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Optimal design of distillation systems with less than $N-1$ columns for a class of four component mixtures

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ABSTRACT

The optimal design of complex distillation systems is a highly non-linear and multivariable problem, with several local optimums and subject to different constraints. In addition, some attributes for the design of these separation schemes are often conflicting objectives, and the design problem should be represented from a multiple objective perspective. As a result, solving with traditional optimization methods is not reliable because they generally converge to local optimums, and often fail to capture the full Pareto optimal front. In this paper, a method for the multiobjective optimization of distillation systems, conventional and thermally coupled, with less than $N-1$ columns is presented. We use a multiobjective genetic algorithm with restrictions coupled to AspenONE Aspen Plus; so, the complete MESH equations and rigorous phase equilibrium calculations are used. Results show some tendencies in the design of intensified sequences, according to the nature of the mixture and feed compositions.

Keywords: Multicomponent distillation; Multiobjective optimization; Genetic algorithms; Pareto front

1. Introduction

Distillation is a widely used separation process, and, also, a very large consumer of energy. A large amount of research work has been done to improve the energy efficiency of distillation systems, in terms of either the design of optimal distillation schemes or improving internal column efficiency. Nowadays, the optimal design of multicomponent distillation systems remains one of the most challenging problems in process engineering (Kim and Wankat, 2004). The economic importance of distillation separations has been a driving force for the research in synthesis procedures for more than 30 years.

For the separation of an N-component mixture into N pure products, as the number of components increases the number of possible simple column configurations sharply grows up. Thereby, the selection of the best configuration for certain mixture was a very large and time consuming problem. This was one main reason that conducts researchers' work in searching general rules, heuristics, able to make a preliminary screening to select a lower number of alternatives to analyze. The selected configurations can be subsequently analyzed with a rigorous method to find the best sequence in terms of energy requirement (Nath and Motard, 1981; Nadgir and Liu, 1983).

At the moment, most of the studies have been focused on complete separation of N component mixtures using $N-1$ distillation columns, with a reboiler at the bottom and a condenser at the top of each column. Glinos and Malone (1989) show the application of thermodynamic principles to the synthesis of distillation sequences. While economic criteria are preferable for synthesis in the general case, the thermodynamic analysis has an advantage when heat integration of the distillation system is planned, or to further

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