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From simulation studies to experimental tests in a reactive dividing wall distillation column

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ABSTRACT

The design and control of thermally coupled distillation sequences have been studied since many years, but the real implementation occurred until middle of the 1980s using a single shell divided by a wall named dividing wall distillation column. In this work, experimental results for the production of ethyl acetate in a reactive dividing wall distillation column are presented for first time. The experimental results are in agreement with those obtained using steady state simulations with AspenONE Aspen plus. These experimental results are important since it is possible to validate most of the previous results generated using simulations.

Keywords: Reactive distillation; Thermally coupled distillation; Production of ethyl acetate

1. Introduction

Distillation has been widely used in chemical process industries over the years; however its versatility to carry out separations is linked to high-energy requirements and low thermodynamic efficiency.

Wright (1949) made one of the first studies reported in the literature, about energy savings in complex distillation columns, in 1949. He proposed a distillation column considering a shell and an internal wall for separating the feed stream and the side stream.

In 1965 Petlyuk et al. carried out a thermodynamic analysis of a column known after as Petlyuk distillation column (Fig. 1) to separate a ternary mixture (A,B,C). This column seemed an excellent option to reduce the energy consumption in distillation processes. Tedder and Rudd (1978) presented a parametric study of eight distillation sequences including conventional distillation sequences and some new designs with liquid and vapor recycles to replace some condensers and reboilers. These distillation sequences with material and energy recycles were known as distillation sequences with thermal coupling (Fig. 2). The results showed that distillation sequences with thermal coupling could achieve energy savings up to 30% in comparison with conventional distillation sequences for the separation of some ternary mixtures. However, despite of the potential energy savings, the industrial implementation of the distillation sequences with thermal coupling was limited, with only some applications in oil industry.

Alatiqi and Luyben (1986) reported a comparison about the control effort between a conventional direct distillation sequence and a distillation sequence with thermal coupling. The results showed that there was not a significant difference in the operation and control between conventional and thermally coupled distillation sequences. In addition, they reported that the recycled streams improved the control properties because they helped to diminish the effect of disturbances in the distillation sequences.

Fidowski and Krolikowski (1986) compared the vapor flows generated in the reboilers of the direct and indirect distillation sequences with those of the Petlyuk and a pseudo Petlyuk column under minimum reflux conditions. The optimal vapor flows were determined using analytical expressions based on the Underwood equation and the necessary stages to carry out

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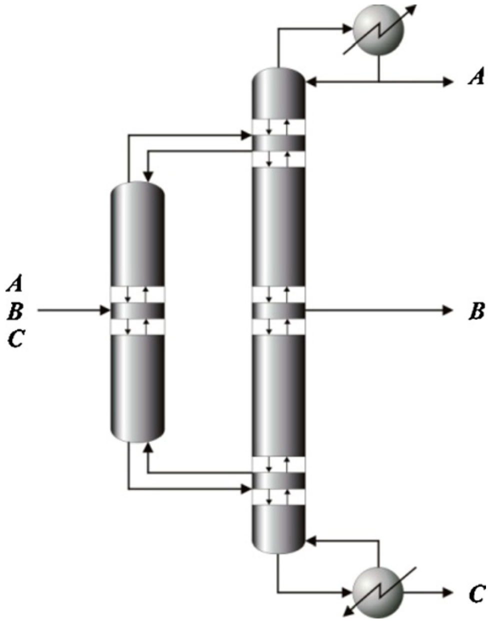

Fig. 1 – Petlyuk distillation column.

