Karlsruhe Institute of Technology

Numerical model of a micro-structured heat exchanger for cryogenic mixed refrigerant cycles

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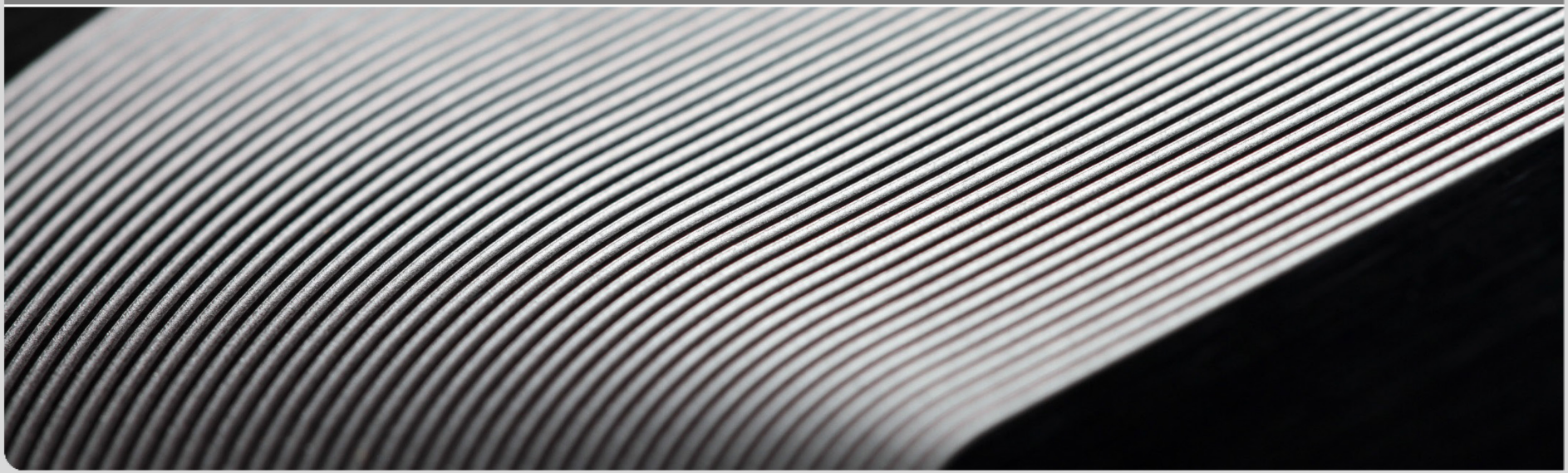
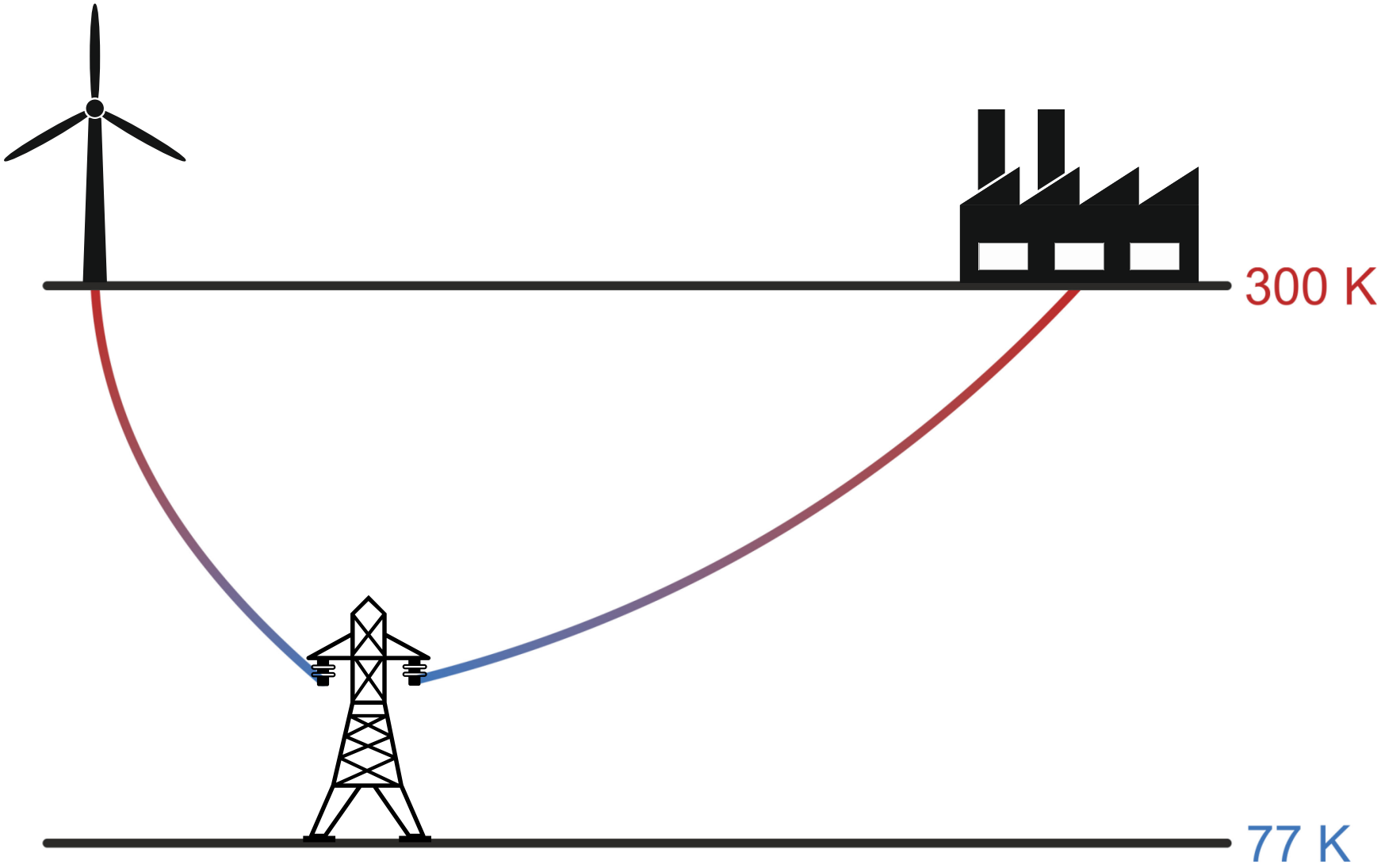
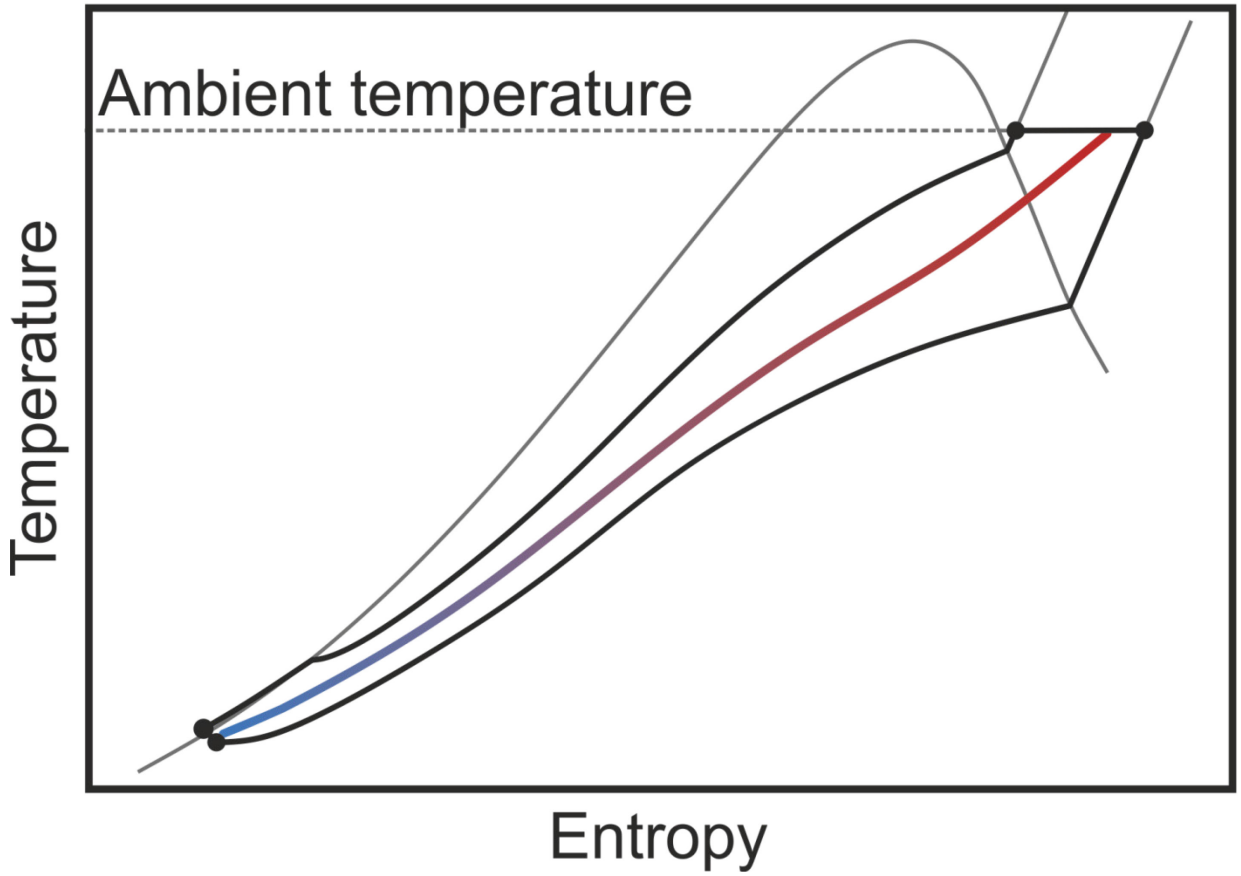
Institute for Technical Physics (ITEP)

