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Debottlenecking of condensate stabilization unit in a gas refinery

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A B S T R A C T

The increase in throughput or reduction in the operational costs is the common example of change in production criteria in retrofit projects. In this study, the condensate stabilization unit of a gas refinery, which is one of the most energy consuming units in natural gas refineries, is considered for analysis and retrofitting study. This unit comprises of a two-stage compressor and a side-reboiler associated with the stabilization column that uses HP steam as hot utility. It is shown that by applying the optimum pressure drops method for debottlenecking of this unit, after 20% increase in throughput, utility consumption can be maintained at existing level, if 1554 m^2 of additional heat transfer area is installed.

1. Introduction

Retrofit projects are commonly designed to maximize the utilization of existing equipments as well as minimize investment on the new unit operation, when the production objectives change. Some examples of change in production objectives are increasing throughput, incorporating new feedstocks, improving the value of products and finally reducing operating costs and energy consumption, which may have some consequences such as limited heat recovery and hydraulics of heat exchanger network, overflow and fouling in distillation column and pressure drop alteration, which causes some bottlenecks in the process [1].

Retrofit for debottlenecking after increasing the petroleum plants throughput has been widely studied in various researches with focus on heat exchanger network and distillation systems.

The retrofit for debottlenecking should be aimed to have a more efficient heat recovery network. A general review of recent studies about retrofit of heat exchanger networks reveals that Ravagnani et al. [2] and Frausto-Hernandez et al. [3] have considered the stream pressure drop alteration in their retrofit studies. However, the optimum pressure drop was not considered in any of the former methodologies.

Panjeshahi and Tahouni [4] developed a method for targeting based on optimum pressure drops, which was effectively applied in the retrofit of a crude oil pre-heat train after increasing throughput. They considered the stream pressure drop as a key variable which optimizes the unit specifications in targeting stage. Smith et al. [5] also proposed a retrofit design methodology of process streams with temperature-dependent thermal properties. Soltani and Shafiei [6] developed a new procedure for retrofit of HENs including pressure drop using numerical methods and Wang et al. [7] presented a new design approach for HEN retrofit study based on heat transfer enhancement, which analyzed the physical insight of enhanced exchangers.

Moreover, the retrofit design and optimization of the utility systems and heat exchanger networks in various oil plants is discussed in some works (Micheletto et al.; Jiandong et al., Piacentino) [8–10]. Micheletto et al. [8] developed a mathematical programming model which is utilized for the operational planning of the utility plant of the oil Refinery, Jiandong et al. [9] introduced a logical modeling method, which is called GDP (generalized disjunctive programming) for modeling the operation of compressors and the flow of pipeline network in the fuel gas system in petroleum refinery and Piacentino [10] utilized several existing methods to analyze the energy consumption of HENs' for retrofit, and presented the relaxation optimization strategies.

Furthermore, retrofit for debottlenecking of distillation systems which utilize high level of energy in petroleum plants have been extensively studied in capacity expansion researches (Gadalla et al., Long et al., Adiche and Vogelpohl) [11–14]. Gadalla et al. [11] introduced a method for optimization of the existing distillation system and its heat-exchanger

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network which decreases the energy consumption and increases capacity while having the minimum capital investment. Gadalla et al. [12] also presented a systematic thermodynamic and hydraulics design procedure for internal heat integrated distillation columns. In this study hydraulic capacities of heat exchange are considered to determine the maximum physical space area available for heat exchanger. Long et al. [13] worked on removing the bottlenecks of the distillation column after increasing the throughput of an existing acetic acid purification process and also design of the optimum column sequence. Adiche and Vogelpohl [14] developed new short-cut design methods providing optimal design parameters for distillation columns which can be applied for monitoring the distillation sequences in capacity increasing projects.

Among the researches, hydraulic-based methods for retrofit design of distillation system after increasing the feedstock in petroleum refinery were developed by Liu and Jobson [1], and Wei et al. [15]. Liu and Jobson introduced FUA (fractional utilization of area) which provides a graphical tool for retrofit design of distillation columns after increasing throughput and Wei et al. established a new economy indicator called SAC (specific annual cost) to sort the available debottlenecking measures, and they verified the corresponding process flowsheets and operation parameters.

Chen et al. [16] proposed a comprehensive mathematical model for analysis and design of the steam power plants in petroleum refinery including the operational optimization, retrofit of existent units and import steam integration.

