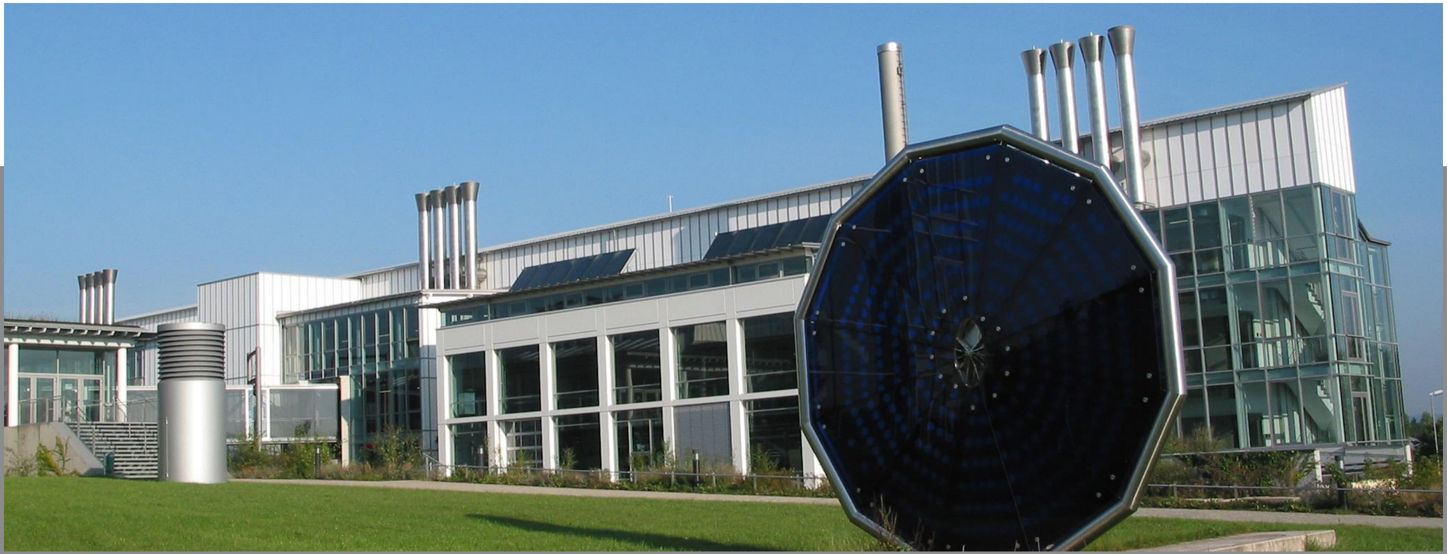

Iterative Approach for the Design of an Organic Rankine Cycle

4th International Seminar on ORC Power Systems, 13-15 Sep. 2017, Milano

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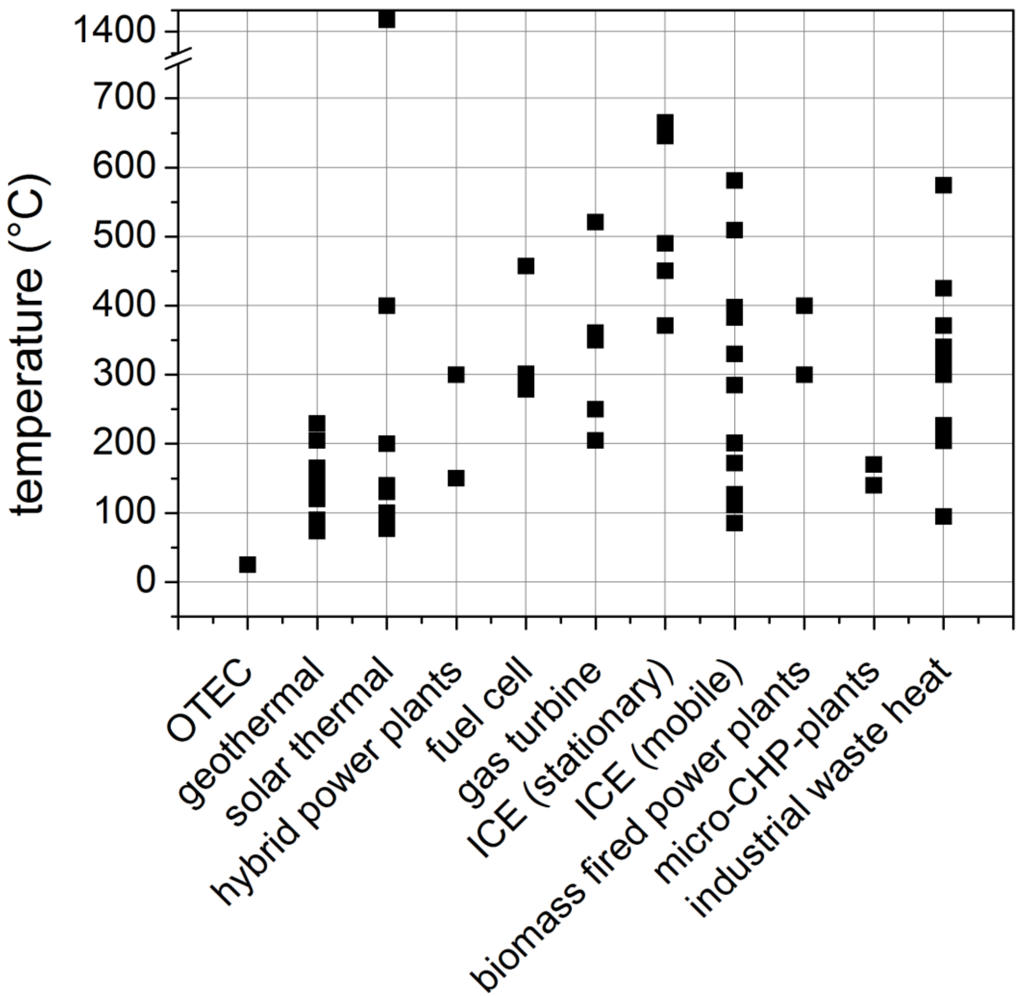
Organic Rankine Cycle application areas



