Advanced Robust MPC Design for Plate Heat Exchanger

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Real processes with heat exchange have usually complex behaviour and are energy intensive. In practical applications, the process variables are always bounded, and it is suitable to include these boundaries into the controller design. The soft-constrained robust model predictive controller has been designed to improve the control performance and energy consumption in comparison with the robust model predictive control with only hard constraints. The plate heat exchanger is a non-linear process with asymmetric dynamics and is modelled as a system with parametric uncertainties. The experimental results confirmed the improvement of the control responses and reduction of energy consumption by introducing the soft constraints into MPC design.

Controlled Heat Exchanger

– liguid to liguid plate-type heat exhanger (Fig. 1),
– model of heat exchanger was identified using experimental data,
– CV: output temperature T,
– MV: volumetric flow-rate of the hot fluid q,
– compensation of non-linear behaviour using a non-linear static characteristic of actuator (Fig. 2).

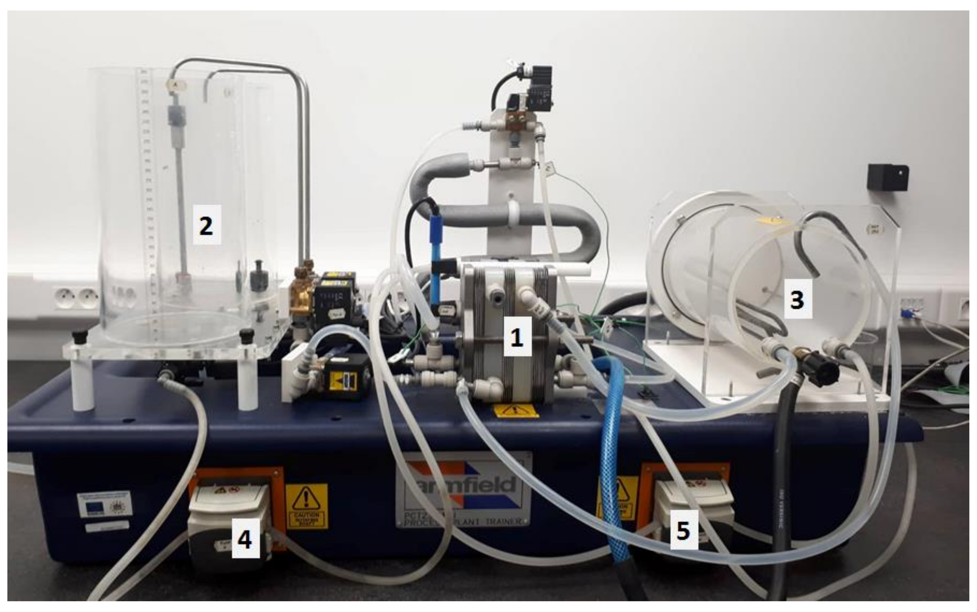

Figure 1: Armfield PCT23, counter-current plate-type heat exchanger (1), retention tanks for cold fluid (2), tank for producing hot fluid (3), pump for cold fluid (4), and pump for hot fluid (5).

Robust MPC Settings

– values of weighting matrices:
$Q_\mathrm{P} = 7 \times 10^{-3},\ Q_\mathrm{I} = 3 \times 10^{-5},\ R = 30, R_\mathrm{soft} = 3 \times 10^{5}$,
– sampling time: $t_\mathrm{s} = 5\,\mathrm{s}$,
– set-point tracking investigated for robust MPC with inactive and active soft constraints (Fig.3-4).

Results of Robust MPC

– offset-free set-point tracking ensured by both control scenarios,
– soft-constrained robust MPC increased the control performance,
– robust MPC with soft-constrained MV ensured the energy savings.

References

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MATLAB toolbox for LMI-based RMPC design.

