ABSTRACT

Process intensification has been identified as the need to develop smaller, cleaner, and more efficient technologies. Because of low thermodynamic efficiency and high energy consumption, distillation is one of the natural candidates for intensification. By lowering the energy demands in the reboiler of the intensified distillation processes, such improved schemes would also have a positive and long-term effect on several factors, such as operating cost and importantly, CO_2 emissions. The intensification in distillation processes can be achieved by means of heat integration. The present research work aims at exploring the feasibility of heat integration by the use of vapor recompression scheme in batch distillation.

It has long been recognized that the highly irreversible operation of batch distillation involves more wastage of energy compared to continuous flow distillation. Although the direct vapor recompression column (VRC) has been known for its application in continuous distillation since the 1960s, the research on vapor recompressed batch distillation (VRBD) has not started yet.

In this research work, we propose the introduction of vapor recompression system in batch distillation columns. This VRBD arrangement accompanies an isentropic compressor that runs at a fixed as well as variable speed. Aiming to ensure the optimal use of internal heat source, an open-loop control policy is proposed for the VRBD that manipulates either the overhead vapor splitting or the external heat supply to the reboiler. The variable speed VRBD additionally involves the adjustment of compression ratio. By simulating a batch distillation column, we investigate the superiority of variable speed VRBD over its fixed speed counterpart in the aspects of energy savings and total annualized cost. In the subsequent studies, therefore, the variable speed VRBD is selected for exploring its novel applications and further advancement.

To overcome the requirement of long batch time for regular batch distillation columns, the two batch column configurations, namely the middle vessel batch distillation and the batch distillation with a side withdrawal, have emerged as attractive alternatives. Aiming to improve further the energetic potential, in this contribution, we explore the economic feasibility of using VRC scheme in these two relatively new batch columns.

A closed-loop control algorithm is developed for the VRBD scheme to meet the end objective of relatively high-purity product discharged at a constant composition. Finally, we simulate a reactive multicomponent and a nonreactive binary batch column to investigate the impact of vapor recompression on energy consumption, cost and greenhouse gas (i.e., CO_2) emissions between the open-loop and closed-loop VRBD schemes.

Keywords: Vapor recompression in batch distillation, Open-loop control, Energy savings, Economics, CO_2 emissions, Closed-loop control, Simulation experiments