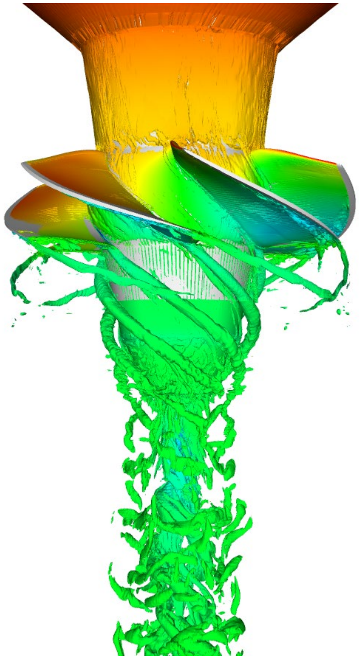
Computational fluid dynamics and machine learning for flexible and sustainable hydropower

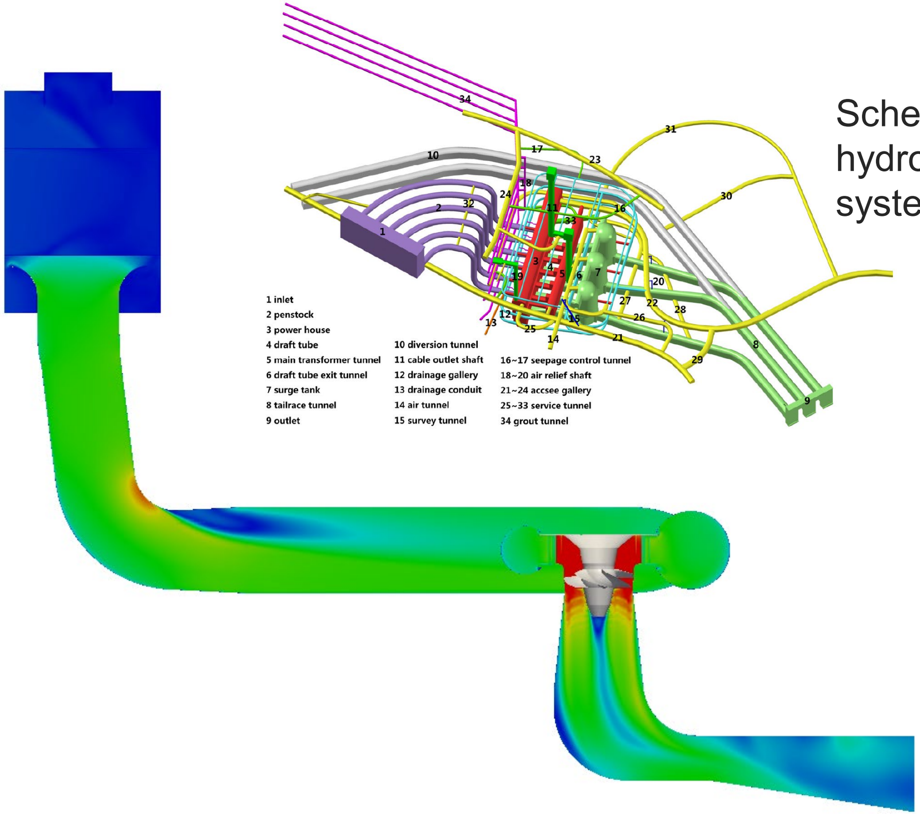
Håkan Nilsson
SVC R&D days 2023-02-23

Department of Mechanics and Maritime Sciences
Division of Fluid Dynamics
Chalmers University of Technology

The hydropower research area (for me)

- fluid dynamics: from details to system dynamics, transient operation and cavitation
- development of methods for numerical simulations of fluid flow