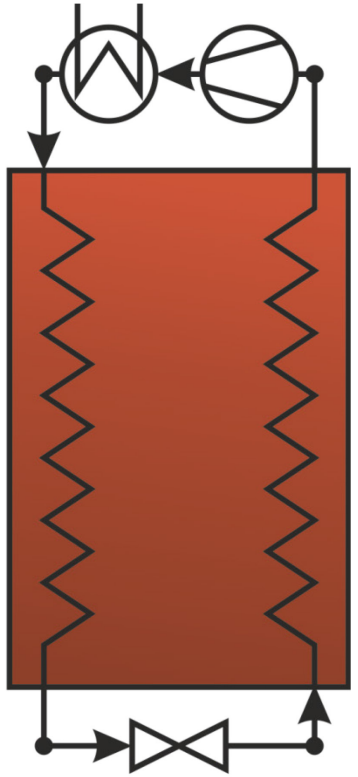


Motivation



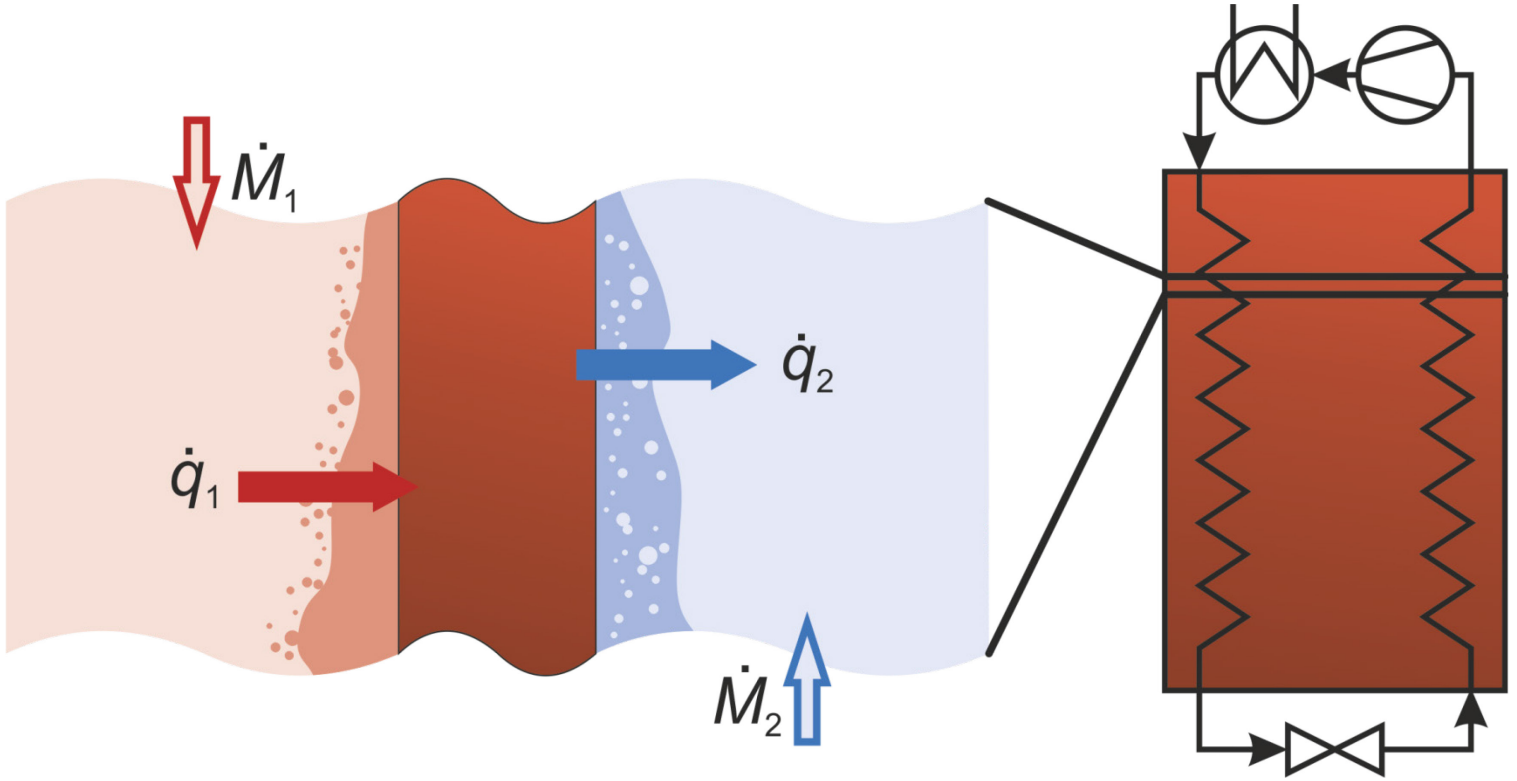
Mixed refrigerant cycle (MRC)





Source: Venkatarathnam, G.: *Cryogenic Mixed Refrigerant Processes*, Springer Verlag, New York, 2008

Heat exchanger design



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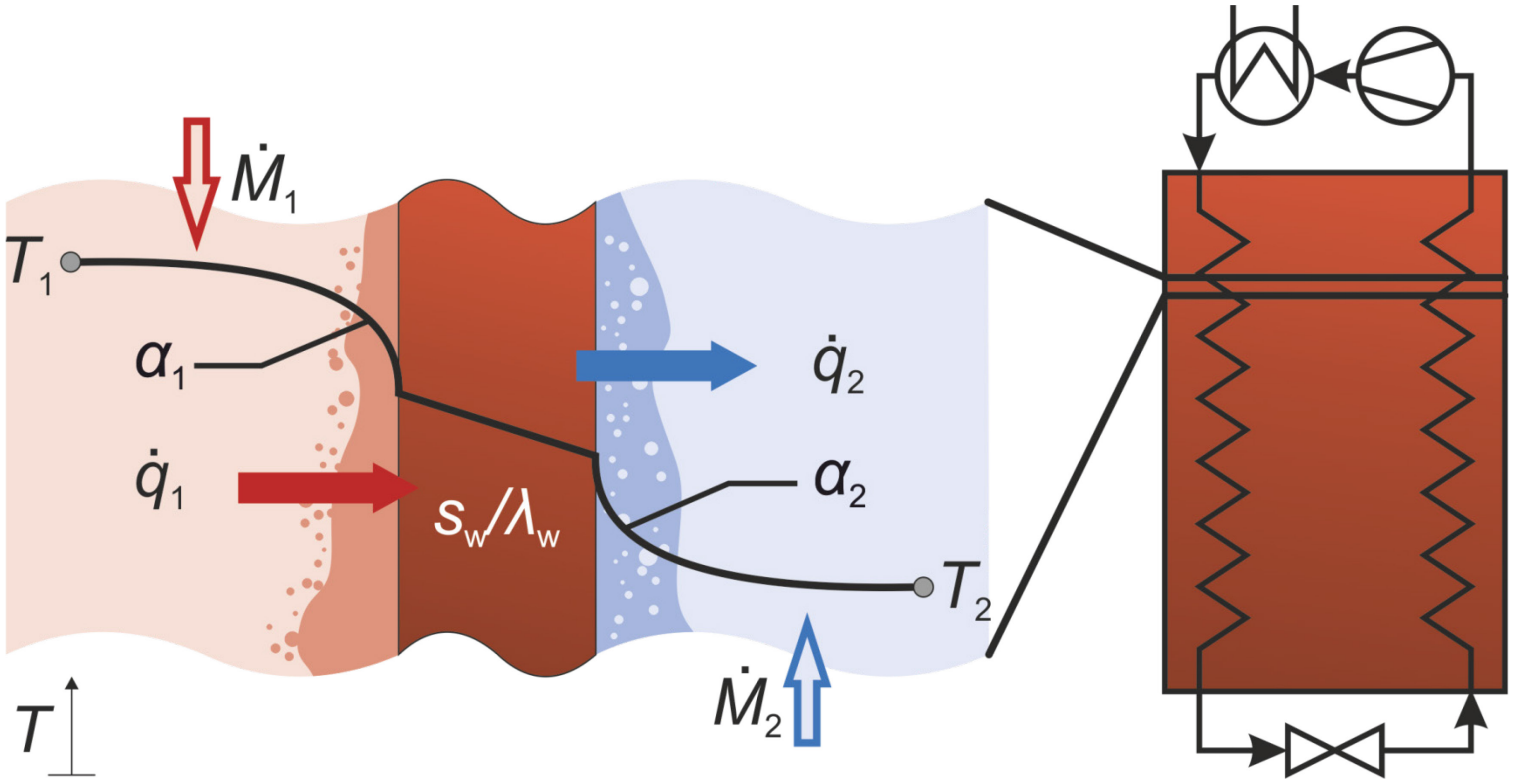

