The structured heat integrated distillation column


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ABSTRACT

This paper describes a unique, proof of the principle test facility and the results of a study carried out to provide experimental evidence needed to properly assess the techno-economic feasibility of heat integrated distillation column (HIDiC) utilizing structured internals to enhance both heat and mass transfer. The plate-packing configuration using structured packing exhibited a superior performance in comparison with the HIDiC based on the plate-fin heat exchanger. Experimental evidence shows that the mass transfer and heat transfer efficiency increase pronouncedly with increasing throughput, which however is accompanied by an increasing pressure drop per stage. Simulation of an industrial scale plate-pack unit revealed that an even better performance can be obtained by increasing the volumetric thermal load via further optimization of internals.

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1. Introduction

Separation processes dominated by distillation are main user of energy and account for about 40–70% of both capital and operating costs in a typical chemical plant (Humphrey and Keller, 1997). Distillation exploits the difference in boiling points, i.e. volatilities between the components in the mixture as separation principle. In general, capital and operating costs increase with decreasing relative volatility. Indeed separations of close boiling mixtures are highly cost and energy intensive, with energy requirements of single super-fractionators columns going up to 90 MW (Olujić et al., 2004). Therefore, striving for more sustainable solutions, present day chemical process industries show special interest in increasing the energy efficiency of the distillation process.

By the virtue of its design, the distillation column is an energy inefficient device, since the heat is supplied in the reboiler at a high temperature level and roughly the same amount of heat is rejected in the condenser at low, often useless temperature level.

Maximizing the energy efficiency of distillation by increasing its reversibility (or, in other words, by reducing its entropy production) has been analyzed by several authors in the past (Benedict, 1947; Flower and Jackson, 1964; Fitzmorris and Mah, 1980; King, 1980). Although, reversible distillation is not economically feasible as it would require an infinite number of stages and heat exchangers (King, 1980), several attempts have been made in the recent past to reduce the irreversibility as associated with operation of a distillation column. These include, among others, side-condensers and side-reboilers (Terranova and Westerberg, 1989; Dhole and Limhöff, 1993; Bandiopiadhavay, 2007), dephlegmators (Bakke, 1997; Wang and Smith, 2005) and heat pumps (Null, 1976).

Side-reboilers use waste heat at a lower temperature than the bottom reboiler and thus increase the exergetic efficiency and reduce utility cost. Similarly, side-condensers are used to remove heat at higher temperature than the top condenser. Dephlegmators or reflux condensers are compact heat exchangers, such as plate fin heat exchangers (PFHEs),