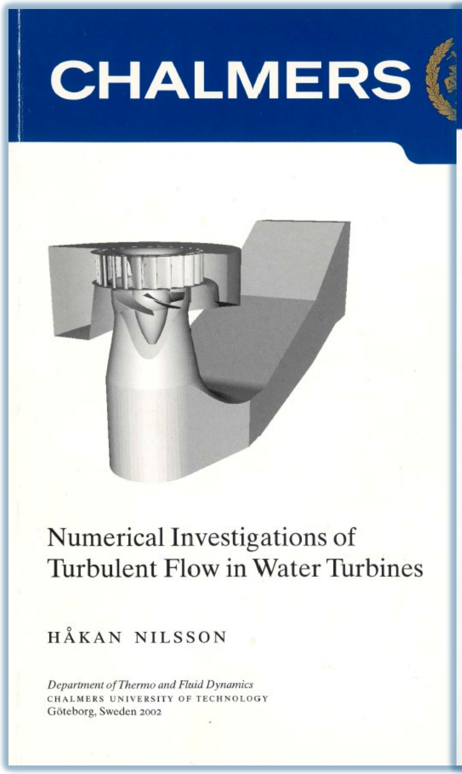


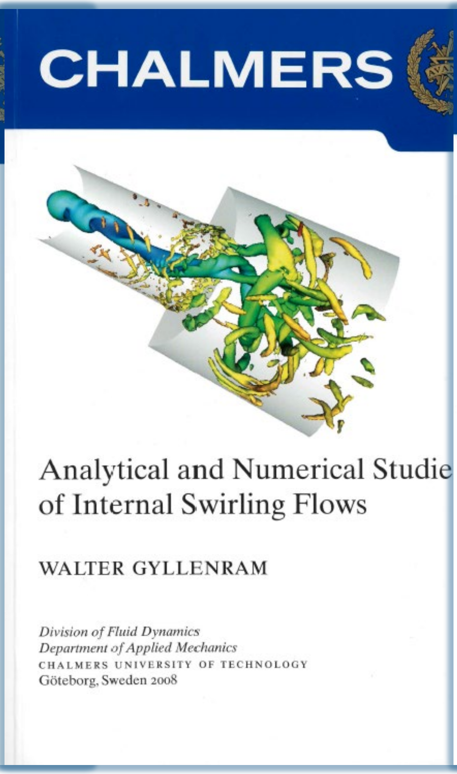
Schematic of hydropower pipe system

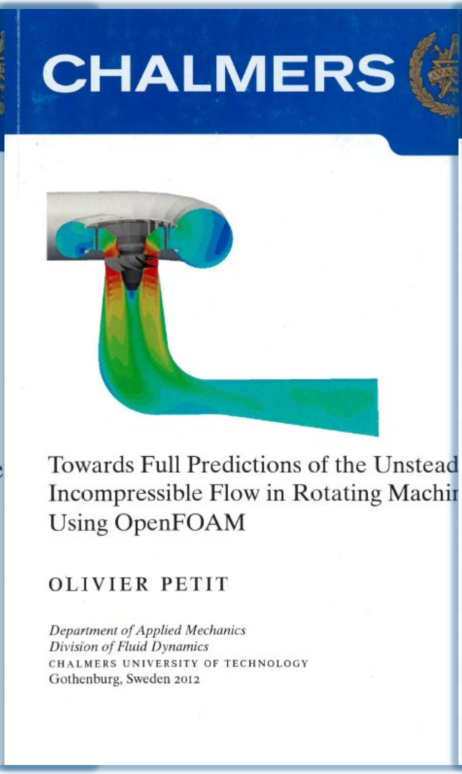
Development of CFD for hydraulic turbines