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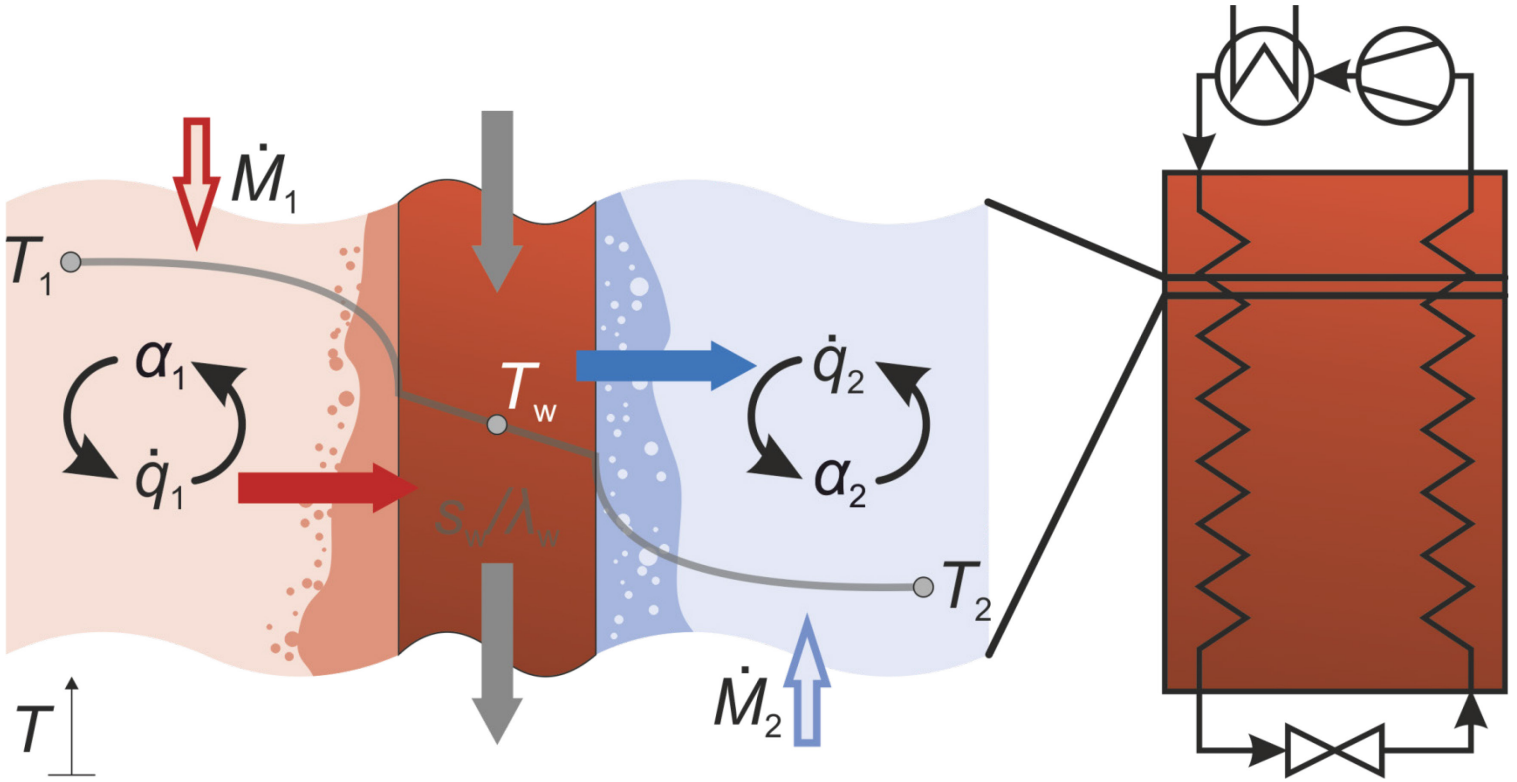
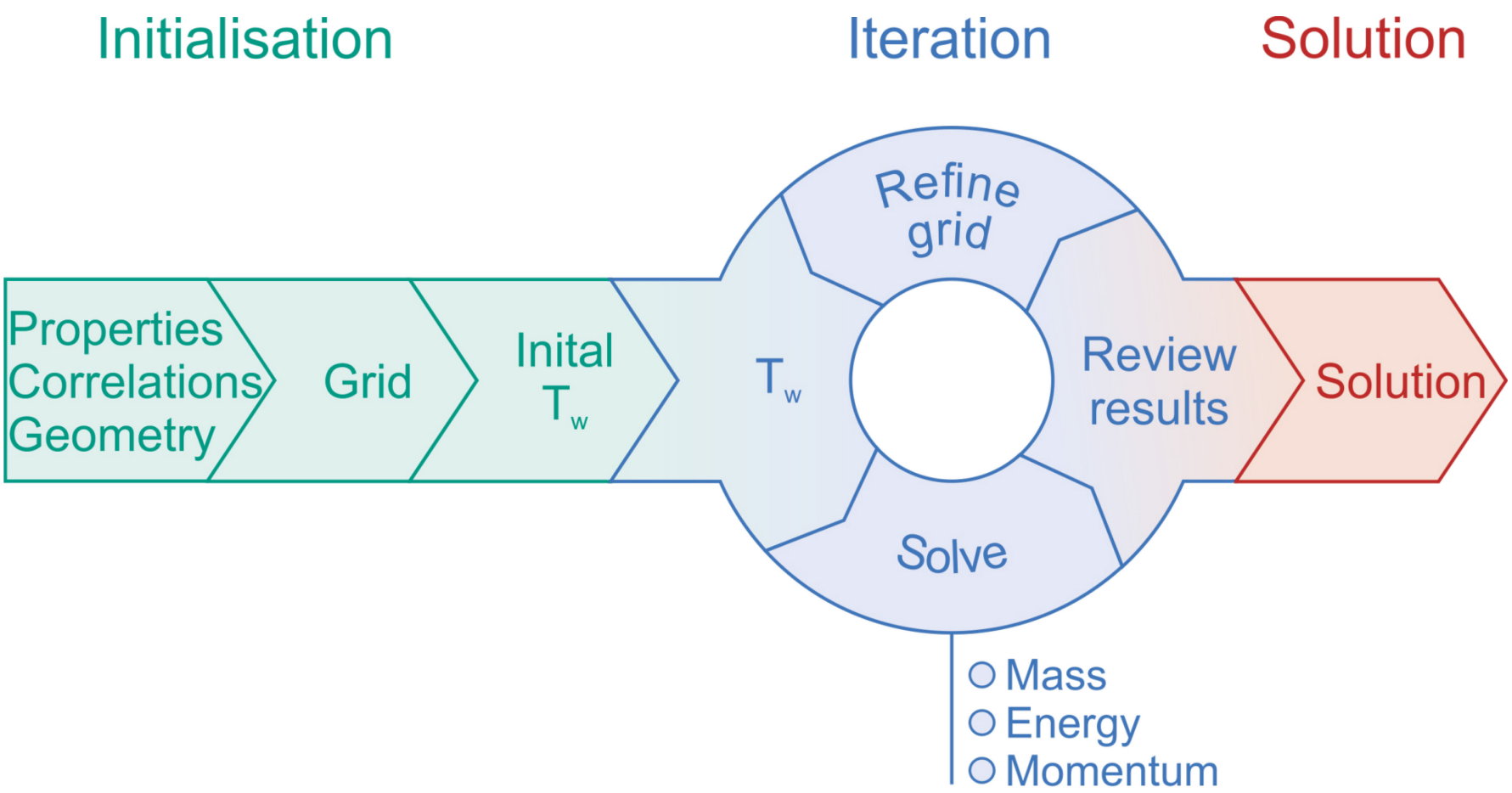
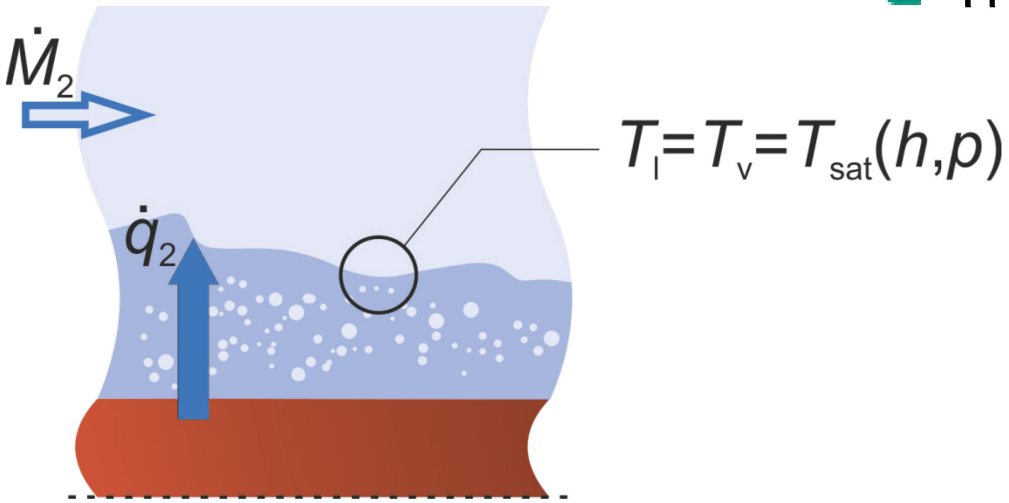


