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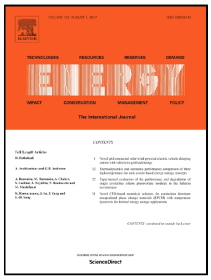

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Towards better styrene distillation scheme: From grassroots design to retrofit

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Abstract

The current state-of-the-art commercial styrene distillation schemes, featured by conventional distillation columns to purify styrene, are introduced with energy, exergy and economic analyses. Amongst all the procedures the separation of ethylbenzene/styrene, the critical close-boiling system, accounts for ~65% of the total energy requirement. To improve the energetic efficiency, double-effect distillation (DED) and heat pump distillation (HPD) are suggested as competitive improvements on conventional distillation schemes (CDSs), which give birth to advanced distillation schemes (ADSs). In addition, sensitivity analysis is carried out to determine the optimal operational parameters of columns in styrene distillation process. Taking the CDSs as benchmark processes, the ADSs with DED and HPD can lower operating costs by up to 30% and 40%, respectively. The synergistic effect makes retrofit proposals' payback period very attractive, through considerably energy costs reduction and uttermost equipment reuse. In the view of total annualized cost (TAC), the ADSs can cut a corner of ~35-40% from the CDSs. Specifically, the ADS using HPD slightly outperforms its DED counterpart in TAC comparison. Despite energetic or monetary advantage, the ADSs also show their environmental drawback of higher exergy losses than the CDSs.

Keywords: Styrene distillation scheme; Conventional distillation sequence; Grassroots process design; Energy-saving distillation technology; Advanced distillation scheme; Retrofit proposals

1. Introduction

Styrene monomer (SM) is the simplest and by far the most important member of a series of aromatic monomers that is used in the plastics industry [1]. It is widely used in synthesizing various polymers and copolymers, such as polystyrene (PS), acrylonitrile-butadiene-styrene copolymers (ABS), styrene-acrylonitrile copolymers (SAN), styrene-butadiene rubber (SBR), styrenic block copolymers (SBC), styrene-butadiene latex (SBL) and adhesives [2]. The capacity of producing SM has increased constantly with the commercial demand. It is estimated over 25 million tons of SM is produced worldwide annually [1-3].

Currently, catalytic dehydrogenation of ethylbenzene (EB), shown in **Fig. 1,** overwhelms in styrene industry [4]. When styrene production happens in dehydrogenation reactor, steam is added to lower partial pressure of EB, boosting styrene conversion and suppressing undesirable byproducts, such as lights (hydrogen, ethylene, carbon monoxide, carbon dioxide etc.), benzene, toluene and other heavy components known as styrene tar [5]. After removal of lights and water from the dehydrogenated products in a three-phase (vapor, aqueous and organic) decanter, the organic phase (SM, benzene, toluene, unreacted EB and styrene tar) is to be separated or recycled in styrene

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