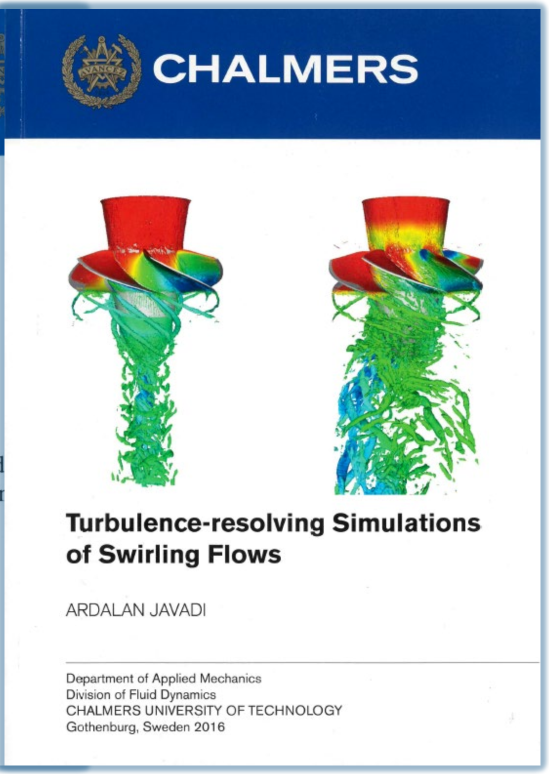
PhD theses, 2002, 2008, 2012 and 2016

CHALMERS
UNIVERSITY OF TECHNOLOGY







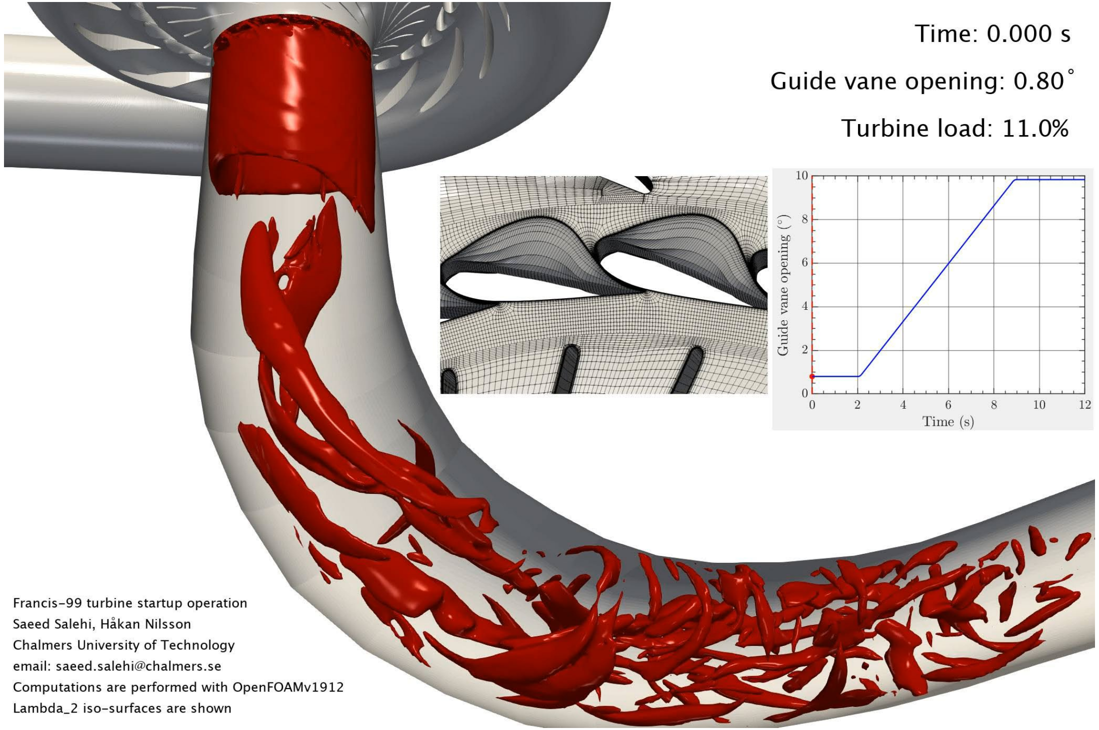


Development of CFD for hydraulic turbines

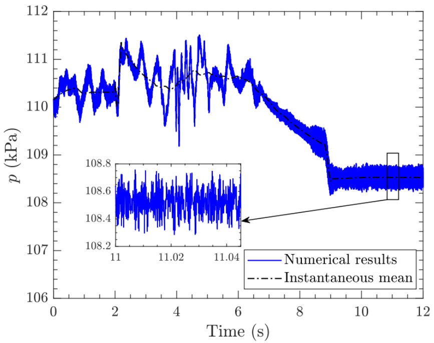
Post-doc Saeed Salehi, 2019-2022

Start-up to BEP, Francis-99

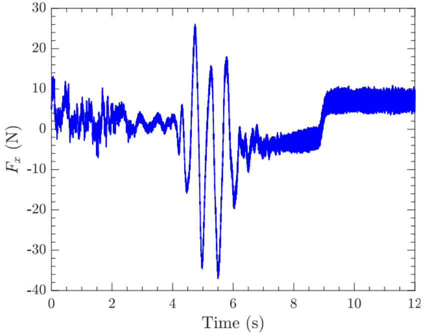
Renewable Energy. Vol. 188, p. 1166-1183
(shut-down in Renewable Energy. Vol. 179, p. 2322-2347 and OpenFOAM Journal. Vol. 1, p. 47-61)



