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Heat Loss Evaluation of an Experimental Set-up for predicting the Initial Stage of the Boiling Curve for Water at Low Pressure

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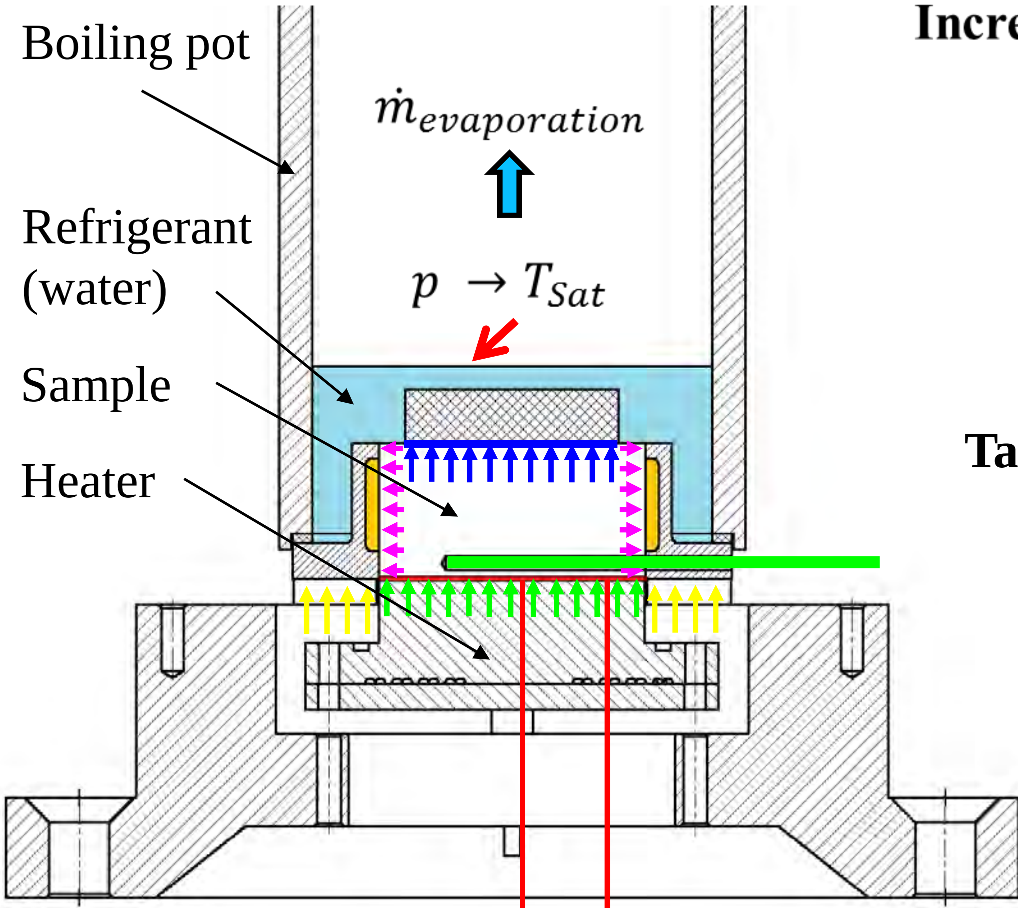
Agenda

- Introduction
- COMSOL Implementation with boundary conditions
- Results
- Conclusion

Introduction



Increasing heaters temperature above T_{Sat}

→ Evaporation of water

Measured values:

- $\dot{q}_{In,\,heat\,flux\,sensor}$
- T_{Sample}
- T_{Heater}

Target values for the Boiling Curve:

- $\dot{q}_{In,\,effective}$
- T_{wall}

$\rightarrow \Delta T_{WSH} = T_{Wall} - T_{Sat}$

Unknown values:

- $\dot{q}_{Loss,\,radial}$
- $\dot{q}_{In,\,radiation-conduction}$

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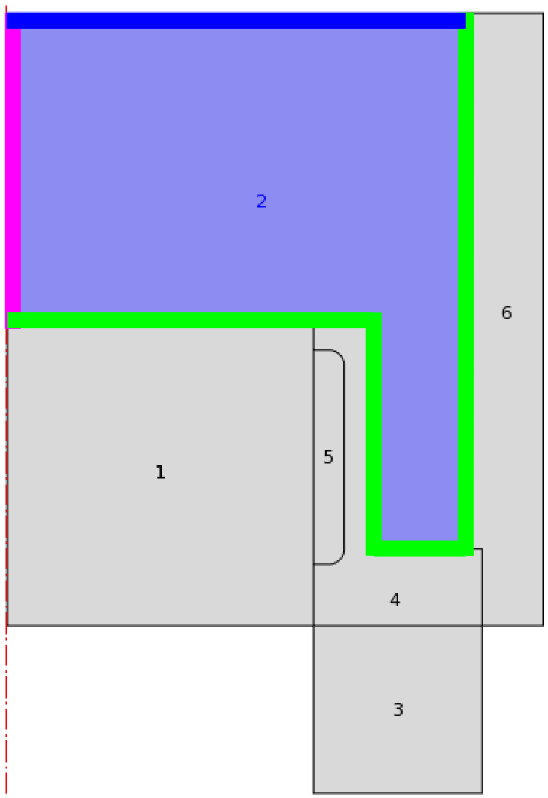
COMSOL Implementation (fluid part)



2-D axisymmetric stationary model

'Heat Transfer in Fluids' (Area 2)

Incompressible Navier-Stokes equation (laminar flow)

$$\varrho(u\nabla)u = -\nabla p + \nabla\eta\left(\nabla u + (\nabla u)^T\right) + \underbrace{\varrho_0 g\beta(T - T_0)}_{\text{Boussinesq term}}$$

$$\varrho\nabla u = 0$$

Boussinesq term

Heat balance from conduction-convection equation

$$\varrho_0 c_p u\nabla T - \nabla(\lambda\nabla T) = 0$$

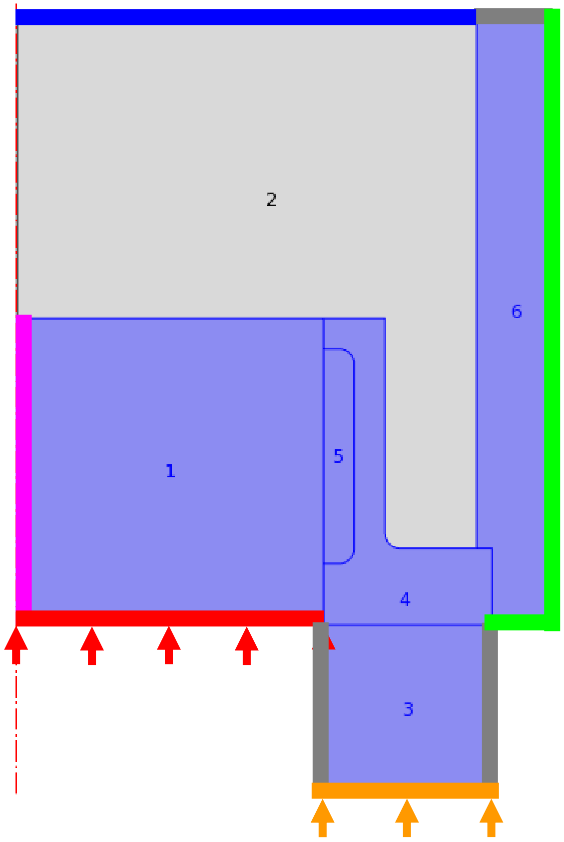
Boundary conditions

Axial Symmetry

Wall 1 → „No Slip", i.e. no fluid movement at the wall

Wall 2 → „Slip", i.e. no viscous effects at the slip wall

COMSOL Implementation (solid part 1)



'Heat Transfer in Solids' (Areas 1, 3, 4, 5, 6)

