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Cluster for Energy and Environment

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Efficient Energy Use

Accelerated prototyping of the next generation pumps

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Tomorrow's Energy Efficiency Solutions Seminar

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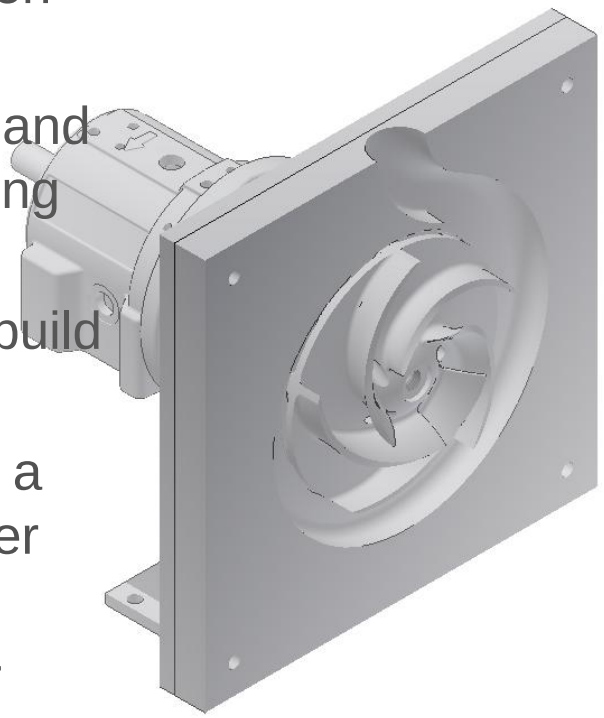
Introduction

- A new type of measurement system has been developed for R&D of pumps
- The new measurement system is air based and utilizes 3D-printing and other rapid prototyping technologies
- Measurement system is modular, cheap to build and flow geometry can be modified freely
- A widely used industrial pumps are used as a baseline for verification of the method (Sulzer A32-100 and A11-50)
- Main goal is to improve the hydraulic and/or material efficiency of small specific speed pumps and thus save energy and reduce costs



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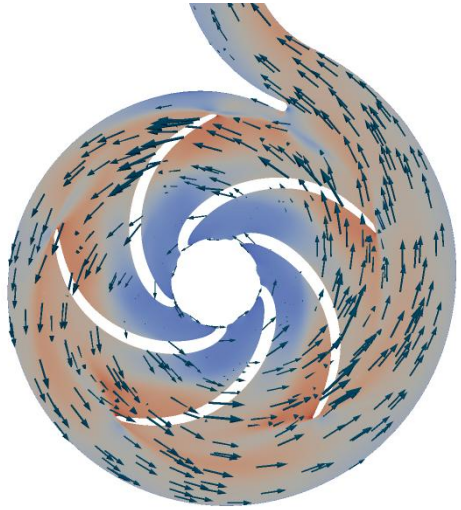
Approach - overview

- Research methods:
  - CFD
  - Laboratory measurements (air based)
- Laboratory measurements are the main method for testing hydraulic designs and can be used to validate CFD results
- Main industrial partner:
  - Sulzer: pumps, ideas for testing and material support
  - ABB: electrical gear for the measurement system



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Approach – air based measurement

- Why air? Why not?
- Flow inside a turbomachine depends mainly on the geometry of the volute and impeller – not on the properties of the (newtonian) fluid
- Absolute pressure level and required power are directly proportional to fluid density, but head is not ($p = \rho g H$)
- Pump operation curves are already presented in the HQ-plane → results are directly comparable
- Viscosity difference (air vs. water) does affect flow friction losses and leakage flows → results will never be exactly the same
- Cavitation cannot be measured (not a problem in initial design phases)