Pressure in drafttube

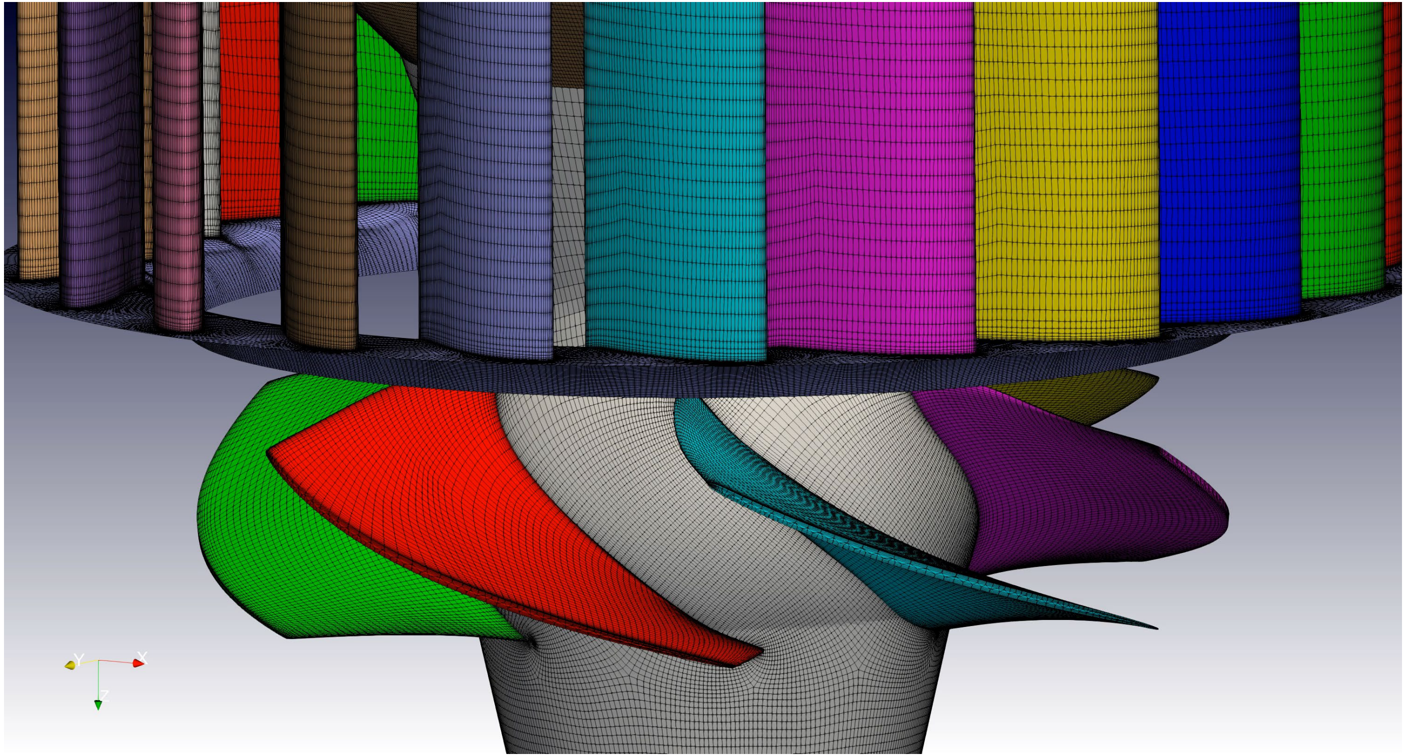


Horizontal force on runner



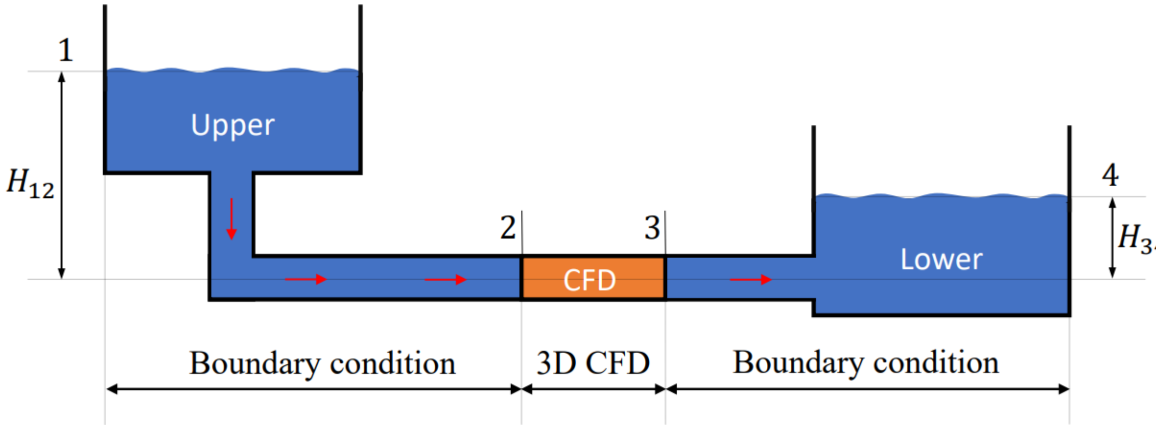
Development of CFD for hydraulic turbines
Post-doc Saeed Salehi, 2019-2022

Kaplan turbine transients
Computer Physics Communications, Volume 287, 2023

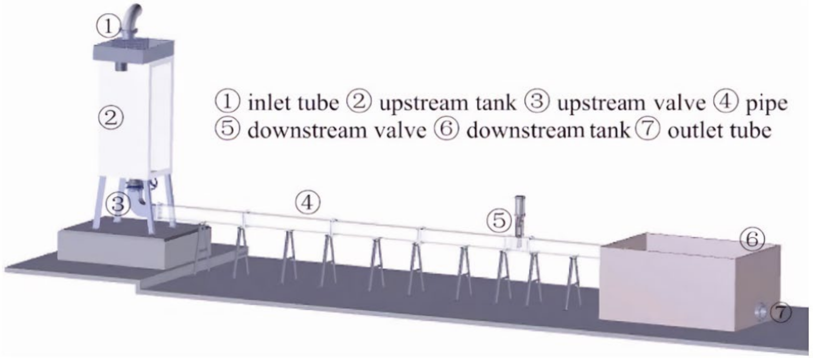


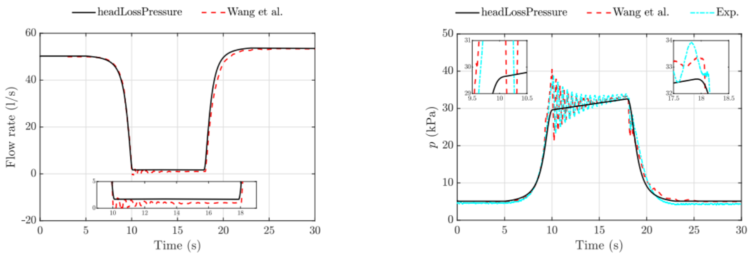
Development of CFD for hydraulic turbines

A head loss pressure boundary condition for hydraulic systems, Fahlbeck et al., OpenFOAM Journal. Vol. 2, p. 1-12



Variable	Description
pFar	Kinematic pressure far from patch, p^*_{Far}
HFar	Elevation far from patch , H_{Far}
dP	Hydraulic diameter of patch, $d_{\mathrm{h,p}}$
minorLossFactors	Minor loss factors: $(d^{\dagger}_{\mathrm{h,l}}, k^{\dagger\dagger})$, name‡‡
frictionLossFactors	Friction loss factors: $(d^{\dagger}_{\mathrm{h,l}}, \epsilon^{\parallel}, L^{\star})$, name‡‡
kDynamic	Dynamic minor loss coefficient, k
dkDynamic†	Hydraulic diameter of kDynamic, $d^{\dagger}_{\mathrm{h,l}}$
flowRate	Flow rate to the reservoir, Q_{r}
Ar‡	Reservoir surface area, A_{r}
dFar§	Hydraulic diameter far from patch, $d_{\mathrm{h,Far}}$
U	Velocity field name
phi	Flux field name
g¶	Gravitational acceleration
Tol	Tolerance for the Colebrook equation
Nitr	Max iterations for the Colebrook equation
fDiff	Max difference between f and fInitial