Steady-state heat equation

$$\nabla(-\lambda\nabla T) = 0$$

Boundary conditions

Axial Symmetry

Heat Flux $\dot{q}$

Temperature (Heater temperature)

Convective Cooling 1 + 2 $\alpha = \frac{Nu\lambda}{L}$, External temperature ϑ_{Sat}

Temperature (Saturation temperature ϑ_{Sat})

Thermal Insulation

- Introduction
- COMSOL Implementation with boundary conditions
- **Results**
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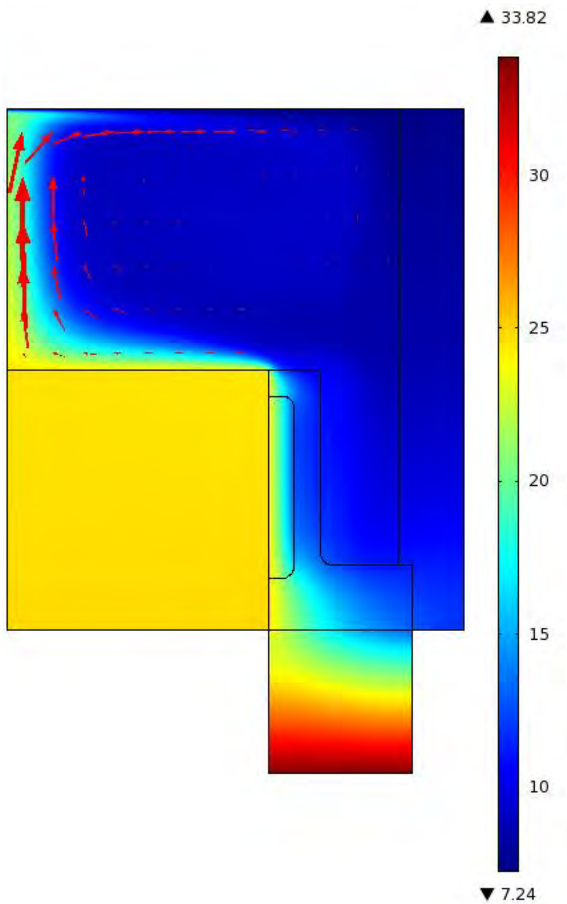
Validation of the model (temperature plot)



