“Politehnica” University of Timisoara
National Center for Engineering of
Systems with Complex Fluids

Romanian Academy – Timisoara Branch
Center for Advanced Research in
Engineering Sciences

Actualitati si Perspective
in
Ingineria Sistemelor
cu
Fluide Complexe

Dr.ing. Sebastian MUNTEAN, CS1

“Politehnica” University of Timisoara
National Center for Engineering of Systems with Complex Fluids

Romanian Academy – Timisoara Branch
Center for Advanced Research in Engineering Sciences

Hydrodynamics and Cavitation Group

Human resources:

- Prof.dr.ing. Romeo Resiga, Director
- Dr.ing. Sebastian Muntean, Senior Researcher
- Dr.ing. Sandor Bernad, Senior Researcher
- Prof.dr.ing. Alexandru Baya
- Prof.dr.ing. Liviu Eugen Anton
- Assist. Prof. Adrian Stuparu
- Eng. Alin Bosioc, PhD Student
- Eng. Constantin Tanasa, PhD Student
- Eng. Alin Anton, Research Assistant
- Eng.Ioan Ninaci, Research Assistant

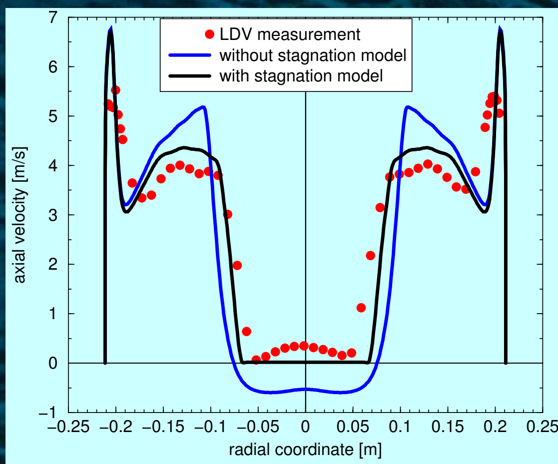
- Acad. Ioan Anton

Hydrodynamics and Cavitation Group

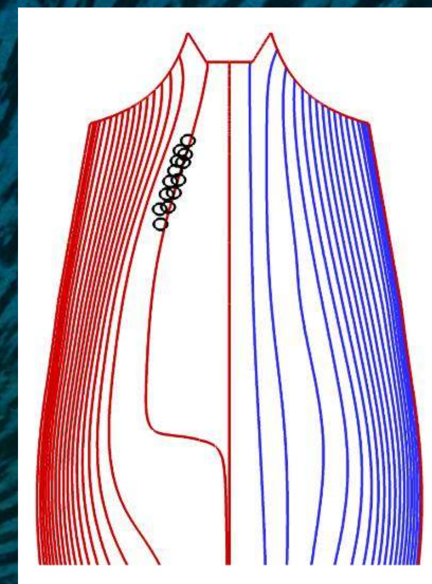
Areas of expertise:

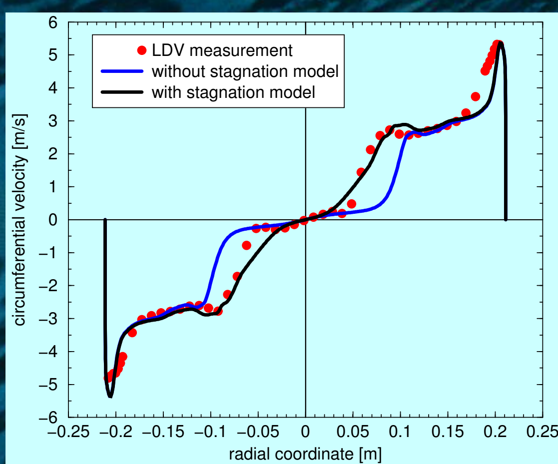
- Numerical simulation of complex flows
- Turbomachinery hydrodynamics and cavitation
- Turbomachinery swirling flow analysis and control
- Turbomachinery inverse design and optimization
- Magnetic liquids and magnetorheological suspension applications
- Biomedical flows (cardiovascular numerical analysis)

Axisymmetric turbulent swirling flow simulation and flow control with axial water jet injection



Meridian velocity (left) and streamlines (right)



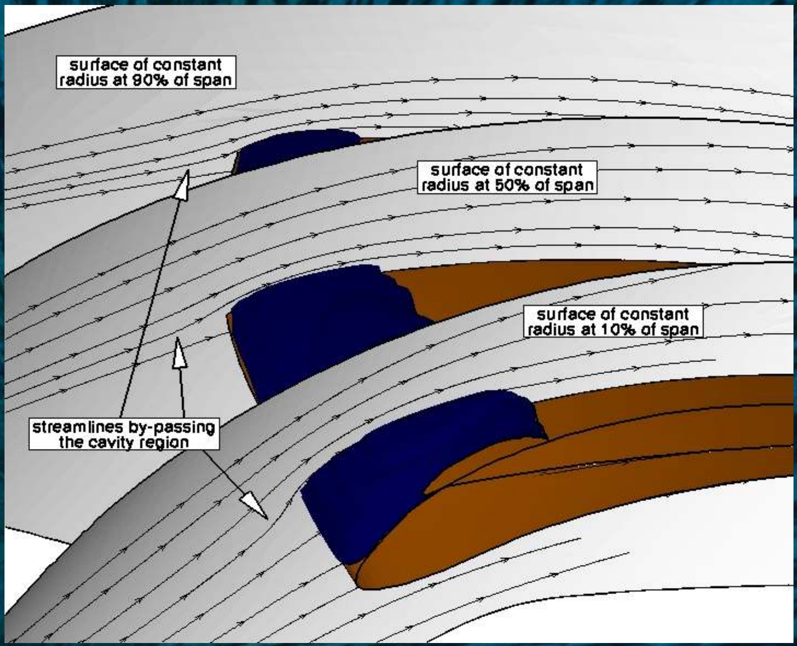


➢ Development of a **new swirling flow model with stagnant region**; validation with LDV measurements for FLINDT case (axial and circumferential velocity components and vortex rope location).

➢ **Novel swirling flow control method with jet injection** along the axis: left half-plane without jet, right half-plane with jet injection → elimination of the central stagnant region and the vortex rope

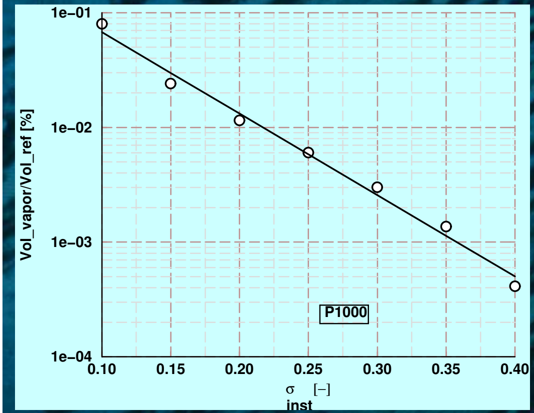
Cavitating flow analysis in Kaplan turbines

- Development of cavitating flow models and FLUENT implementation
- Analysis of Kaplan turbine hydrodynamics and cavitation development on Kaplan runner blades (velocity and pressure fields perturbation due to the cavity presence)
- New cavitation inception criterion based on the exponential variation of the vapor volume with Thoma number

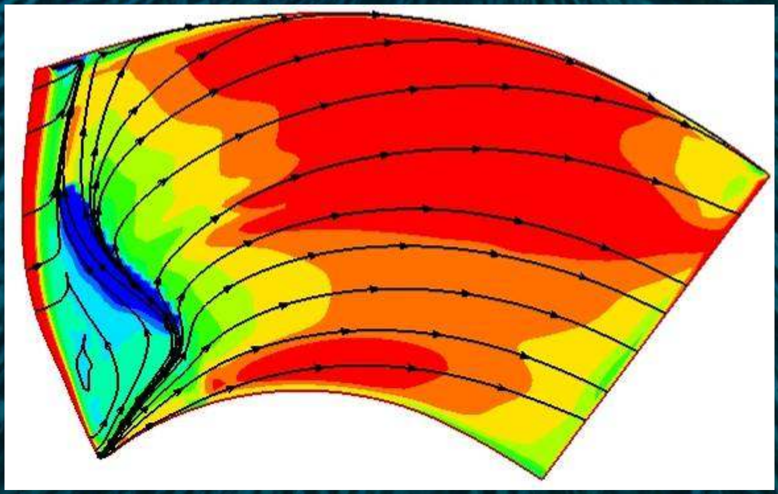


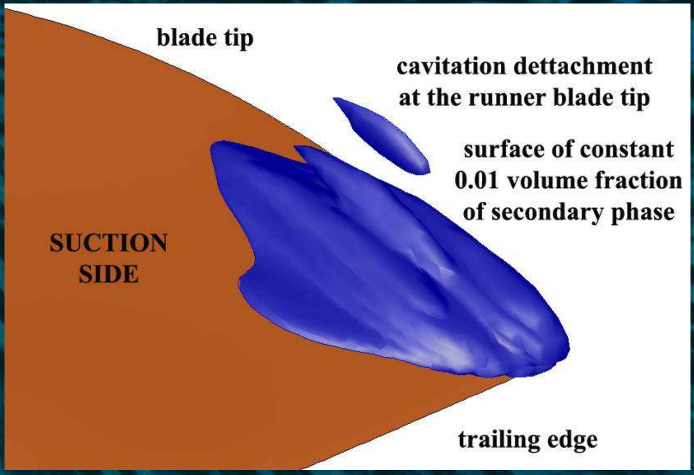
Leading edge cavitation (upper picture) and trailing edge cavitation (lower picture)

Vapor volume versus Thoma number



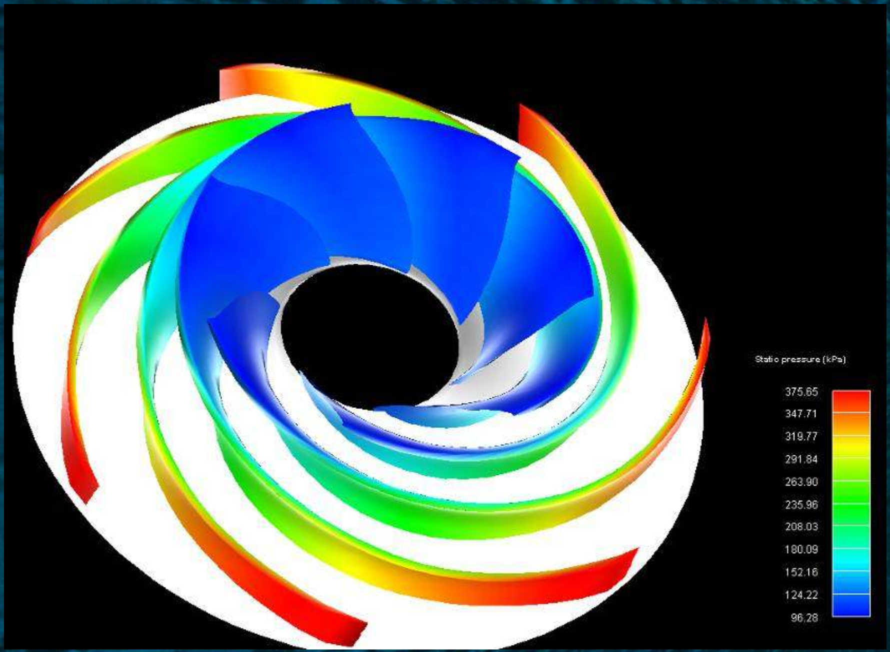
Wall shear stress on the blade suction side

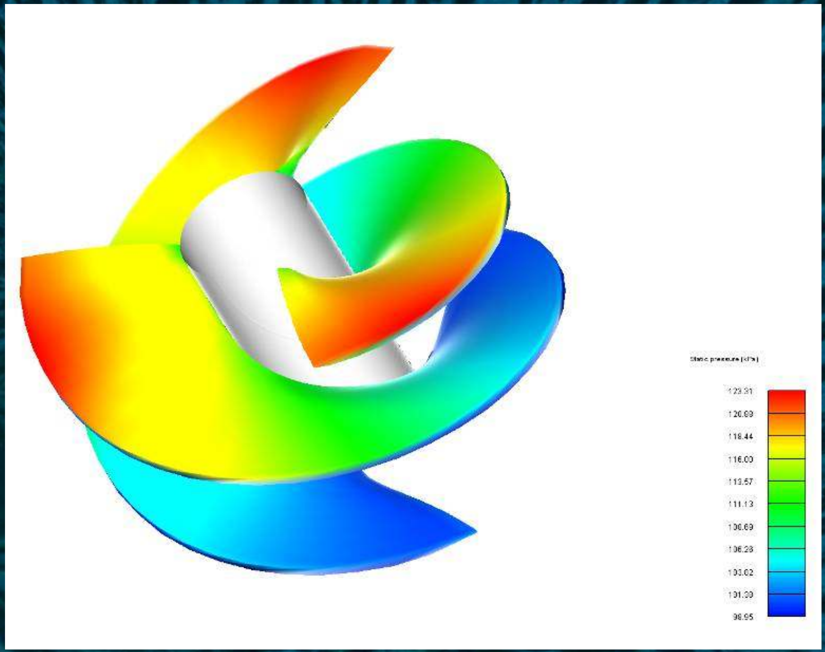


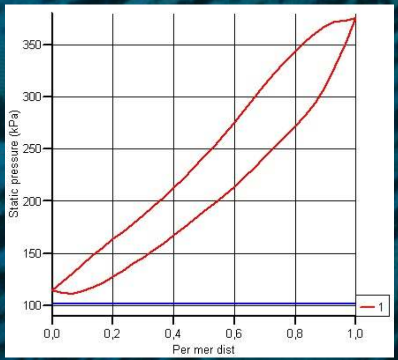


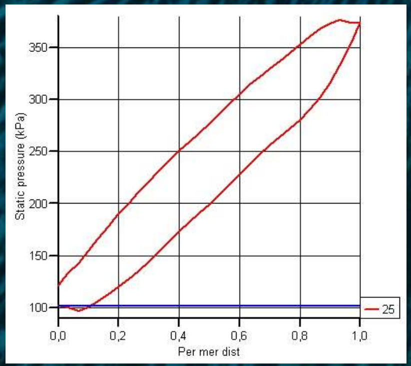
Cryogenic pump optimization with inverse design

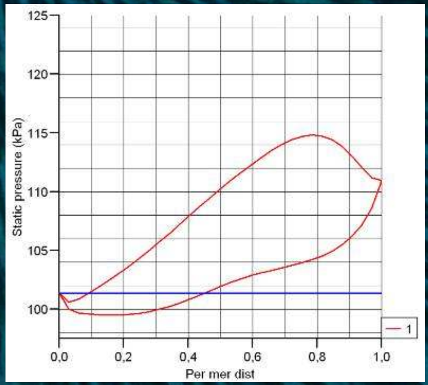
(pump runner and inducer for LNG ships)

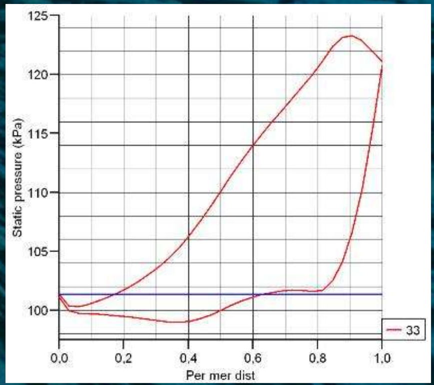




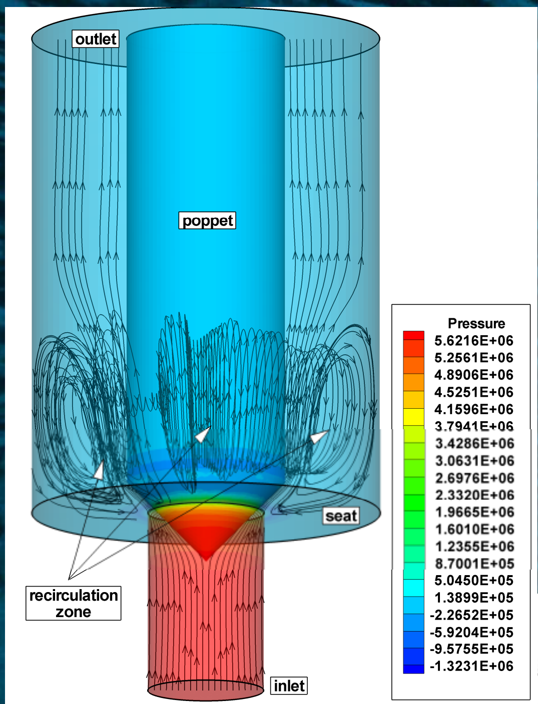




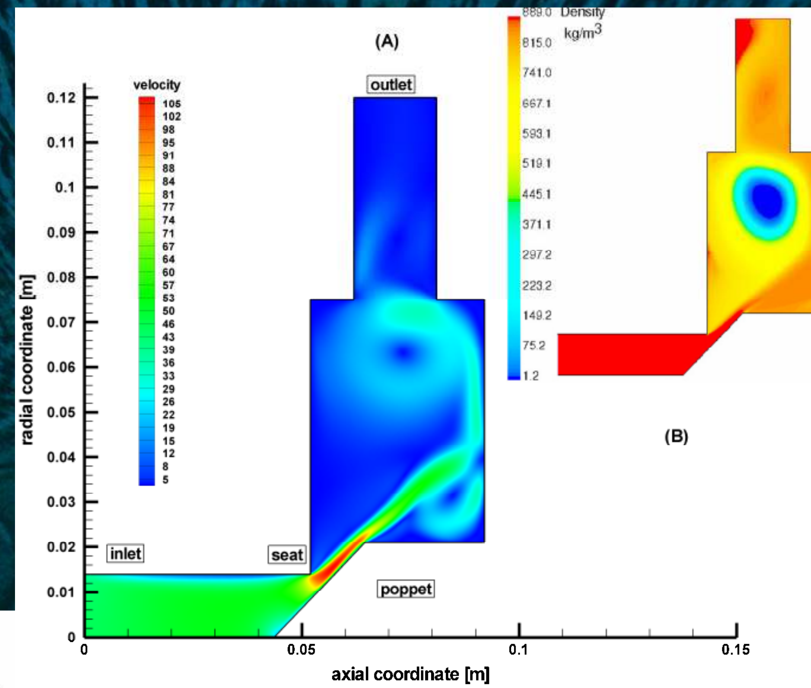




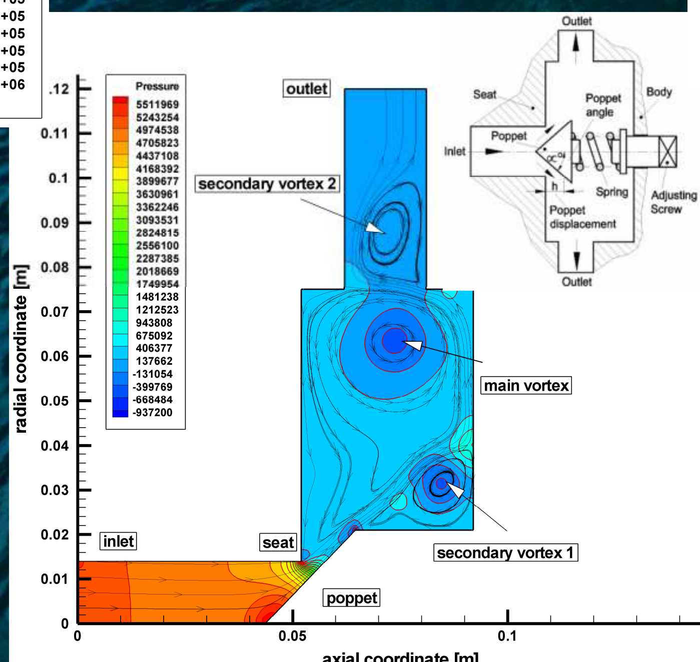
Numerical flow simulation in hydraulic power equipment



Curgerea 3D in supape hidraulice



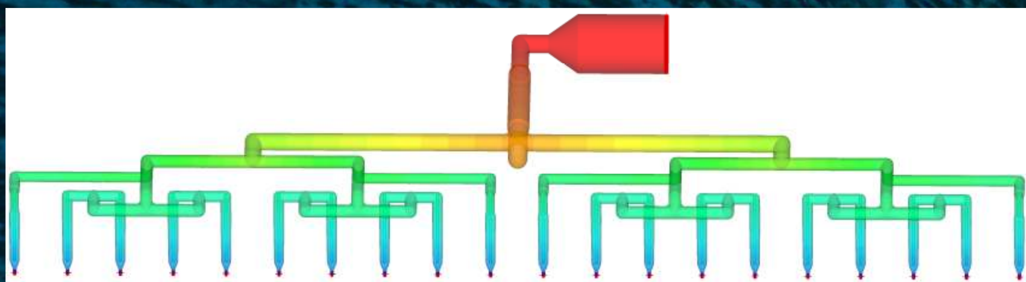
Campul de viteza respectiv fractia volumica gazoasa continuta in vartejul principal



