SYNTHESIS OF ENERGY EFFICIENT SEPARATION PROCESSES USING DISTILLATION AND MEMBRANES

Rakesh Agrawal, School of Chemical Engineering Purdue University, West Lafayette, IN 47907
agrawalr@purdue.edu

With 90 – 95% of all separations in the chemical and petrochemical plants, distillation is among the predominant unit operations. According to one estimate in the literature, there are approximately 40,000 distillation columns in operation in the U.S. with energy consumption equivalent to 1.2 million barrels of crude oil per day. It is therefore essential that more efficient distillation configurations, which are also cost effective, be identified for all applications. However, the prevailing industrial practice whereby a distillation train is synthesized based on heuristics, experience, and creativity of the process designers is far from optimal.

We will first discuss our recent work on the synthesis of nonazeotropic multicomponent distillation configurations. It is known that the number of possible distillation configurations increases rapidly in hundreds and thousands as the number of components in a n – component mixture increase beyond three ($n > 3$). Therefore, the first challenge for a process engineer is to be able to draw all feasible configurations and then narrow down the search to a set of suitable candidates. An easy to use systematic procedure to draw distillation column configurations to separate a nonazeoptropic n – component mixture into n product streams each enriched in one of the components will be presented. We will then share our success with nonlinear programming to optimize thousands of distillation configurations with respect to total heat duty.

Next, progress in energy saving distillation columns will be discussed that will include, (i) synthesis of new heat and mass integrated columns, and (ii) solution for a long standing challenge of controlling vapor split in dividing wall columns. The new method enables process intensification whereby any thermally coupled column configuration can be drawn as a divided wall column configuration leading to reduction in the number of columns.

For membrane based separations, when high product purities and high recoveries are required, use of a cascade is generally needed. Due to cost considerations, it is desirable to minimize the number of recycle compressors/vacuum pumps used in such cascades. Historically this led to drawing of such cascades through inventive activity of process engineers. Here we will present a method to systematically synthesize such membrane cascades.

Finally, we will end the presentation by drawing analogy between distillation and membrane processes for the separation of a multicomponent mixture.