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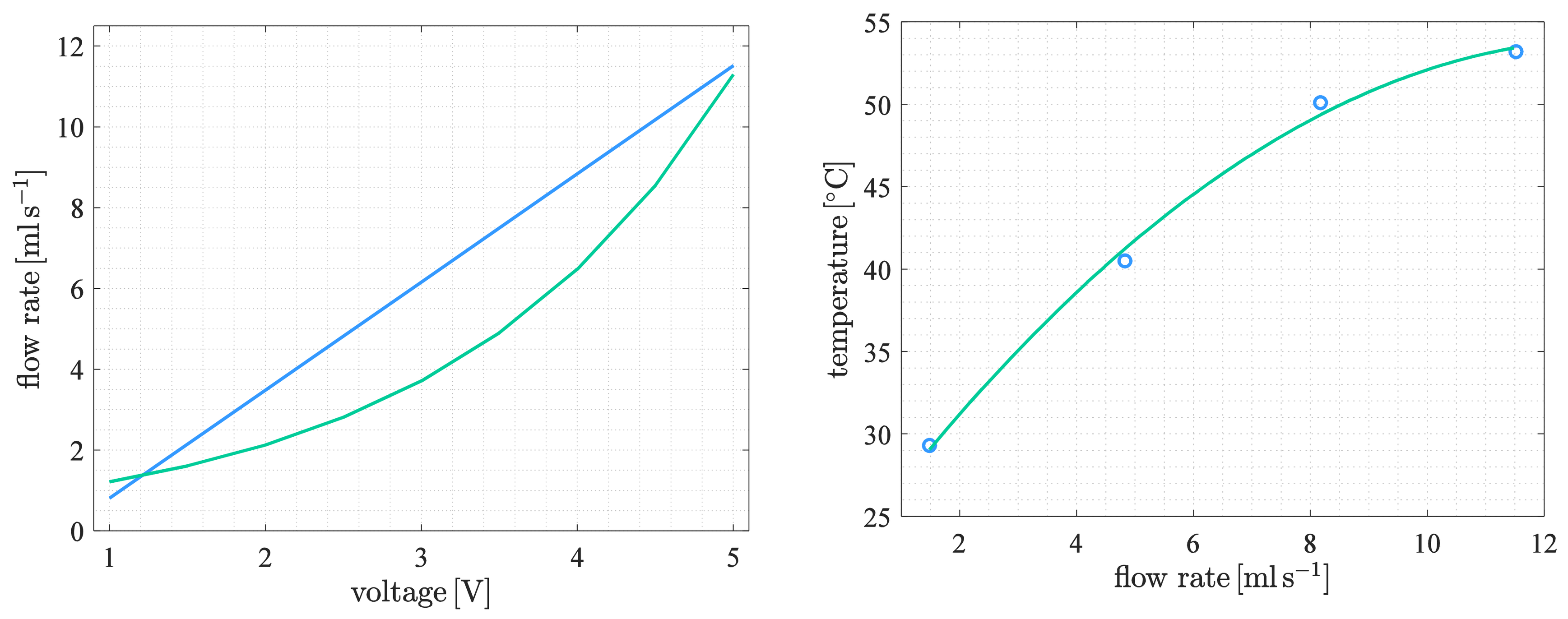
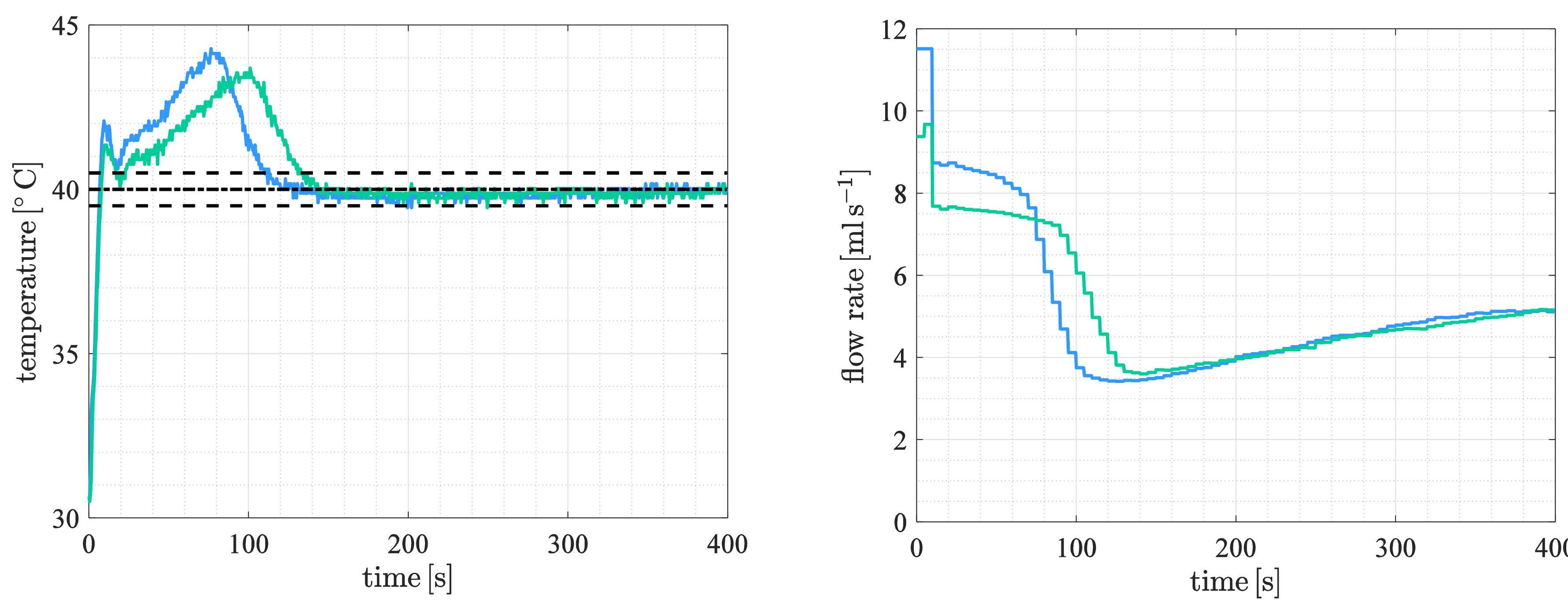
Heat Exchanger Performance