Numerical modelling framework



Basic assumptions

- Simultaneous prediction of enthalpy and pressure assuming:
  - Thermodynamic equilibrium



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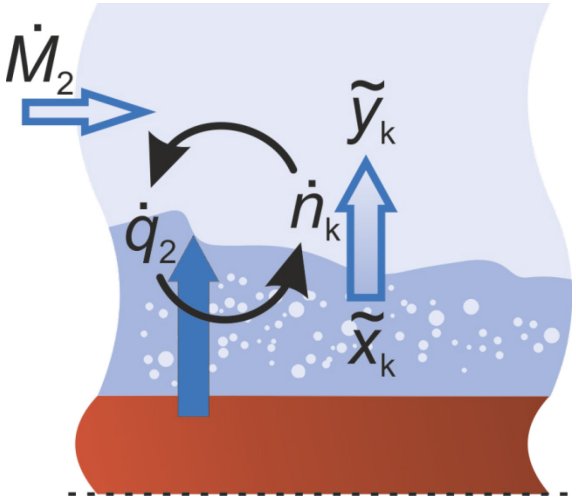

Basic assumptions

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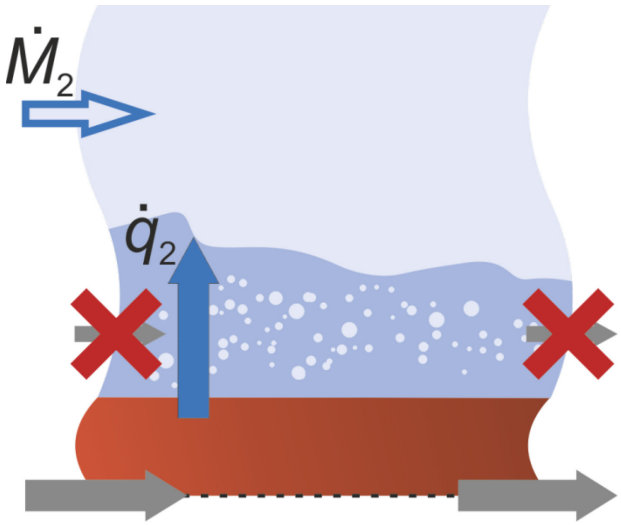

  - Thermodynamic equilibrium
  - Equilibrium model, e.g. Granryd, Silver-Bell-Ghaly
  - Negligible axial conduction in fluid

