Synthesis of Nonsharp Distillation Sequences with Simultaneous Heat Integration and Thermal Coupling

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Abstract

By using nonsharp split as a prefractionator in a multicomponent distillation column system, the thermodynamic irreversibility can be avoided and the energy consumption can be significantly reduced compared to the sharp distillation systems. However, few researchers focused on the synthesis of distillation sequences allowing nonsharp splits with more than one middle component and considering heat integration and thermal coupling simultaneously. This paper proposes a new approach to synthesize heat-integrated thermally coupled distillation (HITCD) configurations, which allow more than one middle component to distribute in nonsharp splits. Thermal coupling and heat integration are introduced simultaneously when synthesizing a distillation configuration. The objective is to obtain the optimal distillation configuration for separating mixtures containing N (N≥4) components into N relatively pure products with a minimum total annual cost. Based on the establishment and traversal of binary tree, a new encoding and decoding method is adopted to represent the separation sequences. A sorting algorithm is developed to identify the interconnections between separation tasks and streams. The thermal coupling structures are equivalently represented by a group of 0-1 integer variables. Through an improved simulated annealing (ISA) algorithm, the complex optimization problem can be effectively solved. As discrete variables, the separation sequences and thermal coupling structures are updated and optimized randomly at a specified probability in the outer loops of the ISA algorithm. For a fixed separation sequence and thermal coupling structure, the operating variables (operating pressure, recoveries of the key components and reflux ratio) of each separation task are updated and optimized in the inner loops. Each separation task is designed through the conventional Fenske-Underwood-Gilliland method. For any identified distillation configuration, its optimal heat integration matches can be determined through the pinch analysis method. Finally, the feasibility and high computational efficiency of the proposed approach are illustrated by an example problem. It’s proved that HITCD configurations can significantly reduce the total annual cost compared with conventional
configurations as well as configurations employing either heat integration or thermal coupling alone.