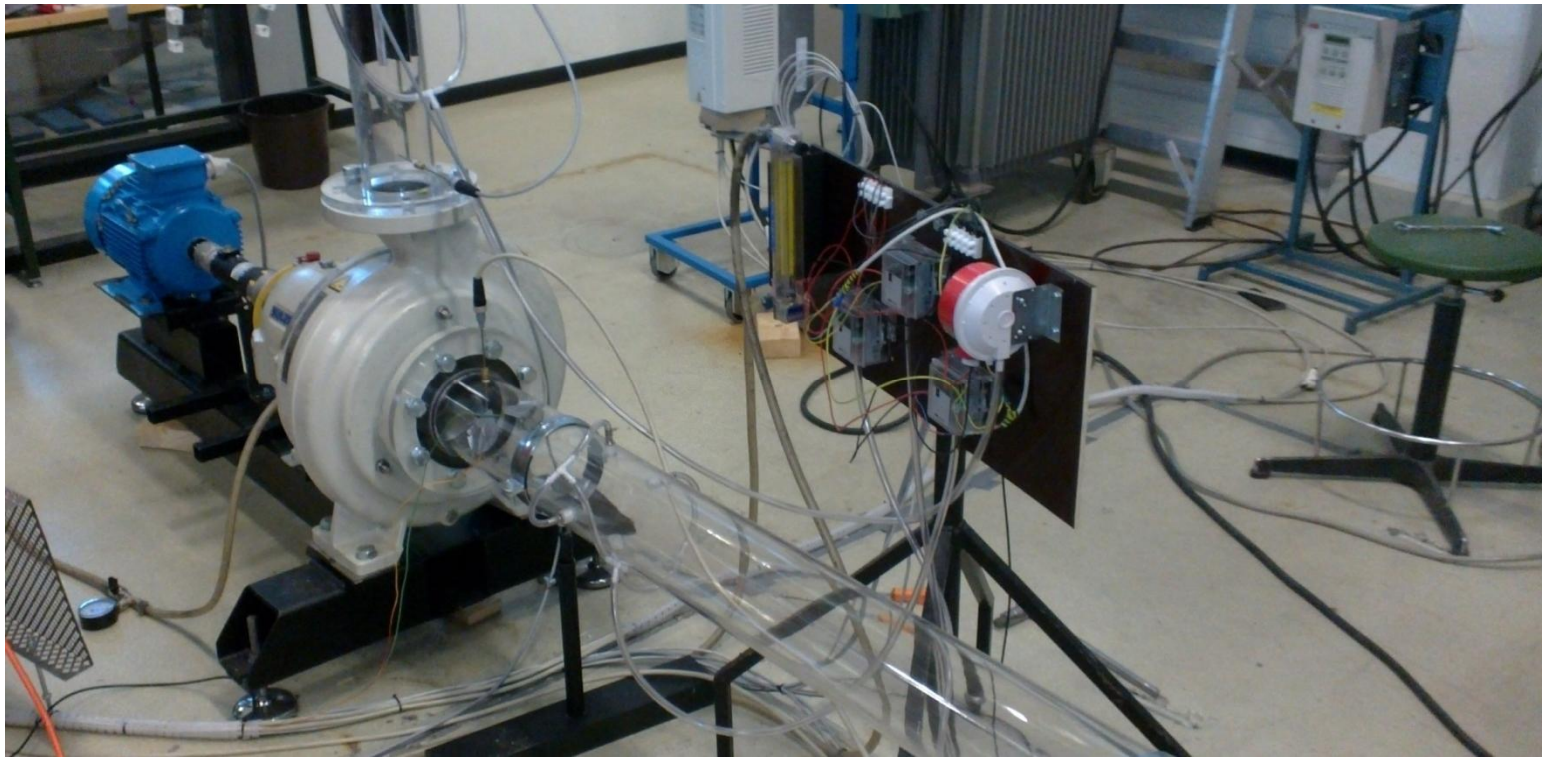

Fig. 1: Air based measurement of Sulzer A32-100 (old system)

This measurement setup was used in diploma thesis to verify that air based measurement can be used and results are reliable.