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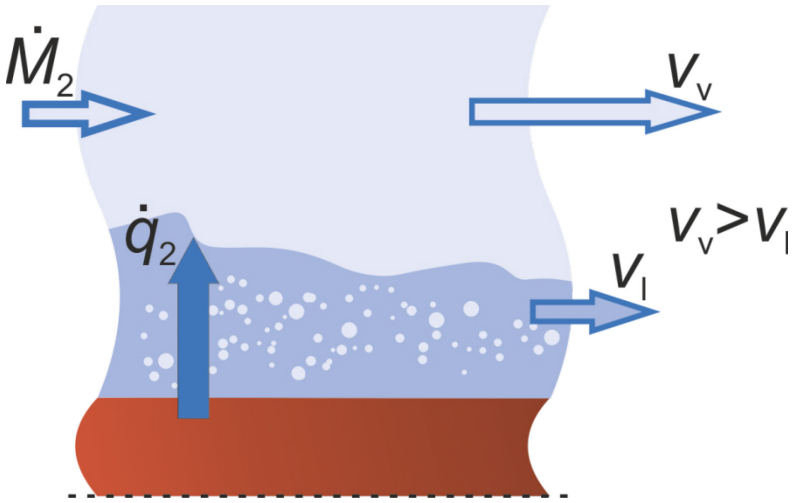
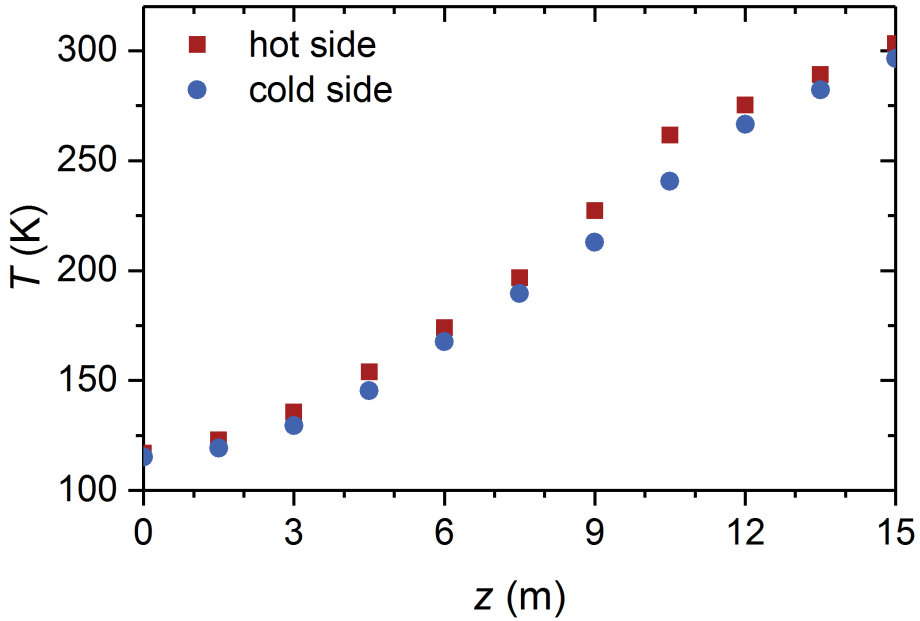


  - Thermodynamic equilibrium
  - Equilibrium model, e.g. Granryd, Silver-Bell-Ghaly
  - Negligible axial conduction in fluid
  - Separated flow
    - Kinetic and potential energy
    - Acceleration and hydrostatic pressure