ORC is a well-known technology for:

- Geothermal power generation
- Biomass fired power plants

Problems of other areas of application:

Wide range of boundary conditions (temperature and heat load of the heat source/sink)

ORC design instruments

Simulation model

- Simulation tool Aspen Plus® Release 8.8
- Stationary simulation
- Detection of optimum system operation

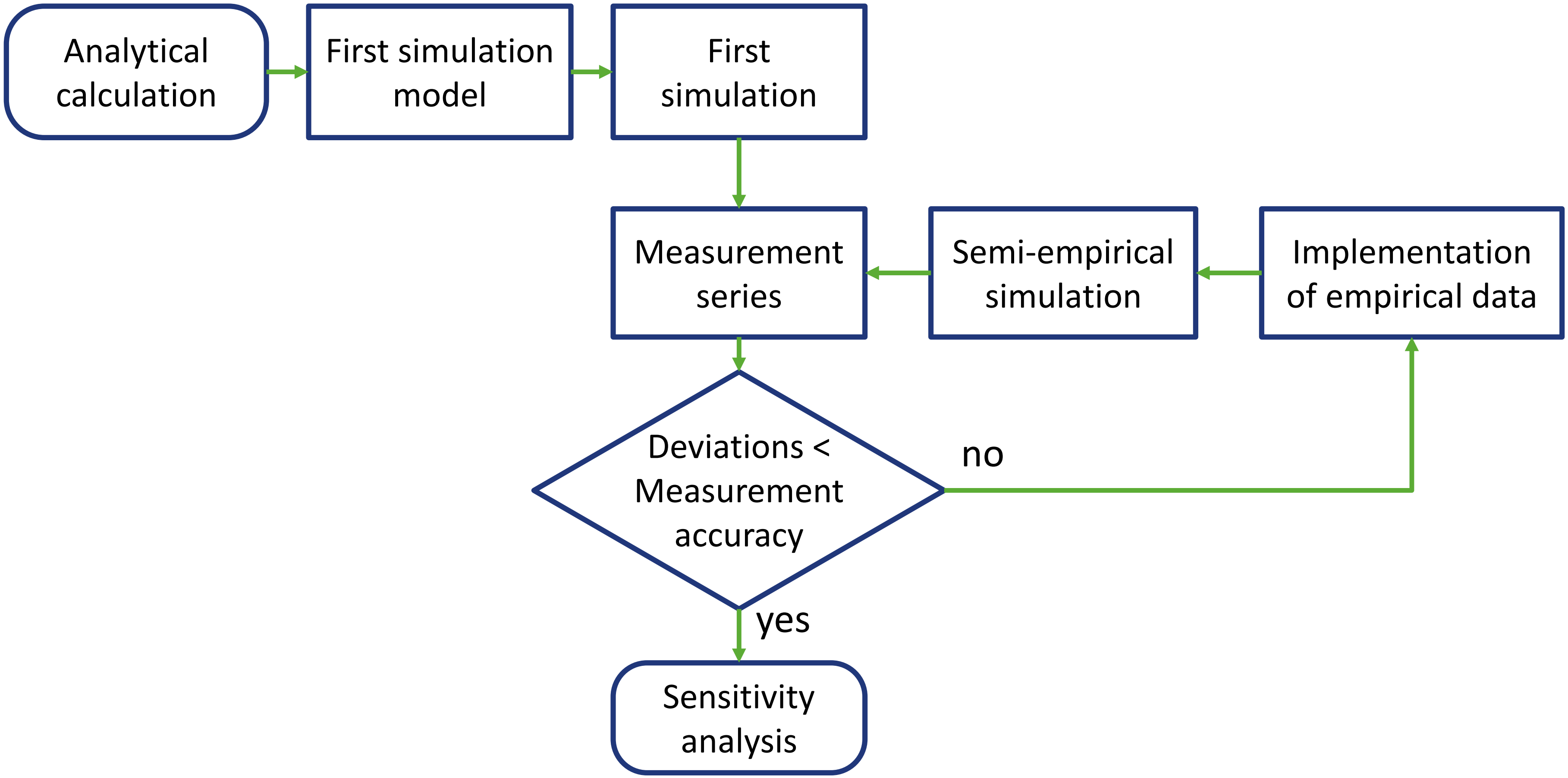
Small-scale test rig

- Thermal oil heated and cooled by water
- 1 kW nominal power, working fluid R365mfc
- Scroll expander and gear pump
- Brazed plate heat exchanger including an internal recuperator