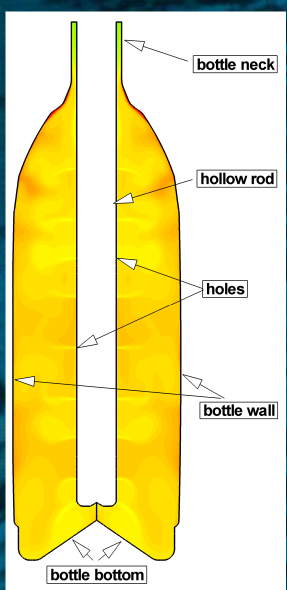
Campul de presiune aferent curgerii 2D prin supapa hidraulica de presiune

Non-newtonian numerical flow simulation

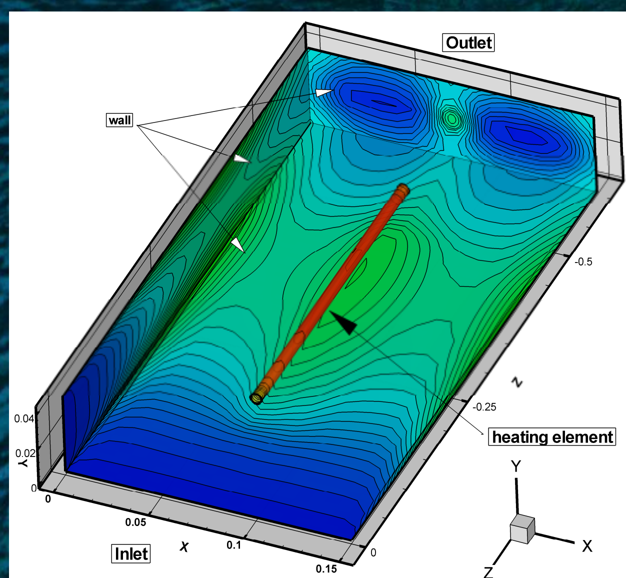
Aplicatii industriale



Retea de turnare



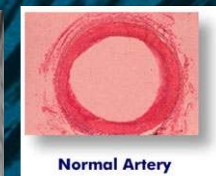
Campul termic aferent procesului de racire al sticlei turnare



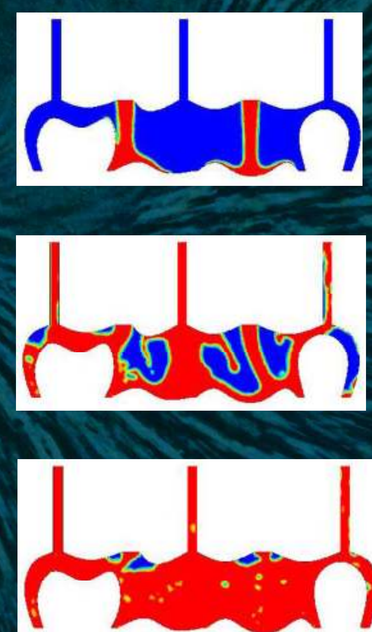
Distributia campul termic in Interiorul cutiei camerei rezistentei

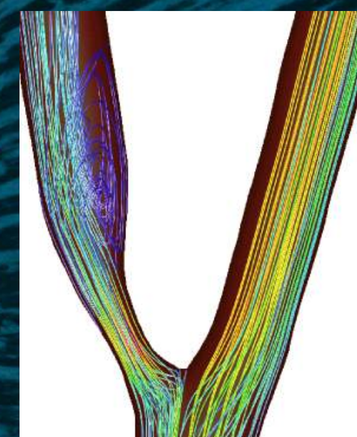
Aplicatii biomedicale

Imagine MRA



Faze intermediare in procesul de turnare al protezelor dento-maxilare

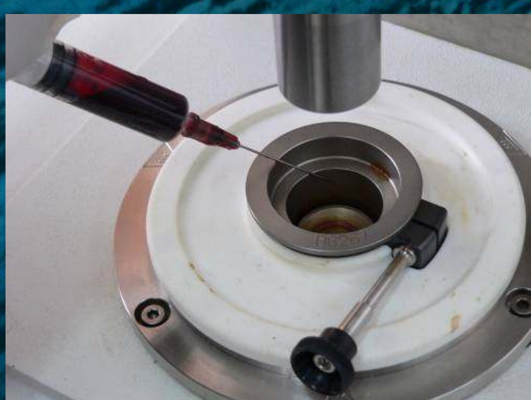


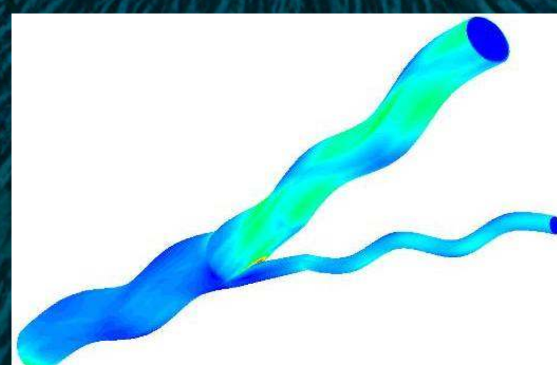


Vizualizarea influentei stenozei asupra modului de curgere in bifurcatia carotidiana

Cardiovascular flow analysis and surgery design

- Analysis of Computer Tomograph data, 3D geometry reconstruction
- Blood rheology
- 3D flow analysis, vortex structure and wall shear stress distribution
- Flow visualization and validation

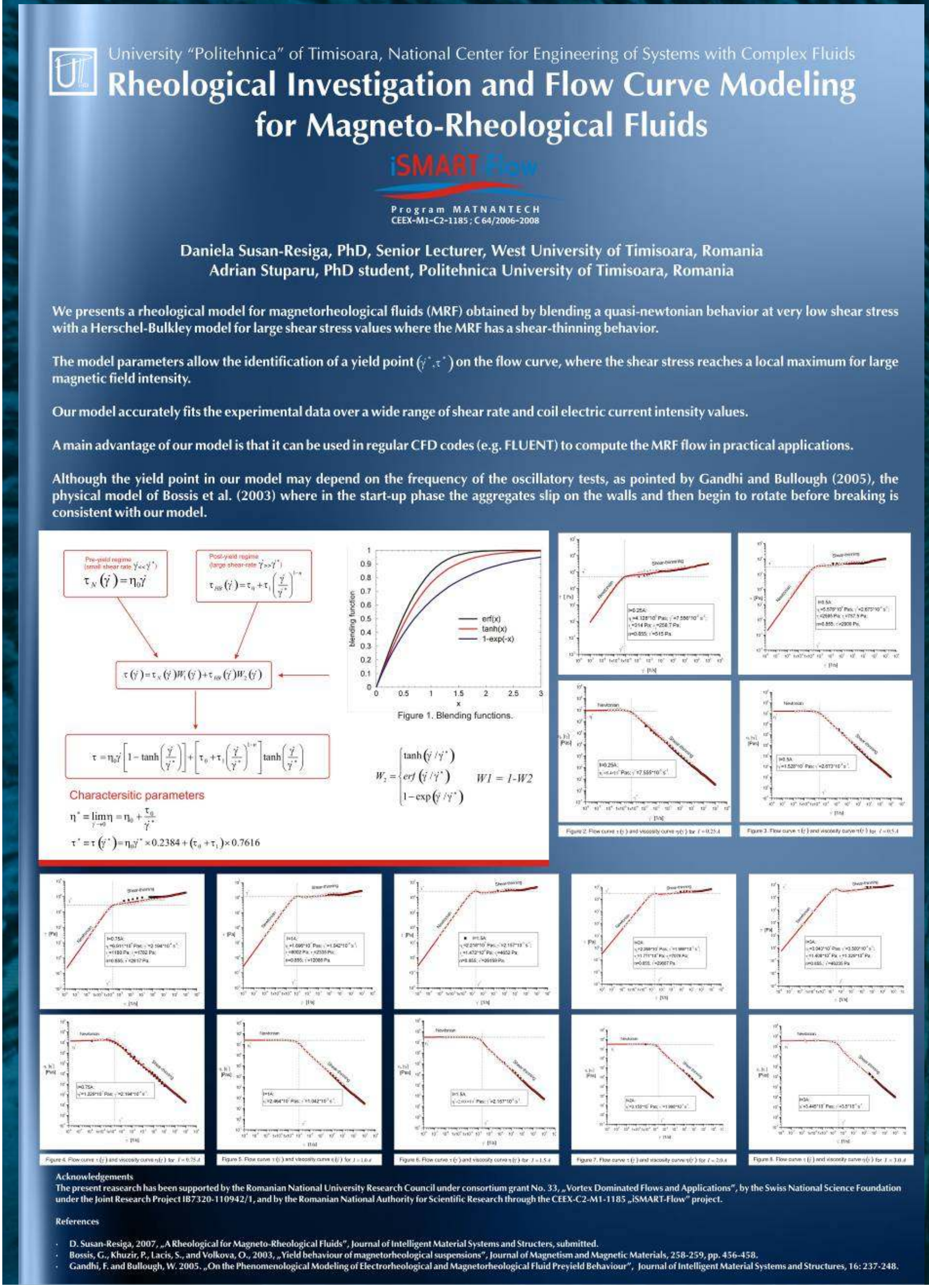




Magnetic liquids laboratory

- Magneto-rheological suspensions: real time flow control by changing the viscosity within several orders of magnitude range with regular magnetic fields; Applications for smart dampers, clutches, flow control devices

- Magnetic liquids preparation and characterization; development of engineering applications (e.g. magnetic liquid seals)


University "Politehnica" of Timisoara, National Center for Engineering of Systems with Complex Fluids

Rheological Investigation and Flow Curve Modeling for Magneto-Rheological Fluids

iSMART Flow

Program MATNANTECH
CEEX-M1-C2-1185 ; C 64/2006-2008

Daniela Susan-Resiga, PhD, Senior Lecturer, West University of Timisoara, Romania
Adrian Stuparu, PhD student, Politehnica University of Timisoara, Romania

We presents a rheological model for magnetorheological fluids (MRF) obtained by blending a quasi-newtonian behavior at very low shear stress with a Herschel-Bulkley model for large shear stress values where the MRF has a shear-thinning behavior.

The model parameters allow the identification of a yield point $(\dot{\gamma}^*, \tau^*)$ on the flow curve, where the shear stress reaches a local maximum for large magnetic field intensity.

Our model accurately fits the experimental data over a wide range of shear rate and coil electric current intensity values.

A main advantage of our model is that it can be used in regular CFD codes (e.g. FLUENT) to compute the MRF flow in practical applications.

Although the yield point in our model may depend on the frequency of the oscillatory tests, as pointed by Gandhi and Bullough (2005), the physical model of Bossis et al. (2003) where in the start-up phase the aggregates slip on the walls and then begin to rotate before breaking is consistent with our model.

Figure 1. Blending functions.

Characteristic parameters

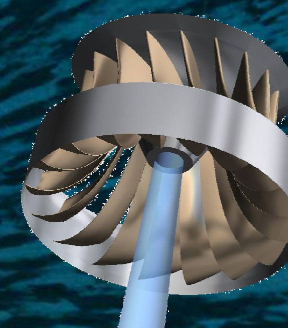
Acknowledgements
The present reasearch has been supported by the Romanian National University Research Council under consortium grant No. 33, „Vortex Dominated Flows and Applications", by the Swiss National Science Foundation under the Joint Research Project IB7320-110942/1, and by the Romanian National Authority for Scientific Research through the CEEX-C2-M1-1185 „iSMART-Flow" project.

References

- D. Susan-Resiga, 2007, „A Rheological for Magneto-Rheological Fluids", Journal of Intelligent Material Systems and Structers, submitted.
- Bossis, G., Khuzir, P., Lacis, S., and Volkova, O., 2003, „Yield behaviour of magnetorheological suspensions", Journal of Magnetism and Magnetic Materials, 258-259, pp. 456-458.
- Gandhi, F. and Bullough, W. 2005. „On the Phenomenological Modeling of Electrorheological and Magnetorheological Fluid Preyield Behaviour", Journal of Intelligent Material Systems and Structures, 16: 237-248.

Hydrodynamics and Cavitation Group

Running projects:



- Novel control methods for swirling flows in conical diffusers; integration of magnetorheological devices
- Analysis and design of cardiovascular surgical procedures
- Optimized inverse design of cryogenic pumps with inducer for liquified natural gas
- Flow analysis for marine propellers
- Flow analysis for marine turbines

Hydrodynamics and Cavitation Group

Infrastructure:

- •Parallel computer **Tyan SPC800**
(10 Intel Xeon L5320-LV quad code 64 bit, 40 GB RAM, Infiniband switch, 1.5 TB HDD), storage server 4.5 TB.
- •Computing cluster 12 workstations
- •FLUENT 6.3 software (parallel license), GAMBIT 2.4, TECPLOT, TurboDesign-1
- •Roland LPX600 Laser Scaner 3D
- •Physica MCR300 magnetorheometer for magnetic fluids and magnetorhelogical suspensions
- •Fluid machinery laboratory; *new test rig for swirling flow analysis and control in conical diffusers*

International partners

- Laboratory for Hydraulic Machinery, EPF Lausanne, Switzerland (Prof. F. Avellan)
- University of Notre Dame, USA (Prof. H.Atassi)
- Institute of Fluid Mechanics and Hydraulic Machinery, Stuttgart University, Germany (Dr. A.Ruprecht)
- Laval University, Quebec, Canada (Dr. G. Ciocan)
- Kaplan Institute, Brno University, Cech Republic, (Dr. P. Rudolf)

Industrial partners

– Sangari Engineering

– Zoppas Industries

– Siemens VDO

– IRCA S.A.

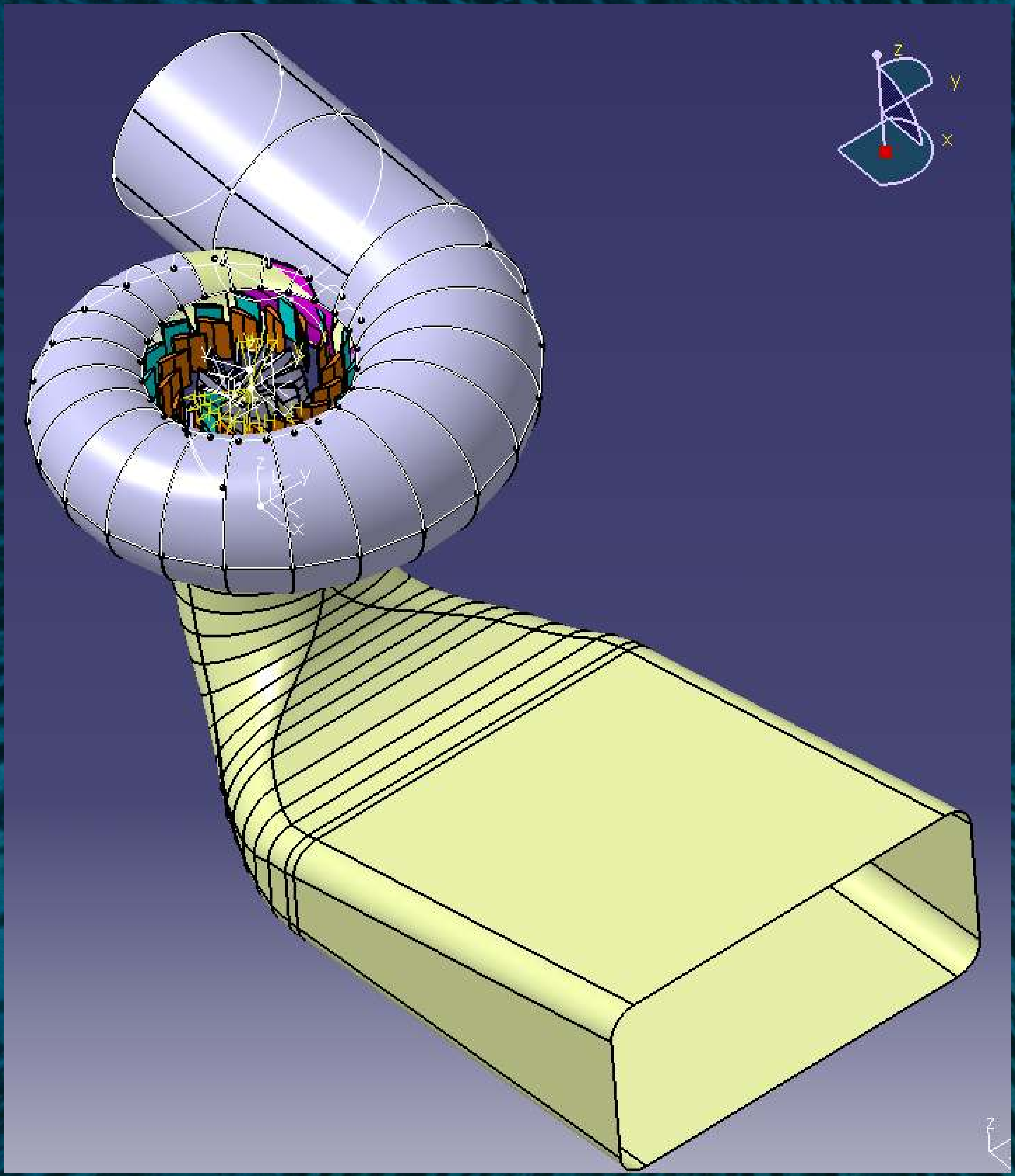
– General Electric Hydro

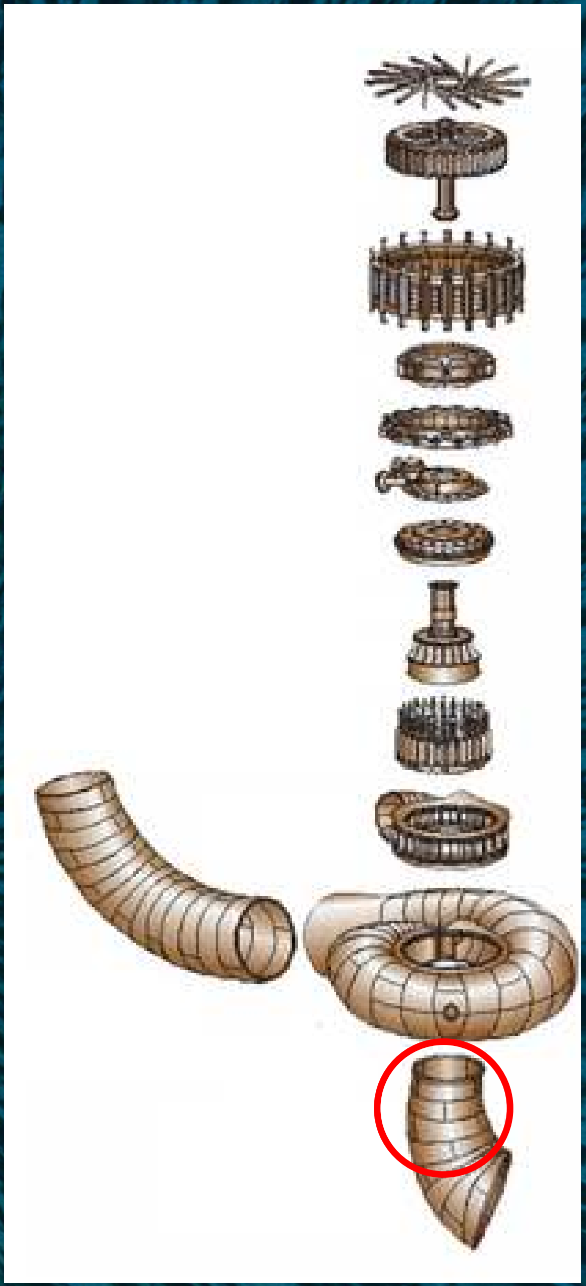
– S.C. Hidroelectrica S.A.

– UCM Resita S.A./S.C. HydroEngineering S.A.