(a) Characteristics of the actuator: linear (blue) and non-linear (green).

(b) Non-linear steady state characteristic of the heat exchanger.

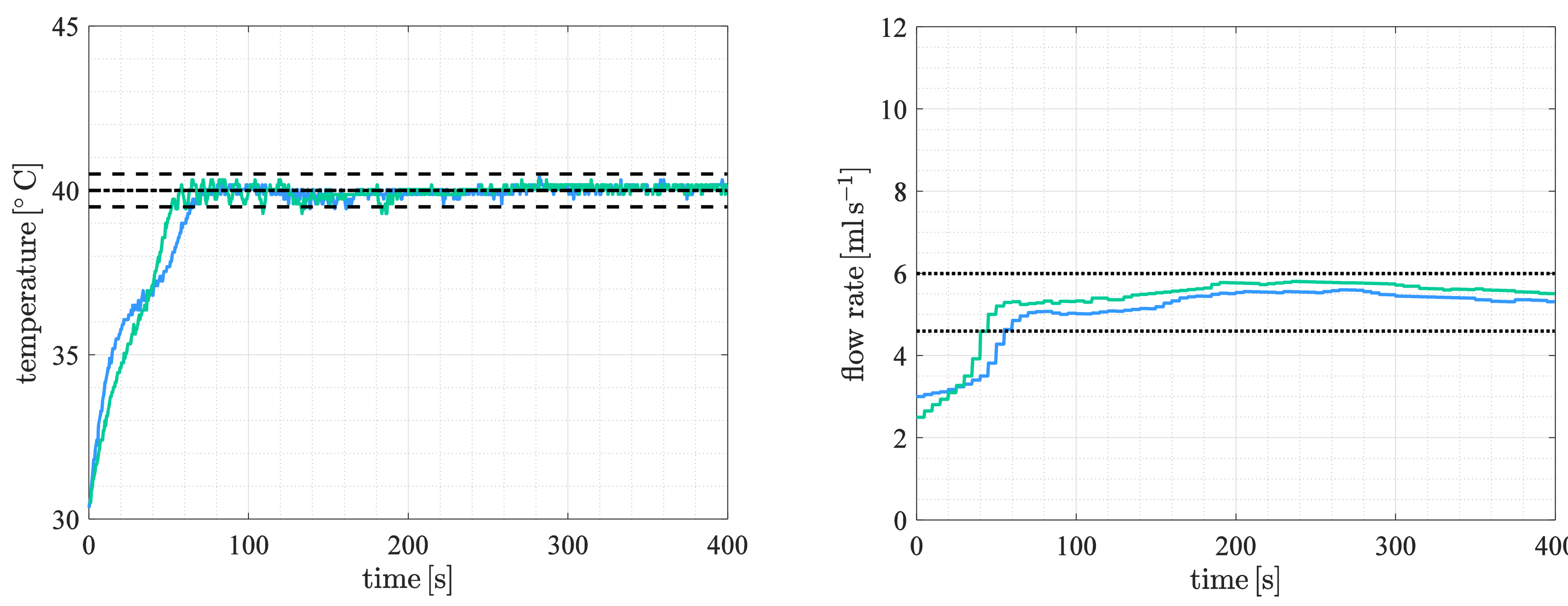
Figure 2: Behaviour of the heat exchanger.



(a) Controlled variable: actuator with linear (blue) and non-linear (green) characteristics, set-point (dash-dotted), and allowed control inaccuracy (dashed).

(b) Manipulated variable: actuator with linear (blue) and non-linear (green) characteristics.

Figure 3: Control performance of robust MPC without soft-constraints.



(a) Controlled variable: actuator with linear (blue) and non-linear (green) characteristics, set-point (dashed-dotted), allowed control inaccuracy (dashed).

(b) Manipulated variable: actuator with linear (blue) and non-linear (green) characteristics, and soft constraints (dotted).

Figure 4: Control performance of robust MPC with soft-constrained MV.

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