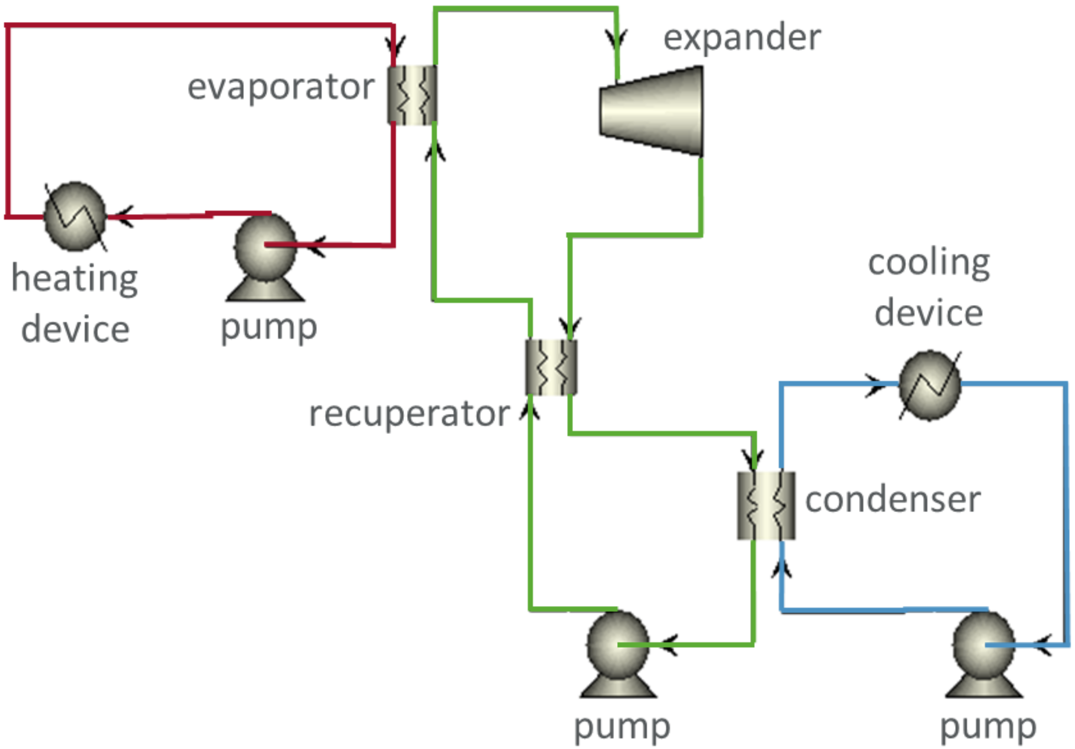
Iterative optimization

- Repetitive comparison of simulation and test rig data
- Improvement of simulation accuracy by empirical test rig data
- Sensitivity analysis

Iterative design approach



Simulation model

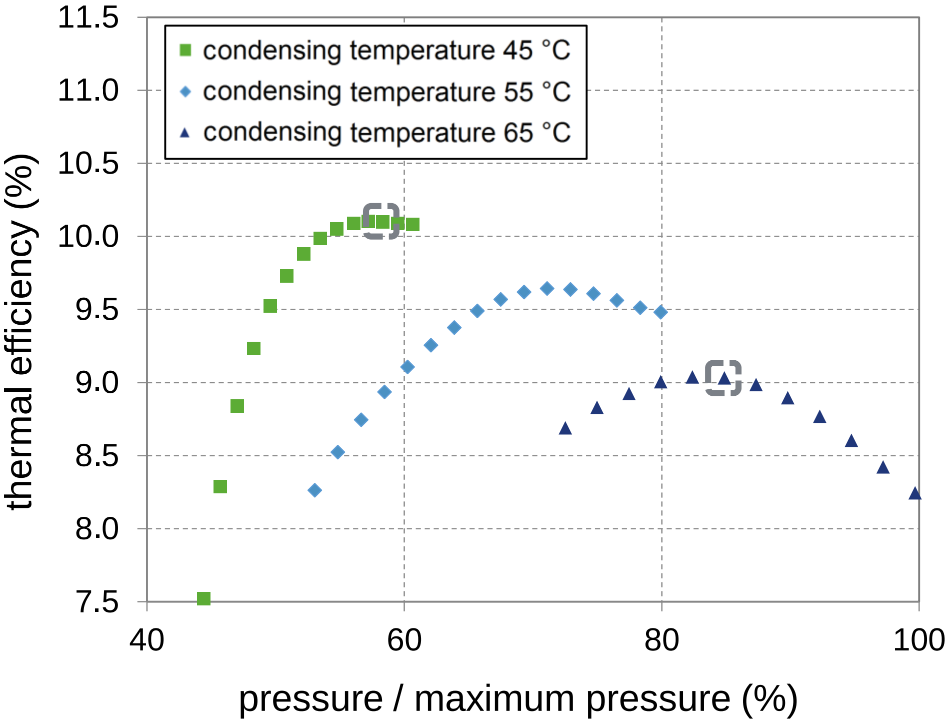


Boundary conditions:

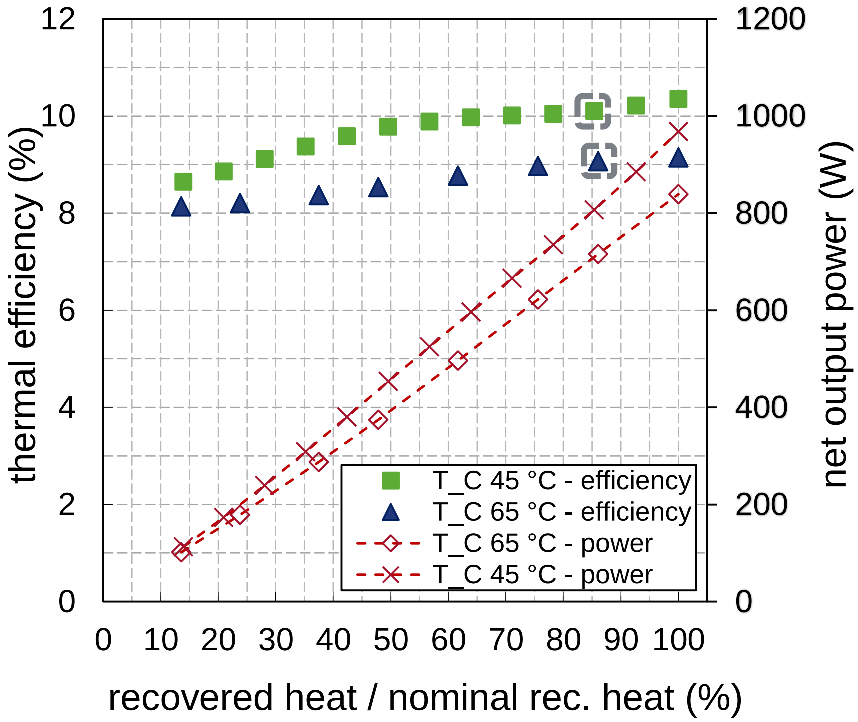
Parameter	Set value
Evaporator thermal oil inlet temperature	200 °C
Condenser pinch	5 K
Subcooling (at the pump inlet)	10 K
Recuperator pinch	18.77 K

First simulation – results

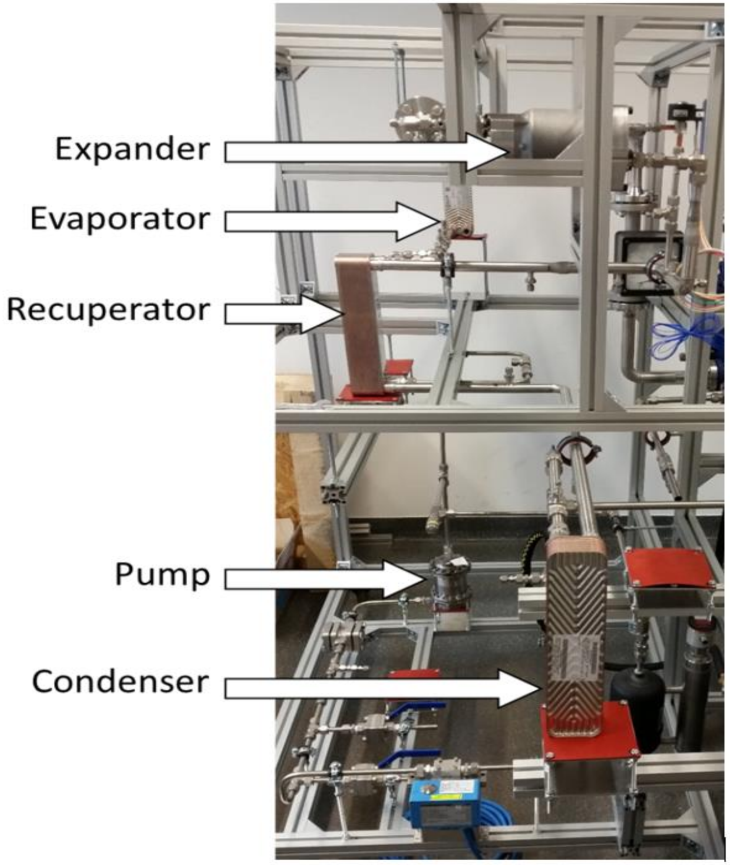
Sensitivity analysis

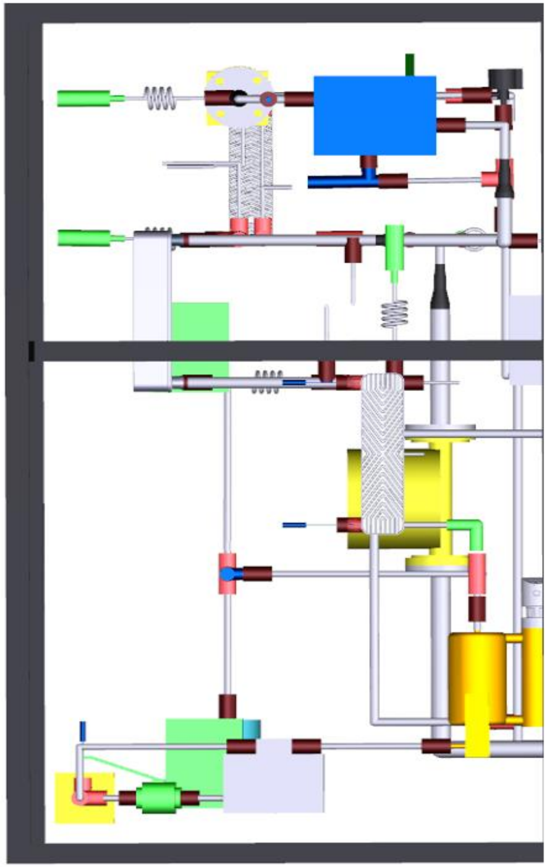


System performance curves



Test rig (I)