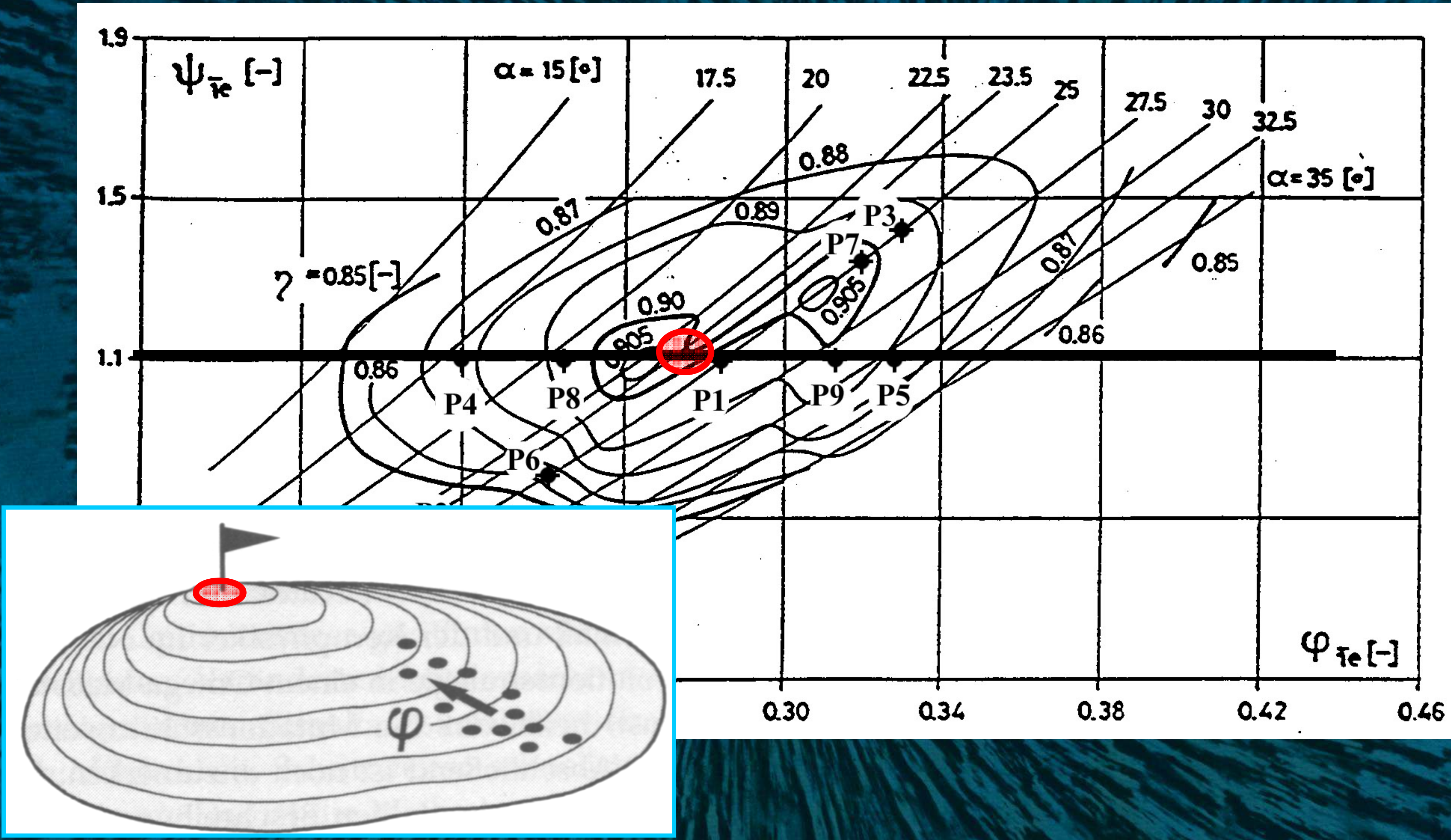
– S.C. RomEnergo S.A./Recont S.A.

Hydraulic turbines. Francis turbine





Francis turbine hill chart



VB in Francis turbine draft tube cone

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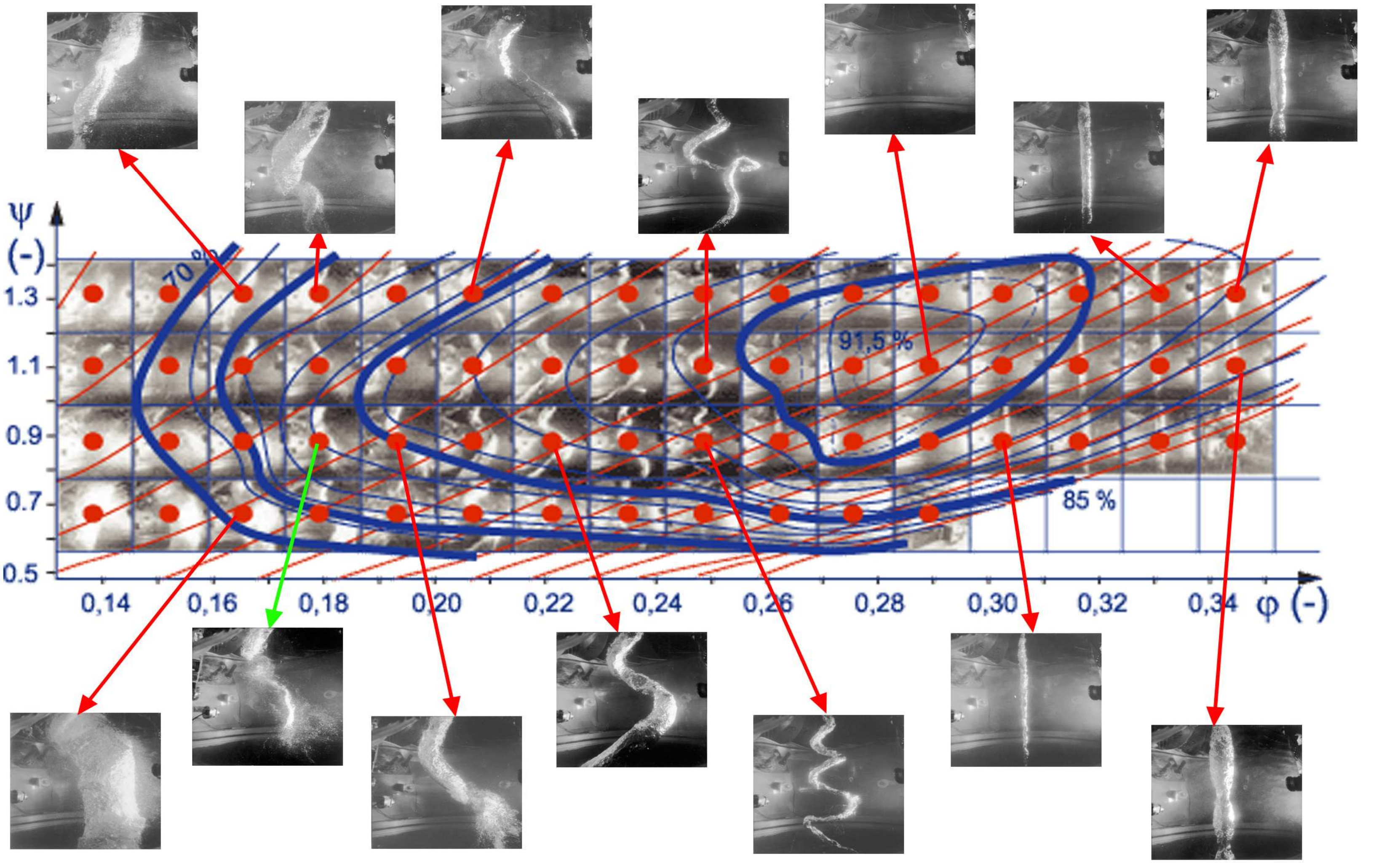


PARTIAL LOAD **BEP** OVERLOAD

T. Jacob (1993), PhD, EPF Lausanne.

Experiments on Vortex Breakdown

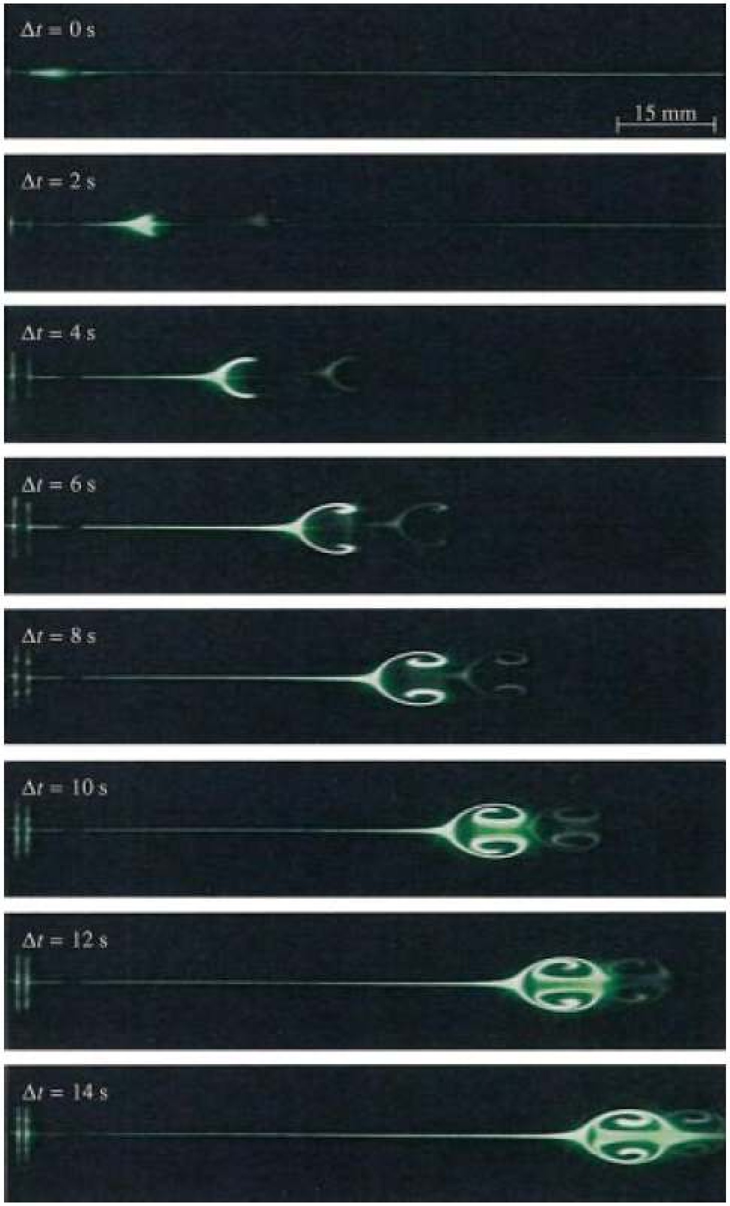
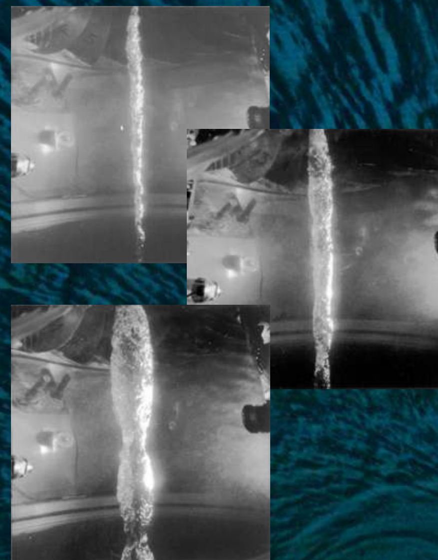
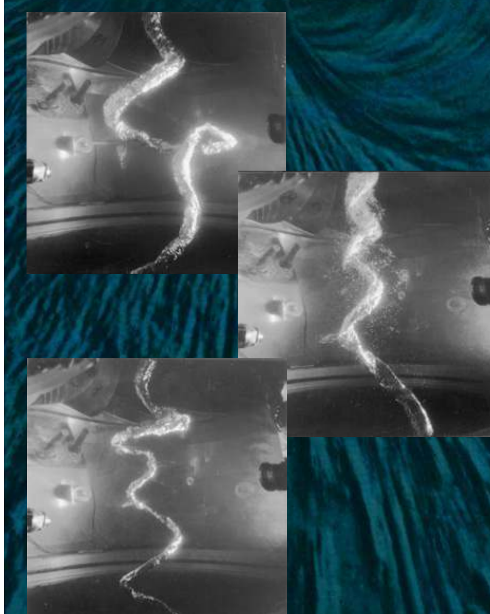


FIG. 1. Laser cross-section of axisymmetric structures.



Jacob (1993)



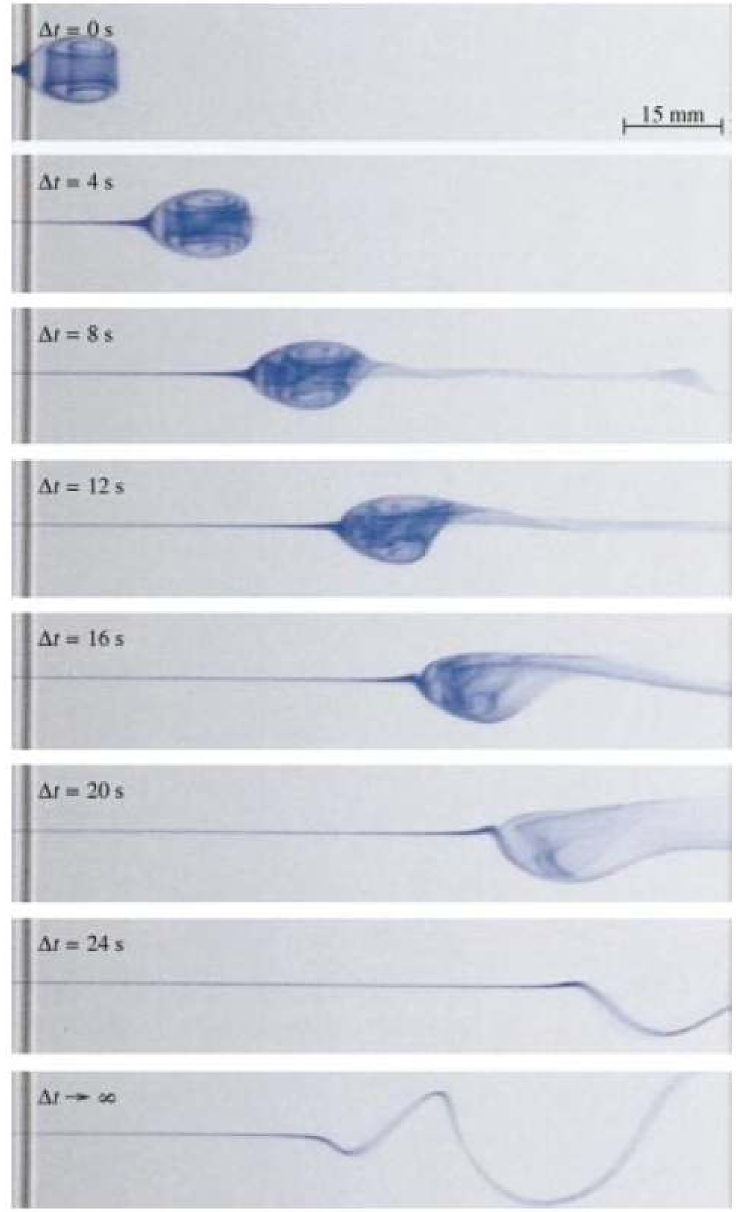


FIG. 2. Evolution to unsteady, nonaxisymmetric flow.

Experimental results on Francis turbine model

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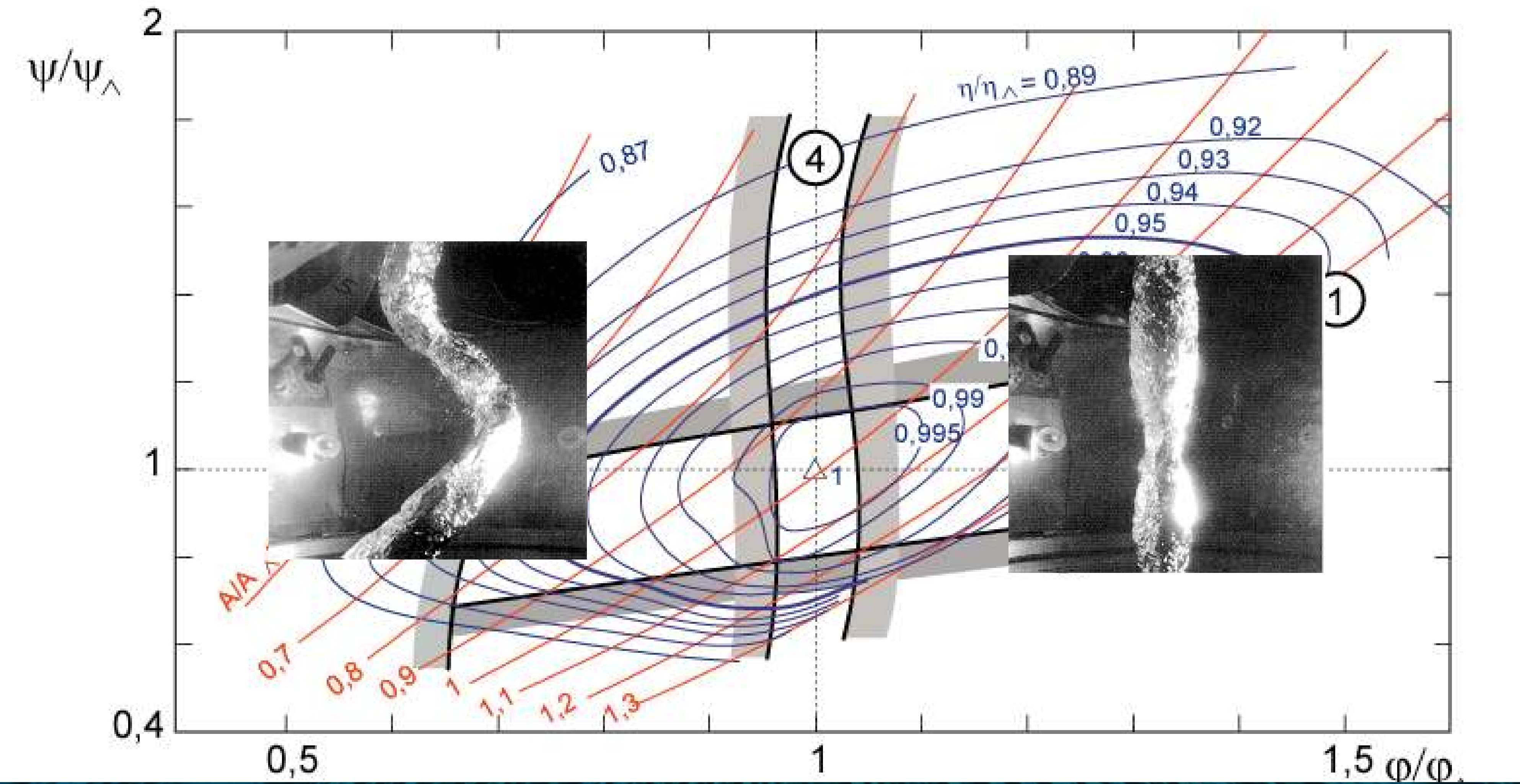

Decelerated swirling flow in Francis turbine discharge cone

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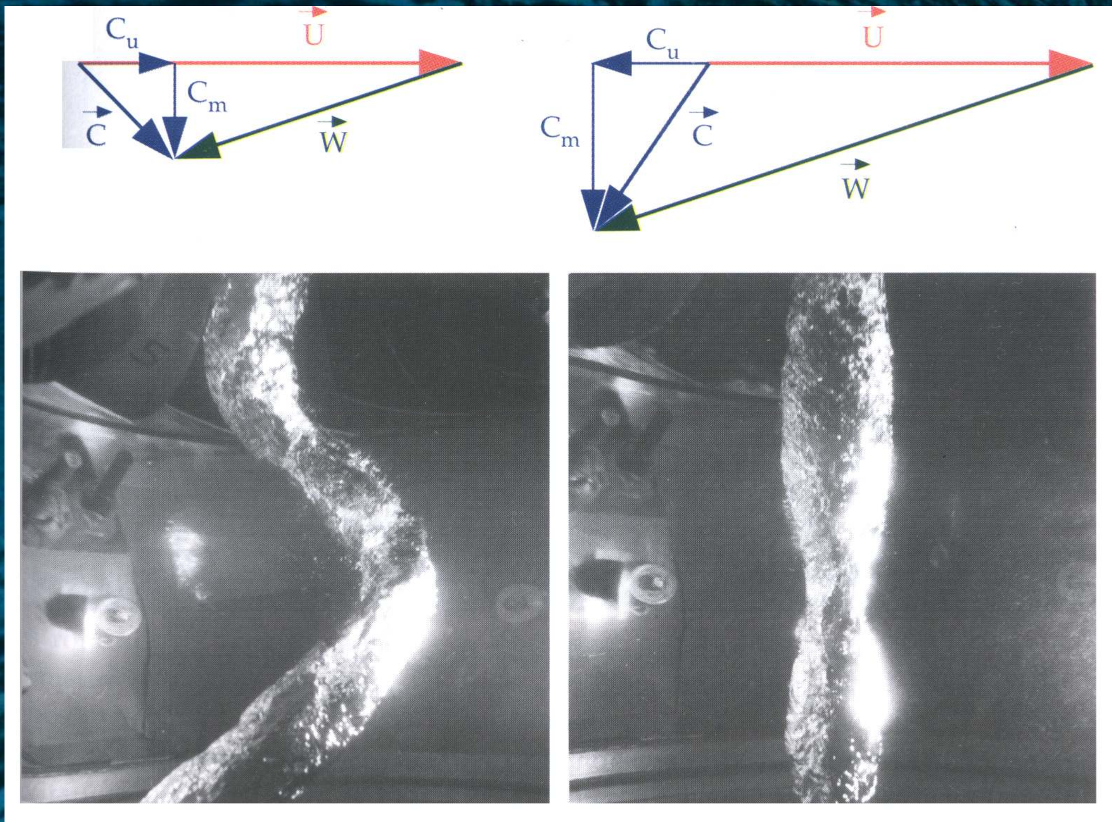
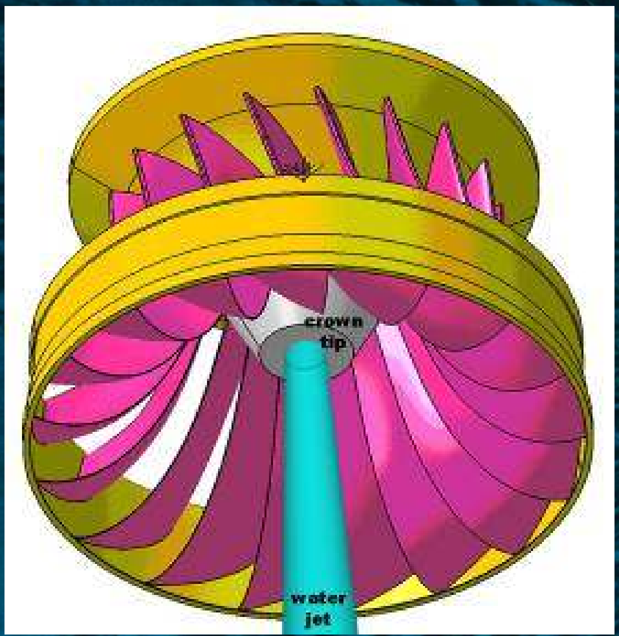


As discharge decreases:

- the swirl number associated with the flow ingested by the draft tube increases;
- the swirling flow changes from supercritical (stable) to subcritical (unstable), Resiga et al., JFE 2006;
- the decelerated swirling flow evolves in vortex breakdown, with large central quasi-stagnant region.

