RETROFITTING DIRECT SEQUENCE DISTILLATION COLUMNS USING DRIVING FORCE METHOD

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To my beloved wife, mother and father

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ABSTRACT

Distillation is the primary separation process widely used in chemical processing. In retrofitting, distillation column problem can occur when it requires additional and major unit operations. Therefore, this research has been carried out in order to achieve a minimum or zero modification of unit operation and design the optimal column sequence with less energy consumption. The large energy requirement of these processes can be greatly reduced by changing the sequence of the existing direct distillation columns by using the driving force method. The objective of this research is to develop a methodology to find the best sequence that can save energy and has better economic performance which consists of four hierarchical stages. In the first stage, the design of existing direct sequence was simulated and the energy used is analysed by using a shortcut method for distillation column in Aspen HYSYS. Then, the optimum sequence was determined by using the driving force method in the second stage. In the third stage, the optimal sequence was simulated and the energy used was analysed using a shortcut method of distillation column in Aspen HYSYS. Finally, the energy requirements from both sequences were compared and the economic performance was evaluated and calculated. A maximum energy saving of natural gas liquids fractionation of 21.2% was obtained with the Return of Investment (ROI) of 6 with 2 months of payback period. The results for hydrocarbon mixture show achievement of maximum energy saving of 39.53% and the ROI of 3 was obtained with 4 months of payback period. All of this findings show that the methodology is able to retrofit the existing direct sequence of distillation columns with minimum energy distillation column sequence in an easy, practical and systematic manner.

ABSTRAK

Penyulingan adalah proses pemisahan yang utama digunakan secara meluas dalam pemprosesan bahan kimia. Di dalam penyesuaian semula, masalah turus penyulingan boleh berlaku apabila ia memerlukan unit tambahan dan besar dalam operasi. Oleh itu, kajian ini dijalankan untuk mencapai pengubahsuaian operasi unit minimum atau sifar dan mencipta urutan turus yang optimum dengan penggunaan tenaga yang sedikit. Tenaga yang besar diperlukan dalam proses ini boleh dikurangkan dengan menukar susunan penyulingan turus yang sedia ada menggunakan kaedah daya penggerak. Objektif kajian ini adalah untuk mencipta kaedah untuk mencari susunan yang terbaik dalam menjimatkan tenaga dan yang mempunyai prestasi ekonomi yang baik yang mana terdiri daripada empat peringkat hierarki. Dalam peringkat pertama, reka bentuk susunan terus sedia ada disimulasi dan tenaga yang diperlukan dianalisis dengan menggunakan kaedah jalan pintas turus penyulingan dalam Aspen HYSYS. Kemudian di peringkat kedua, susunan optimum ditentukan dengan menggunakan kaedah daya penggerak. Pada peringkat ketiga, susunan optimum disimulasi dan tenaga yang diperlukan dianalisis dengan menggunakan kaedah jalan pintas turus penyulingan dalam Aspen HYSYS. Akhir sekali, tenaga yang diperlukan daripada kedua-dua susunan dibandingkan dan kedudukan ekonomi dinilai dan dikira. 21.2% penjimatan tenaga penyulingan cecair gas asli yang maksimum diperoleh dengan Pulangan Pelaburan (ROI) bersamaan 6 berserta 2 bulan tempoh bayar balik. Keputusan bagi campuran hidrokarbon menunjukkan bahawa penjimatan tenaga maksimum 39.53% dapat dicapai dan ROI bersamaan 3 diperoleh dengan 4 bulan tempoh bayar balik. Kesemua penemuan ini menunjukkan bahawa kaedah ini mampu untuk mereka bentuk tenaga yang minimum dalam susunan turus penyulingan dengan cara yang mudah, praktikal dan sistematik.

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LIST OF SYMBOLS

Fij	-	Driving force for component *i* with respect to property *j*
y_i	-	Vapor phase composition of *i*
x_i	-	Liquid phase composition of *i*
B_{ij}	-	Relative separability for component *i* with respect to property *j*
%	-	Percentage
>	-	Greater than
°C	-	Degree celcius
Δ	-	Delta
N_F	-	Number of feed location
N	-	Number of stages
D_X	-	Composition light key
m	-	Mass
kW	-	Kilowatt
X	-	Mole composition
P		Partial pressure

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CHAPTER 1

INTRODUCTION

1.1 Introduction

The needs for energy have been continuously increasing for years and separation units with larger energy consumption to be supplied become more unmanageable. Therefore reconsideration and rationalization of industrial plants are recommended. Reducing energy requirements of distillation systems lead to lower CO^2 emission. This is the reason why the plant designer must take the different energy solutions into account and choose the adequate distillation system for the specific separation task (Gadalla et al., 2006).