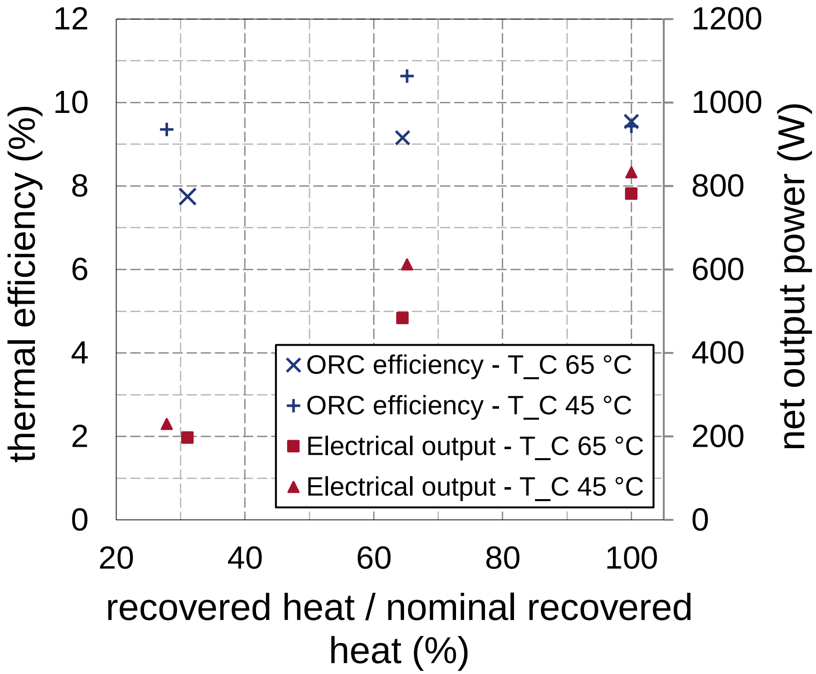


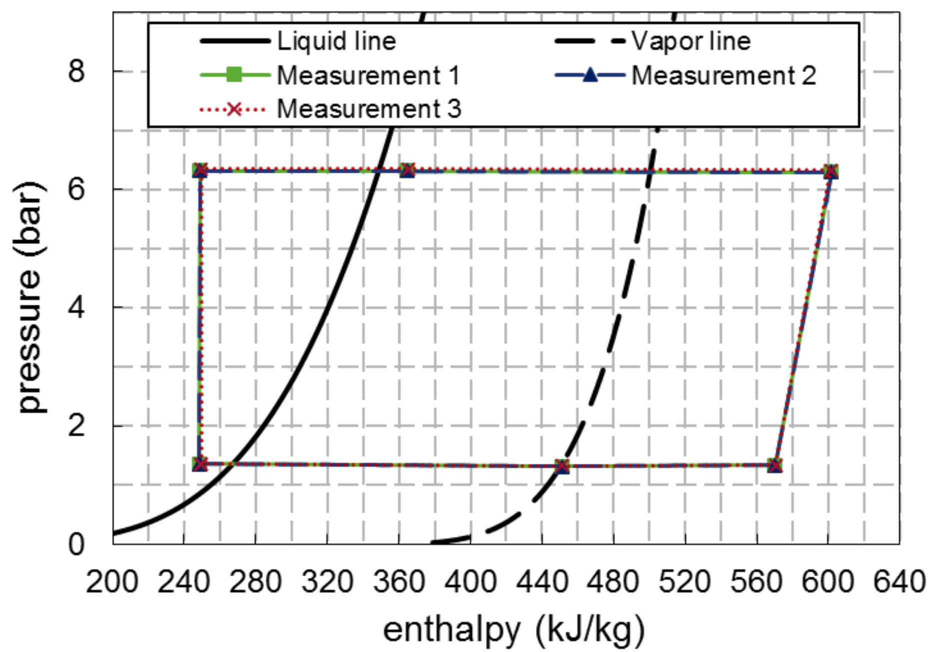


Test rig (II)

Test rig measurements

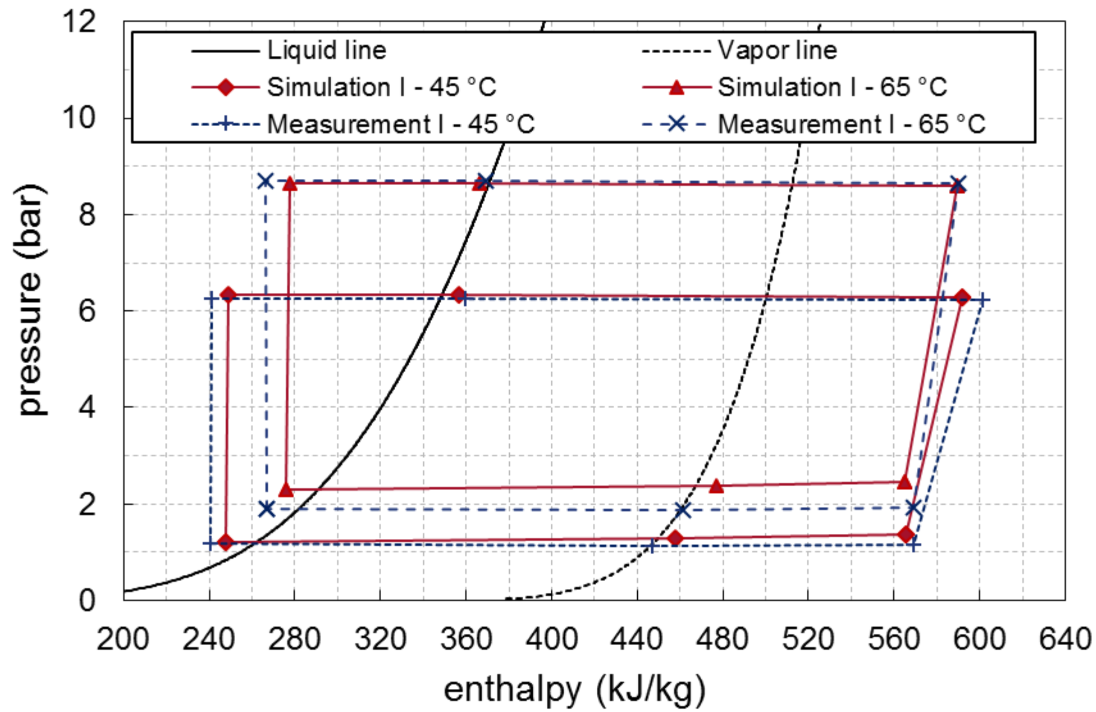
- Examination of nine different simulation points:
  - partial and full load (about 30 %, 65 % and 100 %)
  - condensing temperatures of about 45 °C, 55 °C and 65 °C
- Measurements of 15 minutes with stationary conditions and subsequent averaging