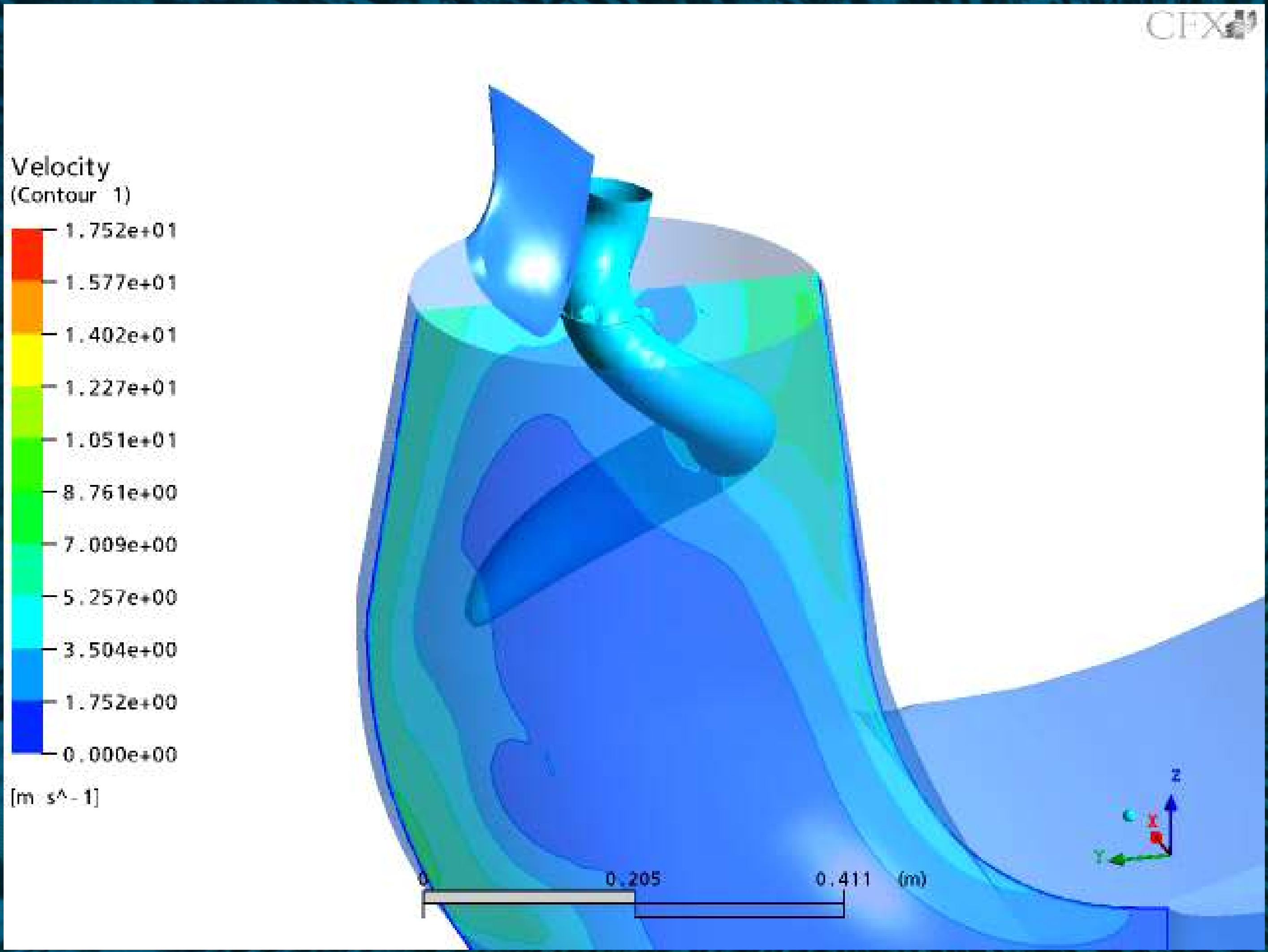
Novel swirling flow control technique: inject axially a high velocity water jet from the tip of runner crown



$$V_{\text{jet}} \approx \sqrt{2gH} = \frac{\omega D}{2}\sqrt{\psi}$$

- ✓ The control jet address the main excitation cause, by removing / mitigating the central quasi-stagnant region and the unstable vortex sheet.
- ✓ By removing the unsteady secondary flow in the discharge cone, the draft tube hydraulic losses are significantly decreased → compensate for the jet hydraulic energy.
- ✓ The control jet is continuously adjustable, and it can be switched off when not needed.
- ✓ Simple and robust, with no changes in the turbine flow passage.

Jet control technique
Animation



- **Beginning: well established strong rope**
- **Onset of jet alters low pressure zone significantly and stabilizes it in the center.**

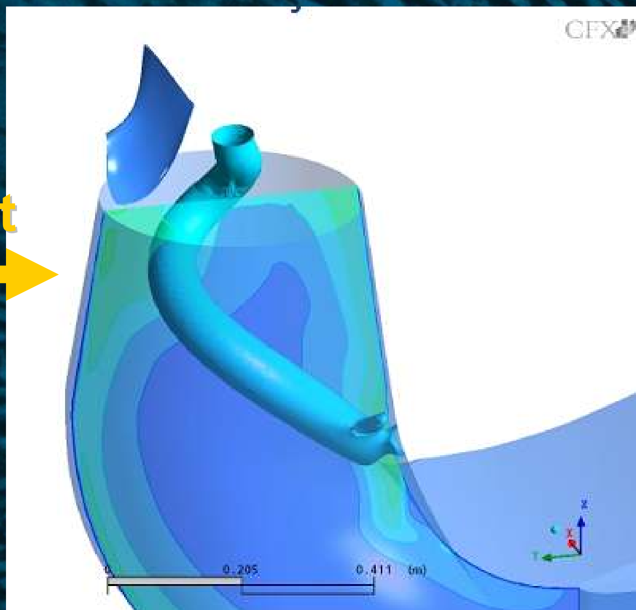
Jet control technique

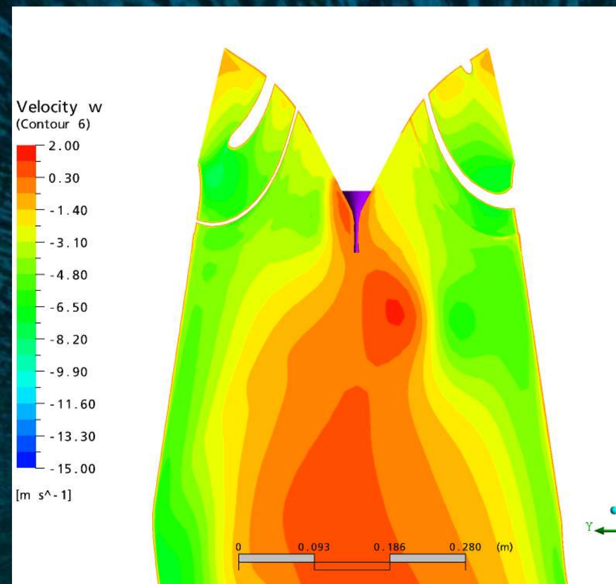
Numerical solution for axial jet control in draft tube

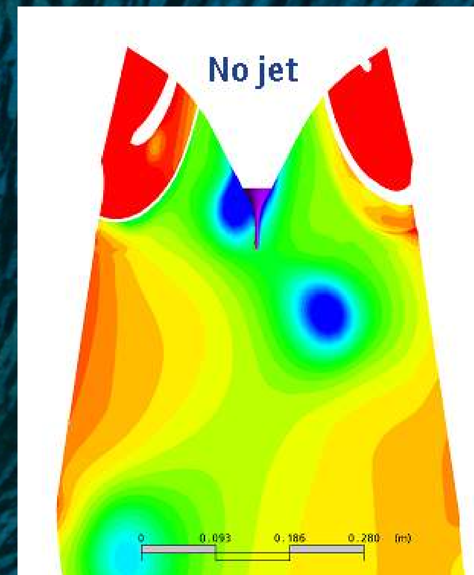
Velocity distribution

Static pressure

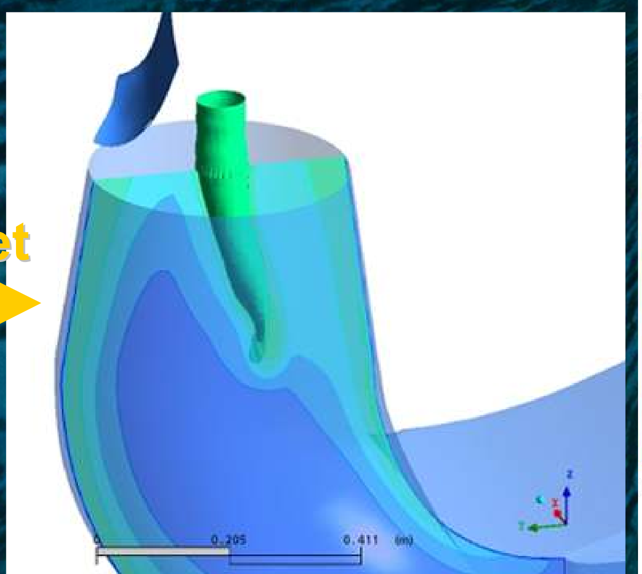
No Jet

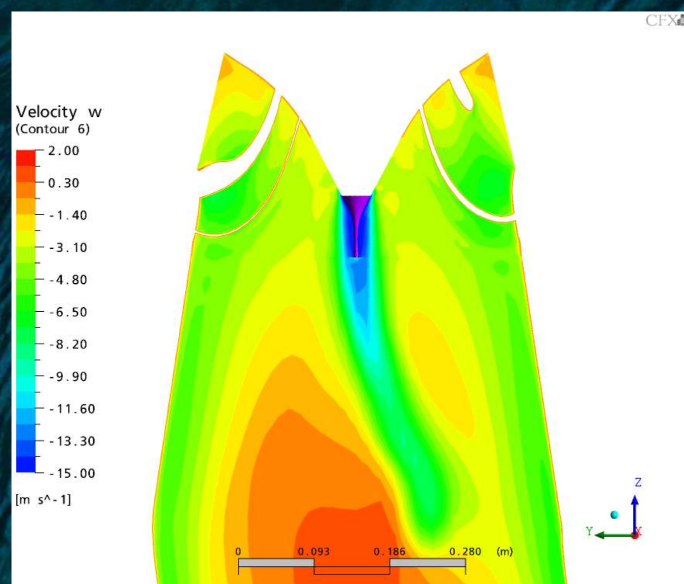






With Jet

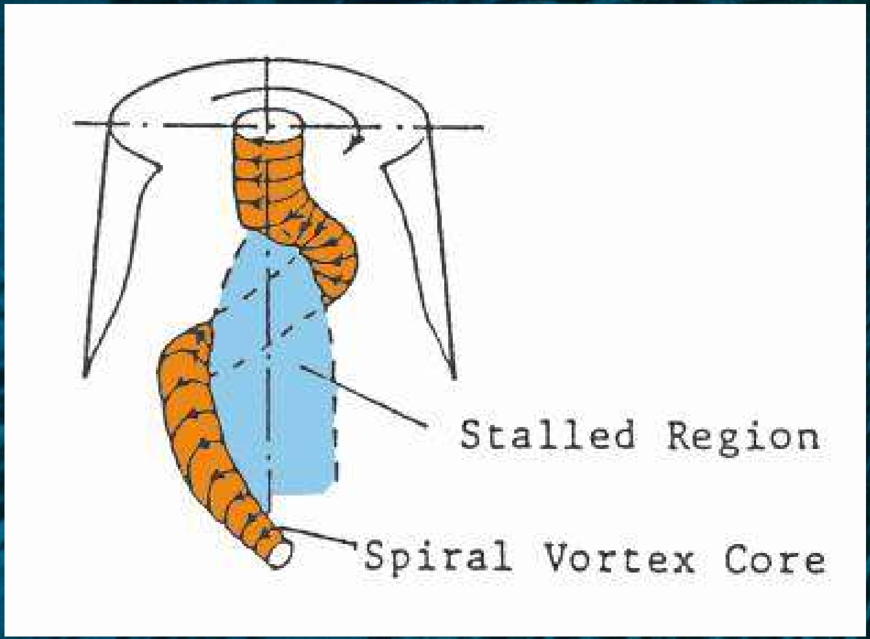




Water jet control technique

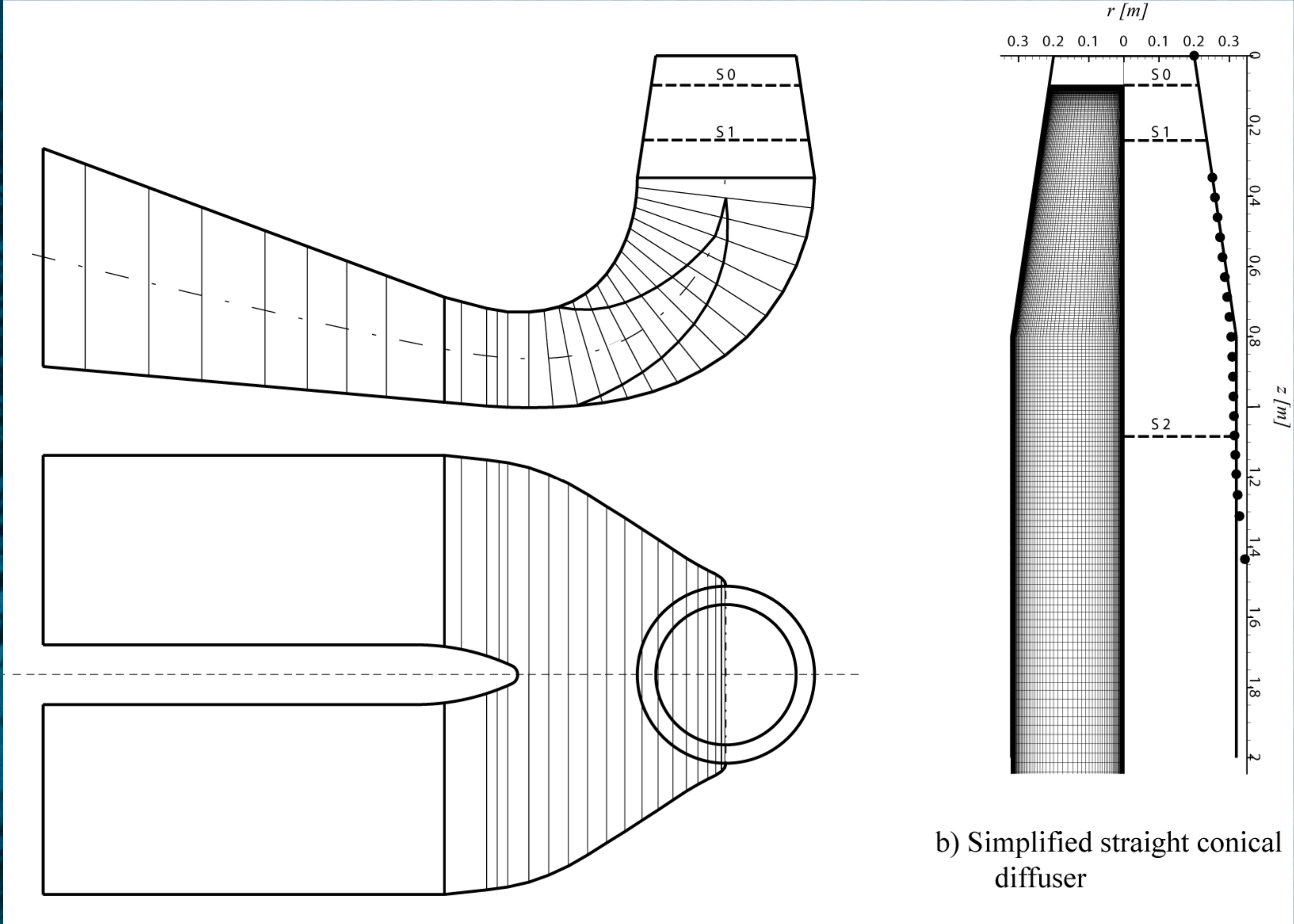
Movie

Precessing Vortex Rope: Helical vortex breakdown in decelerated swirling flows.



- The decelerated swirling flow in Francis turbine discharge cone evolves in helical vortex breakdown (precessing vortex rope) when the swirl number at runner outlet increases above a critical value.
- Nishi et al. (1988) suggest that the circumferentially averaged velocity field in the cone could be represented as a "dead" (quasi-stagnant) water region surrounded by the swirling main flow.
- The spiral vortex is a rolled-up vortex sheet originating between the central stalled region and outer swirling flow.

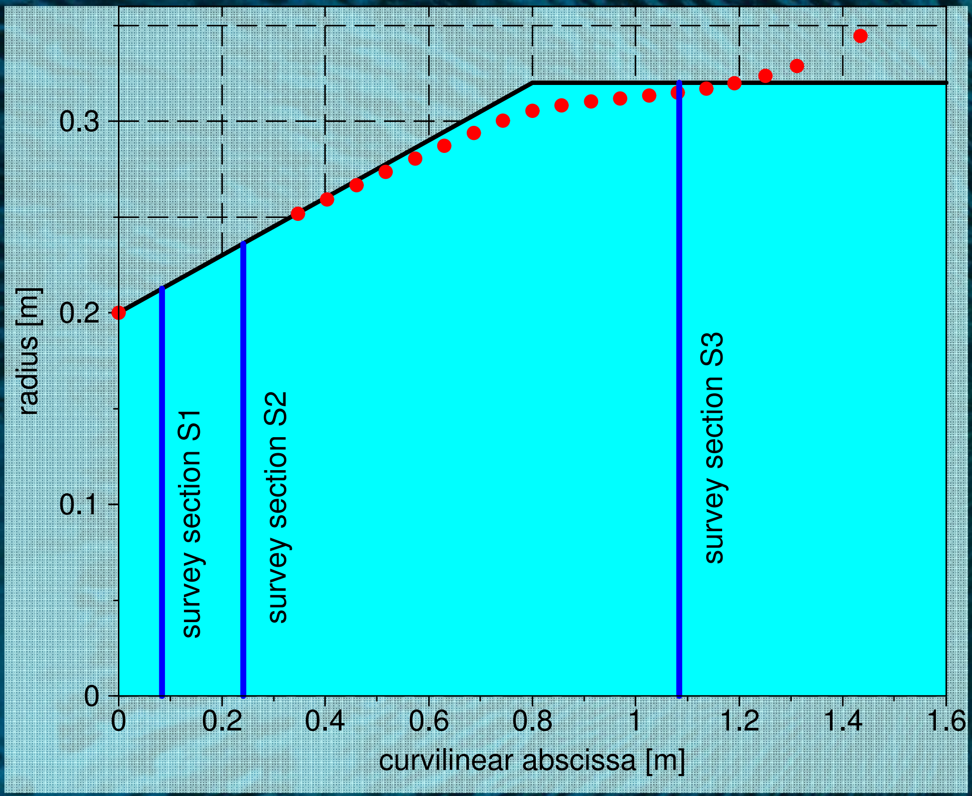
Actual Draft Tube and the Equivalent Axisymmetric Computational Domain



