Utveckling av beräkningsmetoder för flöde i vattenturbiner

Av

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Institutionen för termo- och fluiddynamik

Chalmers

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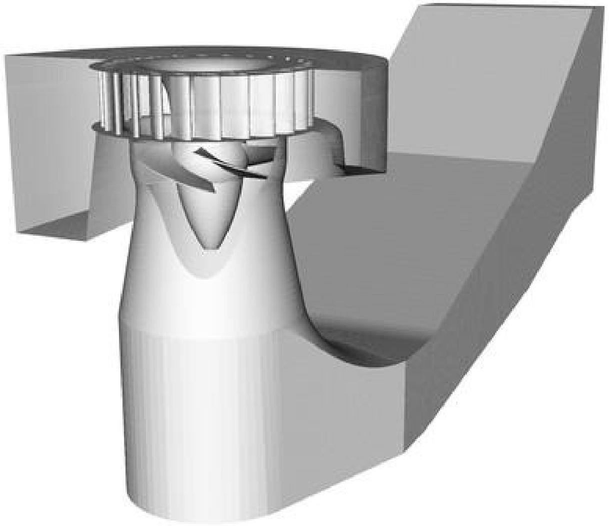
Numerical Investigations of Turbulent Flow in Water Turbines

BY
HÅKAN NILSSON



THESIS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

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Outline

- Background
- Description of the numerical method
- Computational results of the GAMM Francis runner
  Validation
  Visualization
- Computational results of the Hölleforsen Kaplan runner
  Validation
  Visualization
- Numerical verification of the computational results

Purpose of the project

- Develop a numerical tool that accurately predicts the flow in water turbine runners
- Focus on Kaplan tip clearance flow and wake flow
- Verify and validate the results

Financing

- ELFORSK
  (Swedish Electrical Utilities R&D Company)
- Swedish National Energy Administration
- GE Energy (Sweden) AB

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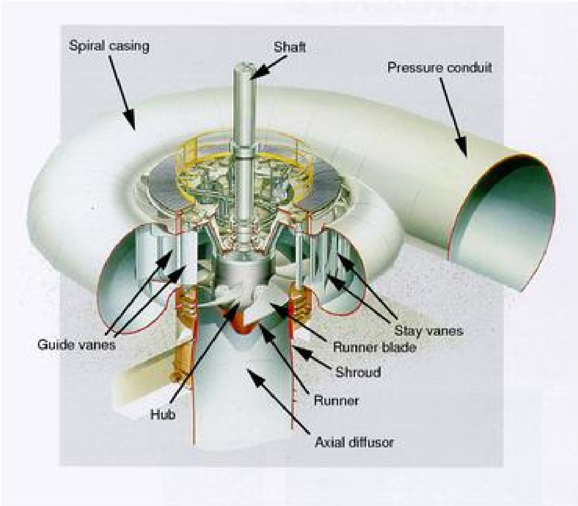
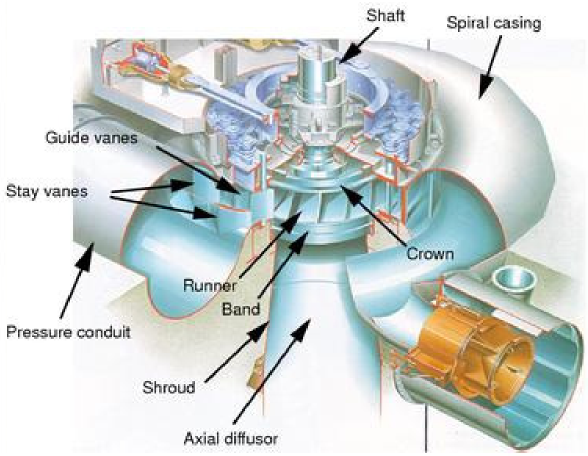
Kaplan and Francis runners





