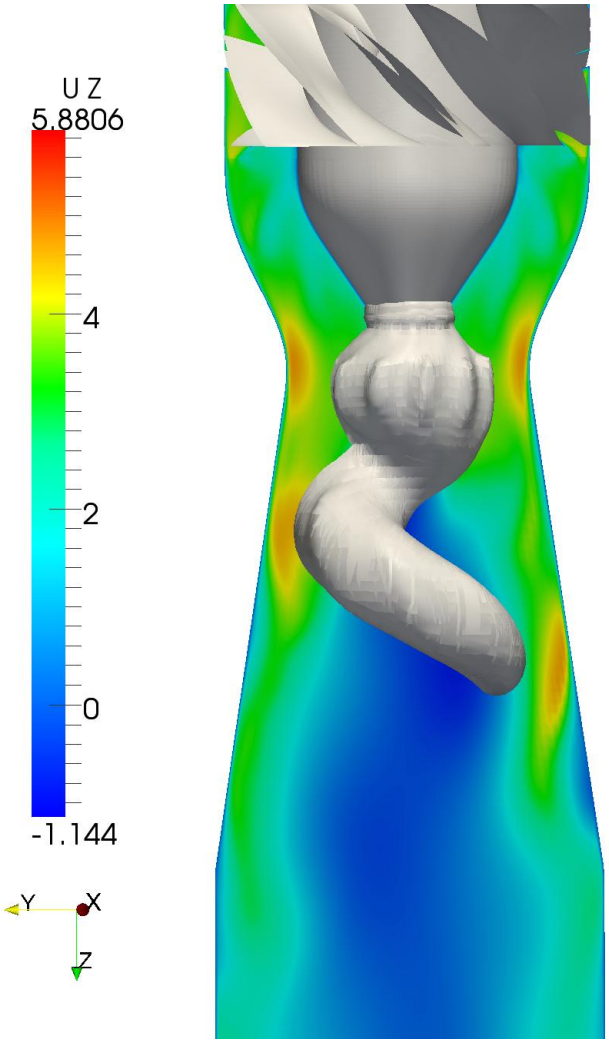




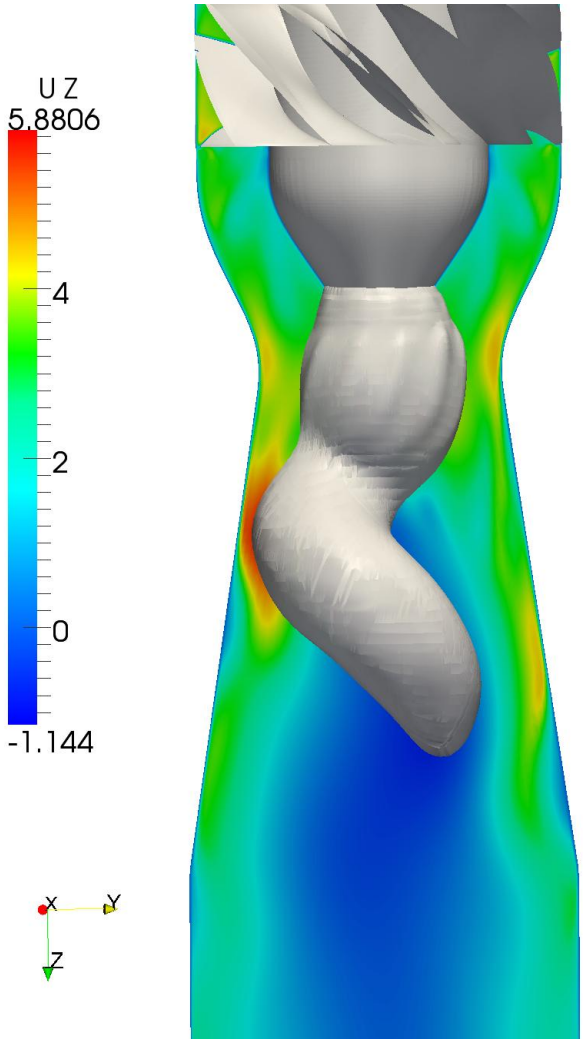




870 rpm



920 rpm



Conclusions

• Unsteady simulations accurately predicts the flow

• 920 rpm was corresponding most with the measurements

• 870 rpm was corresponding most with the theoretical design profiles

• The inclusion of all parts of the swirl generator have added more frequencies to the flow.

• Moment on the runner:

Rotational speed	Moment on runner
920 rpm	-0.55 Nm
870 rpm	0.23 Nm
890 rpm	0.08 Nm

Future work

- Further investigation of the SIMPLE based solver
- Other turbulence model such as LES or DES
- Customize a solver for adjusting the rotational speed in accordance to the moment acting on the runner

Acknowledgements

I would like to give my thanks to:

- Department of Applied Mechanics
- Supervisors Håkan Nilsson and Olivier Petit