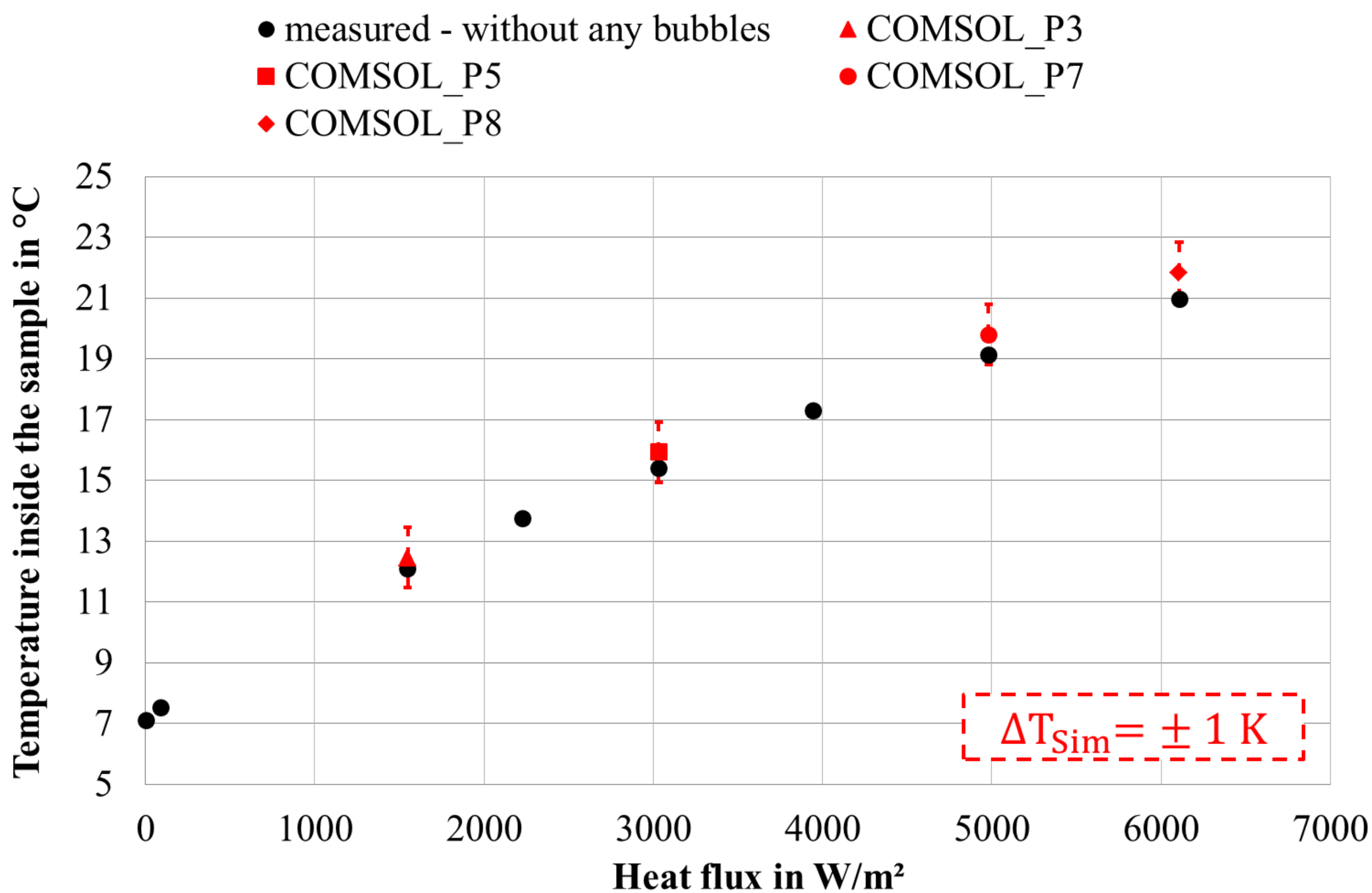
Temperature plot for „COMSOL_P8", i.e. for

- a heat flux input of 6110 W/m²,
- a saturation temperature of 7.24 °C and a
- heater temperature of 33.82 °C.

→ feasible temperature distribution

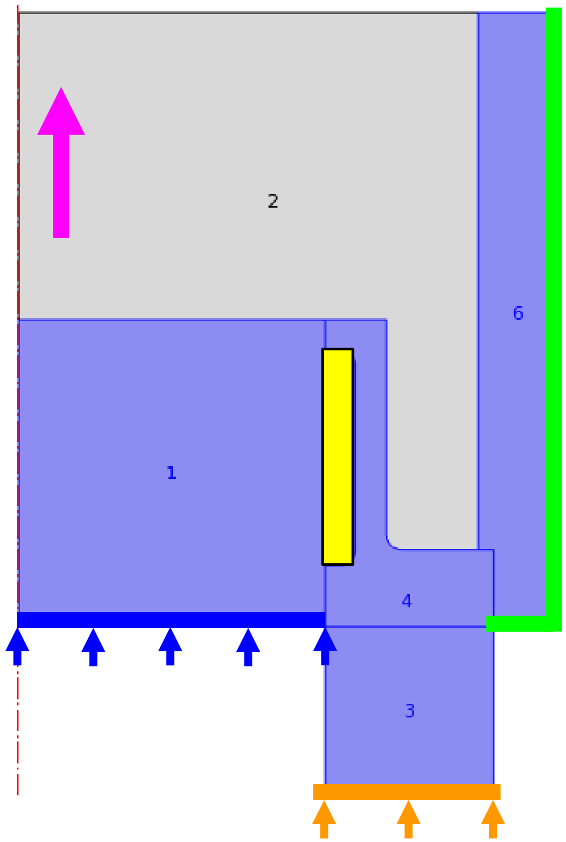
→ feasible vortex orientation analyzing the velocity field