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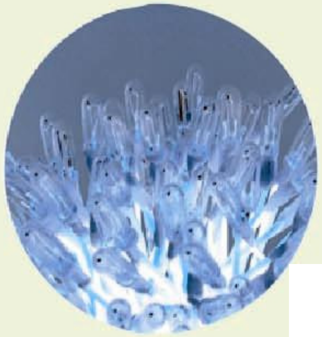
The CALC-PMB CFD solver

- Finite volume method
  Boundary fitted coordinates
  Collocated, structured grid
  Rhie and Chow interpolation
  SIMPLEC (Pressure-velocity coupling)
  2nd order upwind scheme (Van Leer)
- Parallel multiblock solver
  Conformal blocks
  Dirichlet-Dirichlet block coupling
  Parallel solver using message passing (PVM or MPI)
- Turbulence model
  Wilcox -88 standard k-ω Low-Re



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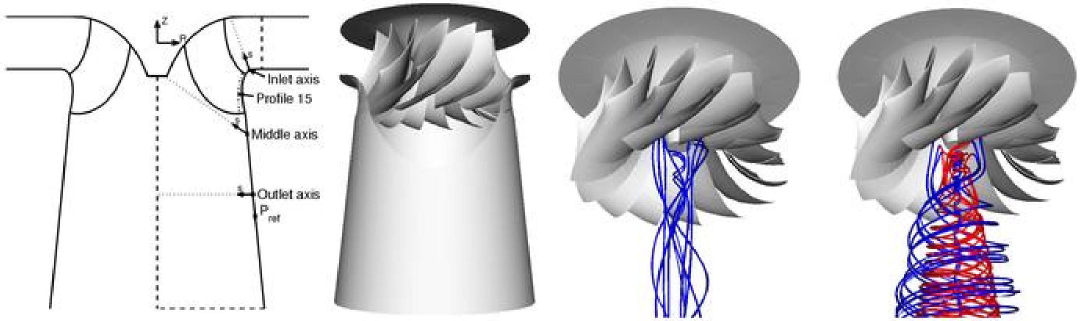
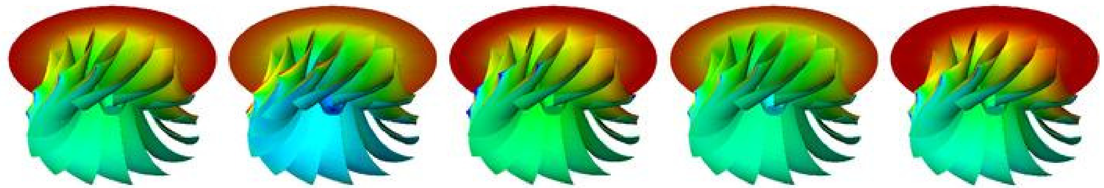
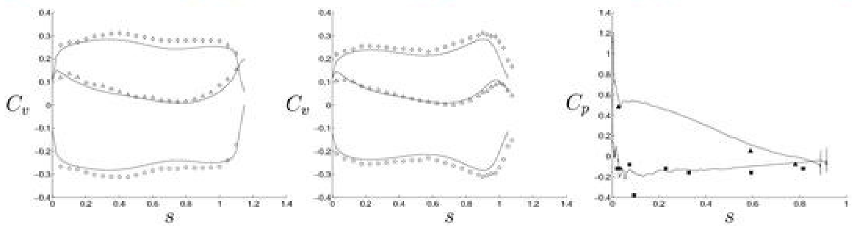
The GAMM Francis runner