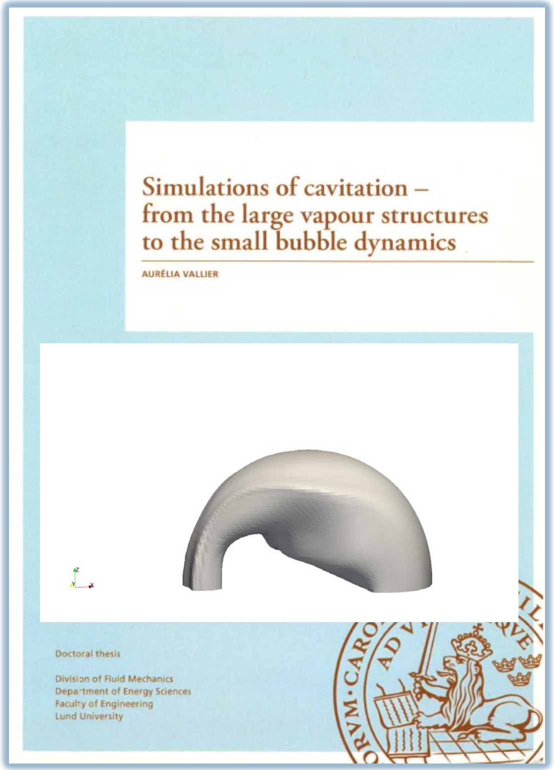




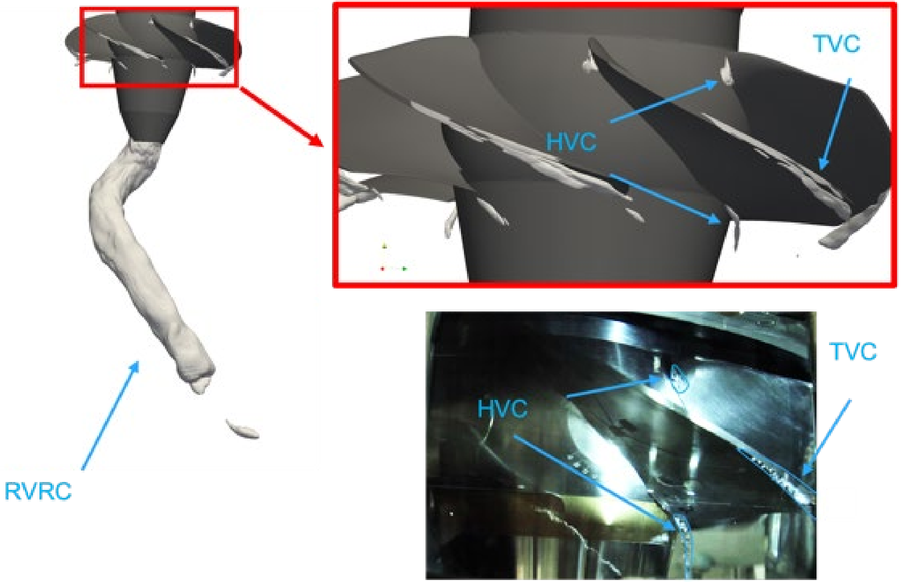
(A) Flow rate (B) Pressure probe

FIGURE 6. Flow rate and static pressure during the transient sequence. Wang et al. [7] is numerical results with MOC and Exp. is experimental results reported by Petit et al. [6].