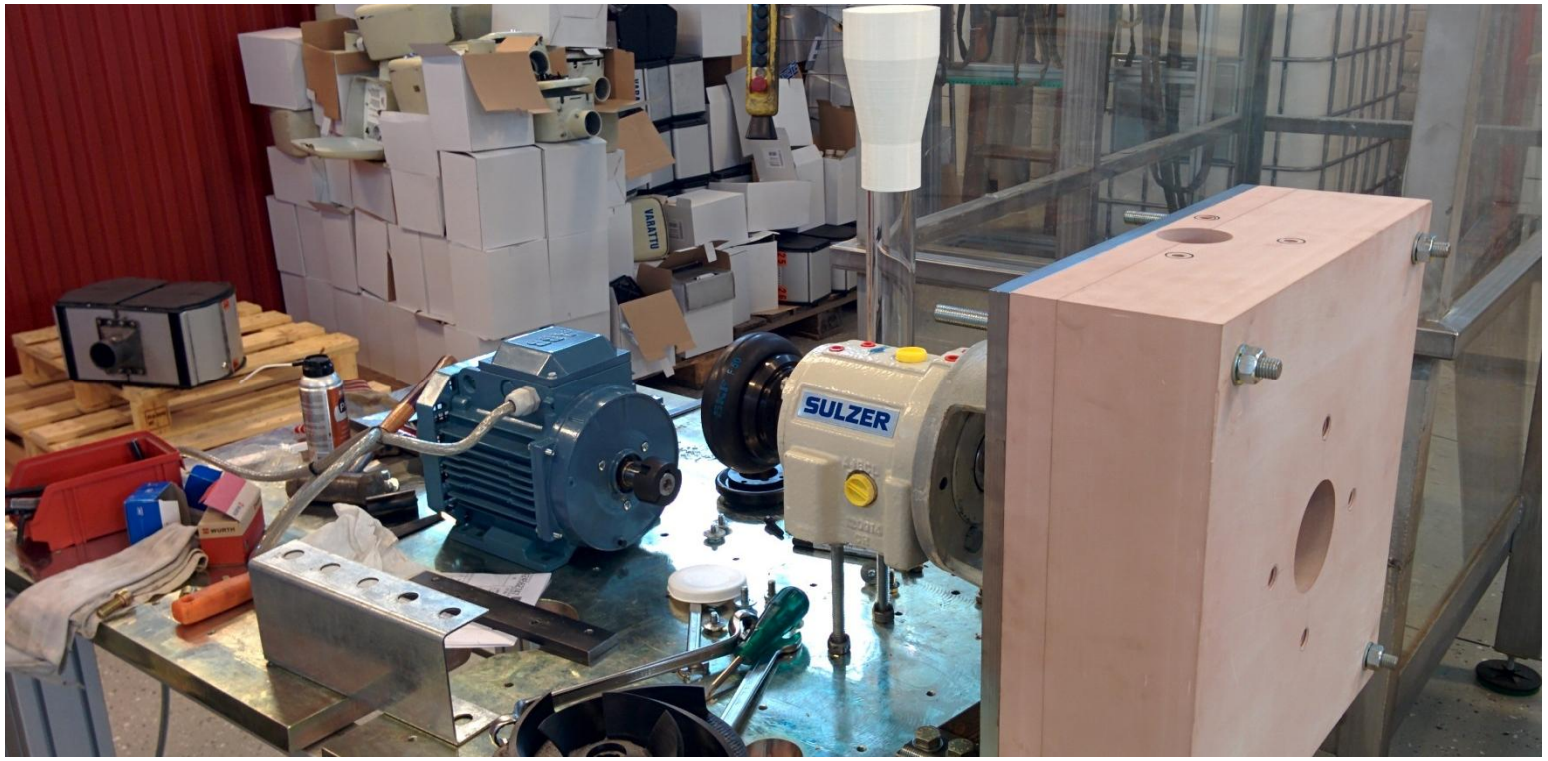

Fig. 2: Air based measurement of Sulzer A11-50 (new system)

The new measurement setup has a modular flow geometry and a custom bearing unit. Volute is splittable and impeller is attached with threads. Impeller or volute change takes less than 15 minutes.