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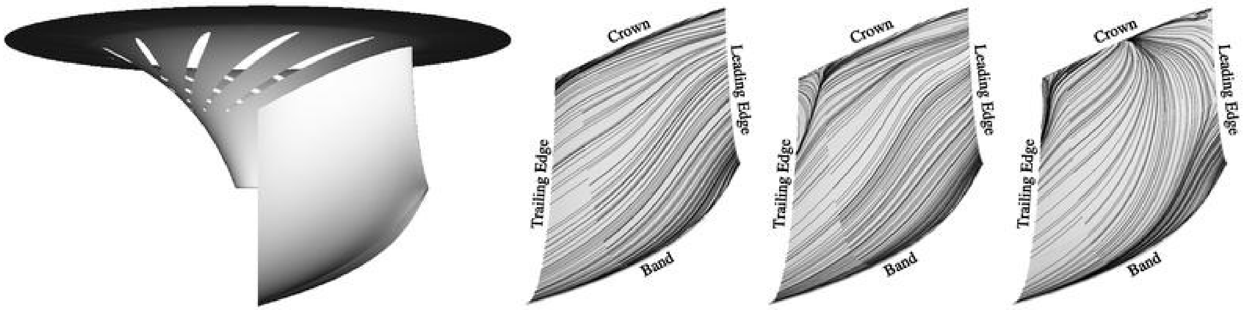
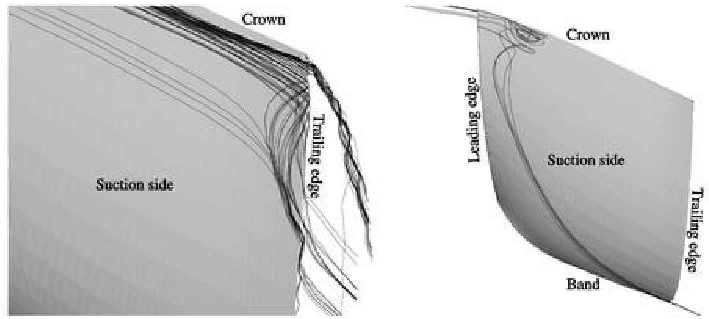
Flow feature identification using smearlines



The investigated runner blade P1, ss P2, ss P4, ss



P2 P4

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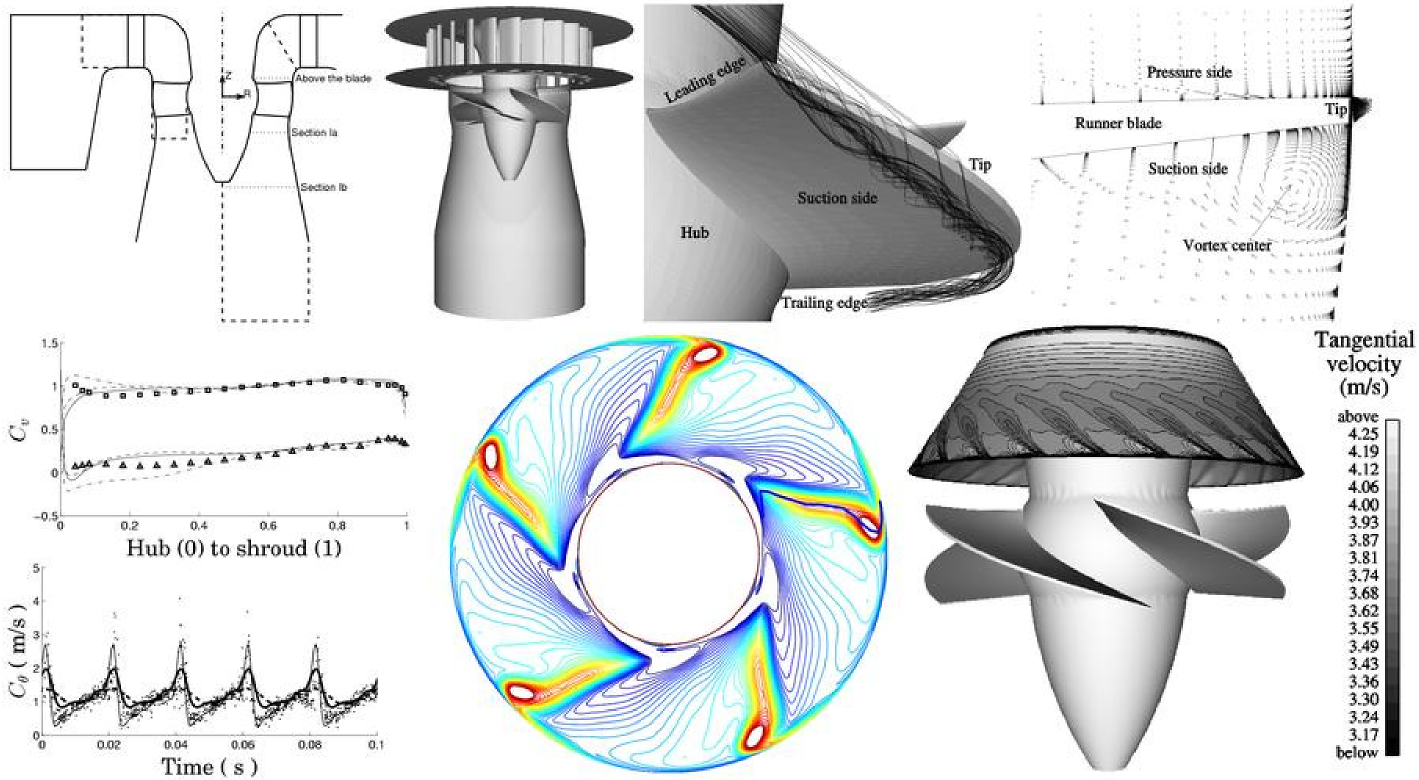
The Hölleforsen Kaplan runner