Comparison of measurement and simulation

- Moderate compliance between simulation and measurement
- Discrepancy of:
  - Condensing temperature/pressure
  - Subcooling
  - Evaporator transferred heat
  - Regenerator transferred heat
  - Condenser transferred heat
  - Expander isentropic efficiency at high rotational speed

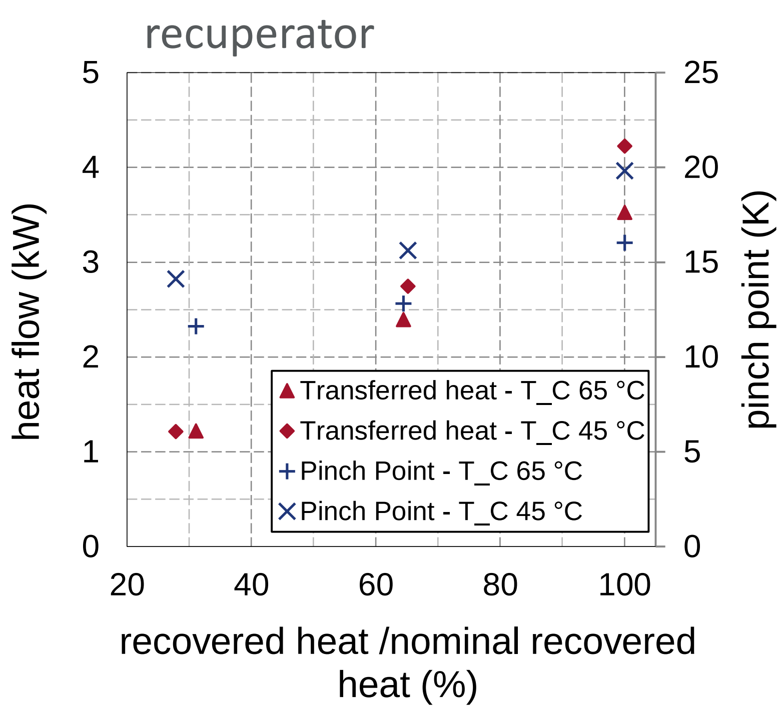


Implementation of measurement data into the simulation model

Empirical correlations were implemented into the simulation model:

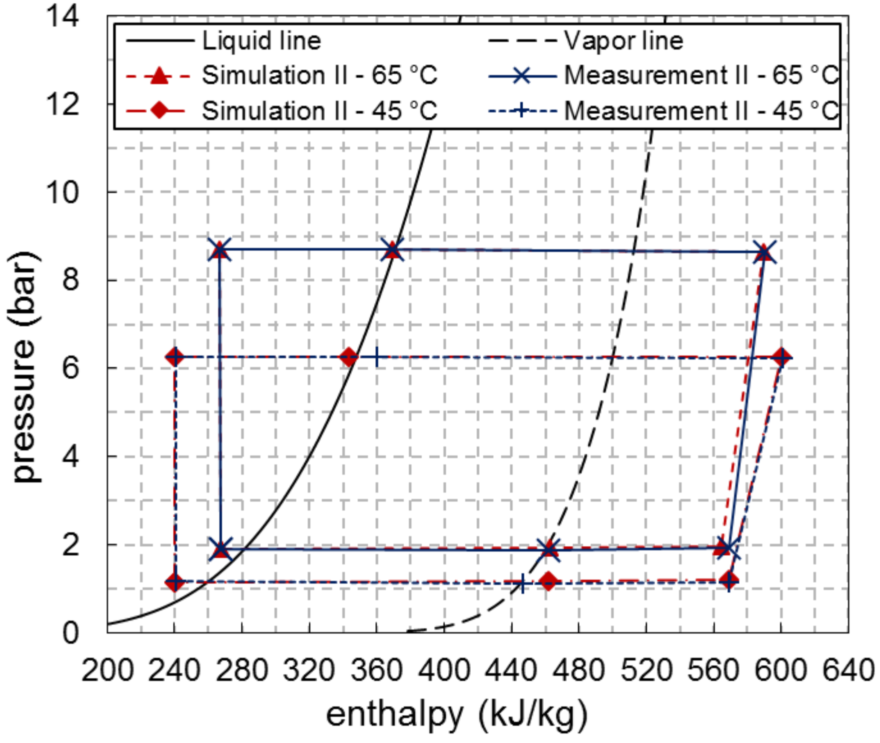
- Subcooling
- Condenser pinch point
  - ➡ Condensing pressure
- Recuperator transferred heat
- Evaporator transferred heat
- Heat and pressure losses

Expander isentropic efficiency was not adapted due to insufficient data.