Validation of the model (experimental vs simulation results)



- Good agreement with deviations of 1 K only
- Experimental data are overestimated in each case

Rough Sensitivity analysis (SA)



Aim

To reduce the simulated sample temperature

SA1 → $\vartheta_{Heater} - 6\ \%$

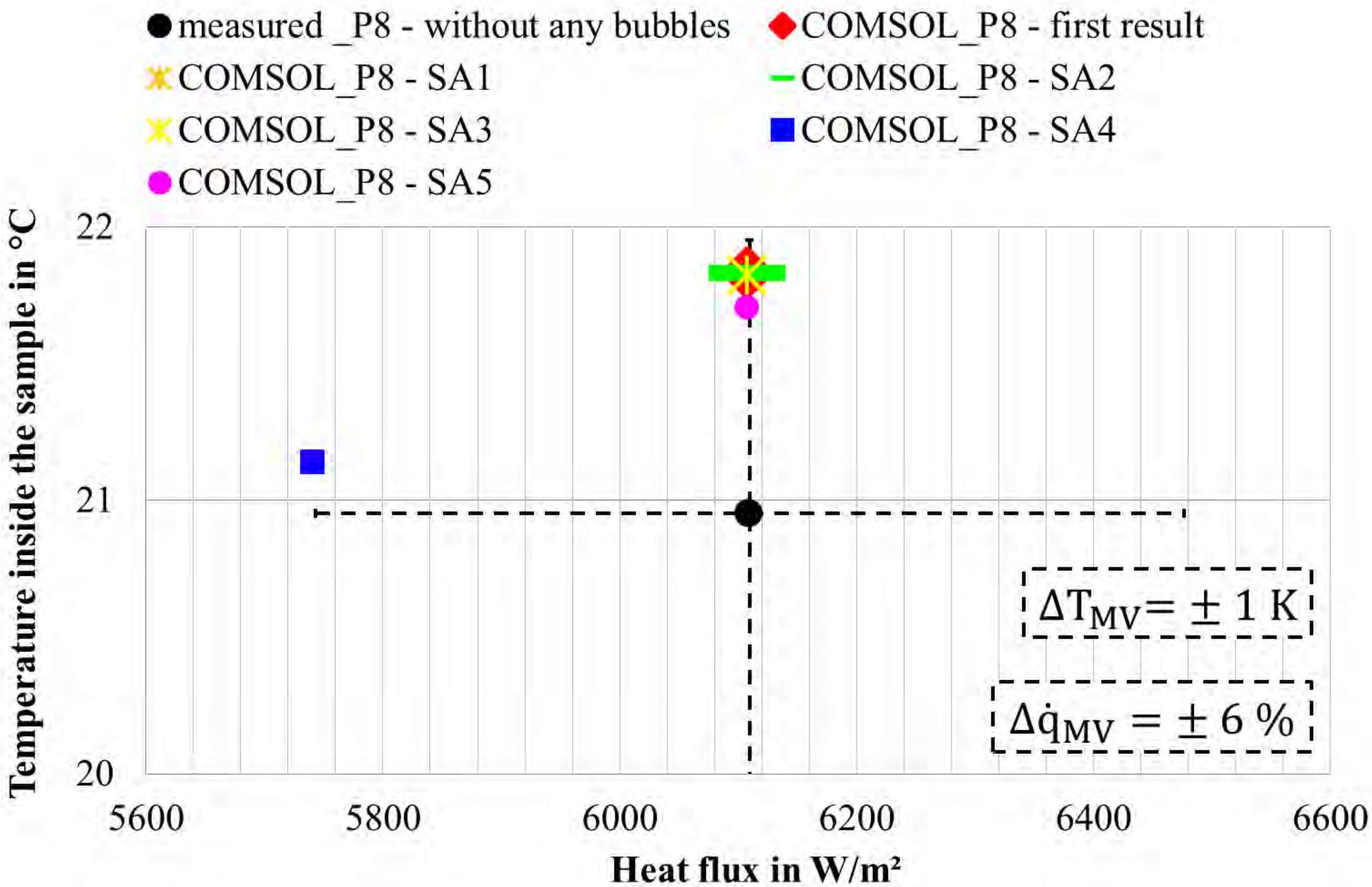
SA2 → $\alpha_{CC} + 6\ \%$

SA3 → $\lambda_{CCR} + 6\ \%$

SA4 → $\dot{q}_{In,HFS} - 6\ \%$

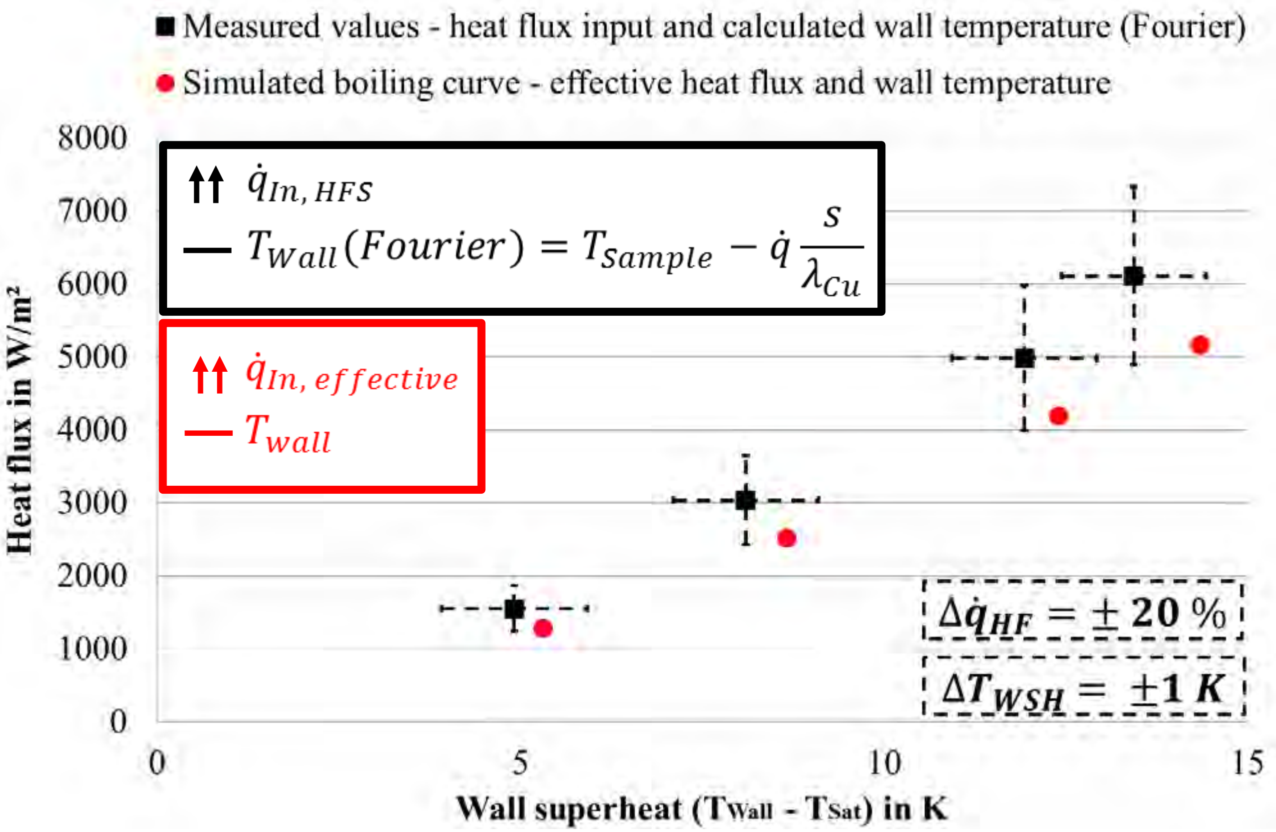
SA5 → $\beta + 6\ \%$ (increasing the buoyancy flow)