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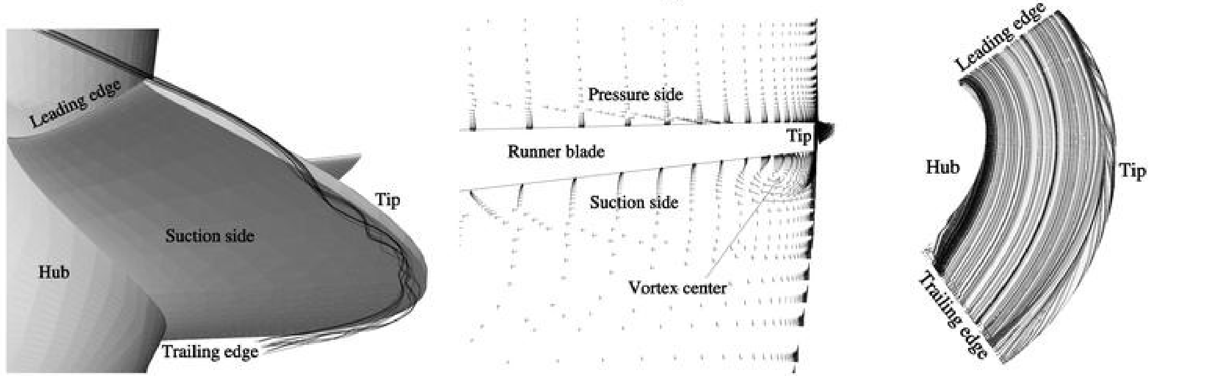
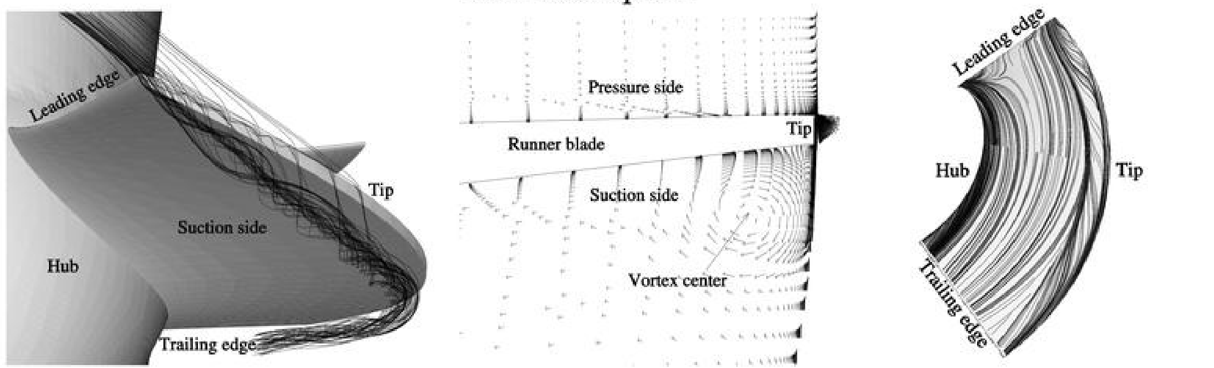
Kaplan tip vortex

