Isotherm Estimation and Batch Process Optimization for Preparative Chromatography

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Abstract

Since chromatographic separation processes usually cause a significant share of the production cost, model-based methods are currently applied to optimize the design and the operation of these processes. In this thesis two issues of chromatography are considered: one is the numerical estimation of adsorption isotherms from chromatograms, the other one is the set-point optimization of batch chromatography in presence of plant-model mismatch.

Adsorption isotherms are the most important parameters in rigorous models of chromatographic processes. In this thesis, a numerical method to estimate them from chromatograms is proposed. In contrast to existing numerical methods, the isotherms are represented by a neural network. The weights and the biases of the neural network are optimized by a nonlinear least squares algorithm. Due to the universal approximating capability of the neural network, this method could theoretically retrieve any form of isotherm from the chromatograms. Several issues of the method are studied, which include the chosen type of the neural network, the choice of the mapping relationship, the initialization of the neural network, the importance of the experimental design used to generate the chromatograms, and the consideration of the physical role of the isotherms. The potential of the new method is illustrated by both simulation and experimental studies.

For the set-point optimization of batch chromatography in presence of plant-model mismatch, an iterative gradient-modification optimization strategy is proposed. This strategy transforms the model-based optimization problem into a series of modified optimization problems, which generate set-points converging to the true optimum of the plant. As process-dependent constraints have to be met, the model-based constraint functions are modified using measured plant information in order to satisfy the unknown real constraints. The gradients of the plant mapping which are required by the iterative optimization strategy are computed by a technique which considers the influence of measurement errors and the number of additional set-point perturbations. Simulation studies illustrate the potential of the strategy in the set-point optimization of batch chromatography when large structural mismatch is present.

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