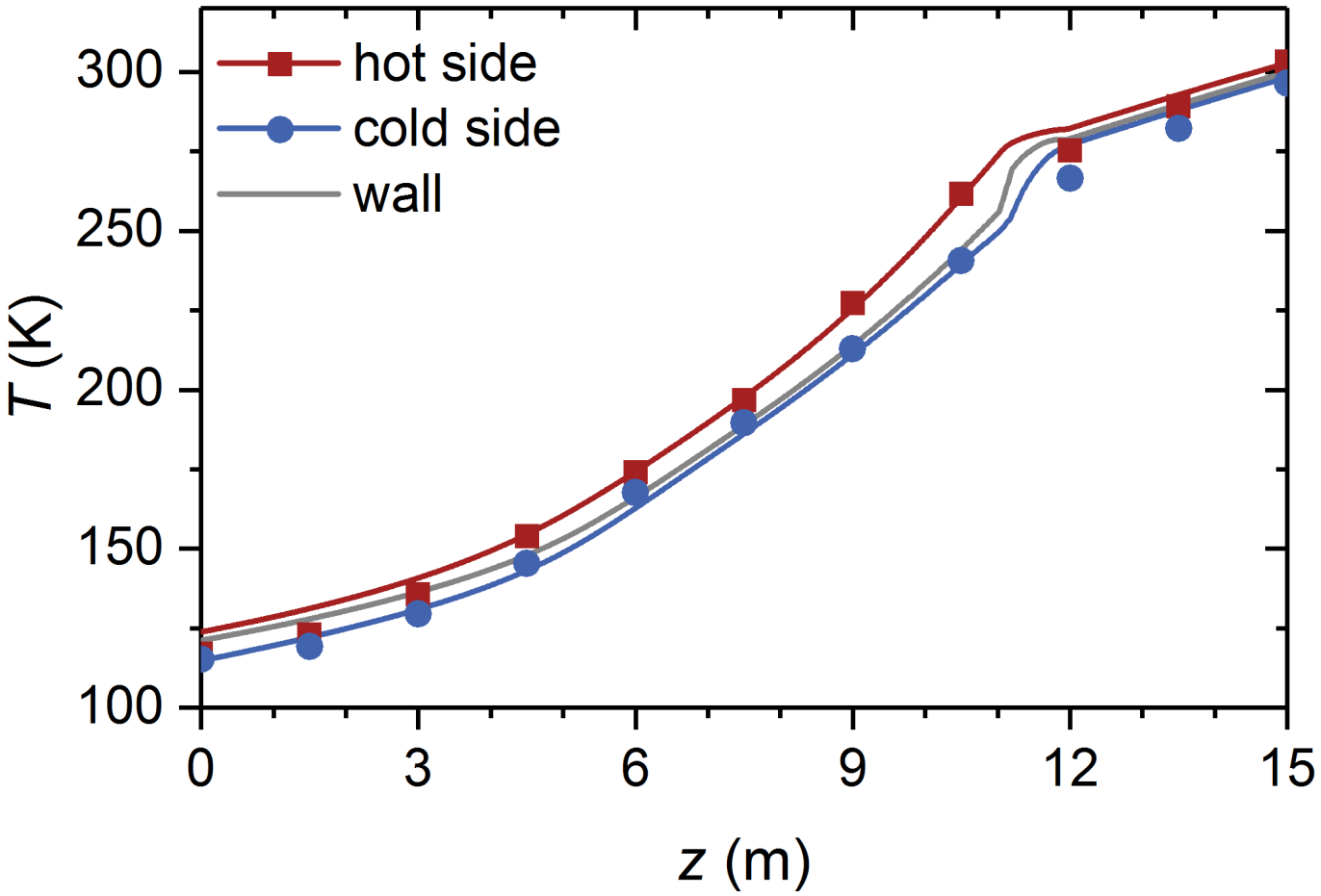
Example calculation

- Tube-in-tube heat exchanger from literature
  - Counter-flow
  - Length 15 m
  - Temperature range 115 – 300 K
  - $N_2/CH_4/C_2H_6/C_3H_8/iC_4H_{10}$ Mixture



Source: Ardhapurkar, P. M. et. al.: Experimental investigation on temperature profile and pressure drop in two-phase heat exchanger for mixed refrigerant joule-thomson cryocooler, *Applied Thermal Engineering* 66, pp. 94-103 (2014)

Results: temperature profile



- 22 data points
- AAD=1.9 %

Sources: Ardhapurkar, P. M. et. al.: Experimental investigation on temperature profile and pressure drop in two-phase heat exchanger for mixed refrigerant joule-thomson cryocooler, *Applied Thermal Engineering* 66,.pp. 94-103 (2014)