Reducing product cost in the chemical industry has been very effectively used in energy saving method for distillation columns by heat integration columns system. Heat integration by two columns is based on an idea to match utilizing overhead vapour of one column in order to provide heat content for boiling up a second column (Annakou and Mizse, 1996). Heat integration column is the process of hot streams was heat exchanged with cold streams. In this process the rectifying and stripping sections were designed by internally coupled through the heat exchanger. These designs prove an enormous improvement by reducing the reboiler and condenser duties will make to energy saving efficiency.

Therefore, the development of process and energy integration techniques have been introduced such as the fully thermally coupled distillation columns (FTCDC or Petlyuk column) and dividing wall columns (DWCs), which can have greater capability in reducing energy consumption. The divided wall column allows reversible splits with no part of the separation being used twice and the main source of its superior energy efficiency over other column configurations. Petlyuk systems have strong interactions between their columns because of the thermal integration, which can inhibit their design and operation.

Thus, this study proposed a new methodology that will enable to design energy efficient distillation columns (EEDCs) sequence from the existing direct sequence. Accordingly, the proposed methodology consists of four hierarchical steps. In the first step, the existing system of distillation column direct sequence is analysed in terms of energy required by using a simple yet reliable shortcut method of distillation columns in the Aspen HYSYS process simulator. Then, in the second stage, the optimal distillation columns sequence is determined based on driving force method. The direct sequence of distillation columns is improved in terms of energy saving by using the driving force method in this step. Once the optimal sequence has been determined, the energy requirement of this sequence is analysed by using process simulator. Finally, the energy requirements for existing and optimal sequences are compared and economic analysis is carried out for both sequences. By applying the proposed methodology, it is possible to make an early assumption on the alternative sequence of distillation column systems that is the best in terms of energy saving.

1.2 Problem Statement

The direct distillation columns sequence requires large amounts of energy to perform the desired separations. Various alternative columns improvements have been proposed but yet not able to be implemented by the industry. For example, in a heat integrated distillation system, additional of major unit operations (i.e. flash column, compressor, heat transfer mediums) needs to be included. These additional units caused higher operating and capital costs as well as additional maintenance.

These factors might be the reasons why the industry has not yet to accept the proposed improvement method such as heat integration column.

The question that need to be answered here is there any method or approach that will able to improve the existing direct distillation columns sequence energy saving performance without having any major modification to the major unit operations. Different distillation columns sequence will require different energy requirement. Most of the existing methods now will analyse every single suggested distillation columns sequence alternatives. The problem will occur if the existing sequences or separation systems consist of more components to be separated.

Therefore, the number of suggested alternatives sequences becomes bigger and the analysis becomes more complex, complicated and time consuming. As a result, designing or retrofitting distillation columns sequence with less energy requirement become more difficult. It is highly demanded now to have a simple methodology that will able to design or retrofit the existing direct sequence of distillation columns with minimum energy requirement. In addition, the design and retrofit solution of these energy efficient distillation columns needs also be practiced for the industry purpose which requires less modification efforts.

1.3 Research Objective

The objective of this study is to develop a new systematic methodology in retrofitting the existing direct sequence distillation columns system which will has minimum energy requirement with less modification efforts. Accordingly, the proposed methodology consists of four hierarchical steps. By applying the proposed methodology, it is possible to make an early assumption on the sequence of distillation column systems that is the best in terms of energy saving.

1.4 Scope of the Study

In order to achieve the above mentioned research objective, the following scope is carried out:

1. Identify the gap in reducing energy technology for distillation columns sequence.

The state-of-the-art of energy efficient distillation columns sequence is reviewed, which details discussed in Chapter 2.

2. Methodology development for of energy efficient distillation columns sequence.

The development of a new methodology for retrofitting the existing direct sequence of distillation columns is done which becomes the main objective in this study. The proposed methodology consists of four hierarchical steps, which details are discussed in Chapter 3.

3. Applications for simple and complex systems

The proposed methodology for designing energy efficient distillation columns sequence is applied in the real case studies which involve the simple and complex separation systems. The application of these case studies are further discussed in Chapter 4.

1.5 Research Significant and Contribution

It is possible to make an early assumption on the sequence of distillation column systems that is the best in terms of energy saving. The new methodology helps engineers to solve EEDCs sequence design problem in a systematic manner. The reason why the research is been carried out in order to develop an algorithm that

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