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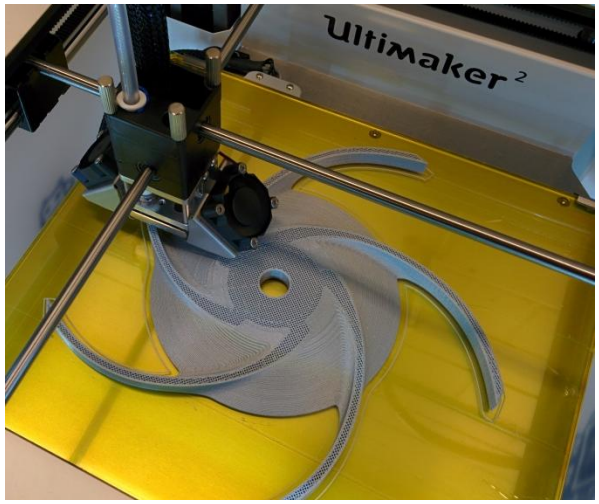
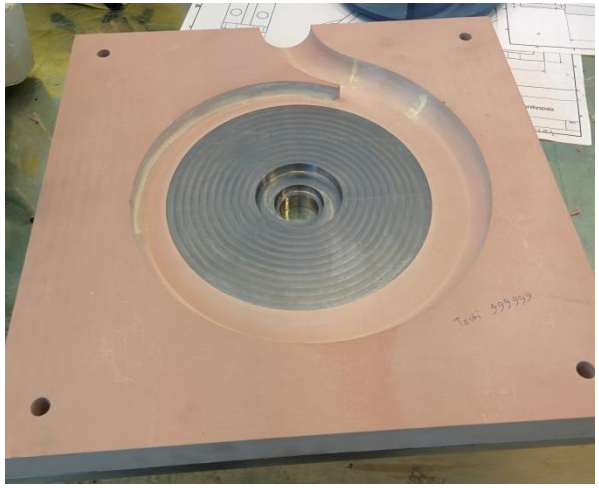
Approach – air based measurement

- 3D printing provides cheap and relatively fast way to create new designs
- Different manufactoring technologies can be seamlessly integrated
- Most importantly – the cost of prototyping is significantly lower → even ”crazy” ideas can be tested
- Measuring efficiency accurately is the main problem because shaft power levels are really low with air
- Ability to reproducible differentiate between test samples is accurate enough – final performance will be tested with water





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Approach – CFD

- Find accurate enough method and turbulence model for engineering purposes
- Validation of CFD calculations against Sulzer reference measurements and laboratory measurements
- Whole geometry is meshed in order to capture all interactions between impeller and volute
- Try to replicate measurement system output with CFD as closely as possible to produce compatible data (location of pressure probes etc.)
- Transient simulations with moving mesh and with advanced turbulence models (LES and hybrid models)