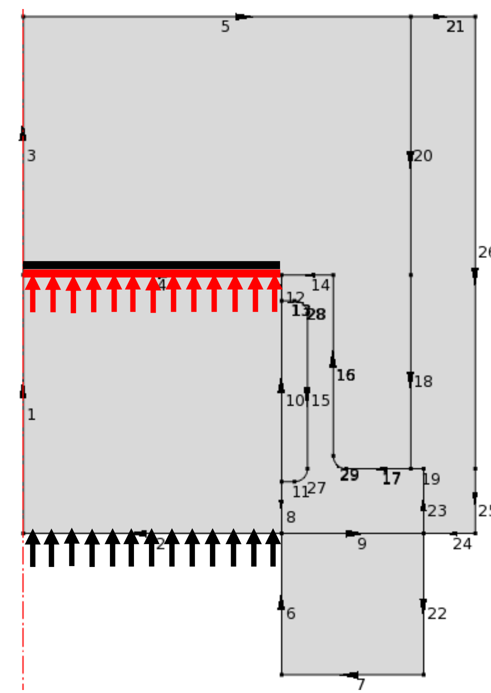
Rough Sensitivity analysis (SA)



- SA4 → most significant influencing parameter
- SA5 → with a decrease of - 0.1 K

Influence of heat losses and gains to the boiling curve of the plain surface structure





- Shows the need for reducing the heat flux (rectification)
- Wall superheat shift → overestimation of the sample temperature

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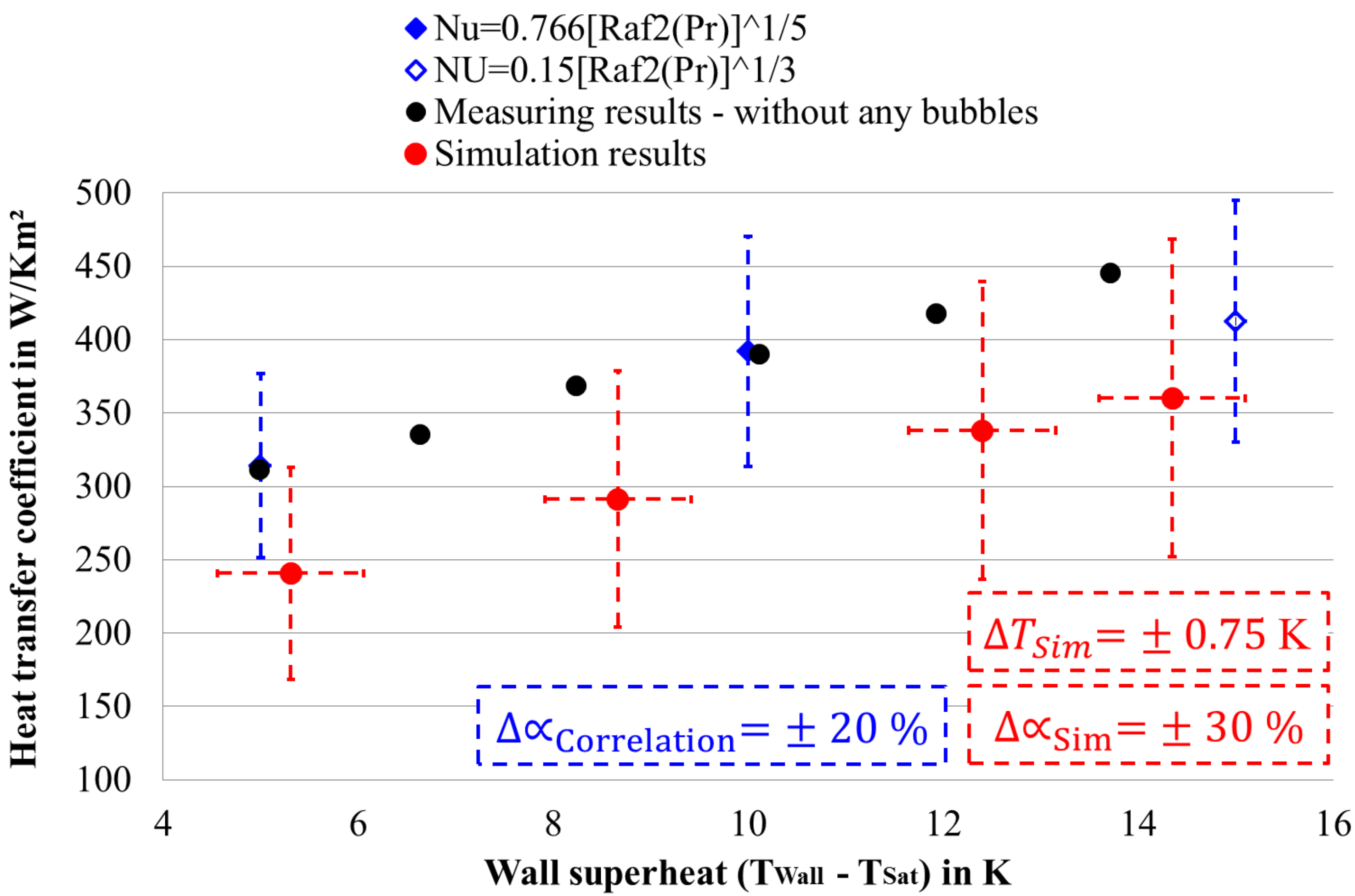
Comparison to literature