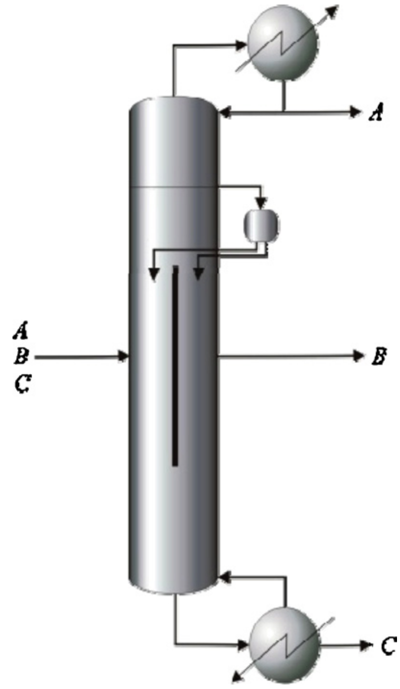

Fig. 3 – Dividing wall distillation column.

the separation were not considered. According to this comparison, the Petlyuk column showed significant savings in the total minimum vapor flow to achieve the separation of a ternary mixture.

Kaibel (1987) patented the dividing wall distillation column shown in Fig. 3, which is thermodynamically equivalent to the Petlyuk distillation column studied by Petlyuk et al. (1965). However, this equivalence is only valid when there is no heat transfer across the dividing wall.

Glinos and Malone (1988) obtained analytical expressions to determine the minimum flow necessary to separate a ternary mixture (A,B,C) using alternative separation designs, including the Petlyuk column. According to the results, they recommended using the Petlyuk distillation column when the molar fraction of the middle component B is low. Also, they found that the maximum savings achieved in the vapor flows were close to 50% in comparison with the conventional distillation sequences. In addition, they showed that distillation sequences thermally linked to side columns can operate successfully when the mole fraction of the middle component on the feed stream is lower than 0.3.

Triantafyllou and Smith (1992) gave an explanation about the higher thermodynamic efficiency of the Petlyuk distillation column. For the case of the conventional direct distillation sequence, for the separation of a ternary mixture, in which each component is removed as overhead product, an analysis of the composition profile of the middle component (B) in the first column shows how it reaches a maximum value below the feed stage and then diminishes as the bottom is reached (Fig. 4). This phenomenon is known as remixing, because the composition of middle component always is low at the bottom of the column. This bottom stream with lower content of

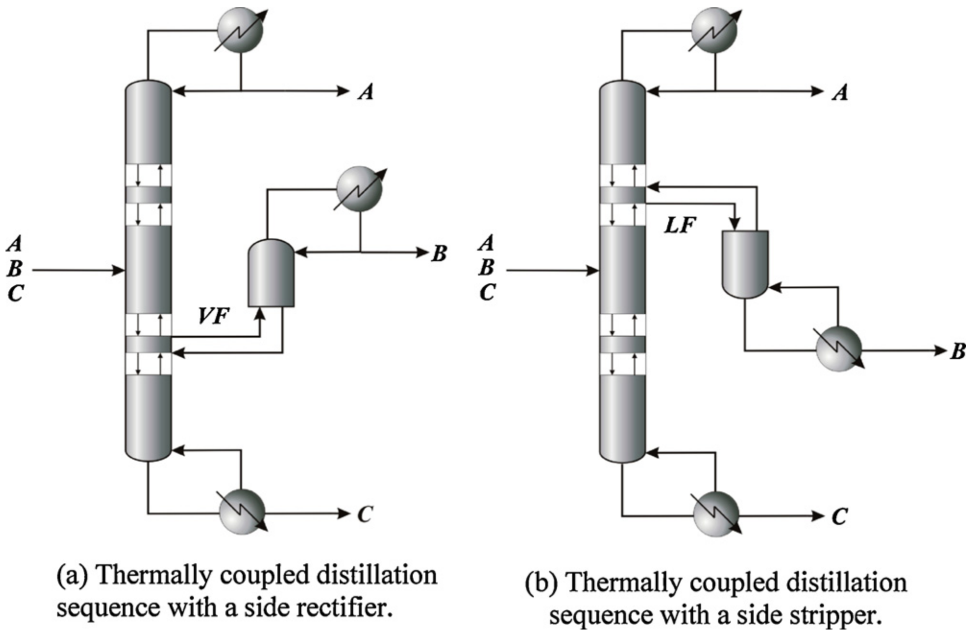

Fig. 2 – Thermally coupled distillation sequences with side columns.