ABSTRACT

Strongly fluctuating fossil fuel prices and uncertainty of their long-term supply, along with the environmental alarm owing to the greenhouse gas emissions, have promoted research work on the improvement of process energy efficiency. For the purpose of enhancing the thermodynamic efficiency, heat integration appears to be the most effective method and has already found wide applications in continuous distillation columns. Particular focus of this research has been on heat integration in batch distillation dealing with the separation of reactive and nonreactive systems.

In this research work, at first, an internally heat integrated batch distillation with a jacketed reboiler (IHIBDJR) scheme is developed. In this thermally coupled column configuration, a compressor is installed in the reboiled vapor line aiming to create a thermal driving force for transferring heat from the high pressure rectifier to the low pressure reboiler. The IHIBDJR column targets to effectively utilize the internal heat source and this, in turn, leads to the reduction of external energy requirements in batch processing. Thermodynamic and economic potentials of this scheme are investigated by a simulated batch distillation example.

Next part of this work configures a thermally integrated batch reactive distillation, in which, the rectification tower runs as usual at normal operating pressure and the concentric reboiler operates under vacuum. Performing numerical simulations for a homogeneously catalyzed ethyl acetate system, the heat integrated scheme shows some improvements over its conventional counterpart in terms of thermal efficiency and cost. For boosting both energetic and economic performance, further intensification is made by proposing an additional arrangement of thermal coupling between the hot overhead vapor (source) and the relatively cold reboiler liquid (sink).

The pressure elevation from the jacketed reboiler to rectifying section opens up another possibility of introducing the direct vapor recompression column (VRC) mechanism in the IHIBDJR configuration. Deriving the general form of this novel VRC-IHIBDJR structure, the features of it are demonstrated by a multicomponent batch distillation that considers a heterogeneously catalyzed esterification reaction. This hybrid scheme further strengthens the advantages over the IHIBDJR structure.

Finally, this work aims at evaluating the proposed VRC-IHIBDJR scheme with reference to the vapor recompressed batch distillation (VRBD) column reported in recent past. For this purpose, a comparative study is performed between them in terms of energy consumption and cost through the separation of a nonreactive binary and a reactive multicomponent system.

Keywords: Internally heat integrated batch distillation, Jacketed reboiler, Reboiled vapor compression, Intensified thermal coupling, Overhead vapor recompression, Thermodynamic feasibility, Energy savings, Economics, Simulation experiments