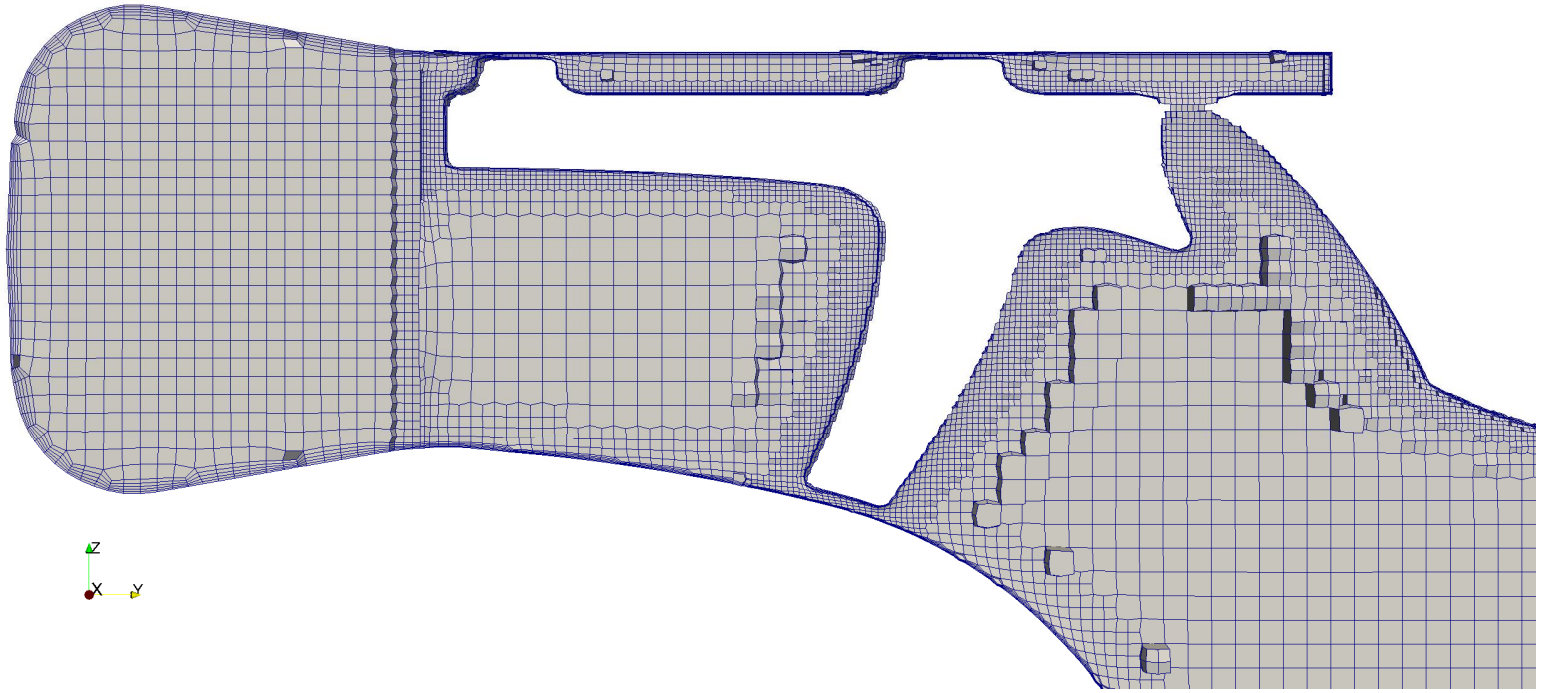

Fig. 3: Mesh details (cutting plane)

This cutting plane shows the complexity of the computational mesh. Gaps between impeller and volute are included. Total mesh size for whole geometry is ~7,1 million cells.

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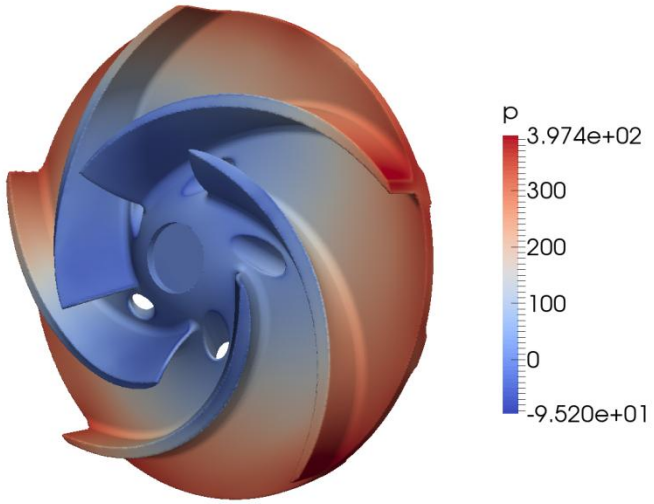
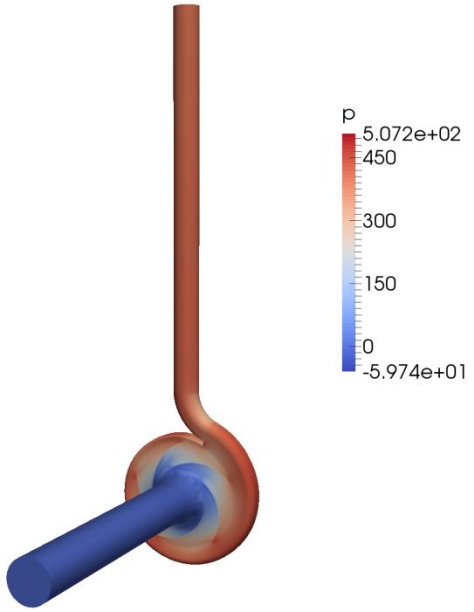
Results and conclusions