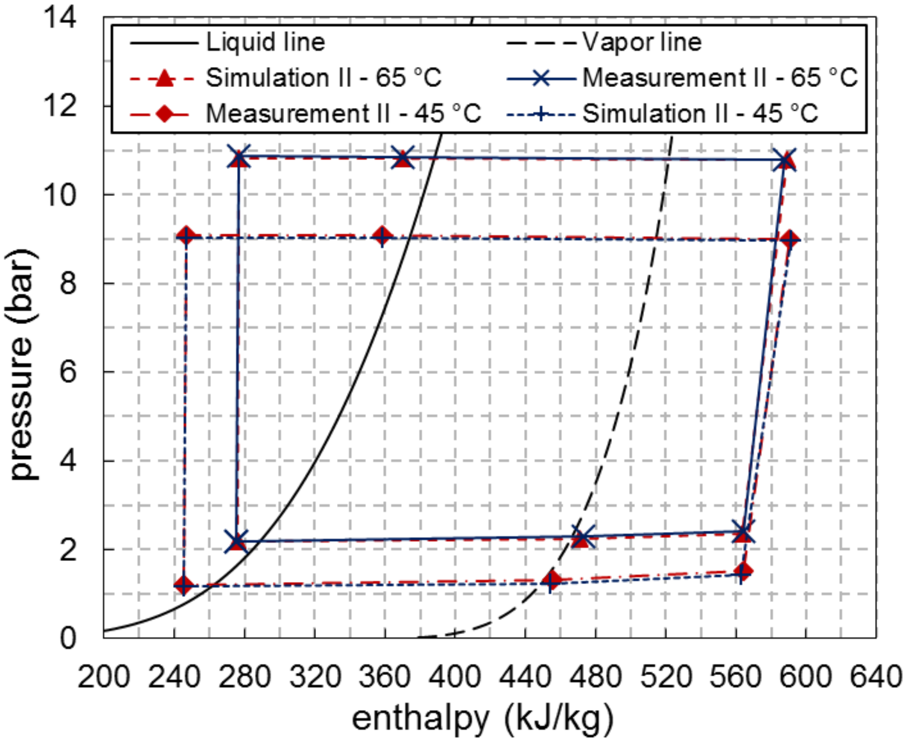


Comparison of new measurement and adopted simulation

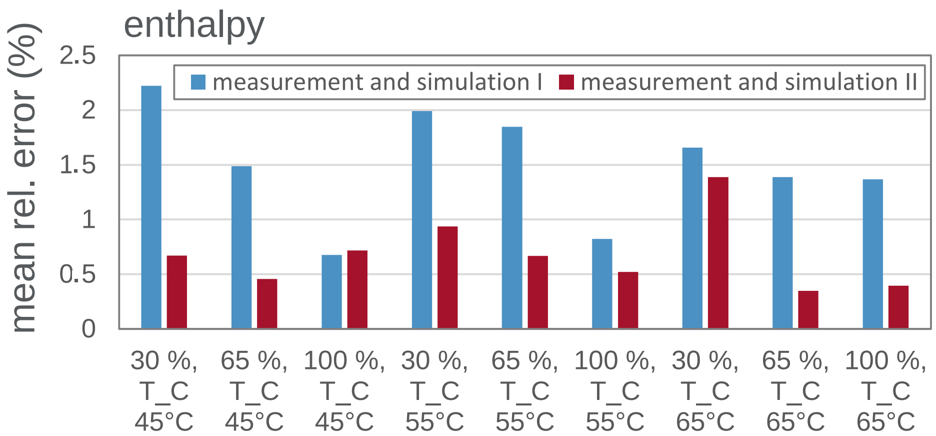
30 % partial load



full load

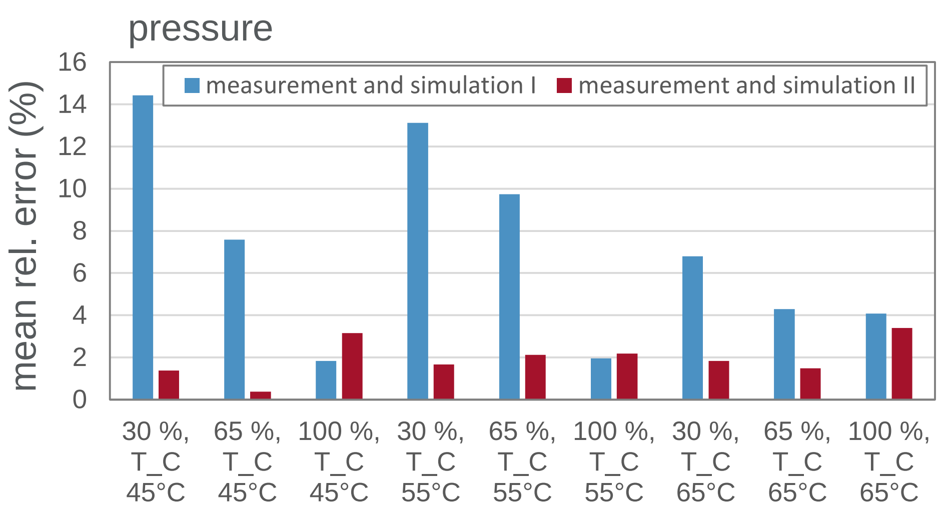


Measurement accuracy assessment and comparison



Average deviation I: 1.50 %

New average deviation (II): 0.68 %



Average deviation I: 7.09 %

New average deviation (II): 1.96 %

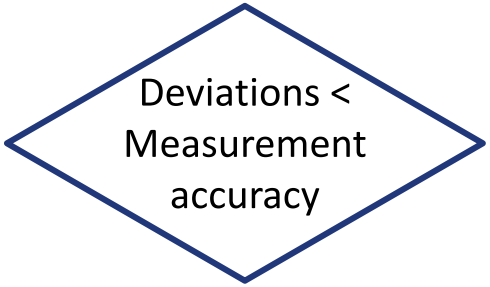
Measurement accuracy assessment and comparison

