Hochschule Zittau/Görlitz
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Dynamic Segment-Resolved Modeling of NaOH–H_2O Ab- and Desorption in a Falling-Film Heat Exchanger

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Motivation

Thermochemical heat storage based on the NaOH–H_2O system enables seasonal heat storage with high energy density.

Existing models describe only steady-state operation and are therefore unsuitable for control purposes.

A dynamic model is a fundamental prerequisite for model-based control strategies (e.g., Model Predictive Control, MPC).

Time-resolved measurement data are not available; therefore, the focus is on a physically consistent model formulation and validation against steady-state conditions.

Results

The model reproduces the steady-state absorption behavior with a concentration change of $\Delta w = 0.105$ (close to the reference value of 0.10).

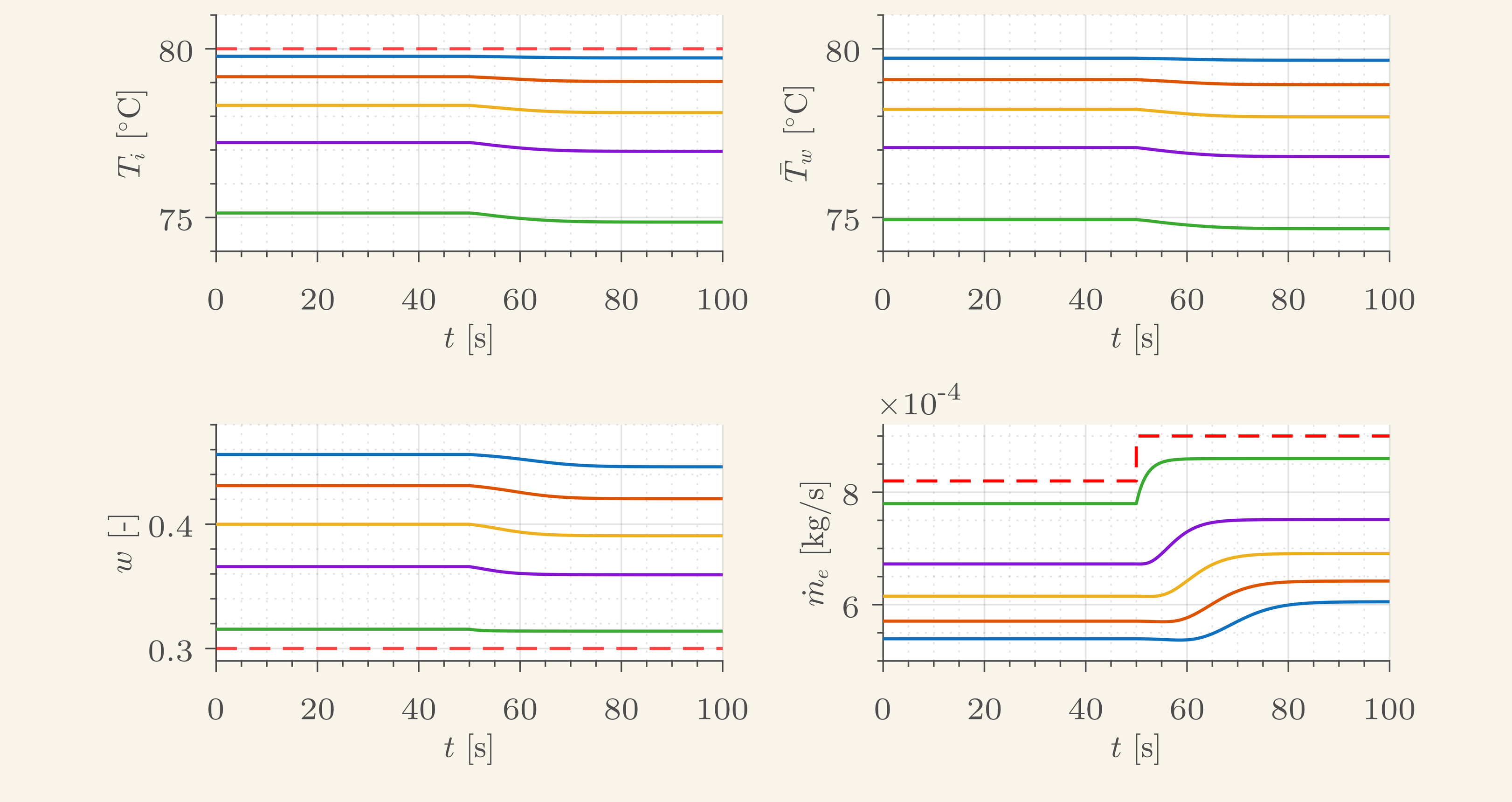
Desorption results in a steady-state NaOH concentration of approximately 45 % (within the reference range of 44–49 %).