Gomse, D. et. al.: Modelling of two-phase heat exchangers with zeotropic fluid mixtures, *Journal of Heat Transfer*, Submitted (2017)

Results: outlet pressure

	Hot stream	Cold stream
$p_{in,exp}$ (bar)	11.7	5.57
$p_{out,exp}$ (bar)	11.01	2.31
$p_{out,pred}$ (bar)	11.38	2.31
rel. deviation (%)	-3.4	0.2

- Excellent agreement
- Strong dependence on correlations

Sources: Ardhapurkar, P. M. et. al.: Experimental investigation on temperature profile and pressure drop in two-phase heat exchanger for mixed refrigerant joule-thomson cryocooler, *Applied Thermal Engineering* 66,.pp. 94-103 (2014)
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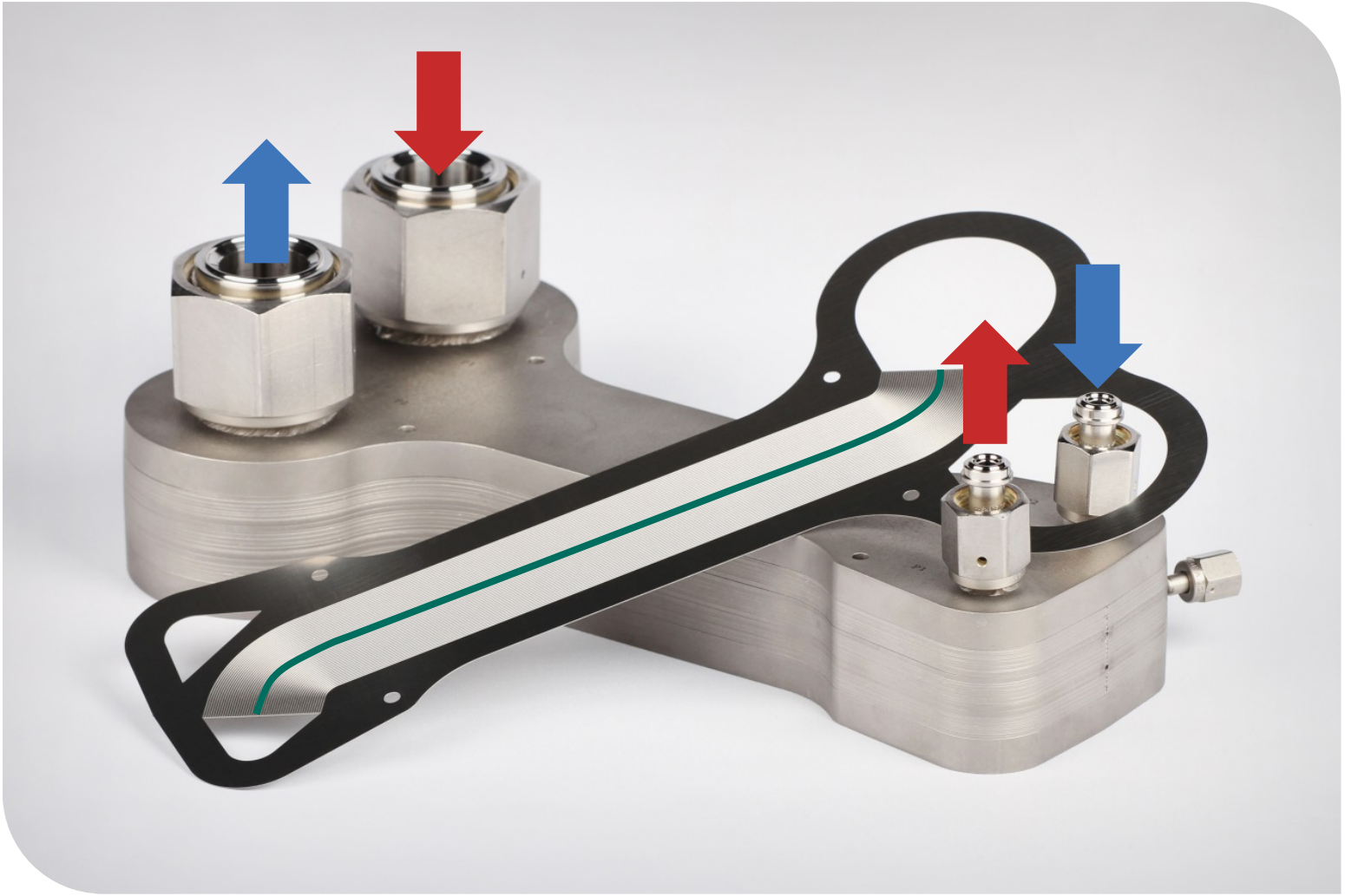
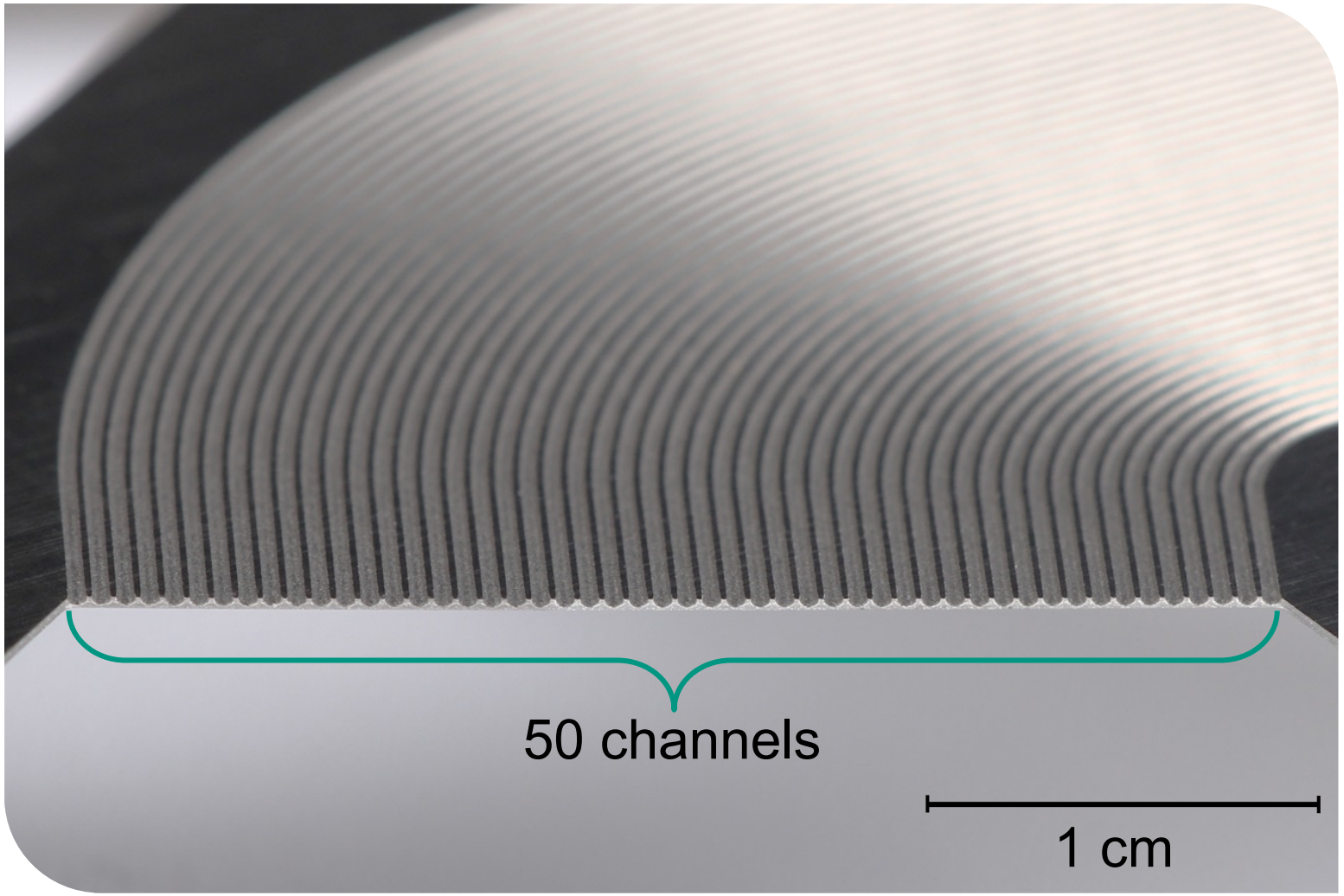
Micro-stuctured heat exchanger prototype