- Air based measurement system works and can be used to determine differences between test samples
- 3D printing can produce impellers and volutes cheaply – this method is available to all pump and fan manufacturers
- CFD results are accurate enough for this purpose and fast enough to use – kOmegaSST turbulence model with MRF will be used in future work





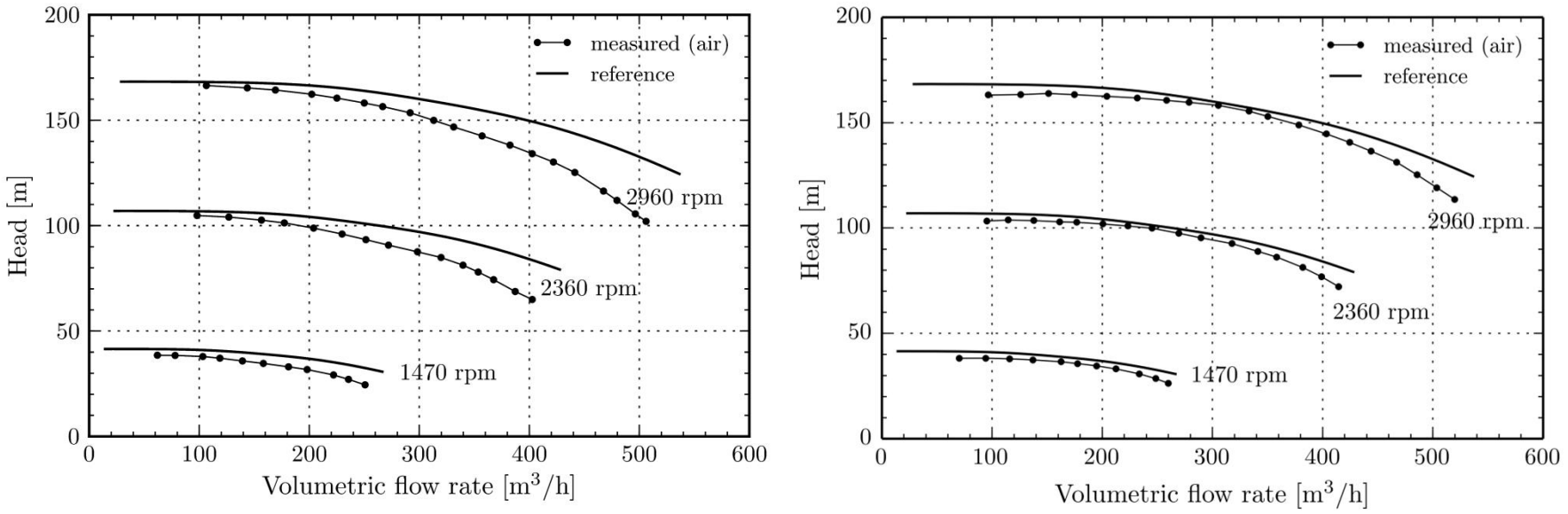


Fig. 4: Measured operation curves with two different impellers, Sulzer A32-100

This figure shows measured operation curves with two different impellers. Reference curves are measured with water and dotted curves with air. Difference between impellers is clearly visible.