a) Side and top view, respectively, of the FLINDT draft tube

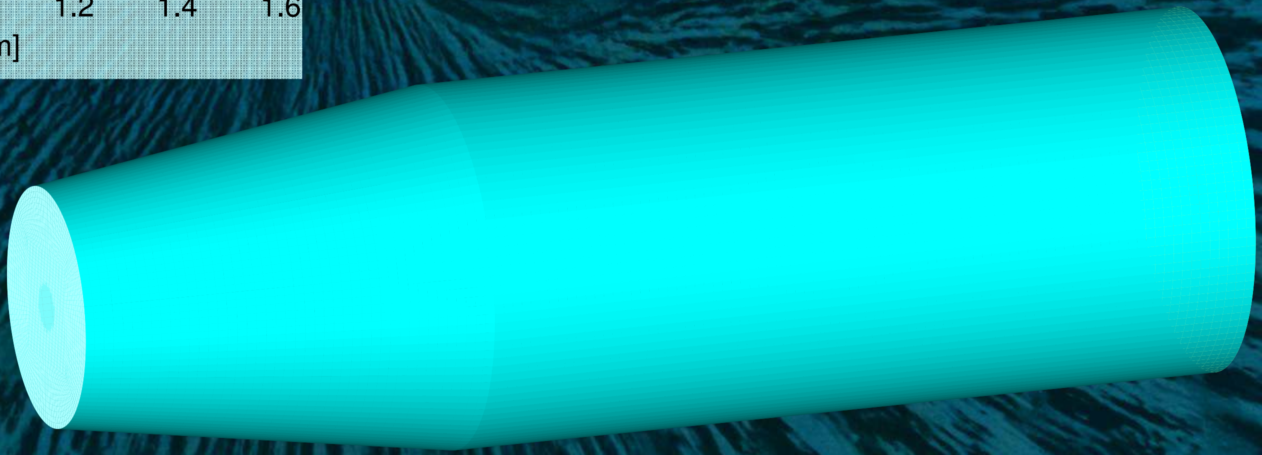
b) Simplified straight conical diffuser

Simplified straight diffuser

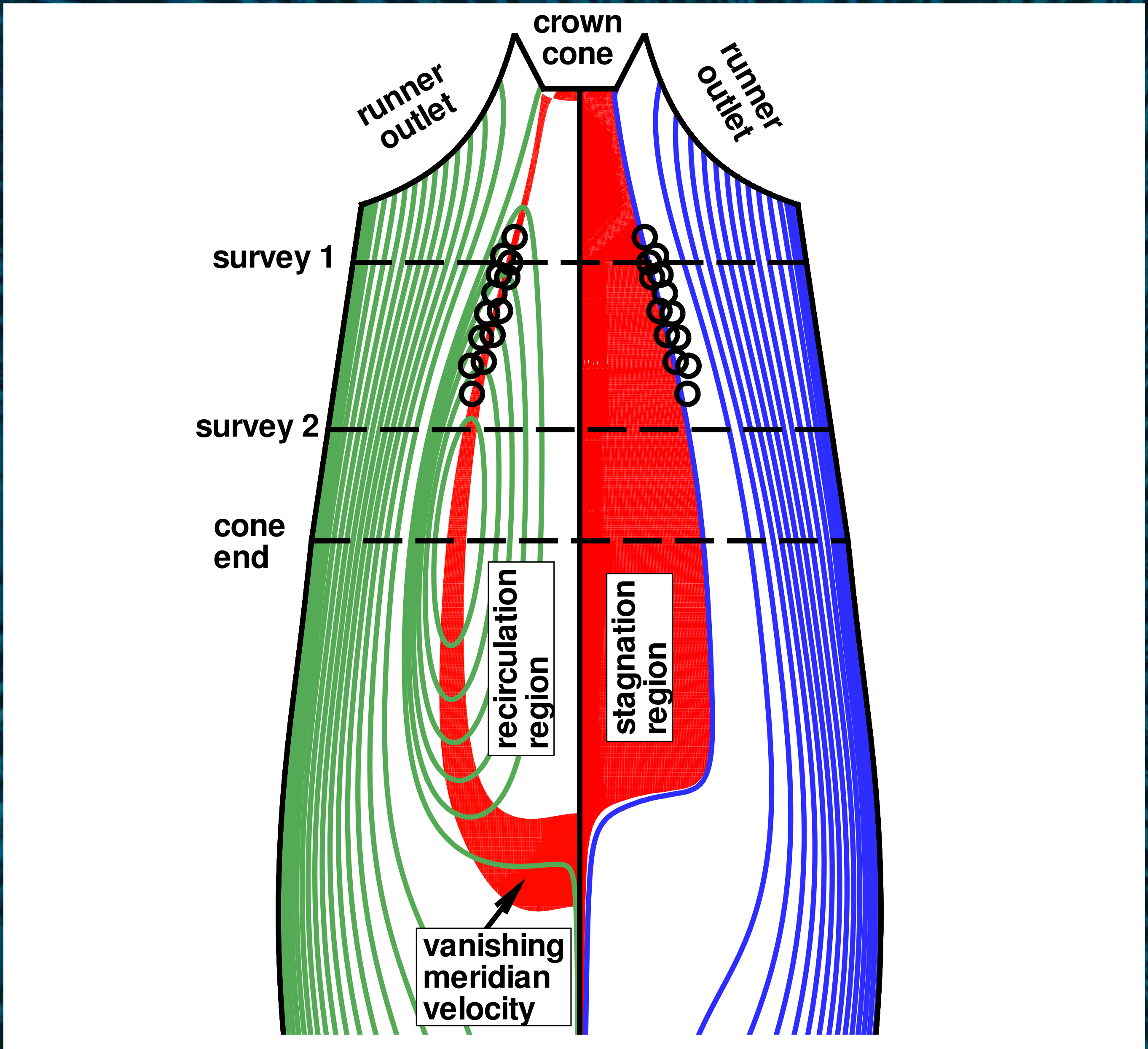


Conical diffuser with 8.5° half-angle and 2.5 x *inlet diameter* in length, followed by a cylindrical section. Inlet/outlet area ratio 2.56.

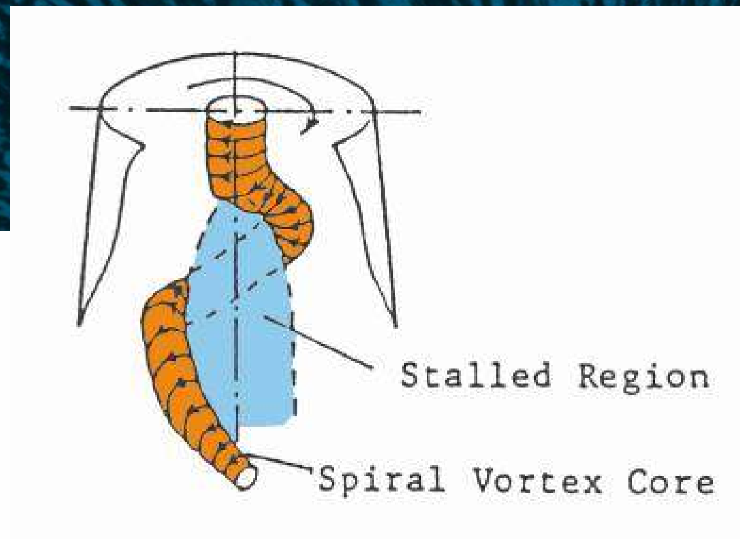
LDA measurements available in survey sections S_1 and S_2 for velocity components and turbulent kinetic energy.



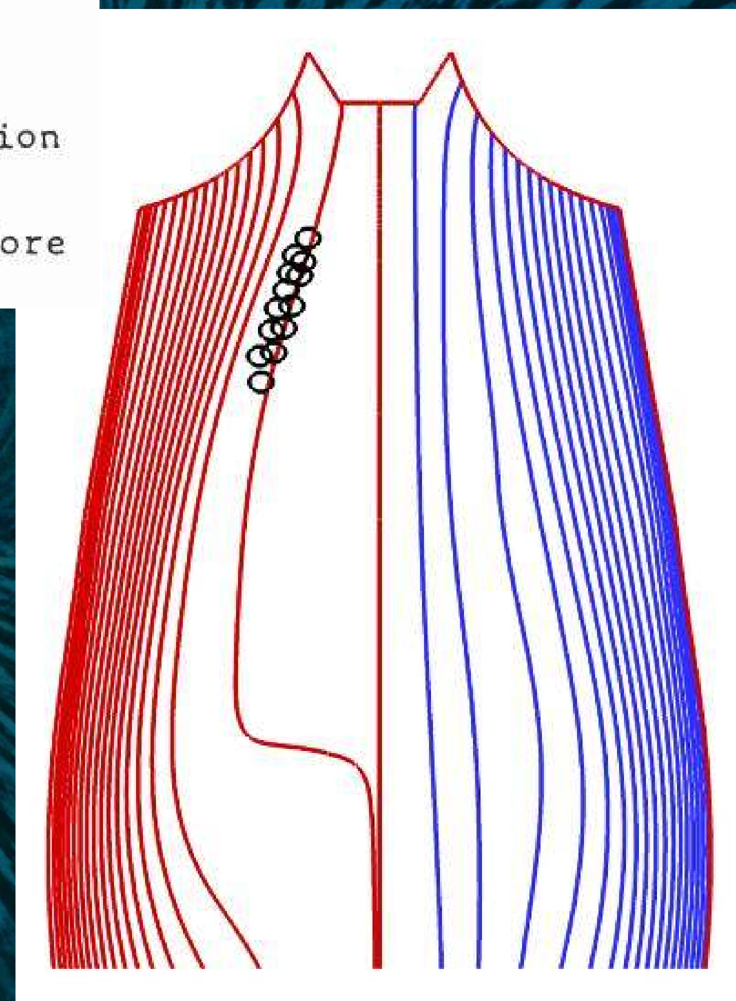
Axisymmetric turbulent swirling flow in Francis turbine draft tube



Axisymmetric turbulent swirling flow simulation and flow control with axial water jet injection



Meridian velocity (left)
and
streamlines (right)



Proiectarea, realizarea standului experimental

Condiţii de proiectare:

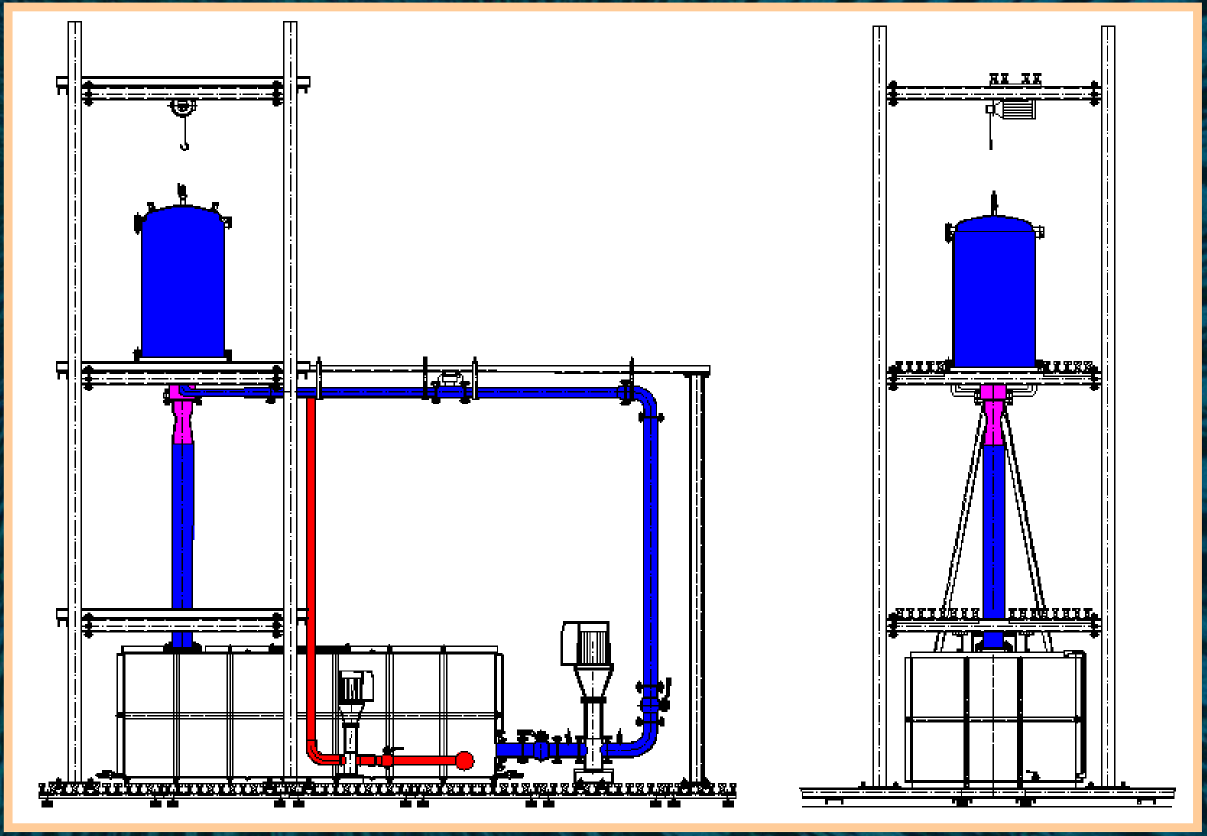
a) realizarea unei curgeri similare in sectiunea de test cu cea de la iesirea din conul tubului de aspiratie

b) vizualizarea cat mai buna a fenomenului

c) diametrul nominal al instalaţiei 100*mm*

Din aceste condiţii s-a ajuns la următoarele caracteristici:

- 5200×1900×6000
- situat pe trei etaje
- compus dintr-o serie de elemente principale si o serie de elemente secundare
- echipat cu sisteme de masură a debitului, presiunii



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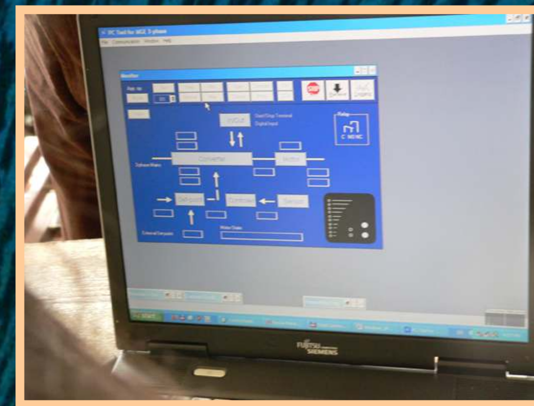
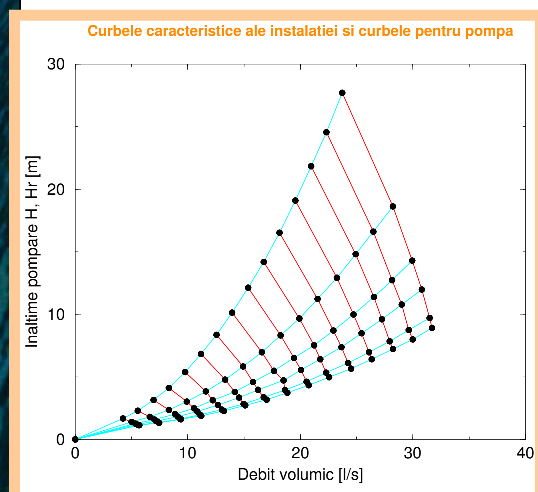
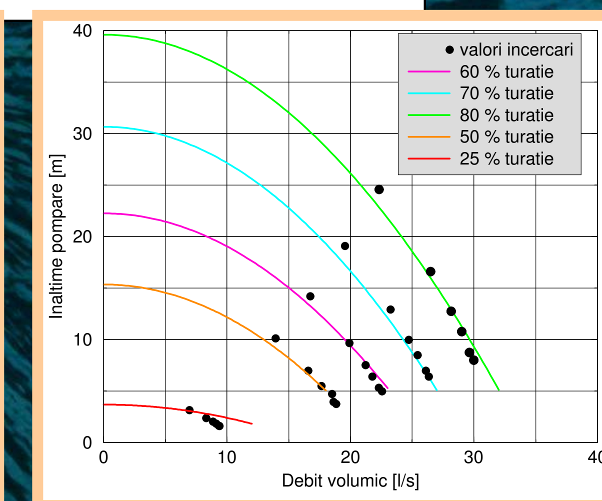
Testarea si efectuarea primelor măsurători



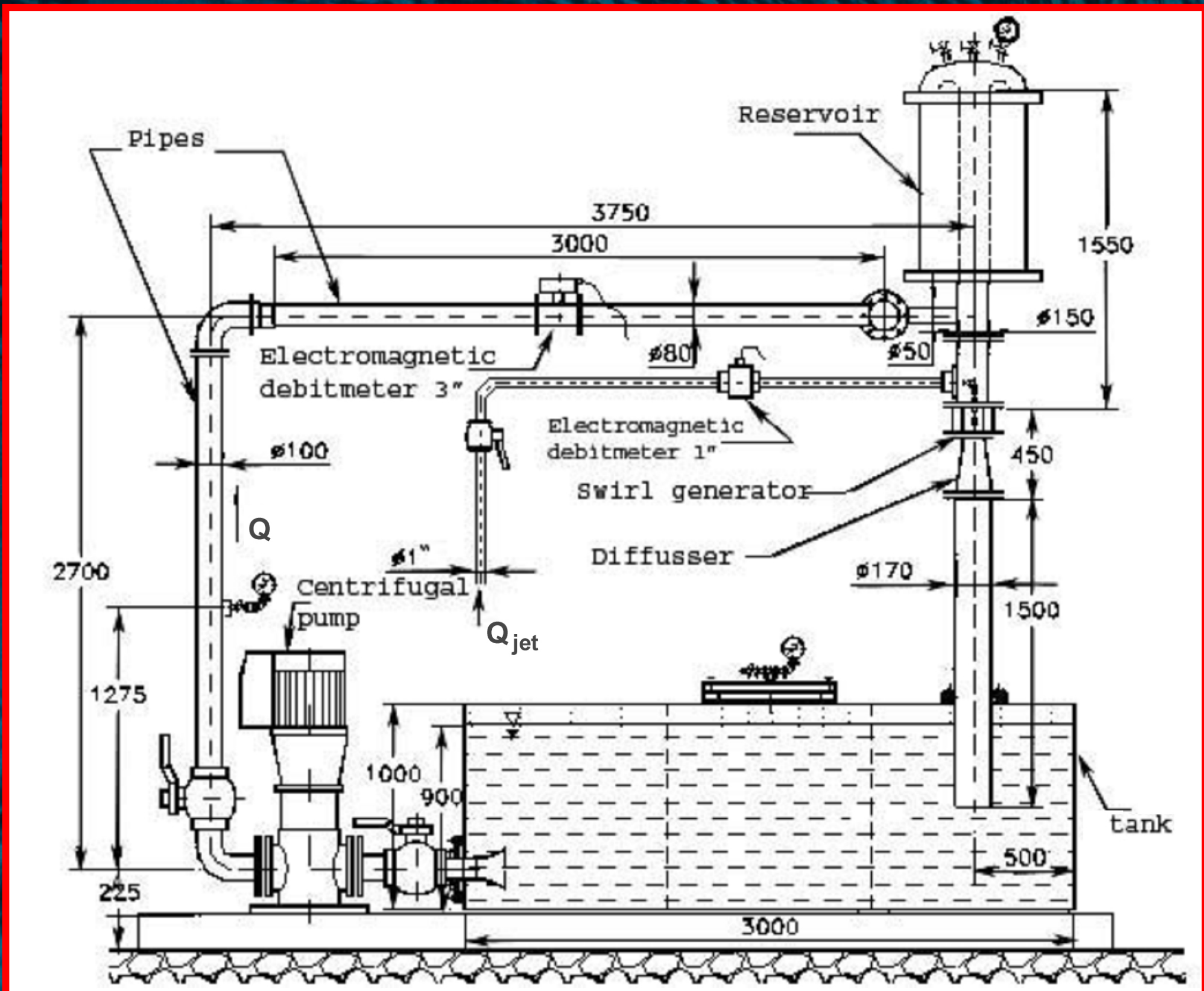
Primele teste efectuate:

- calibrare aparate măsură
- masurare: debit, inalţime de pompare, putere absorbită