Best efficiency



Low unit speed



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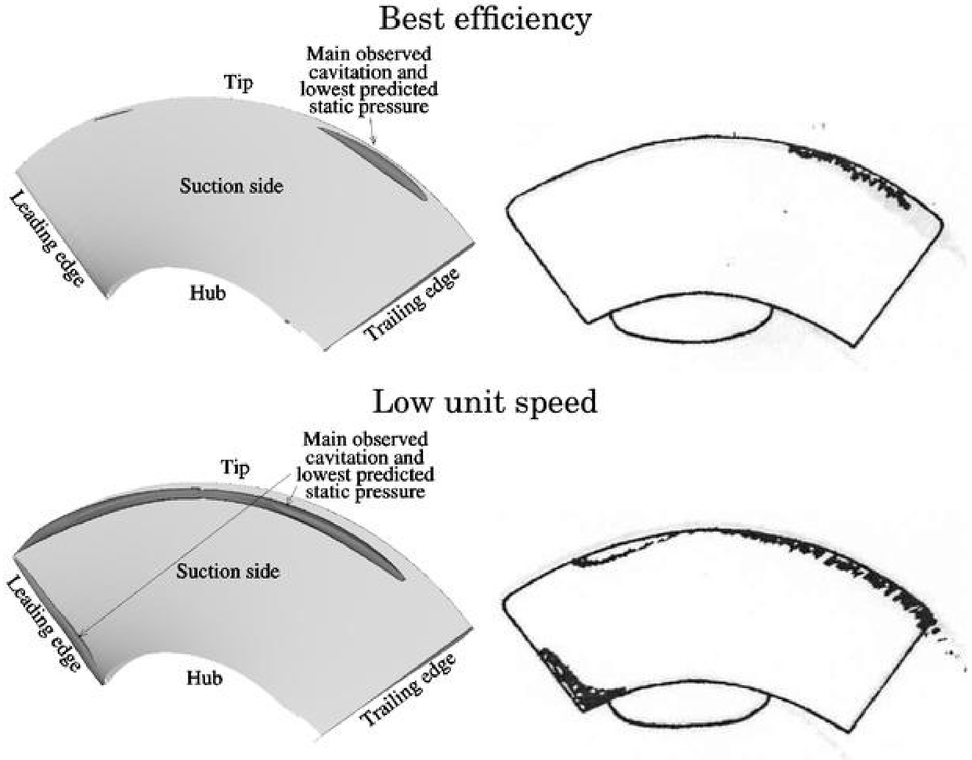
Kaplan low static pressure regions



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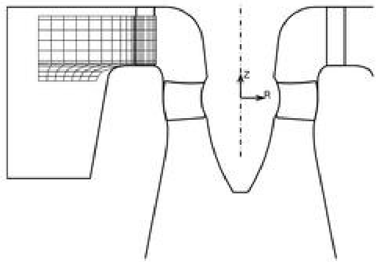
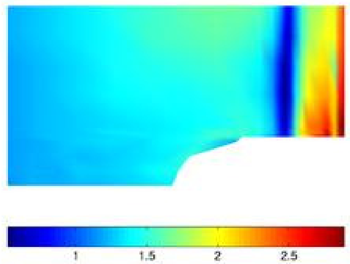
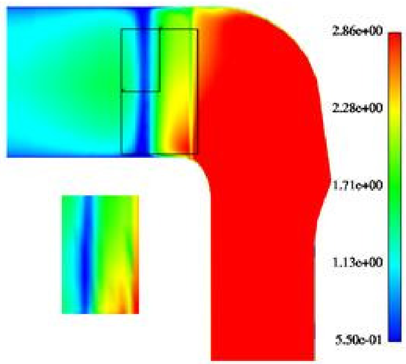
Computed and measured Hölleforsen wicket gate flow