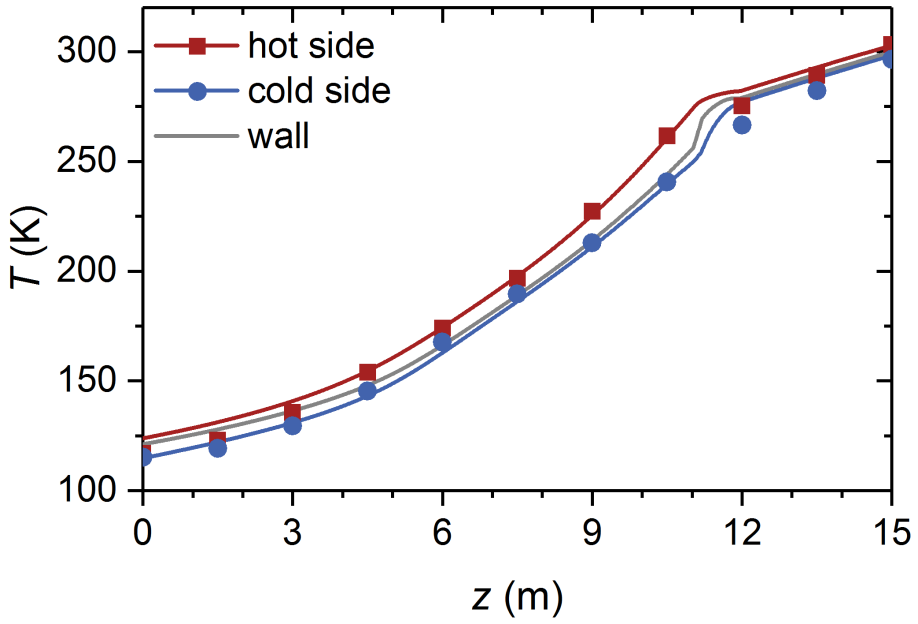


Micro-structured sheet



Summary

- Numerical heat exchanger model
  - Simultaneous prediction of heat transfer & pressure drop
  - Zeotropic fluid mixtures
- Tube-in-tube heat exchanger: excellent results



Outlook

- Micro-structured heat exchanger prototype
  - Experimental investigation of prototype performance and model quality
  - Iterative improvement of model and design

Thank you for your attention!