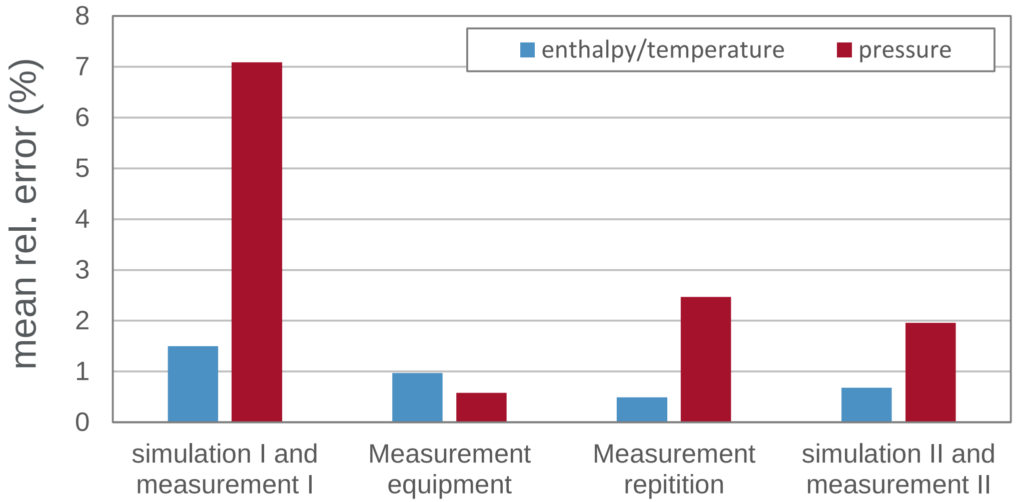
- Mean relative deviation of measurement and simulation:

  enthalpy → ± 0.68 %, pressure → ± 1.96 %
- Mean relative error of measurement equipment:

  temperature → ± 0.97 %, pressure → ± 0.58 %
- Mean relative error of measurement repitition:

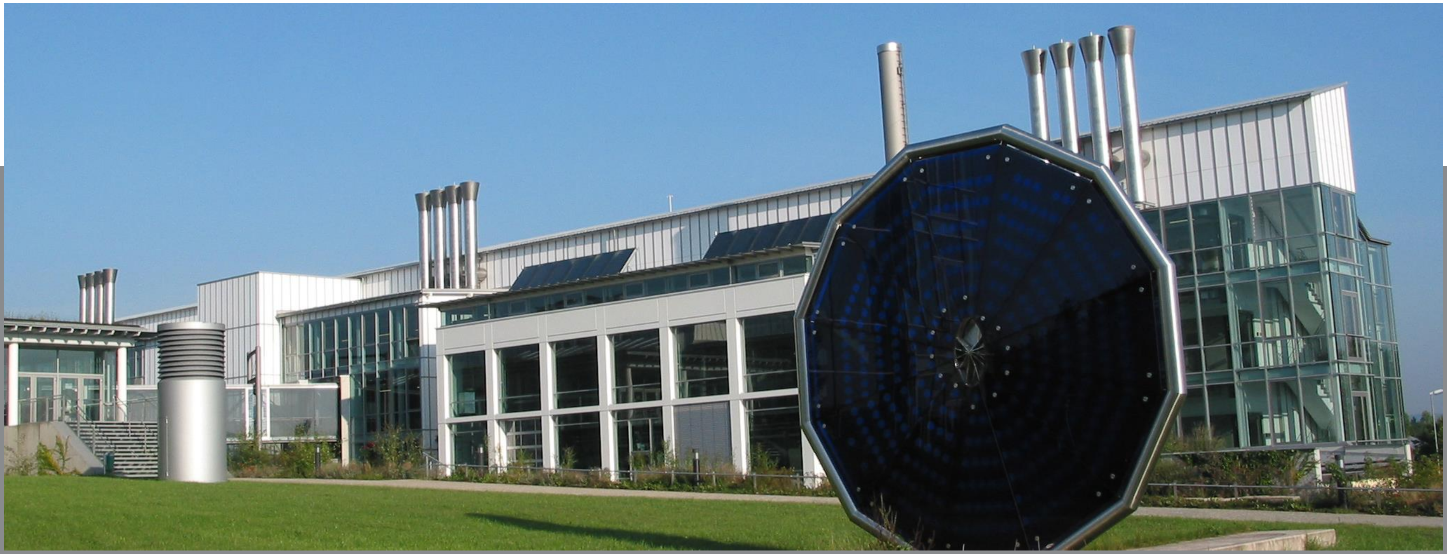
  enthalpy → ± 0.49 %, pressure → ± 2.47 %





Summary

- An iterative approach for the design of an ORC was demonstrated.
- A steady state simulation model was developed and sensitivity analysis were carried out.
- A test rig was built to reproduce the simulation results.
- Simulation accuracy can be highly improved by implementing experimental results of the overall system in the simulation tool.
- The average mean deviation of measurement and simulation could be reduced from 4.3 % to 1.3 % by a single implementation of measurement data.



Thank you

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