Test rig from UPT- NCESCF



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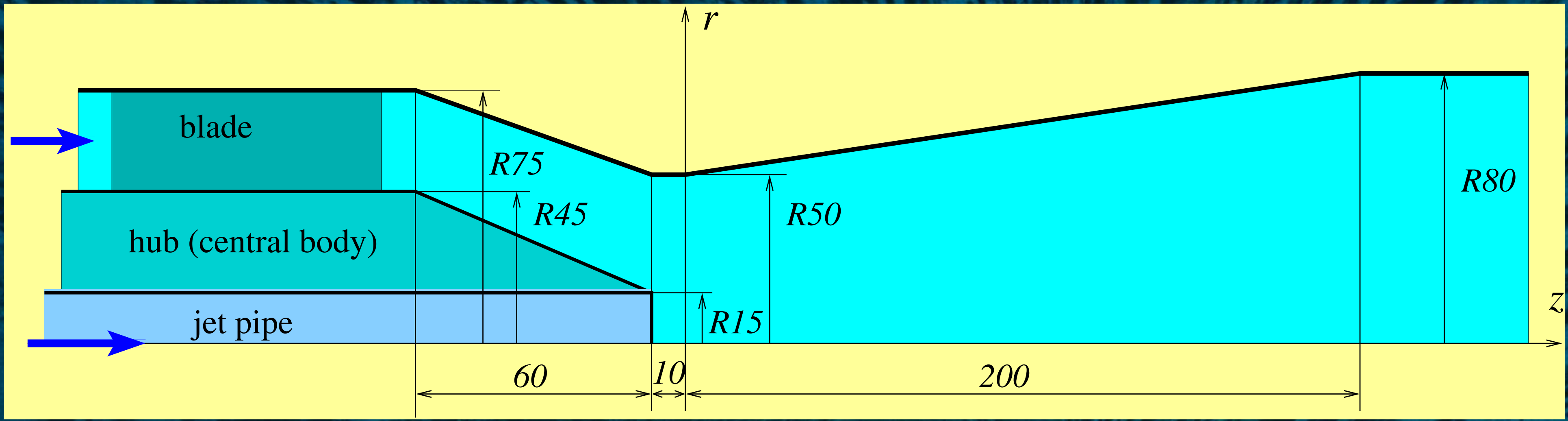
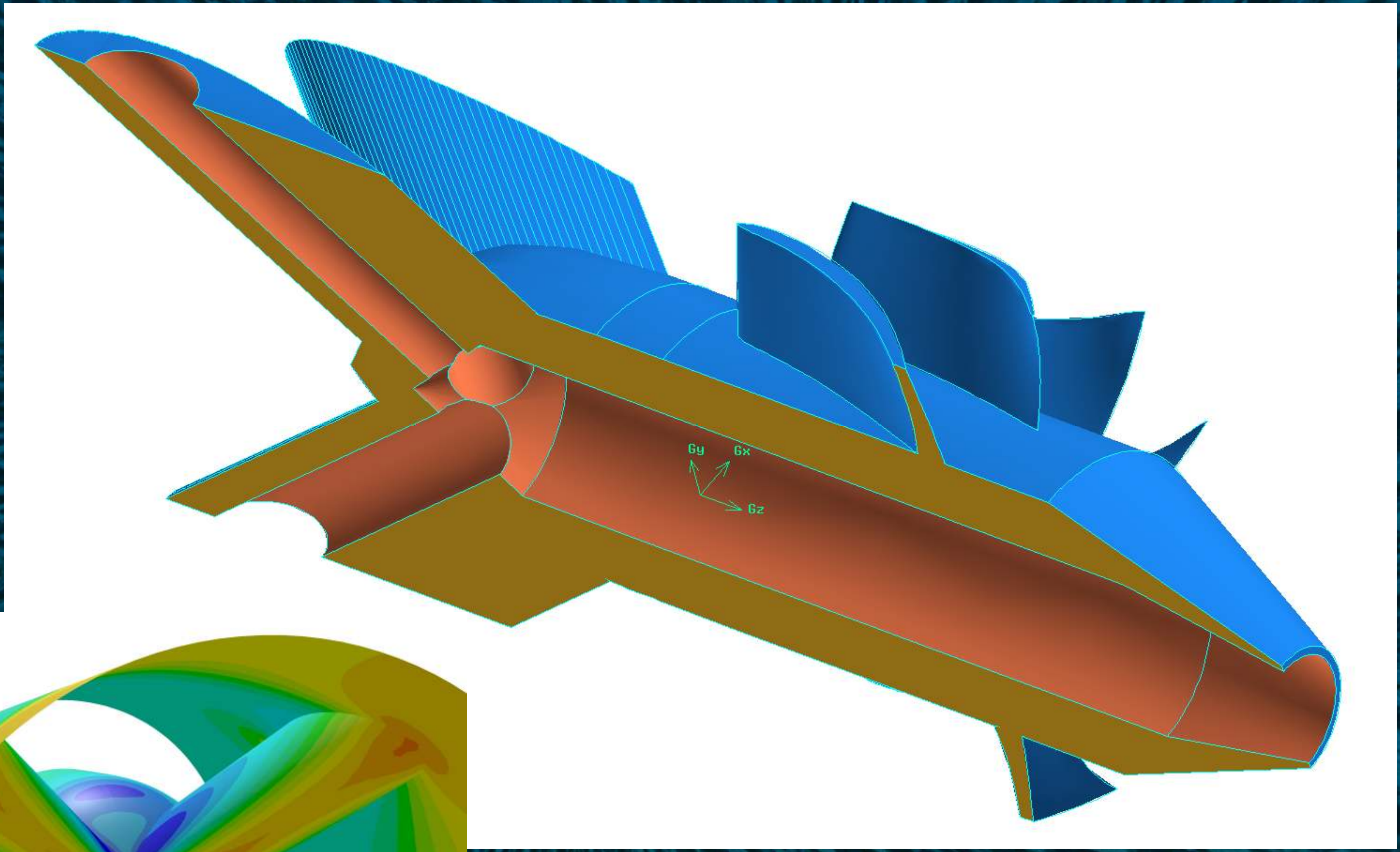
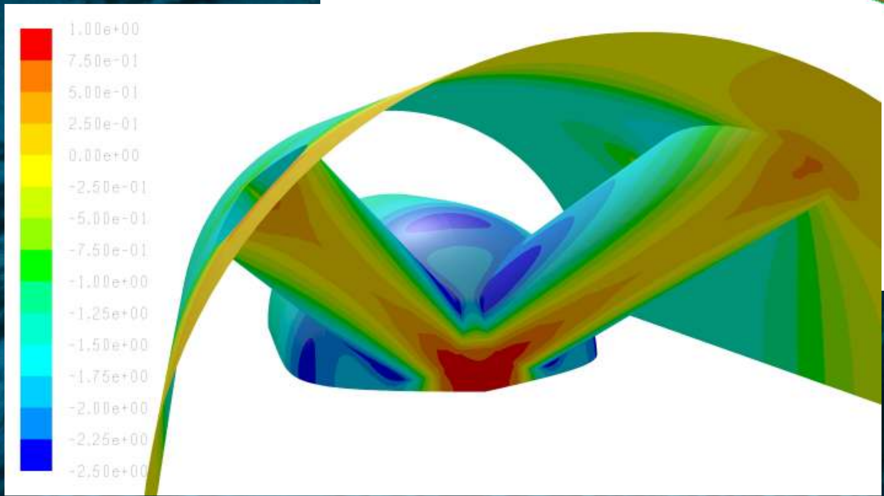
Swirl apparatus test section



- Convergent-divergent cross-section
- Fixed blades in the upstream annular section
- Water injection through the central body
- Throat diameter ø 100 mm
- Throat Reynolds number ~ 4E5
- Diffuser cone included angle 17º, length = 2 x throat diameter

Swirl generator and jet injection system





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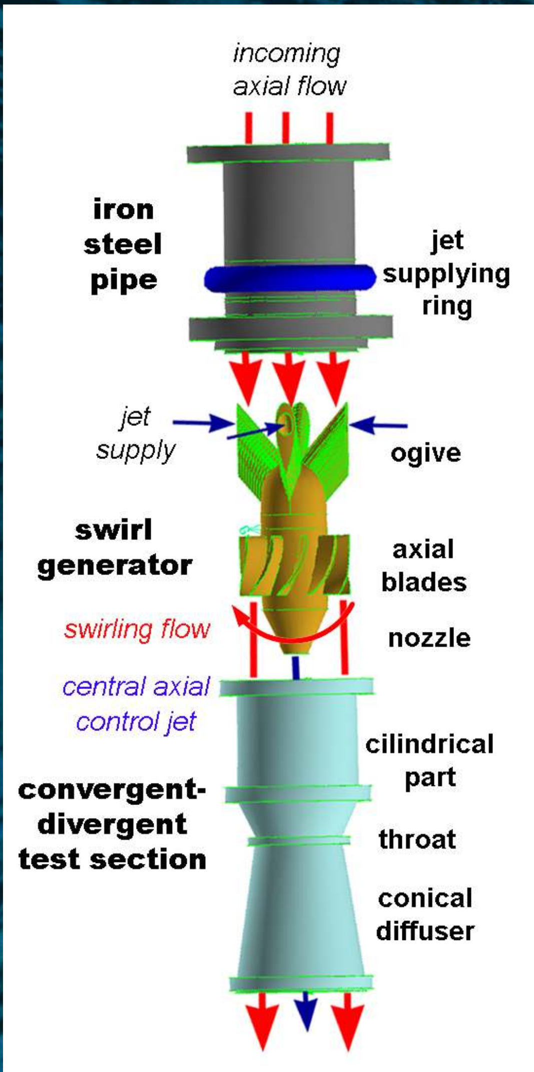
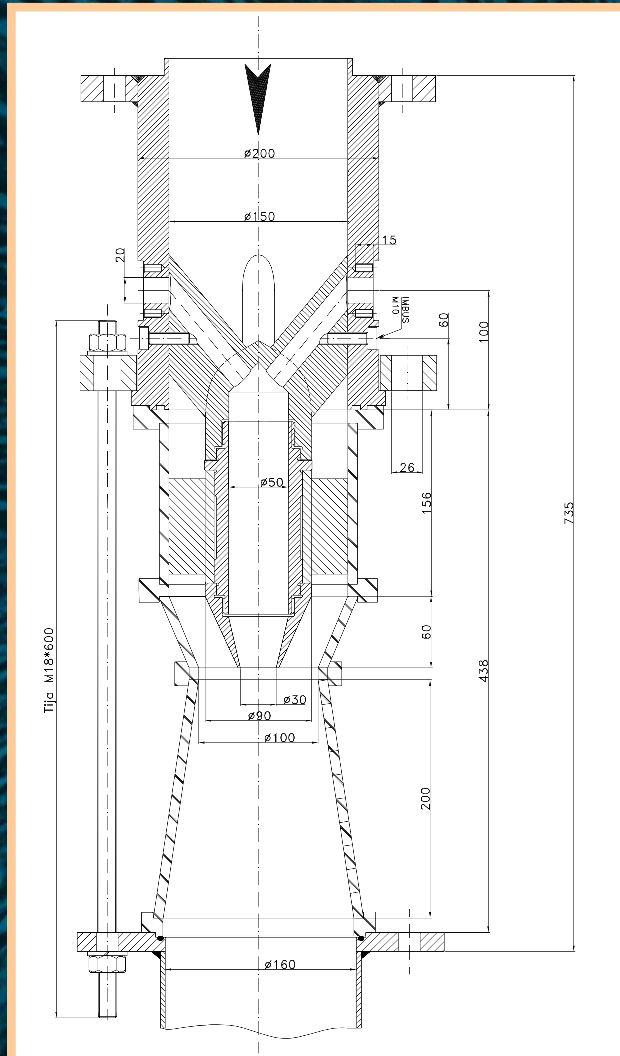
Test section





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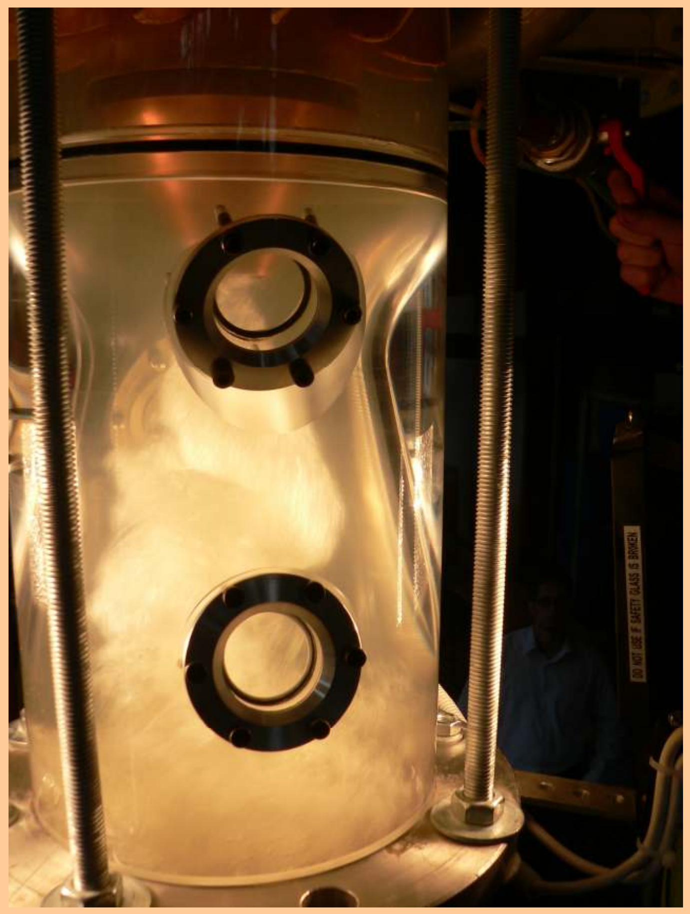
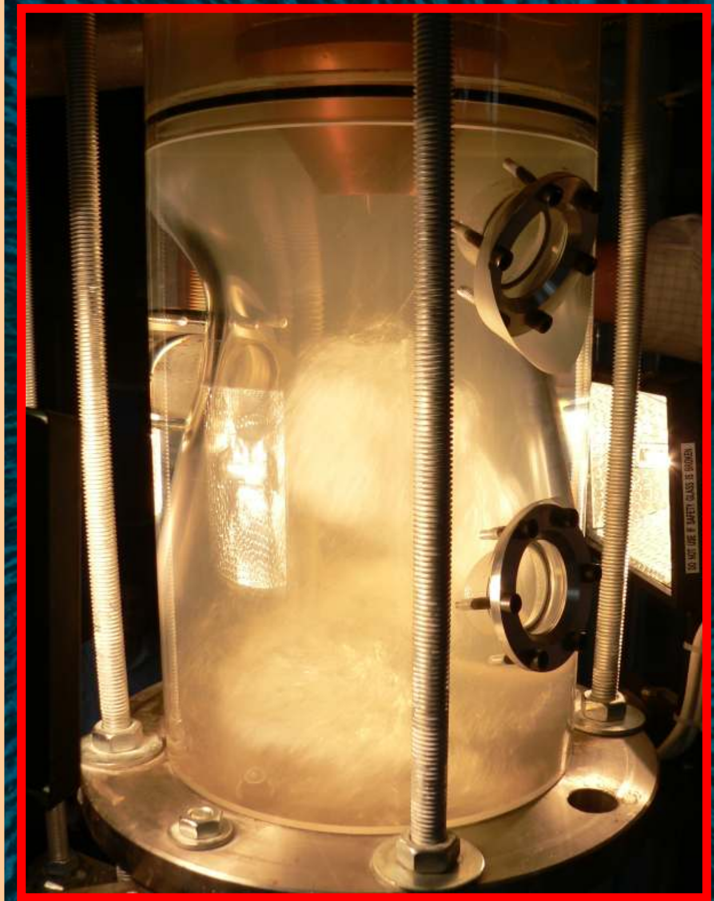
Vizualizarea vartejului funie si distrugerea lui





fara jet

cu jet

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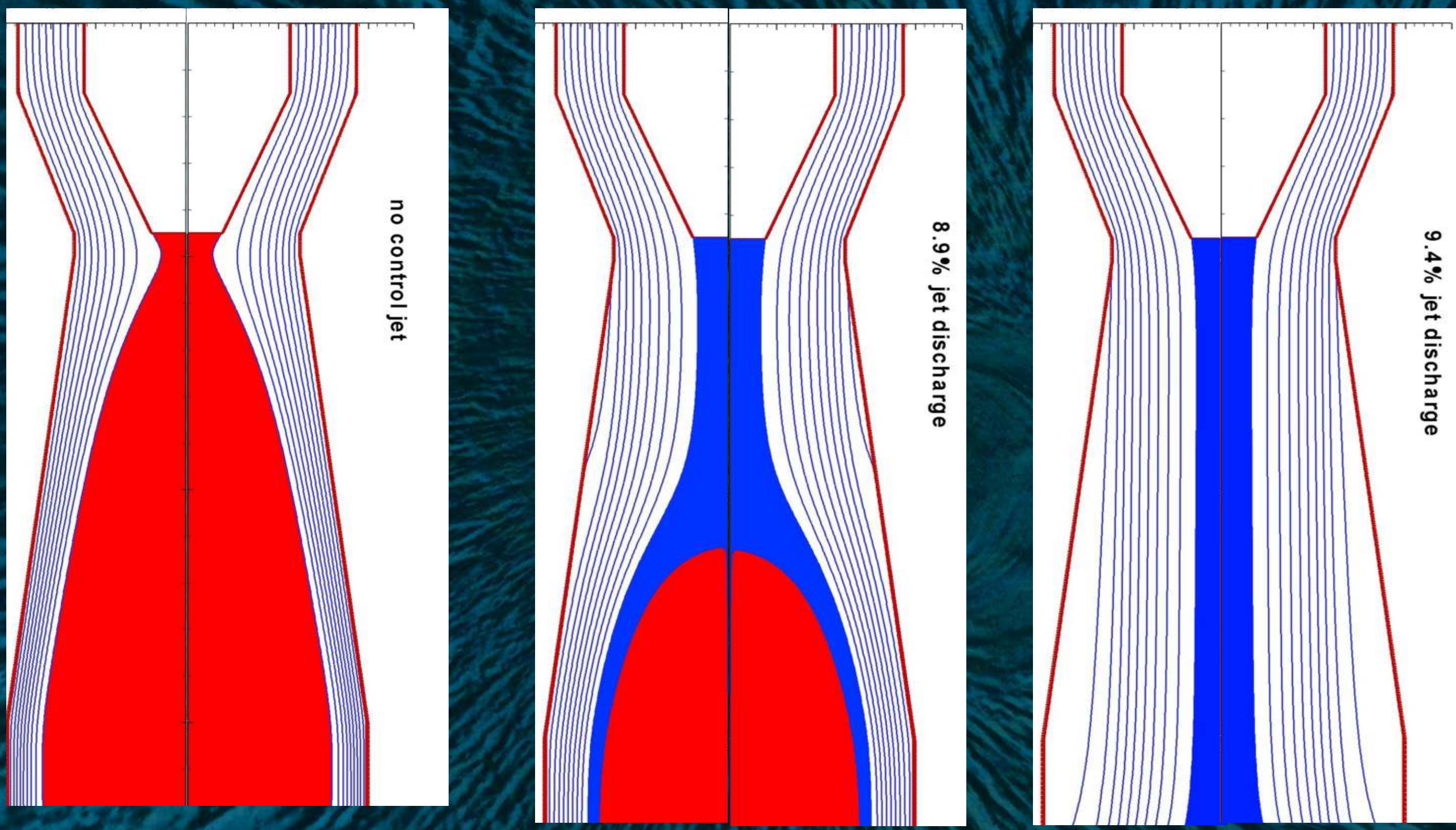
Investigarea numerica pentru determinarea debitului optim al jetului



fara jet - stanga, cu debitul in jet de 8.9% - centru, cu debitul in jet de 9.4%.

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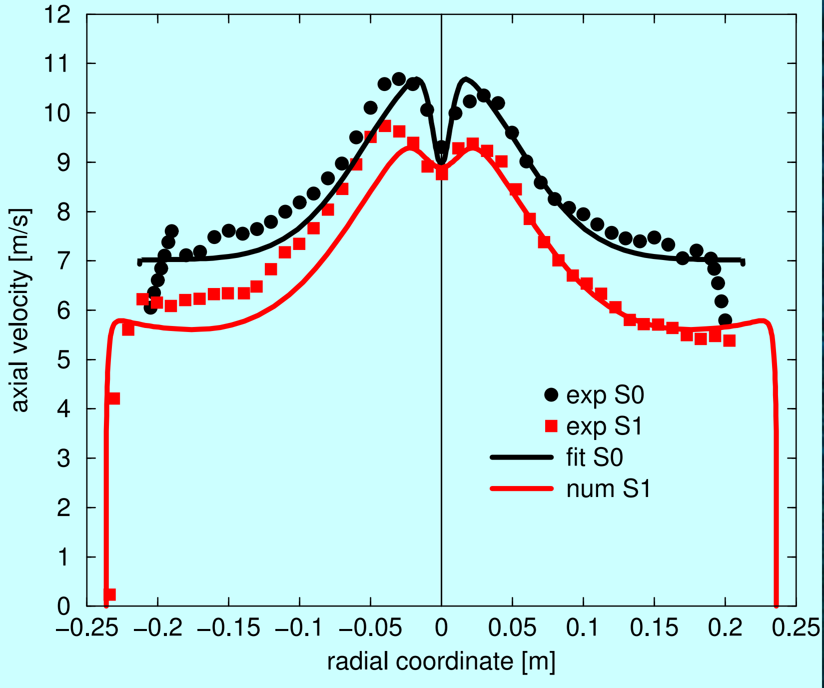
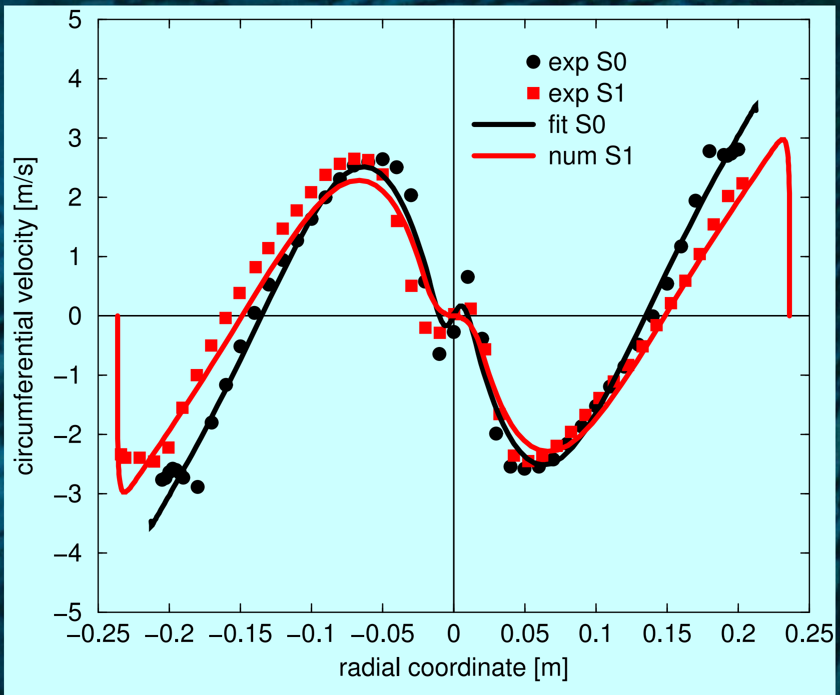
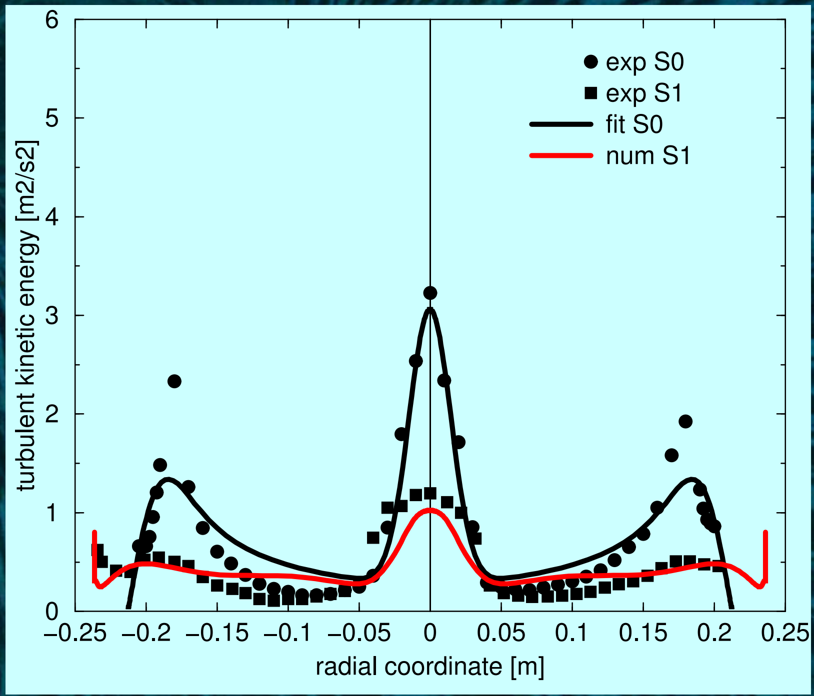
Curgerea cu swirl in con

