Energy-Efficient Distillation Columns Design for an Existing Sequence using Driving Force Approach

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ABSTRACT

In this paper, the driving force approach is used to identify energy-efficient distillation columns design of an individual distillation column in the existing sequence. The driving force curves of all binary splits of a multicomponent are constructed, where each curve is representing an individual column. Then several points located at those curves are selected representing the column design candidates. Three different points (points A, B, C) are selected, where point A is located at the maximum of the curve and points B and C are located slightly below the maximum point. Then, the existing individual distillation column is redesigned based on these points. Different values of reflux ratio and feed location are calculated based on each selected points and then to be used to simulate distillation column using rigorous simulation approach. Once simulation for all design points have been conducted, then all energy requirements of reboilers and condensers for all distillation columns are obtained and analysed. The energy requirements from all sequence designs are compared with the existing sequence. From all the results obtained, distillation columns sequence designed at the maximum points of the driving force curves (57.13 MW) shows 3.68 % reduction compared to the existing sequence (59.31 MW).

Keywords. Energy-efficient, distillation column sequence, distillation column design, driving force approach, rigorous simulation

INTRODUCTION

Distillation columns are an essential process of any chemical plant for the separation and purification of condensable mixtures. However, distillation columns responsible for the largest contribution to the total energy consumption of chemical processes due to their high heat demands. Besides designing new distillation column sequences, one alternative and safe way is to make use of the existing sequence and operate the plant more efficiently, possibly with some of minor modifications. Methodology for energy-efficient distillation columns (EEDCs) sequence which is based on the driving force approach was developed by [1], which can increase energy saving for an existing distillation columns sequence up to 16 % by changing the existing direct sequence to energy-efficient sequence for alcohol separation process. [2] proposed a driving force sequence for the multicomponent aromatic mixture with a 7 % reduction in terms of energy consumption compared to the existing sequence. Meanwhile, [3] managed to save 7.6 % of energy consumption when changing the existing sequence into an energy-efficient sequence for an azeotropic separation process. In this paper, the driving force approach is used to design energy-efficient columns in an existing sequence, in contrast with [1-3] where they changed the existing sequence into energy-efficient sequence.

METHODOLOGY

Methodology for designing energy-efficient distillation columns is developed into four hierarchical stages: Step 1: Existing Distillation Sequence Simulation; Step 2: Distillation Design using Driving Force; Step 3: Distillation Sequences Simulation; and Step 4: Energy Comparison. In Stage 1, the existing distillation sequence is simulated. Then, in Stage 2, the driving force curves of all binary splits are constructed. Three different points A, B, C located at those curves are selected representing the column design candidates, where point A is located at the maximum point of the curve and points B and C are located slightly below the maximum point. Then, all individual distillation columns are redesigned based on these points. Different values of reflux ratio and feed location are calculated based on each selected points and then to be used to simulate distillation column in Stage 3. Once simulation for all design points have been conducted, then all energy requirements for all distillation columns are obtained and compared in Stage 4.

RESULT AND DISCUSSION

Case study of four components hydrocarbon is used to verify the used of driving force approach in designing individual energy-efficient columns in an existing sequence. Driving force curves of all binary splits of a multicomponent are constructed as shown in Figure 1. As can be seen, there are three different points (Points A, B, C) located at those curves representing column design candidates. Different point will have different values of reflux ratio and feed location. Then, several sequences are redesigned using combination of these three points i.e. Design AAA, Design BBB, Design ABC, and then simulated. Once simulation for all sequences have been conducted, all energy requirements for all distillation columns of each sequence are obtained and compared as tabulated in Table 1.

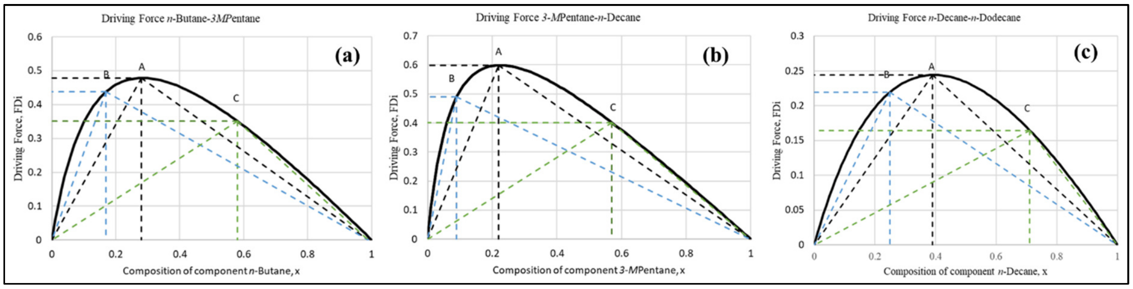

Figure 1. Driving force diagram for column (a) *n*-Butane/*3*-Mpentane, (b) *3*-Mpentane/*n*-Decane, (c) *n*-Decane/*n*-Dodecane at P = 200 kPa and T = 93.18 ^{o}C.

Table 1. Energy comparison for several sequence designs.

Sequence	Existing	AAA	BBB	CCC	ABC	ACB	BAC	BCA	CAB
***Q* (MW)**	59.31	57.13	58.75	61.80	69.41	62.00	87.12	59.49	61.13
Difference (%)	-	-3.68	-0.94	4.20	17.03	4.54	46.89	0.30	3.07

The results show that distillation columns designed at the maximum points at driving force curves (Design AAA) require less energy than those in the existing or other sequences.

CONCLUSION

This paper proposes an approach to design energy-efficient distillation columns in the existing sequence. Accordingly, all individual distillation columns in the existing sequence are redesigned using driving force approach. Designing distillation columns at the maximum points of driving force curves (Design AAA) produces energy-efficient sequence with 3.68 % energy reduction compared to the existing sequence.

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