

On the model-based monitoring of industrial batch crystallizers

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On the model-based monitoring of industrial batch crystallizers

Marcella Porru
Dept. of Electrical Engineering, CS
Eindhoven University of Technology
De Zaale, 5612 AJ Eindhoven
The Netherlands
Email: m.porru@tue.nl

Leyla Özkan
Dept. of Electrical Engineering, CS
Eindhoven University of Technology
De Zaale, 5612 AJ Eindhoven
The Netherlands
Email: l.ozkan@tue.nl

1 Introduction

Crystallization is an important separation process to obtain high value-added chemicals in crystalline form from liquid solution in pharmaceutical, food and fine chemical industries. As most of the particulate processes, the quality of the solid product is determined by its particle size distribution (PSD). The achievement of the desired quality targets of the fine crystalline products relies on an efficient online process monitoring for separation supervision and control. However, hardware analyzers able to online measure the PSD and the solute concentration are rarely available, due to their costs [1]. These unmeasured process variables can be estimated by state estimators that combine information from the process model and secondary measurements. The problem of designing state observers for online monitoring the PSD evolution has been mostly addressed under the assumption that some PSD measurements were available (see [6] and literature therein), which is not likely in practice. This work proposes a methodology to assess the feasibility of using common measurements (e.g. temperature and liquid fraction) for estimation purposes based on local observability [2] and detectability [3] arguments. The results are supported using a data-derived technique, with data generated by a simulation model of the industrial crystallizer. Based on the results of the observability analysis, the structure of a state estimator is proposed.

2 Observability analysis for the batch crystallizer

The effectiveness of the process monitoring with state observers depends on the observability and detectability of the nonlinear model of the batch crystallization process. Since temperature and liquid-fraction measurements are commonly available in industry, the feasibility of observing the PSD and the solute concentration through these measurements is evaluated. To this end, the observation spaces are separately calculated for both measurements and the associated observability codistributions are analyzed. It was found that the concentration is distinguishable while the PSD is not. The results of the observability analysis are supported by using the measures of topological relevance (MTR) [5] on the self-organized map (SOM) [4], which is a data visualization technique offering the possibility to display and quantify similarities among the behavior of process

variable.

3 State detectors for online PSD monitoring

The previous results suggest to use a state detector where temperature and liquid-fraction measurements are used to correct the prediction of the temperature, solid concentration, crystallization volume and crystal production, while the PSD is inferred through the model in "open loop" fashion. Preliminary simulation results of the estimator functioning under the assumption of a crystallization process dominated by the crystal growth phenomena show that the estimator with the proposed structure is capable to give a better estimation than the model without corrections when the initial conditions are affected by uncertainties.

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