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Abstract

The original program (MPC@CB) was developed under Matlab for single input single output (SISO) model predictive control (MPC) for constrained optimization problems (trajectory tracking, processing time minimization...) [1]. The control structure is an adaptation of MPC with internal model control (IMC) structure. In this work, it is adapted for multiple input multiple output (MIMO) constrained systems and validated on a polymerization process.

Process control strategy

Nonlinear model

$$\begin{cases} \frac{dx_m}{dt} = f(x_m, u) \\ y_m = g(x_m) \end{cases}$$

Process :

y_p : measure(s) or estimate(s)

c_i : n_c output(s) constraints

u : constrained input(s)

Optimization formulation

$$\min_p J_{tot} = J(p) + J_{ext}(p)$$

$$J(p) = \sum_{j=k+1}^{k+N_p} L(y_p(k), y_m(j), u(p(j)))$$

$$J_{ext}(p) = \sum_{j=k+1}^{k+N_p} \sum_{i=1}^{n_c} \max^2[0, c_i(j)]$$

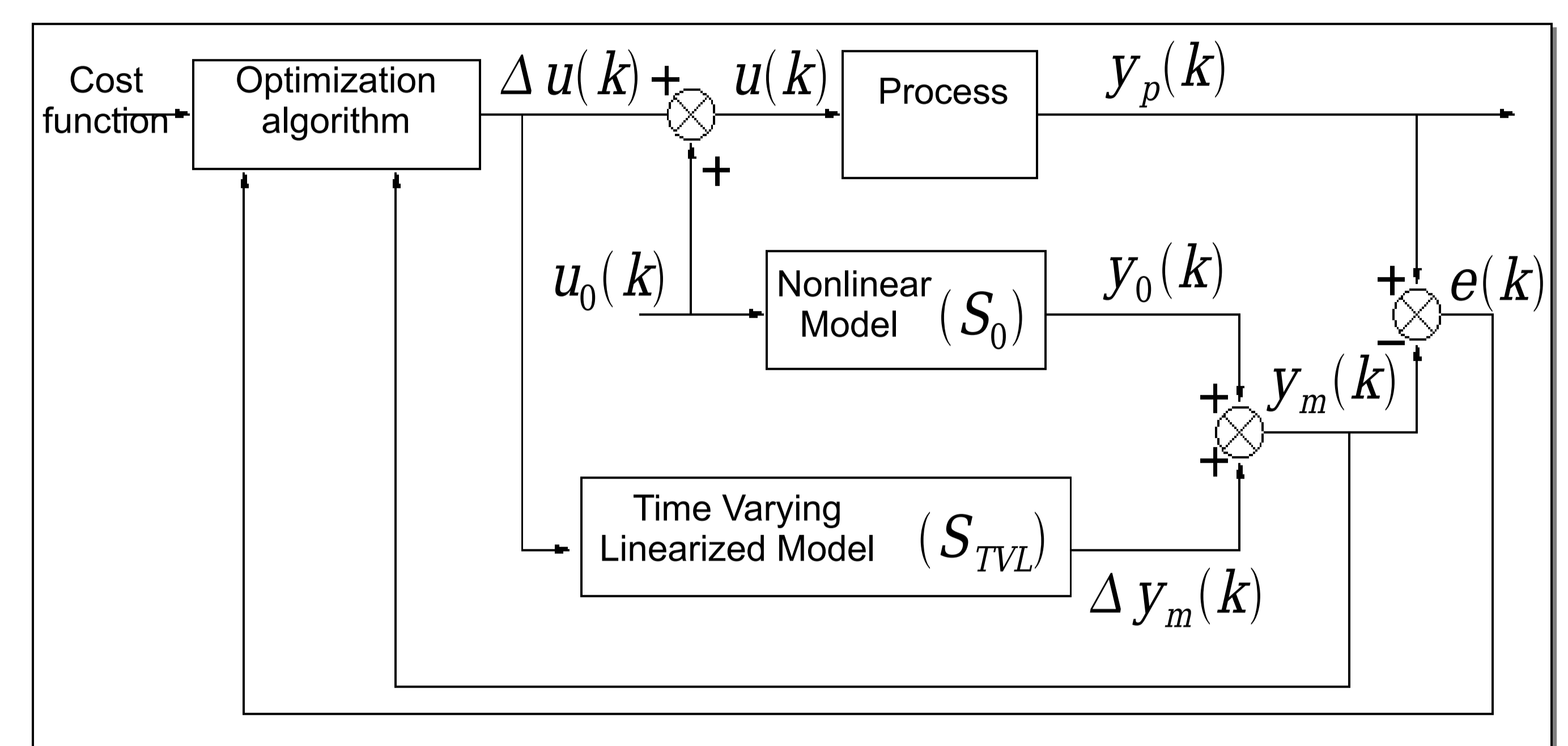
J_{tot} : cost function

p : unconstrained input parameter

N_p : prediction horizon

k : actual discrete time

j : future discrete time



General linearized IMC-MPC structure

MPC@CB software features

The number of states in the SISO or MIMO model is not limited. The model may be linear or nonlinear, time variant or time invariant, based on ordinary differential equations (ODE) and/or on partial differential equations (PDE). A Levenberg Marquardt algorithm based optimizer is used. Simplicity for the user to solve control problems by various choices:

- MPC for a custom cost function (trajectory tracking, processing time minimization...), with or without output constraints
- SISO, MISO, SIMO or MIMO model (a new feature introduced in this work)
- Closed loop control with PID in order to compare the control performances with the MPC
- A software sensor (observer) can be introduced
- Possibility of open or closed loop control
- Possibility of real time application [2]

Case study: Styrene emulsion polymerization

A nonlinear model of emulsion polymerization [3]

4 ordinary differential equations

The state is assumed to be measurable by calorimetry

Objective:

- Maximizing the reaction rate (which implies to attain as fast as possible the maximum allowable heat produced by the reaction)
- Constraint on the concentration of monomer in the particles

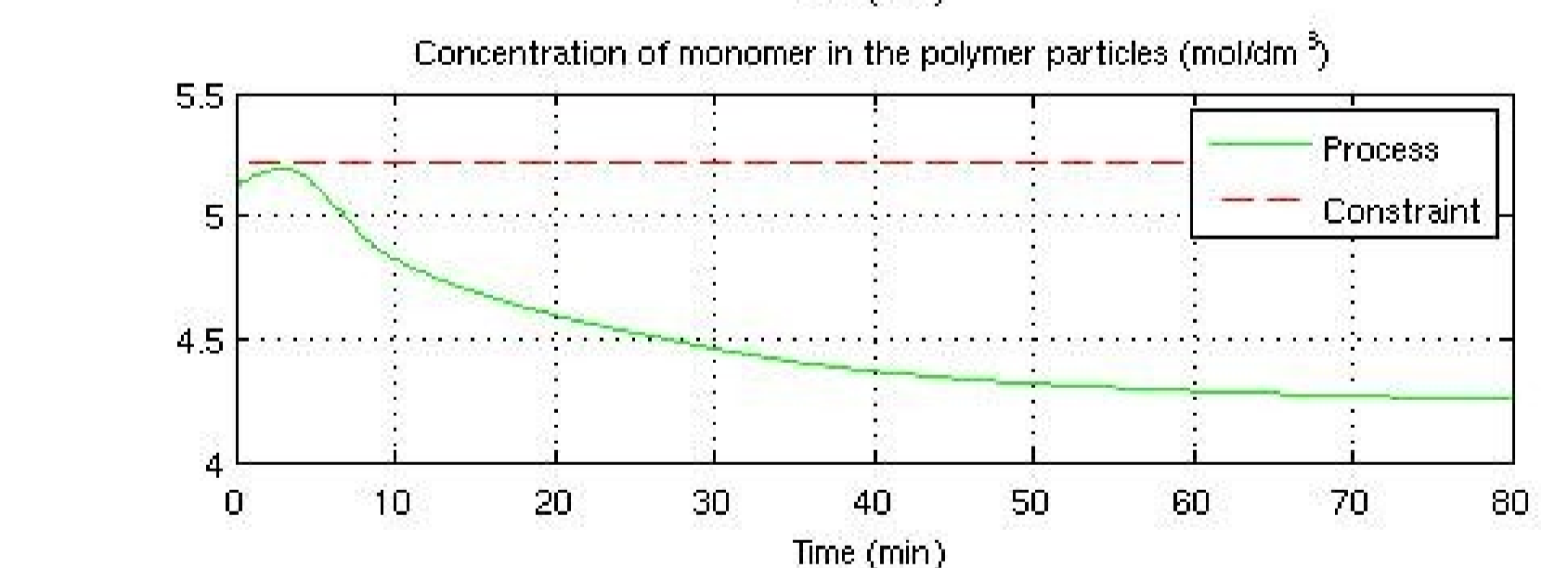
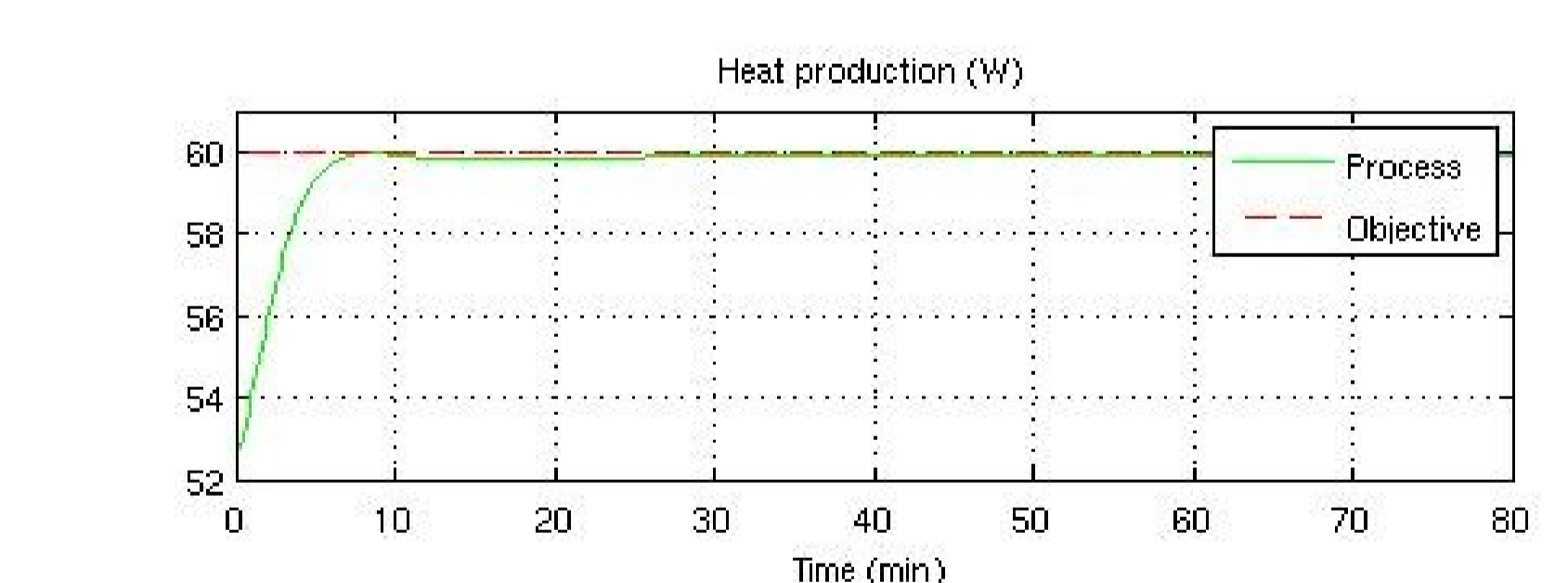
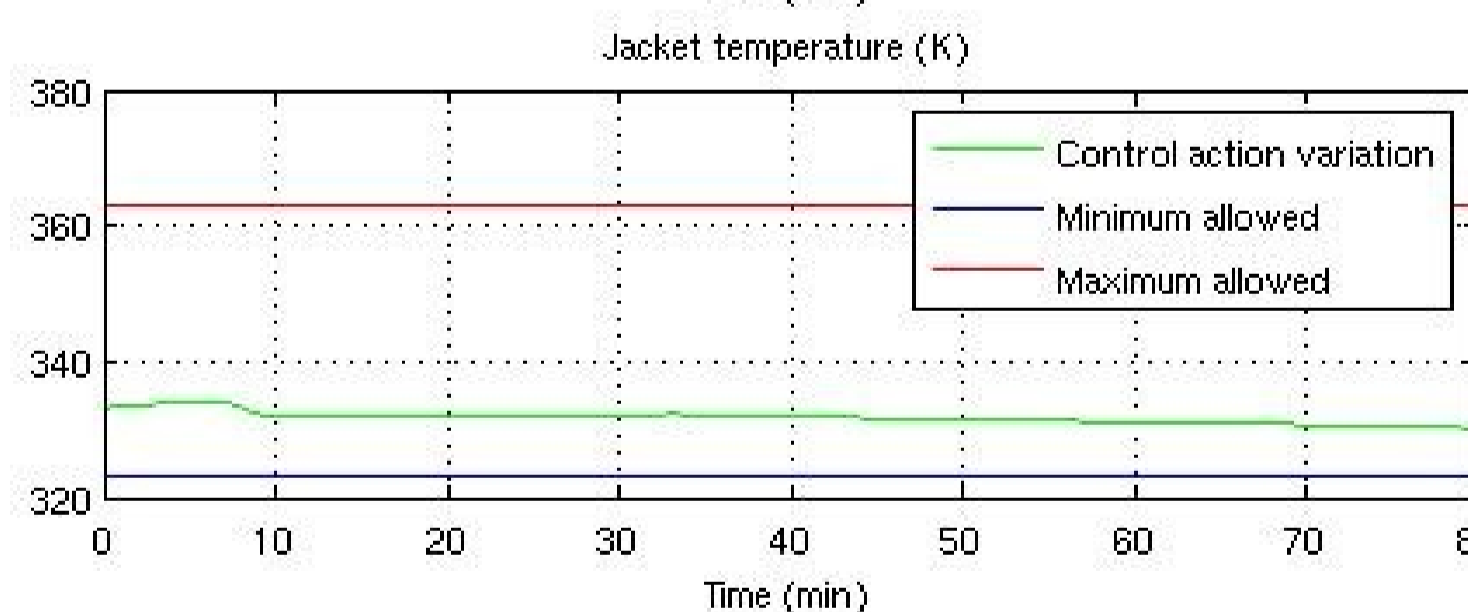
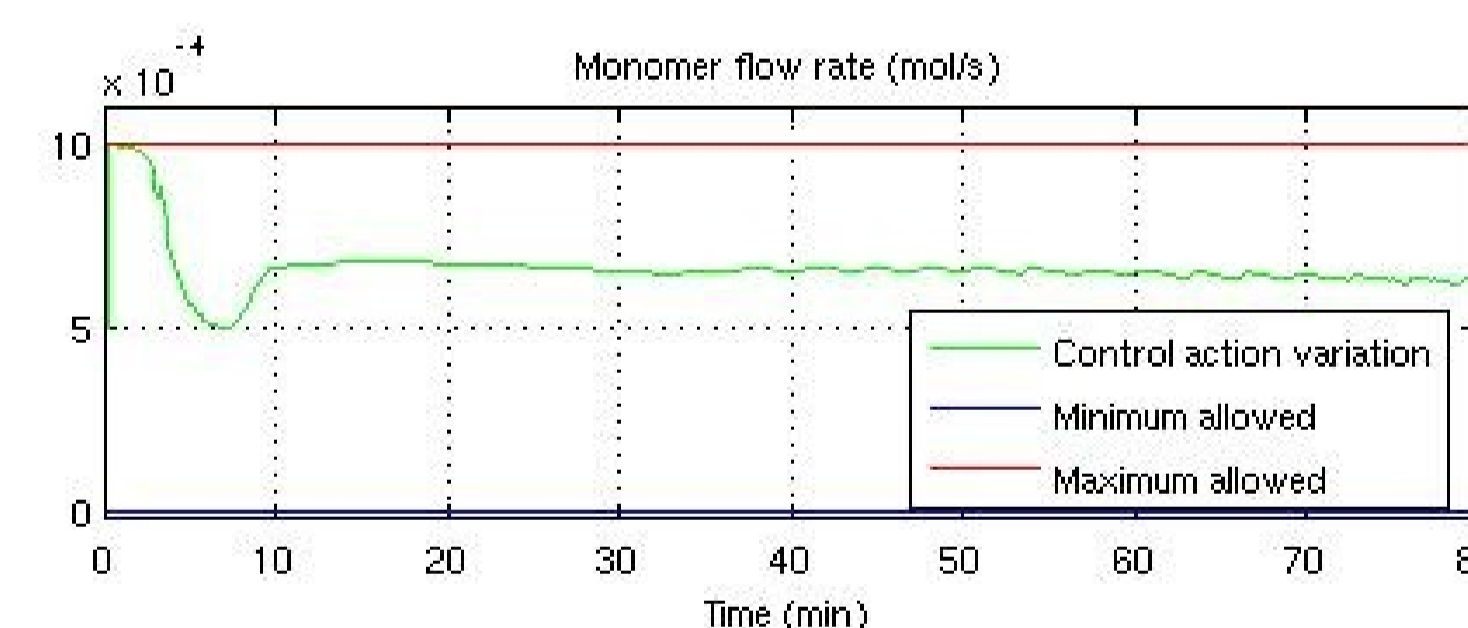
The desired heat production is reached rapidly by manipulating the both monomer flow rate and the jacket temperature.

2 constrained inputs:

- maximal admissible monomer flow rate
- physical limitations of the jacket temperature

2 constrained outputs:

- heat production
- concentration of monomer in polymer particles



Conclusion

MPC@CB software was successfully extended for multi-variable use.

Drawback of MPC is the computational time aspect → MPC@CB algorithm allows decreasing the computational burden during on-line control.

The predictive control strategy used in this software is robust and is tuned by few adjustable parameters.

MPC@CB software offers a turnkey solution for a constrained nonlinear multi-variable predictive control.

Possibilities to control the particle size distribution of a styrene emulsion polymerization (nonlinear PDE) with the multi-variable strategy of this software are under study.

References

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- [3] M. Alamir, N. Sheibat-Othman, S. Othman, Constrained nonlinear receding horizon control for maximizing production in polymerization processes, IEEE Transaction on Control Systems Technology, vol. 15:6, pp. 1167-1182, 2006.