472b Design of a Tame Reactive Distillation Process Using Feasible Regions

Scott L. Turnberg, Warren R. Hoffmaster, and Steinar Hauan

Traditional process synthesis involves decomposing the problem into unit operations. These unit operations include reactors, mixers, separators and heat exchangers. One problem with this approach is it does not take into account hybrid units that perform multiple operations. Process intensification through hybrid units is able to realize dramatic increases in capital and utility savings. However, limited conceptual design methods for multifunctional units have hindered adoption of this technology. We will present a conceptual design approach for reactive distillation and demonstrate this approach in the design of a TAME synthesis process.

Based on difference points, we have shown how feasibility of a full column emerges from feasibility of column sections[1]. This applies to columns with extractive side feeds, side products and reactive stages. From this knowledge we are able to construct feasible regions for column section [2]. Feasible regions are important tools in the conceptual design of distillation systems, limiting the possible solution space and giving insight into the system.

TAME is formed by the etherification of two isomeric isoamylenes with methanol. In total the system consists of four components and three kinetically controlled reactions. The traditional TAME process has a reactor followed by a distillation system with a significant amount of recycle. Previous attempts at intensifying the process have included adding catalytically active stages to the product distillation column, as well as a second reactor fed by a column side stream [3]. We have previously identified an alternative approach where a side product is recycled to the primary reactor, eliminating the need for a second reactor[4]. In this design the reactor effluent, feeding the column, is distributed over multiple column stages.

In this paper we will use feasible region analysis of column sections to find feasible and optimal process alternatives for TAME synthesis. We will present a conceptual approach to design based upon difference points and feasible regions. We will show the range of design parameters including catalyst densities, and the location of side draws and side feeds. We will use feasible regions to find the ranges of valid operating parameters including side stream flow rates. Finally, we will analyze the economic benefit of design alternatives in terms of liquid holdup and recycle flow rate.

References:

[1] Hauan,S. and Ciric, A.R. and Westerberg, A.W. and Lien, K.M. "Difference points in extractive and reactive cascades. I - Basic properties and analysis." Chem.Eng.Sci. 59(17): 3671-3693, 1999.

[2] Hoffmaster, W.R. and Hauan, S. "Difference points in extractive and reactive cascades. III - Properties of column section profiles with arbitrary reaction distribution." Chem.Eng.Sci. 55(16): 3145-1075, 2004.

[3] Aittamaa, I.E. and Eilos, I. and Jakkula, J. and Lindqvist, P. "Process and apparatus for preparing tertiary alkyl ether." U.S. Patent 5,637,777, 1997.

[4] Hoffmaster, W.R. and Hauan, S. "Designing complex reactive columns with feasible regions to optimize feed distribution, catalyst placement, and column pressure." Proceedings of FOCAPD 2004, pp 269-272, Princeton, NJ, July 2004.