Kovač et al. [17] extended the developed sequentially optimize retrofits to a stepwise simultaneous super structural approach in methanol plant. Bao et al. [18] worked on process integration and cogeneration analysis of GTL (gas to liquid) processes and Park et al. [19] proposed the concept of a retrofit design for a boil-off gas handling process in liquefied natural gas using a fundamental analysis.

Recently, heat recovery enhancement techniques were investigated by Pan et al. [20,21]. Sreepathi and Rangaiah [22] studied exchanger relocation approaches for HEN retrofitting. Jiang et al. [23] presented an approach to a cost-effective HEN retrofit with a fixed network structure.

In this study, we focus on Retrofit of heat exchanger network of a natural gas refinery unit, which has not been thoroughly considered in the literature. The crucial element which discriminates the retrofit study of natural gas refinery from the same study in oil refineries is the absence of the furnace in gas refineries, as equipment that often causes bottleneck after increasing throughput in heat recovery network of oil refineries. The high pressure steam is often used as the hot utility in gas plants and thus will cause high energy consumption and also high utility investment; therefore it will be one of the critical points in heat recovery system of these plants.

However, as mentioned before, there is not any special framework for the retrofit of heat exchanger network in gas refinery units. In this paper, the retrofit for debottlenecking method presented by Panjeshahi and Tahouni [4] is applied for debottlenecking of the heat exchanger network in condensate stabilization unit of SPGC (South Pars Gas Refinery). The procedure is applied for debottlenecking of a gas refinery to show the ability of their method in such refineries, which don't have any furnaces.

As can be seen, the side-reboiler of condensate stabilization column, heated by high-pressure steam is considered as hot utility and the main objective in this study is to keep the load of this match unchanged after increasing throughput, which causes bottlenecks in the process and should be removed by implementing some additional area.

2. Retrofit of heat exchanger network for debottlenecking

Debottlenecking of heat exchanger networks is applied in two main steps of targeting and design of network.

In the targeting step, stream pressure drops are defined as key parameters, which will increase as the throughput increases and will result in the more film coefficient and thus the more heat transfer coefficient [4]. The increase of heat transfer coefficients will lead to less required heat exchanger area and hence less capital cost of new heat exchangers. In contrast, higher pressure drops will require an investment on new pumps and/or compressors and thus the running cost will increase. Therefore, the trade-off between the capital cost of the new heat exchanger surface areas and capital cost plus additional power cost associated with pumps and compressors should be carried out.

The procedure of targeting can be summarized by the following stages [4]:

- Simulation of the existing process operating at the desired increased throughput.
- Identifying the area efficiency (α) after increasing throughput using area–energy plot. Area–energy plot is drawn by energy and area targeting at each $\Delta T_{\min}$. It is not necessary to plot the whole plot, instead the ideal energy and area is calculated at $\Delta T_{\min}$ equivalent of current energy consumption. The area efficiency is defined by:

$$\alpha_{\text{existing}} = A_{\text{A}}/A_{\text{B}} \tag{1}$$

where A_{A} is the ideal heat exchanger network area calculated after increasing throughput based on increased new stream pressure drops and A_{B} is existing network area [24].

- Calculating the pseudo-network area (A_{D}), which is a virtual area based on allowable stream pressure drops by fixing the area efficiency.

$$\alpha_{\text{existing}} = A_{\text{C}}/A_{\text{D}} \tag{2}$$

where A_{C} is ideal heat exchanger network area calculated based on allowable stream pressure drops.

- Determining the optimum targeting point, which is set using operating costs. Having obtained the pseudo-network area, the targeting curve will be drawn. The start and the end point of targeting curve demonstrates the attainable energy savings and their corresponding points of investment in new area.
- Evaluation of required additional heat transfer area to reduce the increased hot utility to current level.

$$\Delta A_{\text{DEB}} = A_{\text{T}} - A_{\text{B}} \tag{3}$$

where A_{T} is the targeting area at new level of energy and A_{B} is existing network area at current energy level.

In the second step, design for debottlenecking will be done and eventually, the detailed design of the heat exchanger network is carried out. In the network design, we want to make as few changes to the network structure as possible and prefer to change "thermal positioning" of a heat exchanger by correcting loads or input/output temperatures instead of relocating the unit. Also, it is important that well-placed units are remained unchanged. The retrofit procedure consists of four steps of analysis of existing network, improving the poor heat exchangers, installing new area and evolution of network. Analyzing the

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