Studies of cavitation
PhD thesis 2013 and post-doc 2020-2022



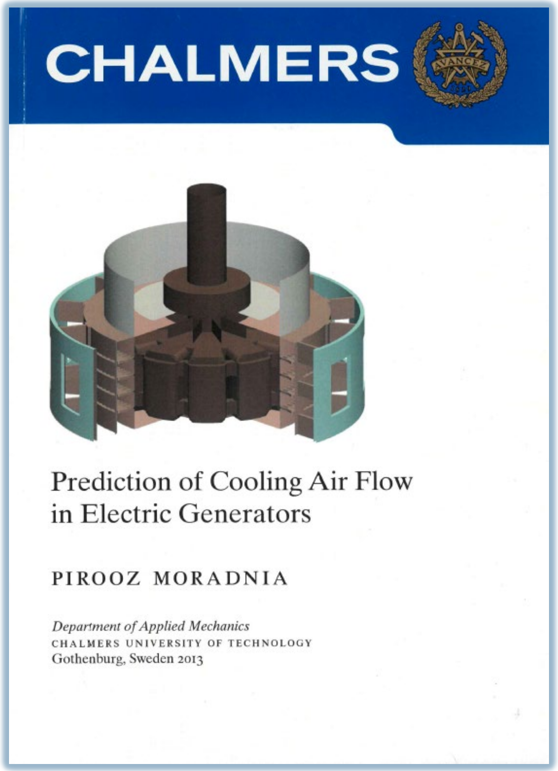
Post-doc Mohammad Hossein Arabnejad

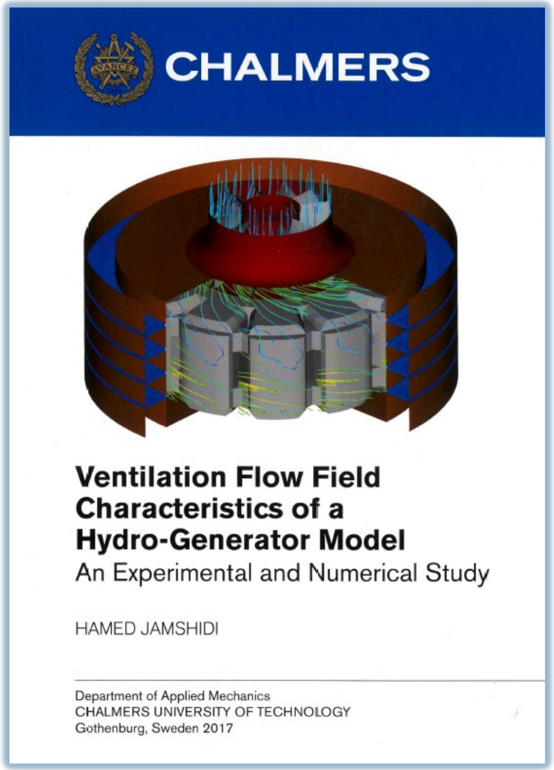


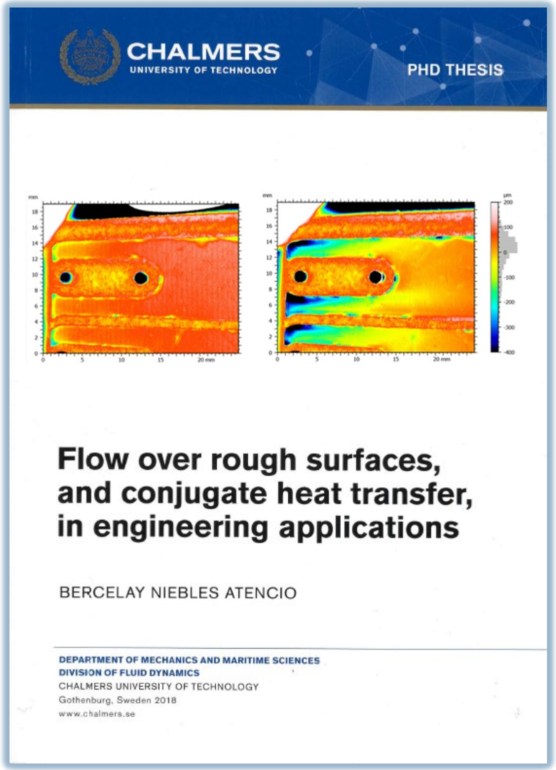
PL ($\sigma = 0.31$)

Studies of cooling air flow in generators
PhD theses, 2013, 2017 and 2018

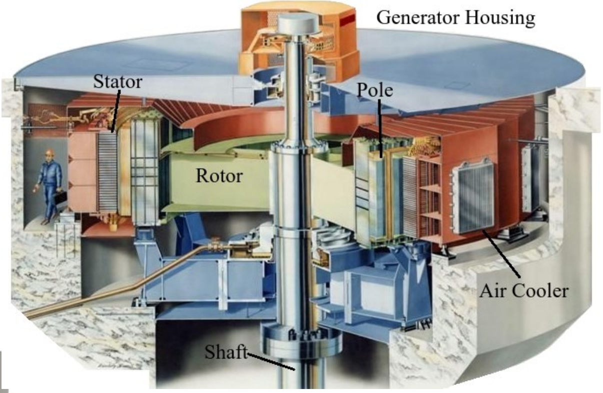
CHALMERS
UNIVERSITY OF TECHNOLOGY

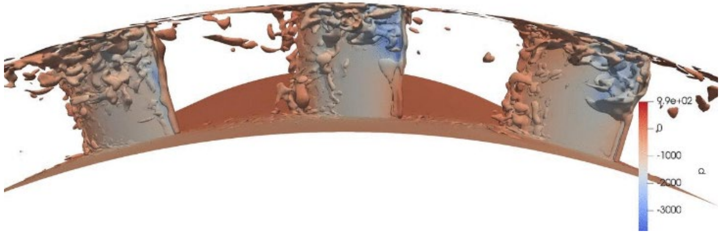


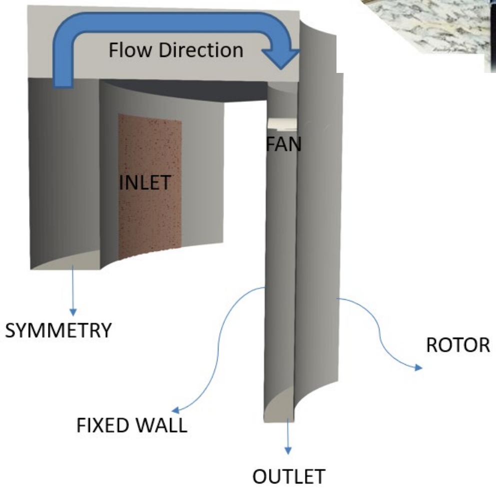


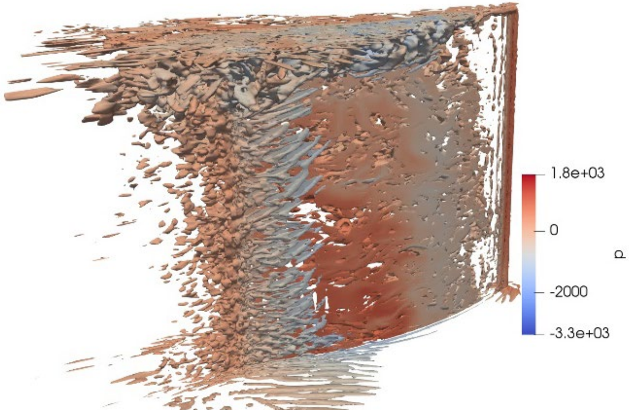


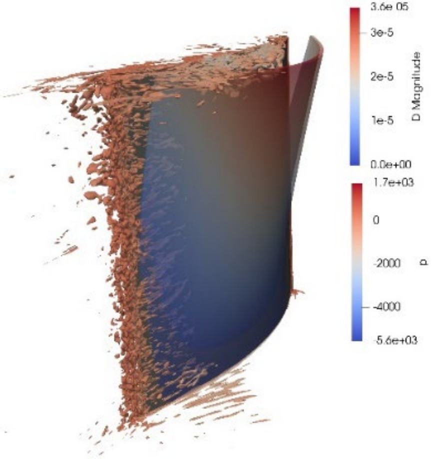
Studies of cooling air flow in generators
Post-doc Saber Mohammadi, 2019-2021