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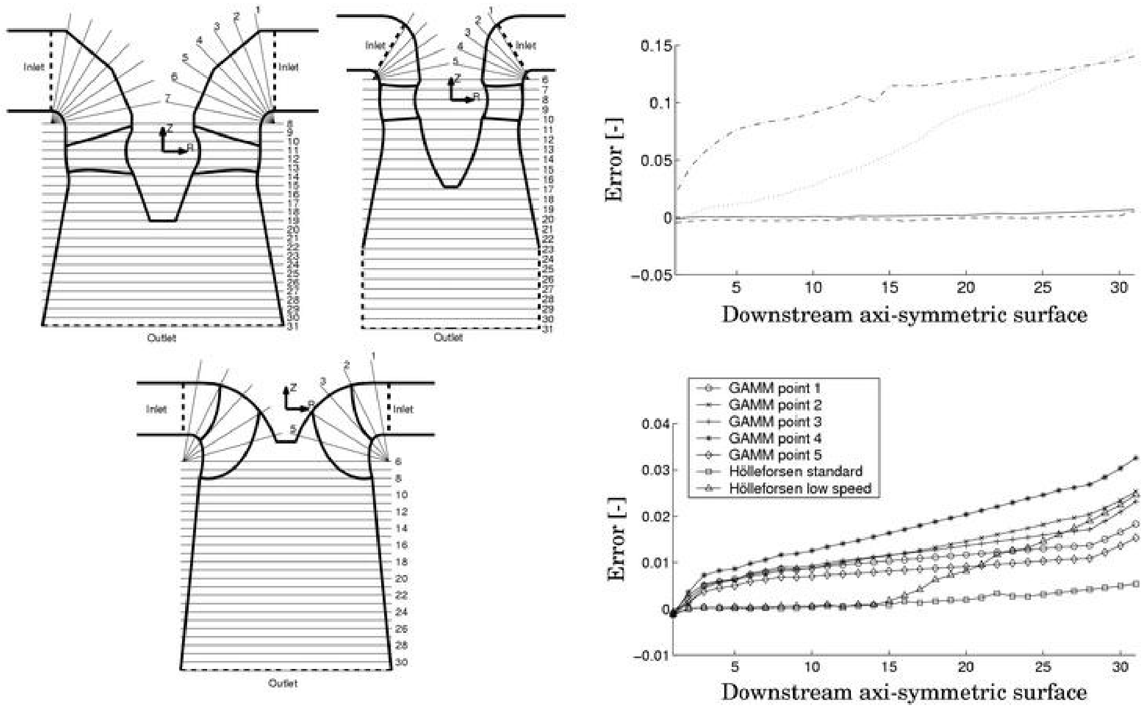
Angular momentum balance method

$$\int_{CS} rF_{s\theta}dA + \int_{CV} rF_{b\theta}dV + \int_{CV} 2r\Omega U_r \rho dV = \int_{CS} rU_\theta \rho(\mathbf{U}\cdot\mathbf{n})dA$$



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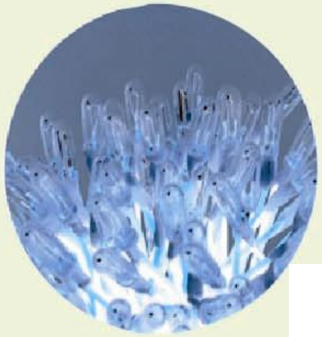

Conclusion

- Water turbine runner flow is predicted qualitatively correct
- Grid quality/density/distribution and discretization order are very important and need to be further studied
- Preservation of thin wakes in coarse grids needs to be further studied
- Visualization and analysis techniques need to be developed