Control of Simulated Moving Bed Chromatographic Processes

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1 Introduction

Simulated moving bed (SMB) chromatographic processes are used for continuous separation of mixtures of components with very close physical properties which are difficult to be separated by other processes. These processes have application in the petrochemical, biotechnological and pharmaceutical industries. The process configuration for binary separation consists of preparative chromatographic columns connected to each other forming a ring (Figure 1). The mixture to be separated is fed into the SMB plant through the feed port. The more adsorbed component travels to the extract port while the less adsorbed one travels to the raffinate port. Fresh solvent is introduced through the desorbent port. In order to achieve countercurrent movement of the liquid and solid phases the columns are repositioned in direction opposite to the liquid flow after some time period called switching time. Usually these processes are operated in open-loop mode due to their complexity and because of the high sensitivity to the disturbances at the optimum operating point with minimum solvent consumption, often sub-optimal operating conditions are applied. Here, to hold the process close to the optimal operating point and to reject the disturbances we propose different feedback control strategies.

2 Modelling and Simulation

Mathematical modelling of the SMB chromatographic process leads to a system of partial differential alegbraic equations (PDAEs):

$$\begin{cases} \varepsilon \frac{\partial C_{i,k}}{\partial t} + (1-\varepsilon)\frac{\partial q_{i,k}}{\partial t} + \varepsilon v_k \frac{\partial C_{i,k}}{\partial z} = \varepsilon D_{ax}\frac{\partial^2 C_{i,k}}{\partial z^2} \\ \frac{\partial q_{i,k}}{\partial t} = k_{m_{i,k}}\left(q^*_{i,k}(\boldsymbol{C}) - q_{i,k}\right) \\ q^*_{i,k} = f(\boldsymbol{C}) \end{cases} \quad (1)$$

where the first equation describes the change of the concentration of the components in the liquid phase, the second in the solid phase, and the third one describes the thermodynamic equilibrium between the two phases and it is called adsorption isotherm. For the solution of this system in our previous work [1] we used a numerical algorithm based on the conservation element/solution element (CE/SE) method.

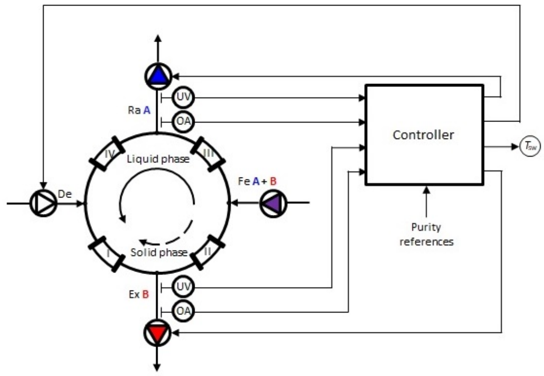

Figure 1: SMB process with the control configuration

Results showed that this method is faster than the popular cell method used in some commercial chromatographic simulators which makes it a suitable choice for use in on-line optimizing control such as model predictive control (MPC).

3 Control Strategy

For the control of the SMB process, classical PID control, as well as MPC, are developed and discussed, highlighting their respective advantages and disadvantages. The goal of the controller is to maintain the product purities at the specified reference values while at same time minimizing the solvent consumption. To achieve this in real time, information from the SMB plant is needed. The product purities are measured by an online analytical analyzer and the concentration front movements inside the columns are detected by two UV sensors on each of the outlet ports. Manipulated variables are the cycle duration T_{sw} and the liquid flow rates inside every column which are maintained by the pumps on each of the outlet ports as well as on the desorbent port. The feed flow rate is specified from the upstream operations and acts as a disturbance which has to be rejected by the controller.

References

[1] Chernev; Vande Wouwer; Kienle, *Efficient Simulation of Chromatographic Processes Using the Conservation Element/Solution Element Method*. Processes 2020, 8, 1316.