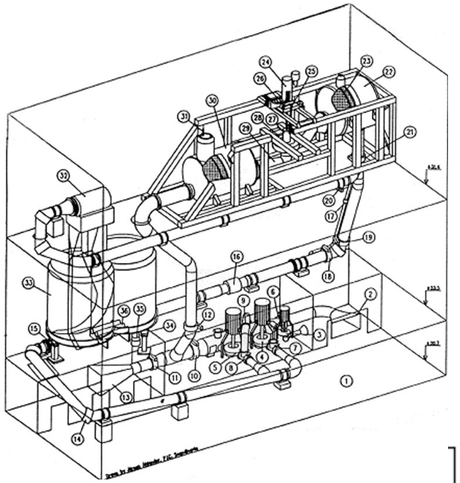




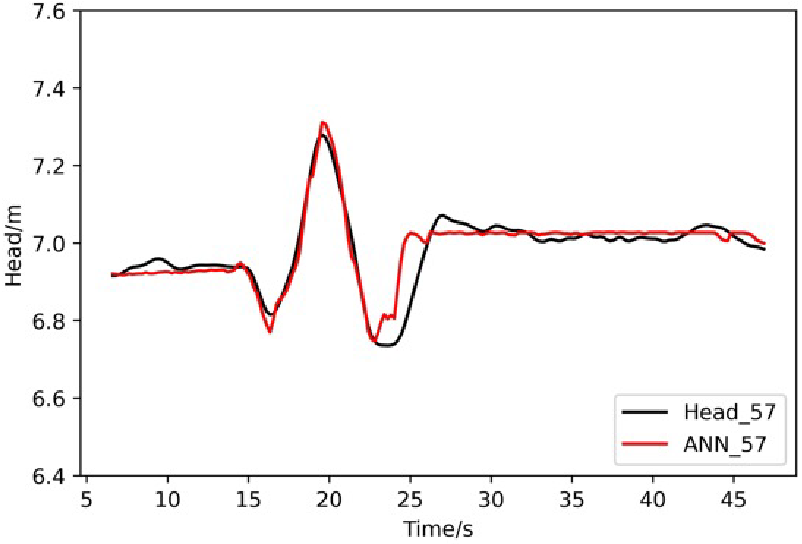


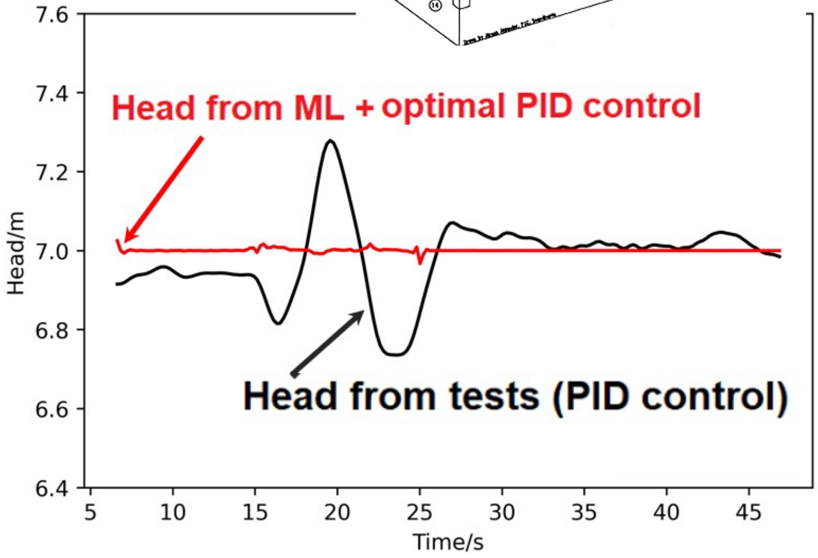


Machine learning in hydropower
Short PhD student pilot-project, Xiao Lang, 2022



Data_57





Present group, working in hydropower

Saeed Salehi

Martina Nobilo

Xiao Lang

Mohammad Sheikholeslami

Jonathan Fahlbeck

ALPHEUS

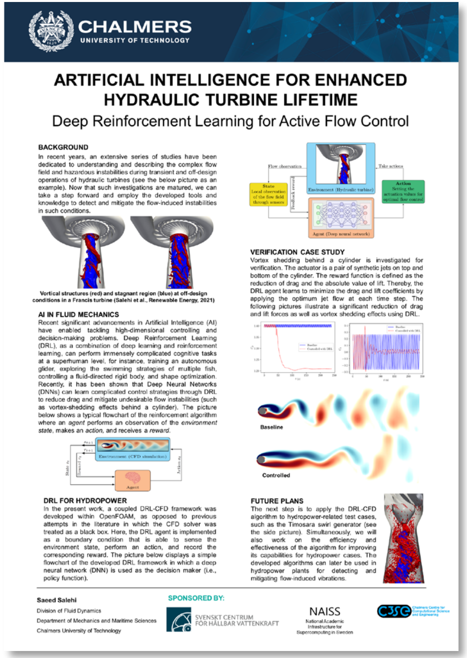
Håkan Nilsson

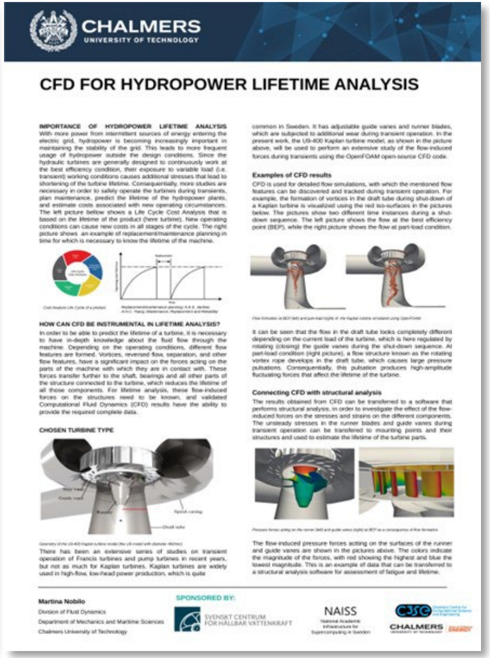
Additional academic supervisors:

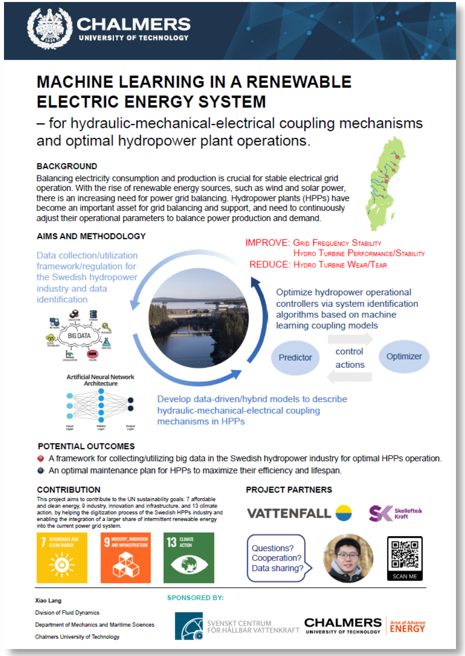
Wengang Mao[1], Arash Eslamdoost[1], Yujing Liu[2], Rickard Bensow[1]

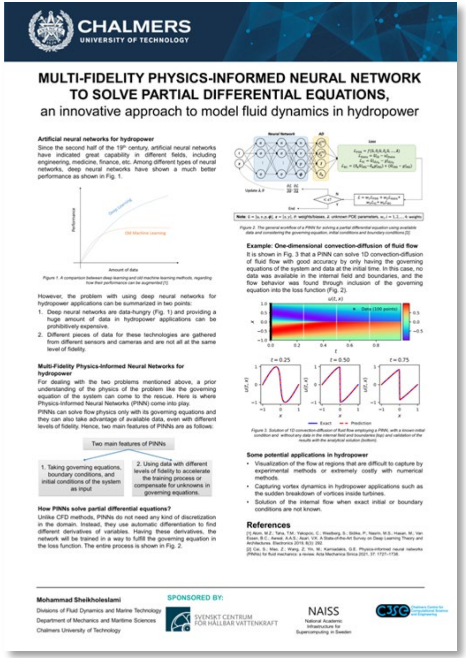
[1] Division of Marine Technology
[2] Department of Electrical Machines and Power Electronics

Visit posters for SVC-financed projects!









Some notes on the ALPHEUS EU project…

Low head pumped hydro storage

- ALPHEUS – EU H2020
  - Heads from **2 – 20 m**
  - Power of **10 MW** / unit
  - Round-trip efficiency of **70 – 80%**
  - Asses **environmental** and **ecological effects**
- Allow energy storage in flat regions
  - E.g. south of Sweden, Denmark, Netherlands, etc.
  - Energy islands with the sea as one *reservoir*
- At Chalmers we evaluate contra-rotating pump-turbines
  - Stationary operations
  - Transient procedures to limit detrimental loads

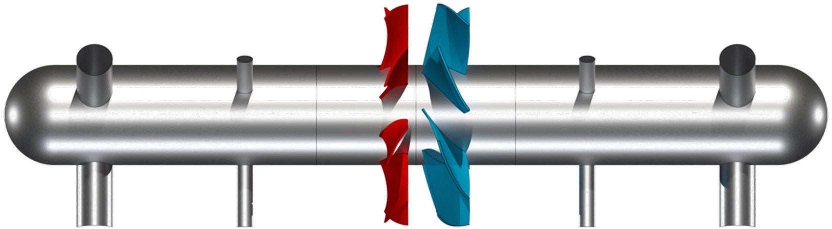


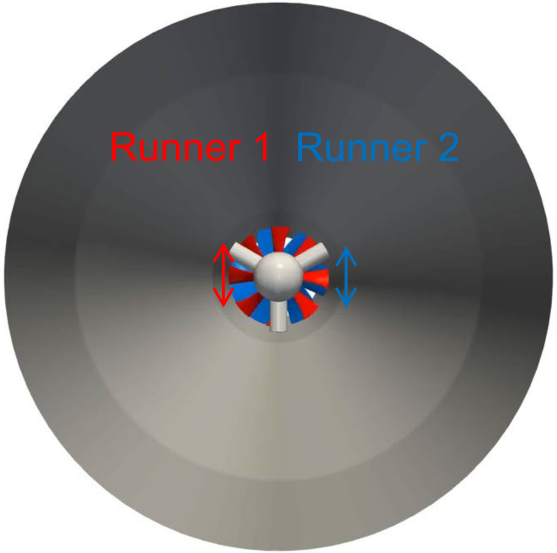
Figure: Shaft driven contra-rotating pump-turbine in model scale

Figure: Rim driven contra-rotating pump-turbine

Shaft driven contra-rotating pump-turbine

Model scale

Pump Mode



Turbine Mode

Operating conditions (Pump Mode)

Power	49	kW
Flow rate	420	l/s
Net head	10	m
Hydraulic efficiency	87	%

Operating conditions (Turbine Mode)

Power	17	kW
Flow rate	290	l/s
Net head	7	m
Hydraulic efficiency	89	%

Thank you for your attention!

Acknowledgements:

- SVC
- The ALPHEUS project
  - EU Horizon 2020, No 883553.
  - Website: https://alpheus-h2020.eu/
- NAISS
  - Grant agreement No. 2022-06725
- OpenFOAM developers and community

AVANCEZ

1829

CHALMERS

UNIVERSITY OF TECHNOLOGY