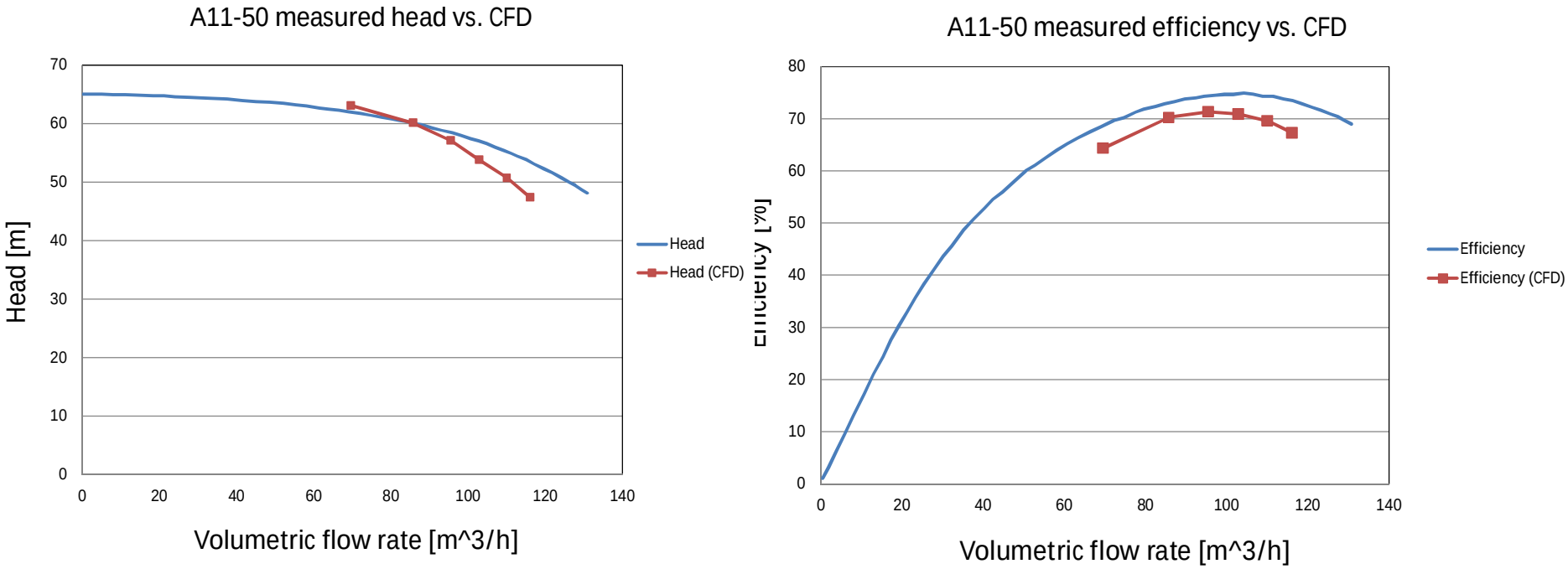


Fig. 5: CFD calculated operation and performance curves, Sulzer A11-50

CFD results compared with reference results. The operation curve shows increasing error when flow rate increases, efficiency curve has more even error distribution. Behaviour of results is consistent and error levels are acceptable.

