Abstract for David Harvey

Continuous chromatography is an attractive alternative to traditional batch chromatography because it can have higher productivity, solvent efficiency, and product concentrations. However, several barriers prevent further use continuous chromatography. There are many operating parameters that must be determined when designing continuous systems making it difficult to achieve high purity, yield, and productivity. Through the identification and strategic combination of the key dimensionless groups that control a continuous separation, it is possible to design highly productive systems that produce products with high yield and high purity. In this dissertation, three examples were selected to demonstrate the significance of a model-based method when designing continuous chromatography systems. (1) The Speedy Standing Wave Design and simulated moving bed splitting strategies for the separation of ternary mixtures with linear isotherm. (2) The Standing-wave Design of Three-Zone open-loop non-isocratic SMB for purification. (3) The Continuous Ligand-Assisted Displacement for the separation of Rare Earth Elements.

In the first example, the Speedy Standing Wave Design equations were developed for multicomponent separations with linear isotherms and a systematic splitting strategy was developed for the design of multiple sequential Simulated Moving Beds (SMBs). By performing the easiest split first, the overall productivity and solvent efficiency can be significantly improved. Rate model simulations were used to verify that the SSWD equations achieved target yields and purities. In systems where only one component is desired, the sorbent should be selected such that this component is the most or least retained so that it can be separated in a single SMB.

In the second example, the Standing Wave Design Method was extended to non-isocratic three zone open loop SMBs. That standing wave design equations were derived and then verified using rate model simulations. In two case studies it was shown that non-isocratic SMBs designed using the standing wave design show an order of magnitude higher productivity than a comparable batch system when the impurities are weakly adsorbing. When the impurities are competitive, the SWD method produces SMB systems with 2 orders of magnitude higher productivity than comparable batch systems. Because the design is based on dimensionless groups, the resulting designs are easily scalable and no rate model simulations are required to design high yield, high purity, and high productivity SMBs.

In the third example, the constant pattern design method was extended to continuous LAD systems. A continuous operation mode was developed that reduced the cycle time of LAD systems

to further increase the productivity. In cases where the feed was equimolar, the continuous configuration increased the productivity between 20-50%. A multizone continuous LAD configuration was developed for the separation of a complex mixture of Dy, Nd, and Pr that simulated a crude magnet feed. The resulting overall productivity for this system was 190 kg/m^3day which was two orders of magnitude higher than a single column batch system and 70% higher than a multizone batch system. The robustness of the constant patter design method was demonstrated through a simulated case study and it was determined that adding a safety factor through the reduction of the flowrate was more effective than reducing the design length.

Using a model-based design allows for the consistent design of continuous chromatography systems. The effects of a change in a feed or operating condition can be more easily understood through the lens of the model. This means that adjustments can be made pre-emptively when necessary and the new designs can be tested with virtual experiments before being implemented. The understanding of key dimensionless groups allows for designs that meet key design criteria at all scales of operation and thus allows for the easy transition from one scale to another.