Energy balance errors remain below 0.05 %, confirming high numerical consistency and stable implementation.

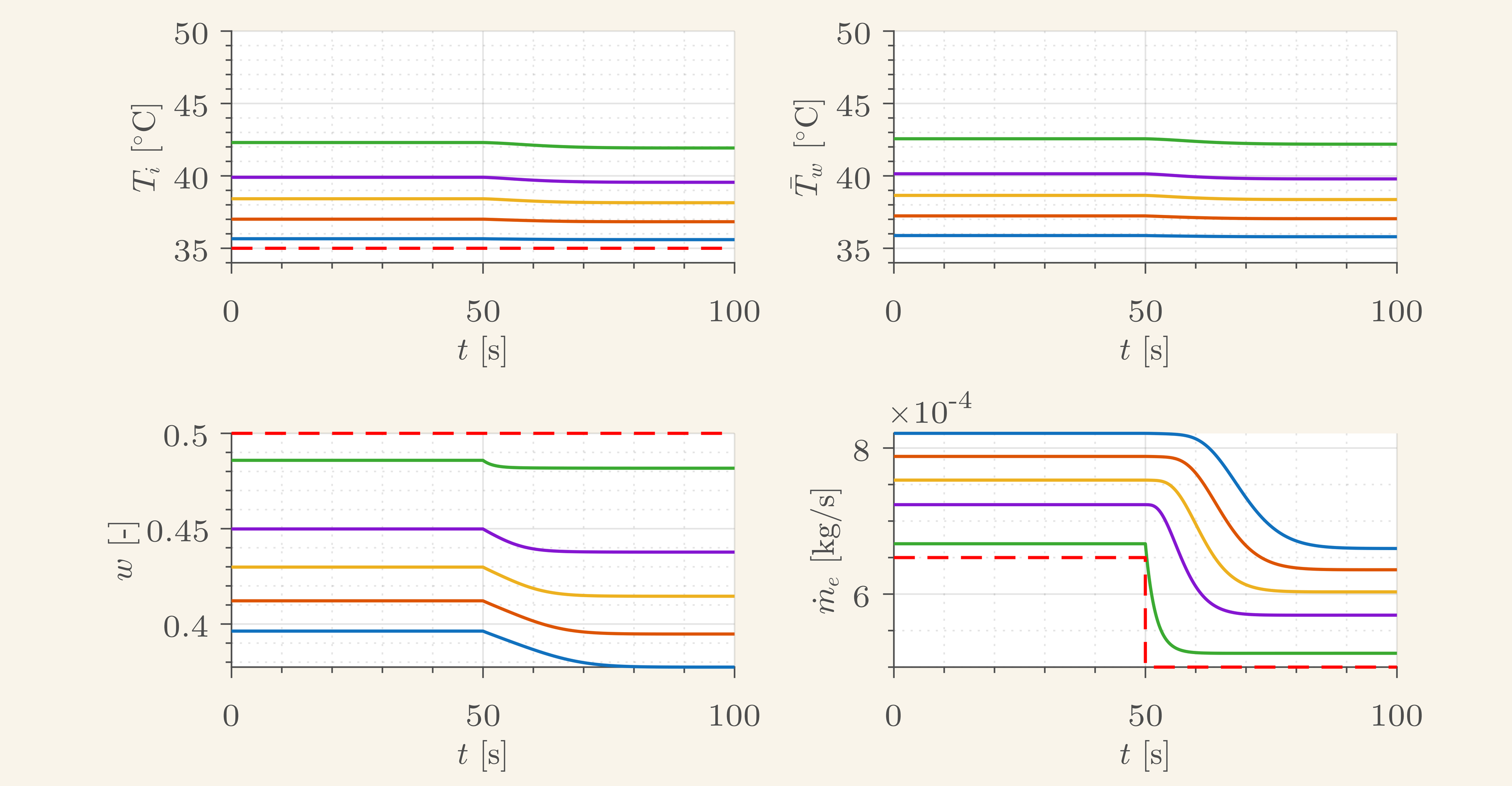
Steady-state results are independent of the PT1 time constant τ (sensitivity analysis).

Model results are strongly influenced by the external heat transfer coefficient and the number of tubes.