Compararea rezultatelor numerice ale modelului 2D cu swirl cu datele experimentale



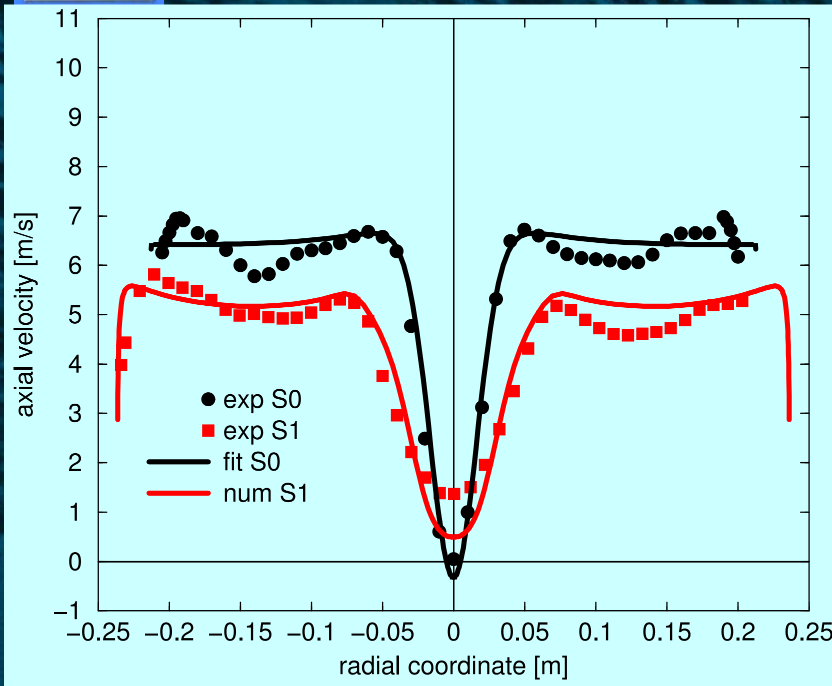
Discharge coefficient φ=0.410 (1.11 Q_{BEP})



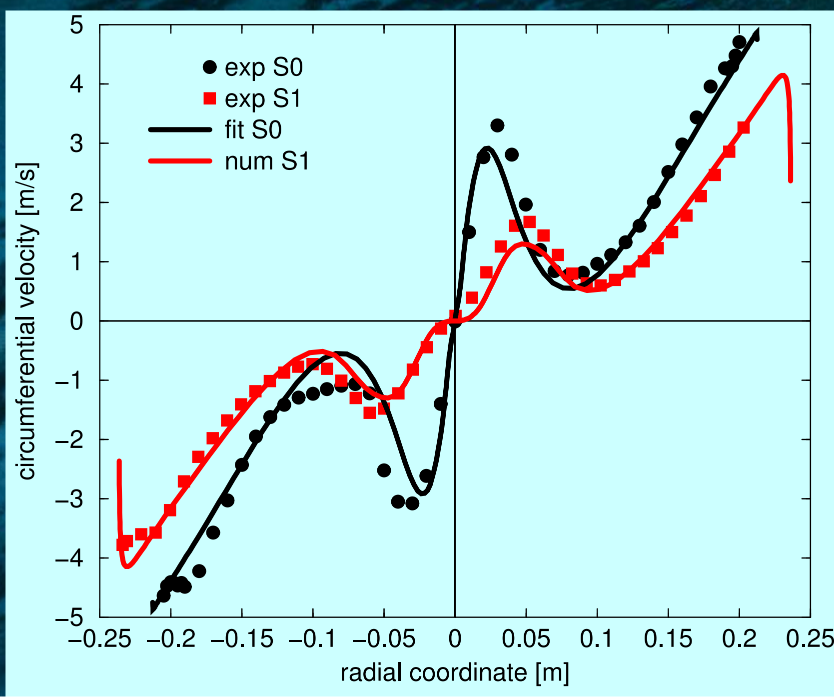


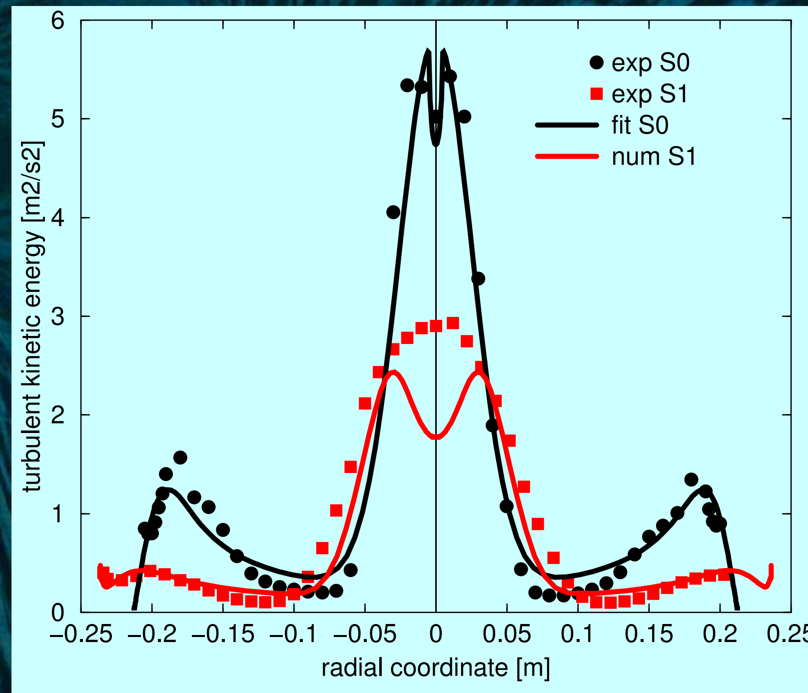
Curgerea cu swirl in con

Compararea rezultatelor numerice ale modelului 2D cu swirl cu datele experimentale

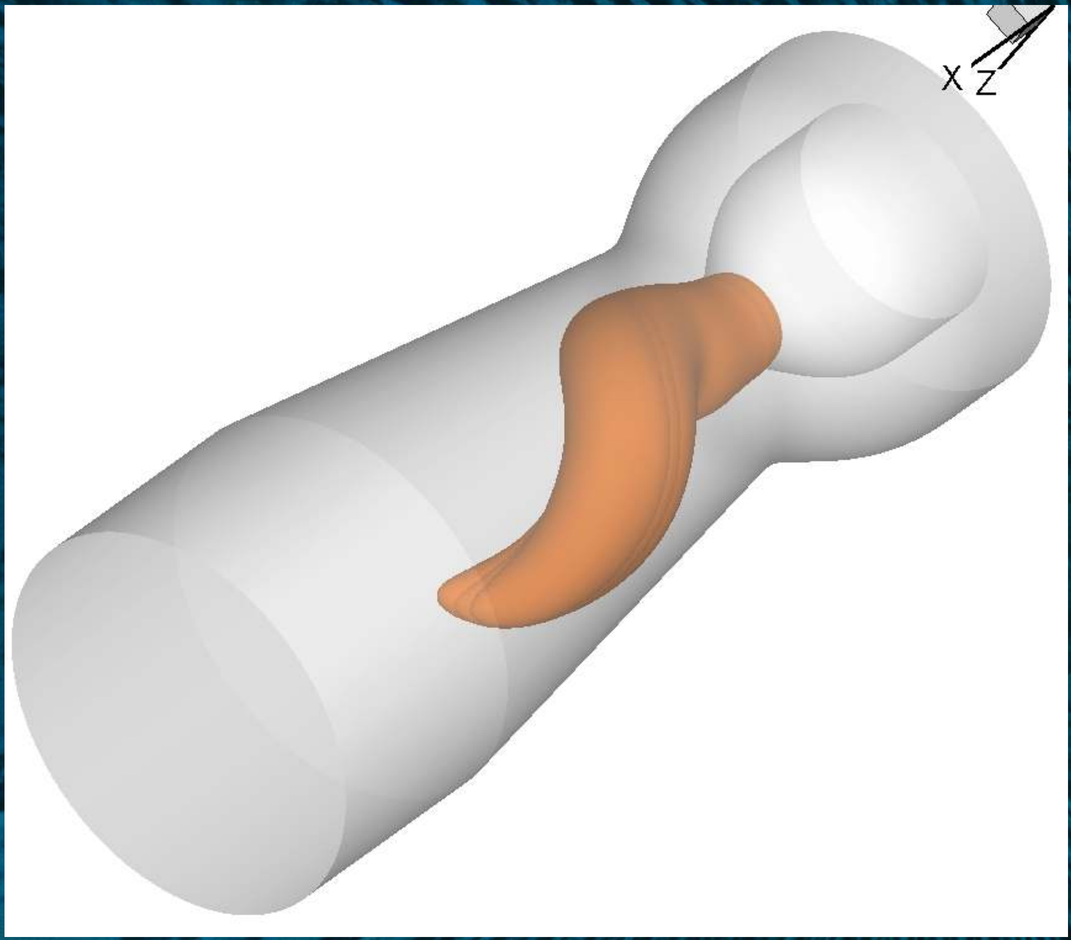


Discharge coefficient φ=0.340 (0.92 Q_{BEP})





Simularea 3D a vartejului funie



Simularea curgerii 3D nestationare turbulente cu vartej central (8 procese) → 60 zile (2 luni)

Super-computer TYANPSC:
5 noduri x 2 procesoare, 40 Gb RAM
3Tb stocare,
Windows Computer Cluster +
Fluent (licenta paralela 16 procese)

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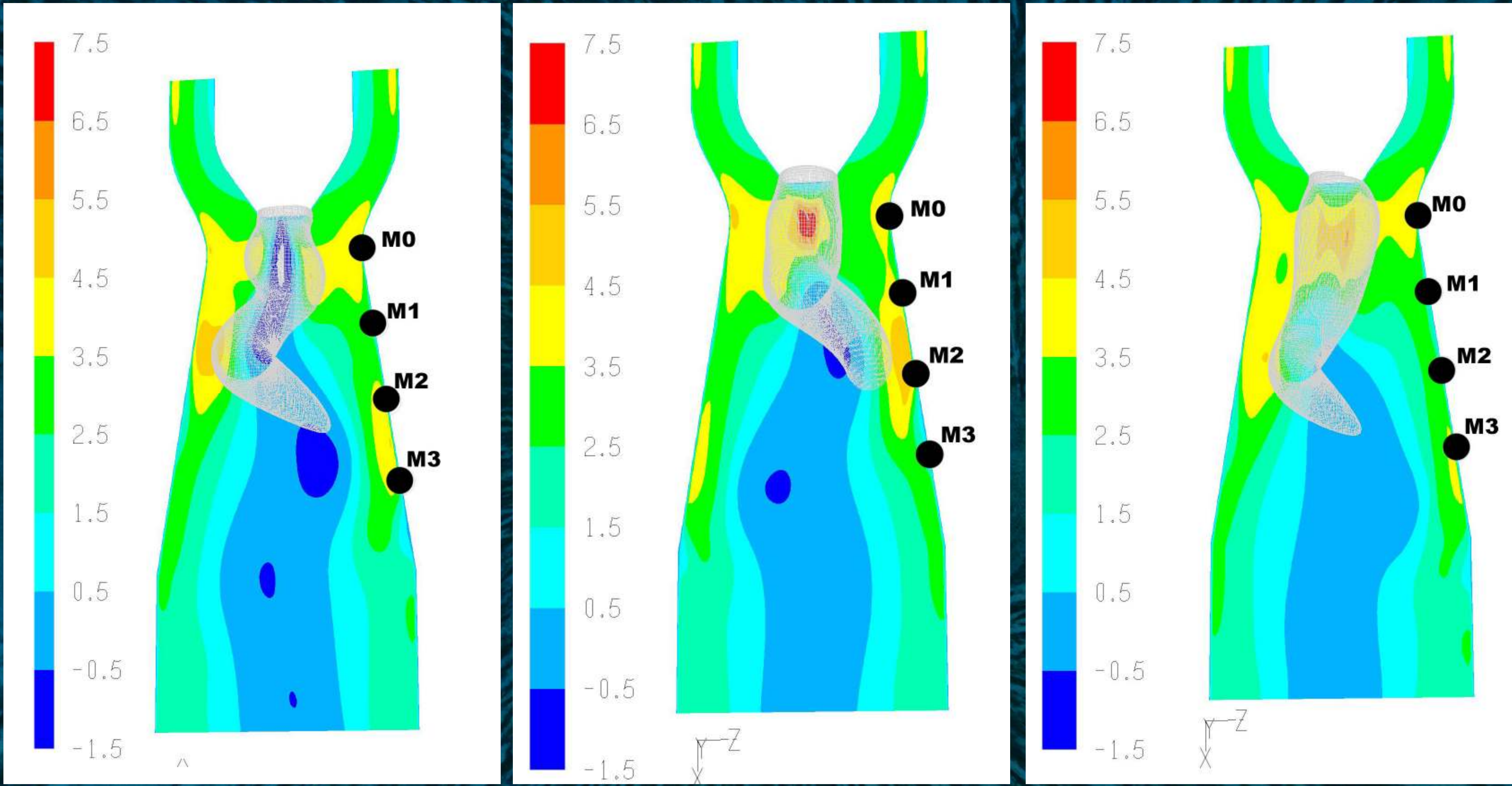
Simularea 3D a vartejului funie
(cu/fara injectie de apa)



fara jet

V= 1 m/s

V= 2 m/s

cu jet

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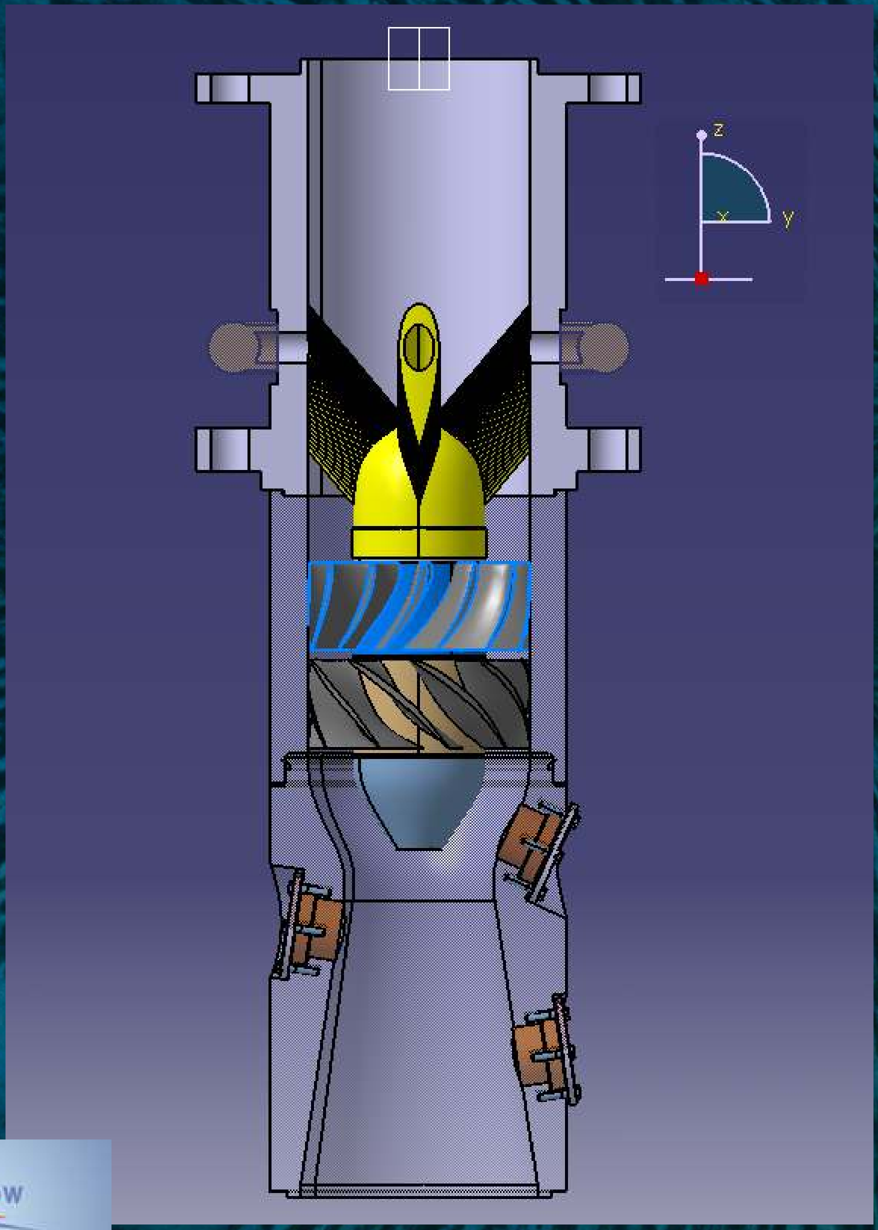
Standul experimental pentru curgerea cu vartej. Investigarea campului de viteza cu LDV



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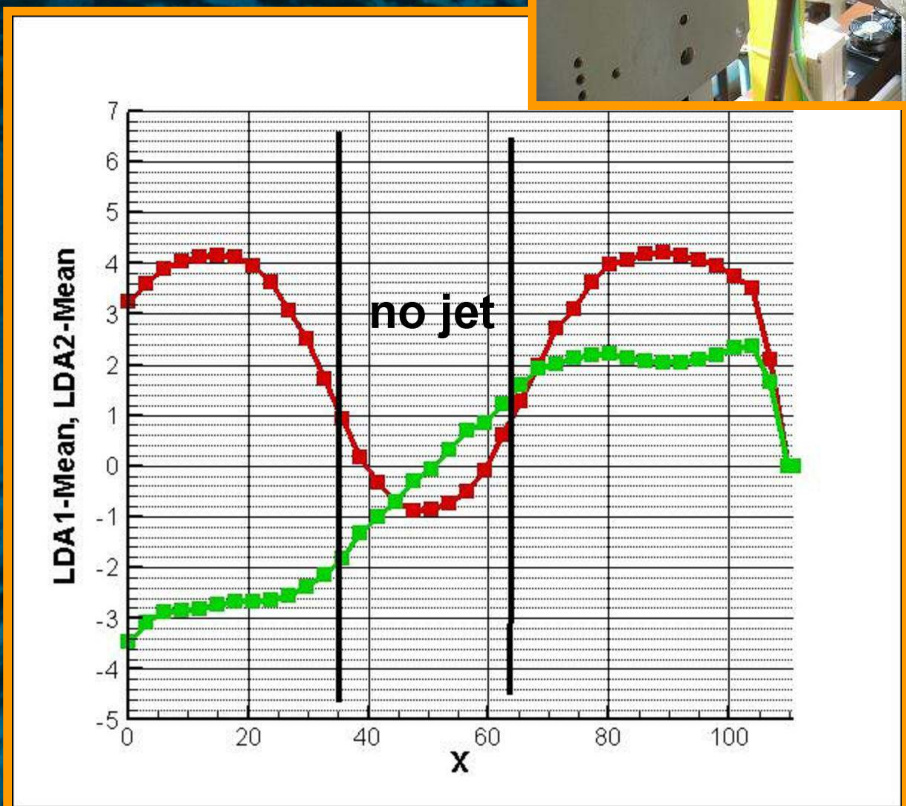