- Very good agreement of experimental results and correlation
- Nevertheless, rectifying measuring data seems to be plausible..

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Conclusion

- A reasonable model has been developed in order to estimate heat losses and gains for the boiling curve of a plain surface structure
- Appropriate adaptation parameters have been identified for further adapting the model to experimental data
- The need for rectifying the boiling curve could be shown
- The comparison to literature could show a very good agreement between the experimental data and the correlation BUT simulation results seem to be more plausible

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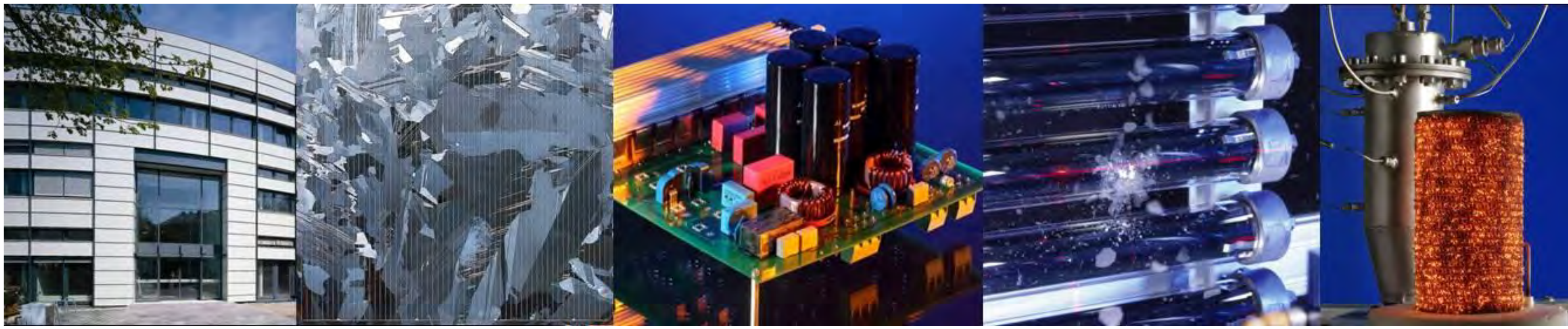
Thank You Very Much for Your Attention!



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