Future plans

- Use developed measurement system to improve pump efficiency (some tests are already planned for new modular system)
  - Test open type impeller (would improve material efficiency significantly if applicable)
  - Test modified volute outlet (radial type outlet instead of central line)
  - Test different impeller–volute combinations to find optimal flow geometry
  - Use measurement setup in teaching
- Try to further improve CFD results – find a ”reference” CFD method to check results from kOmegaSST
- Help to create a new high efficiency small specific speed pump product line in collaboration with Sulzer and ABB

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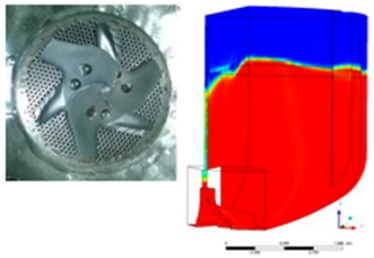
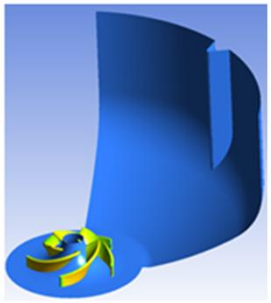
Related research at TUT

Bale pulper

Old design: P=100kW



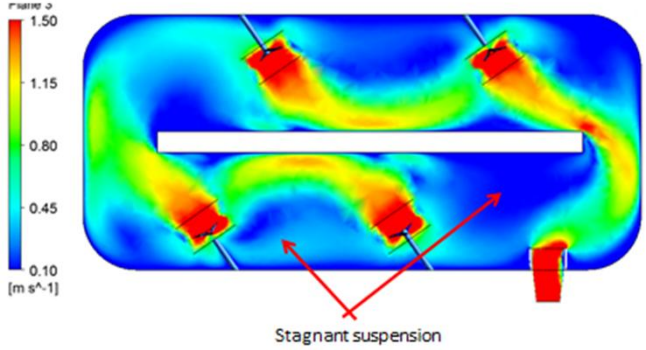
New design: P=50kW



50 % reduction in energy consumption confirmed in measuments at Inkeroinen mill

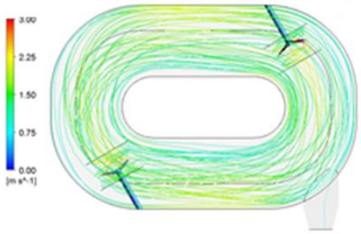
Drum pulper: mixing of fiber suspension flows in inefficient

P = 32510 W



New drum pulper tank

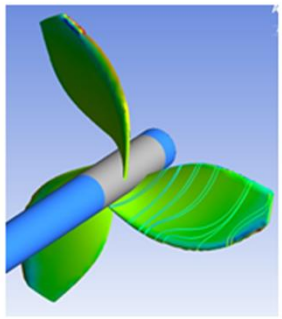
P = 14710 W



-40 % energy consumption

New propellers have been designed

Further -20 % energy consumption



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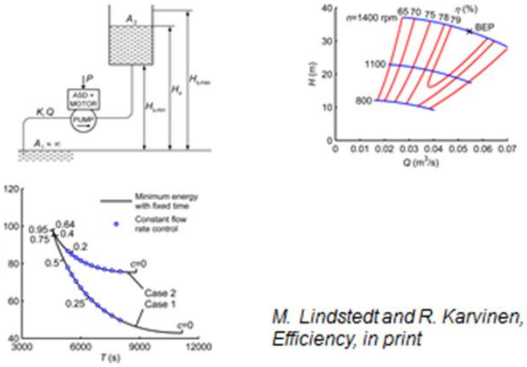
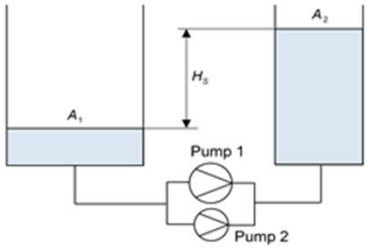
Related research at TUT

- **Optimal Control of Pump Rotational Speed in Reservoir Filling: Minimum Energy Consumption with Fixed Time,**



M. Lindstedt and R. Karvinen, Energy Efficiency, in print

Present problem: reservoir filling using parallel pumps



- M. Lindstedt and R. Karvinen, ECOS 2015,30 June-3July, Pau, France

Experimental setup for measurement of fiber-suspension flows

Rotating vane rheometer

Pulsed Ultrasound Doppler Velocimeter (PUDV) measurement

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