Simulation results for Desorption N = 10



Simulation results for Absorption N = 10



Green – Tube 10, Purple – Tube 7, Yellow – Tube 5, Orange – Tube 3, Blue – Tube 1.
Red dashed – prescribed boundary condition values

Methodics

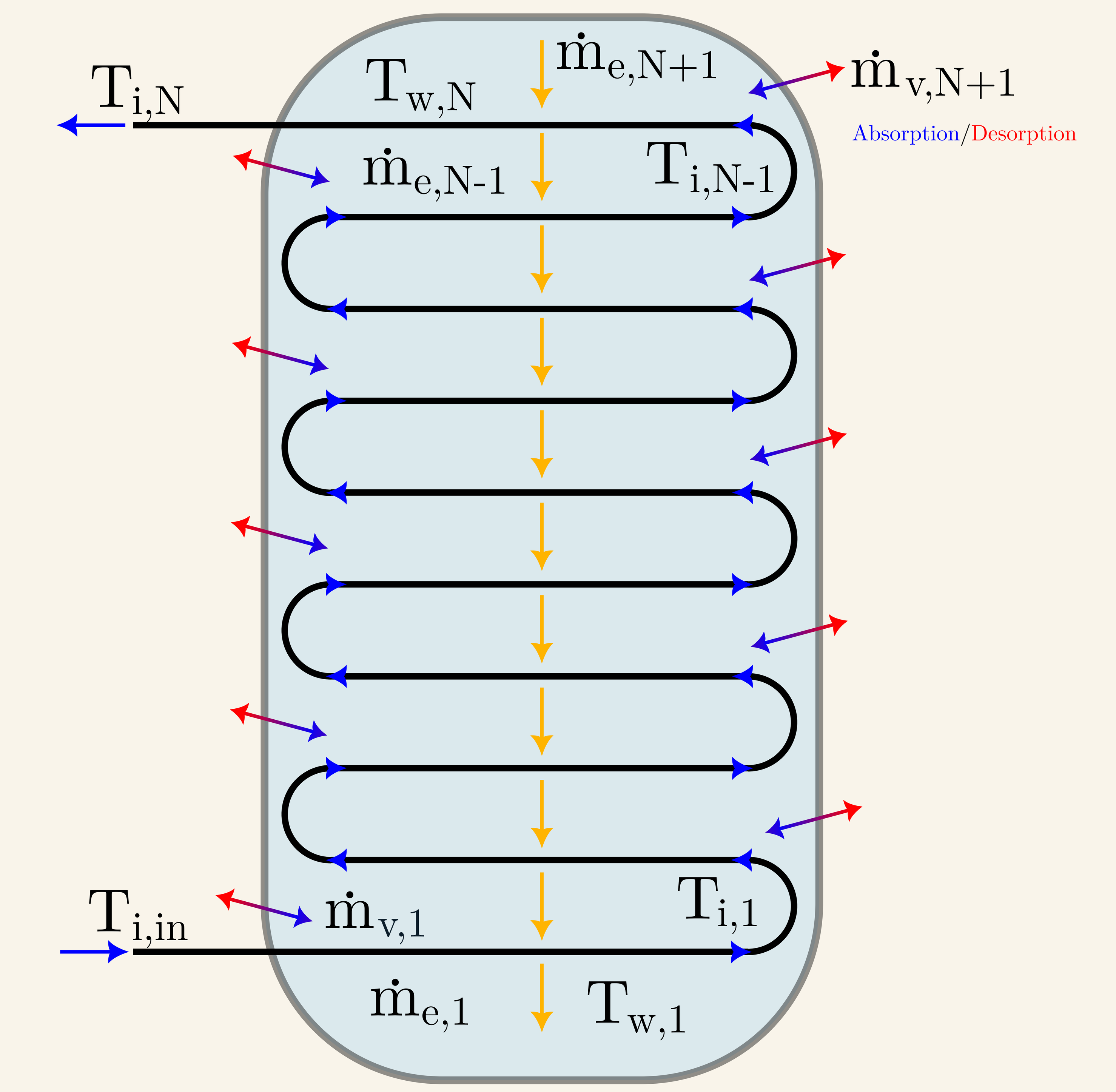
Spatial discretization is performed into N segments (N corresponds to the number of tubes), with each segment described by four coupled ordinary differential equations.

The state variables for each segment are the inner water temperature, wall temperature, external solution mass flow, and concentration.

The dynamics of mass flow and concentration are represented using first-order PT1 elements with a time constant of $\tau = 2$ s (conceptual time scale).

Phase-change mass transfer is calculated iteratively using the Newton–Raphson method under the assumption of thermodynamic equilibrium, combined with property data from a NaOH solution library and steam tables.

Discretization of the Heat Exchanger



Outlook

Further development of the model through dynamic validation using time-resolved experimental data as soon as they become available.

Coupling with a model-based control strategy (e.g., MPC) for operational optimization of absorber and desorber systems.

Extension of the physical model to include axial dispersion, non-ideal flow effects, and detailed film/drop hydrodynamics.

Improvement of the property database (NaOH–H_2O) using experimentally validated correlations within the relevant operating range.

Investigation of scalability to industrial systems (higher capacities, more segments/tubes, alternative geometries).

Development of a reduced-order model for real-time capability and control applications.

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