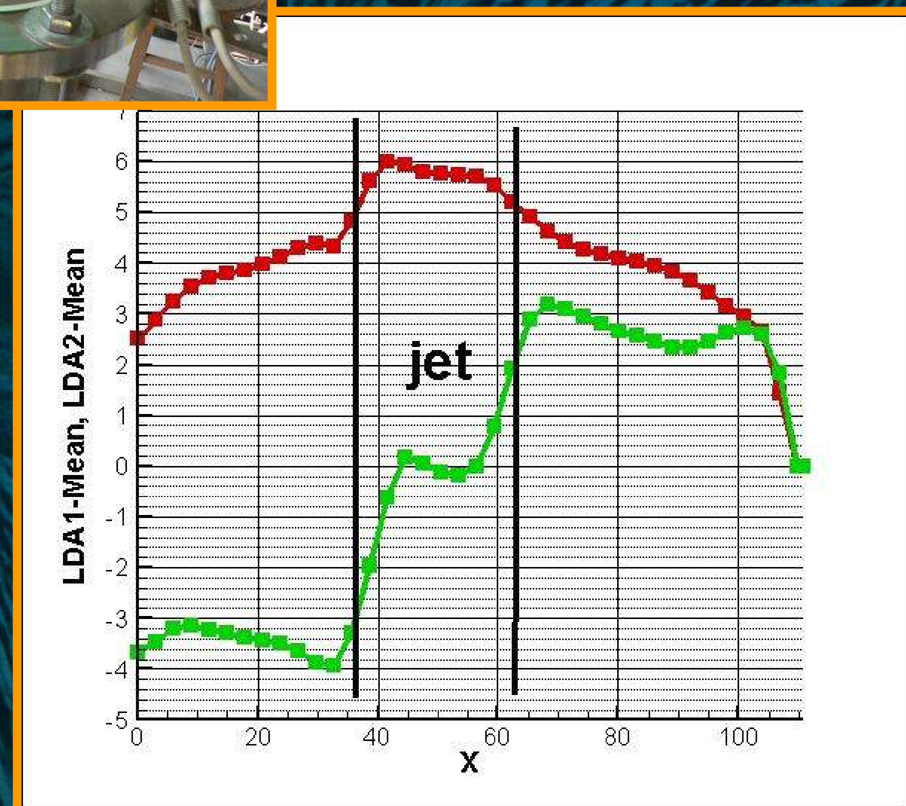

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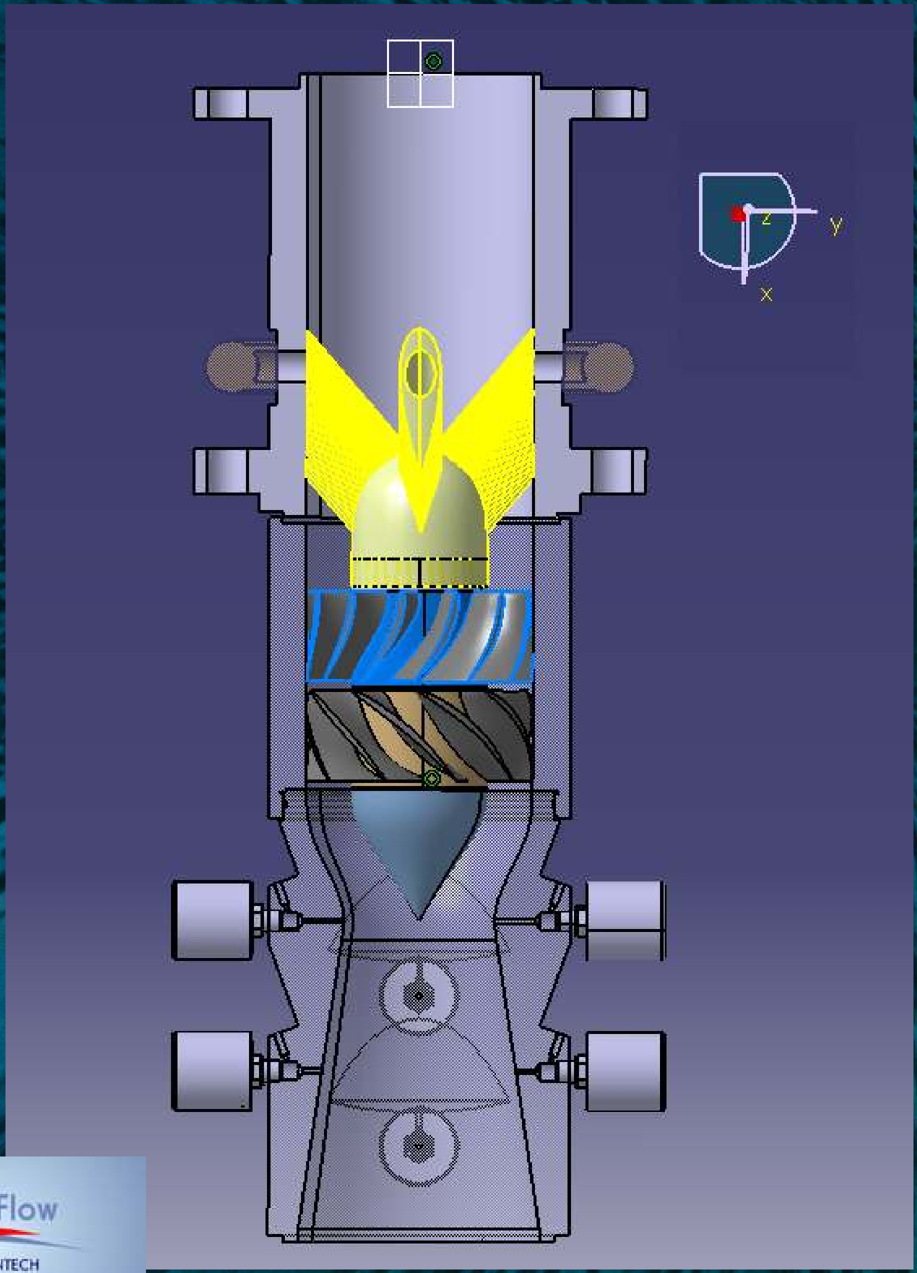
Standul experimental pentru curgerea cu vartej. Investigarea campului de presiune



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S.C. Hidroelectrica S.A. – SH Caransebes

CHE Ruieni – FVM 78 - 326

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S.C. Hidroelectrica S.A. – SH Cluj

CHE Munteni – FVM 30 -140

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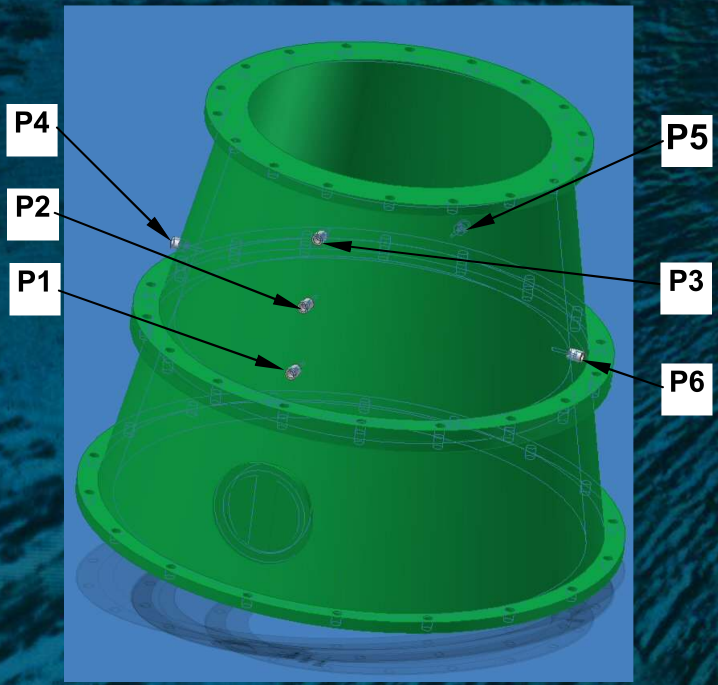
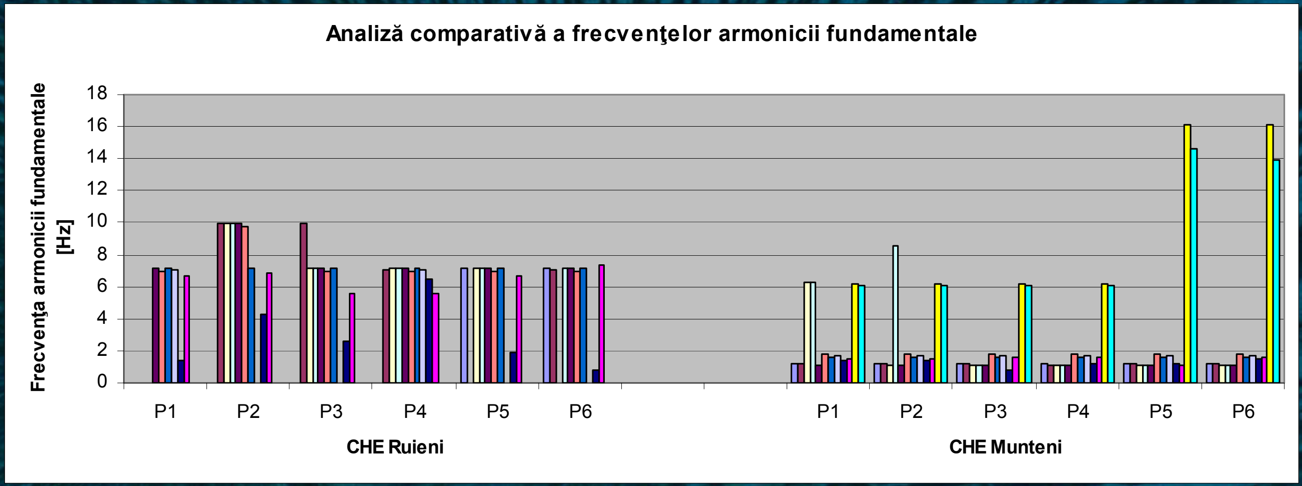
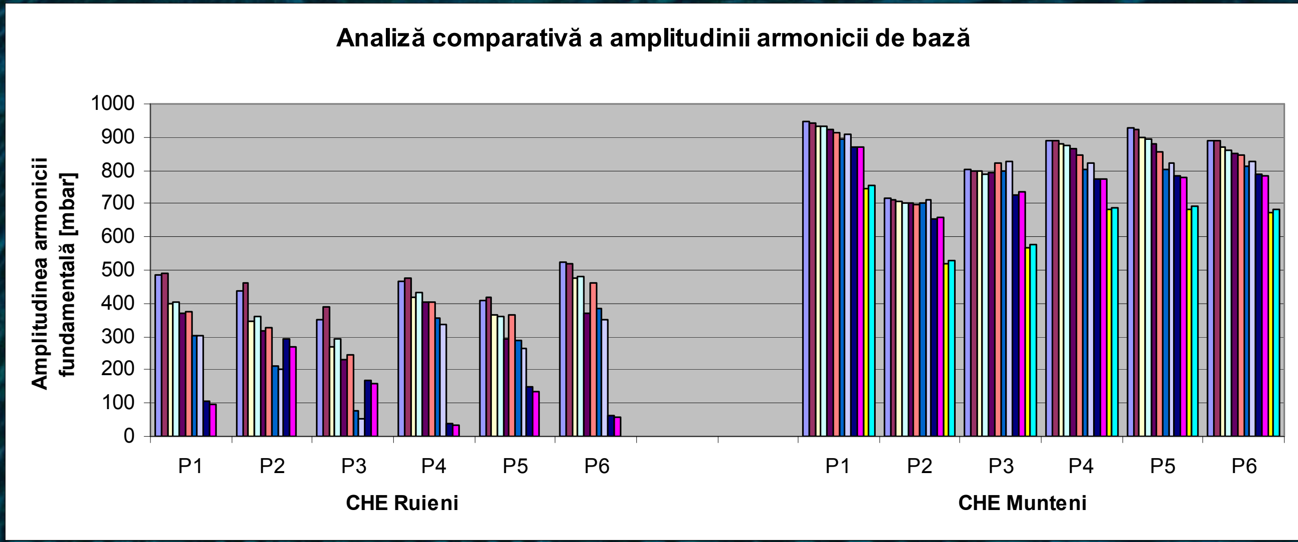
CEEX-M1-C2 1185; C64/2006

Rezultatele investigatiilor in CHE Ruieni si CHE Munteni

amplasarea prizelor de presiune pe conul tubului de aspiratie







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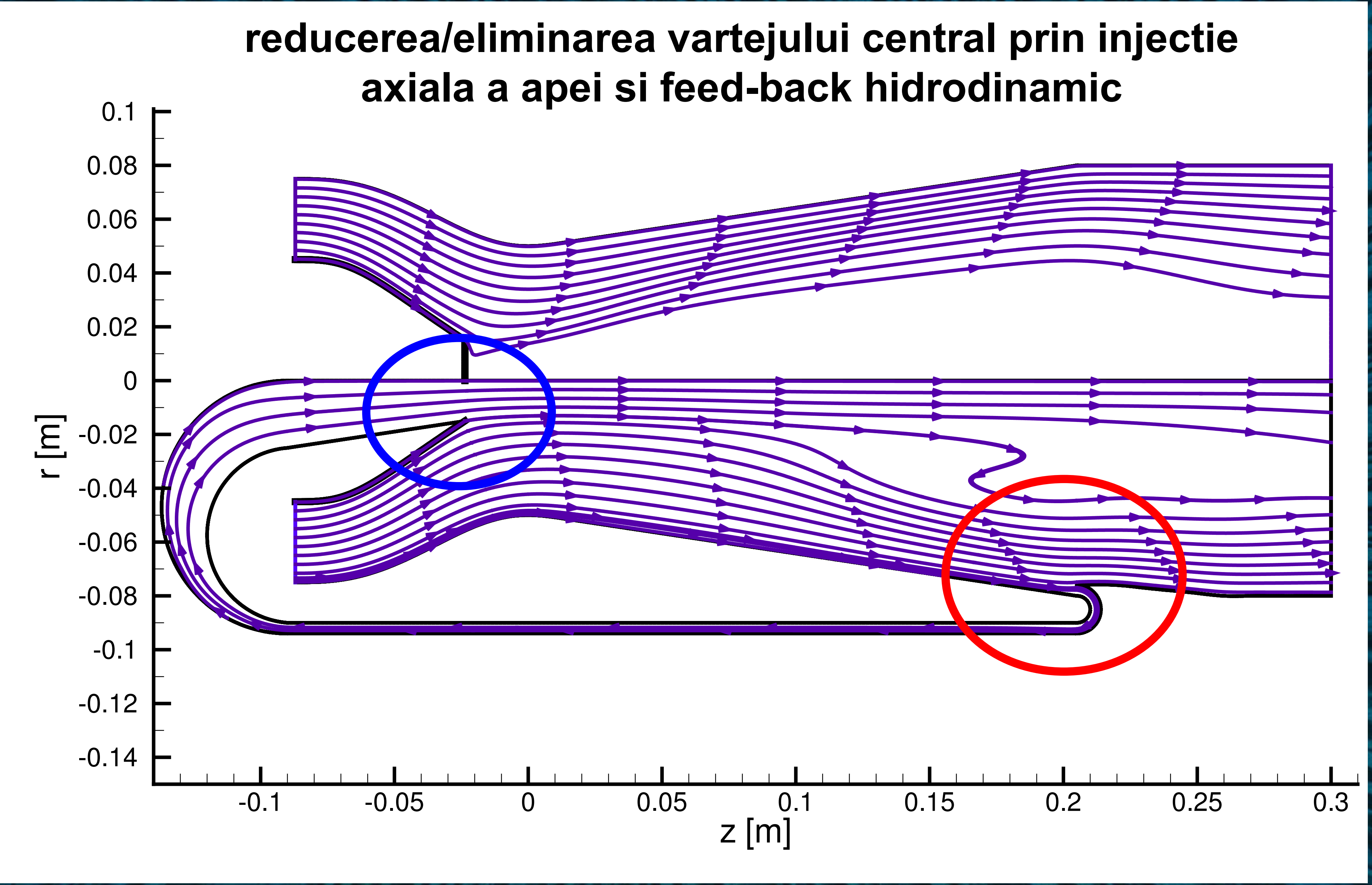
Perspective

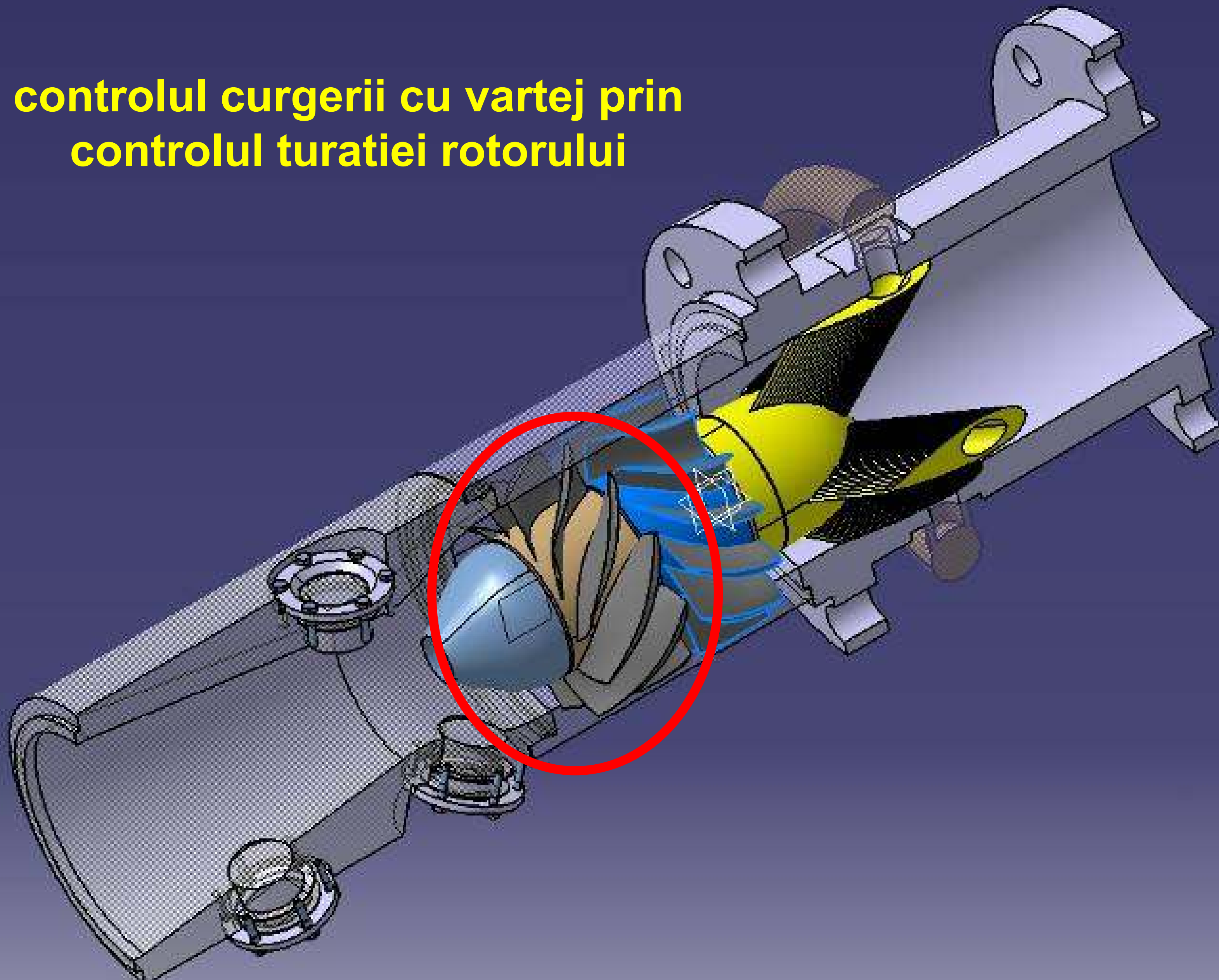


Perspective

Solutia de implementare cu feed back hidrodinamic pe standul experimental

Perspective

controlul curgerii cu vartej prin
controlul turatiei rotorului



Perspective

Analiza de stabilitate a curgerilor cu vartej

→ determinarea conditiilor de la iesire din rotor

➔ conditii de proiectare a rotoarelor turbinelor hidraulice pentru limitarea/evitarea vartejului central

ACKNOWLEDGEMENTS

• National University Research Council (CNCSIS) Consortium Grant 33/2005-2007 "Vortex Hydrodynamics and Applications". http://mh.mec.upt.ro/accord-fluid/

• Romanian National Authority for Scientific Research through the CEEX-C2-M1-1185, C64/2006-2008 „iSMART-flow" project, http://acad-tim.tm.edu.ro/iSMART-flow/

•Swiss National Science Foundation under the Joint Research Project IB7320-110942/1, 2006 – 2008.

•National Authority "Cercetari teoretice si experimentale pentru realizarea unui model de turbine Francis in domeniul turatiilor specifice ns=350-400 rpm destinat valorificarii eficiente a potentialului hidroenergetic din diferite amenajari cu aplicatie la CHE Cindere", PN2-INOVARE-1047, C59/2007-2009.