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Research paper

Performance improvement of a crude oil distillation unit

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HIGHLIGHTS

- The improvement capability of a crude distillation unit (CDU) was investigated.
- The process improvement methodology included exergy and heat integration analysis.
- The overall energy demand of the CDU was reduced within considerable investment.

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ABSTRACT

This study builds on an earlier investigation carried out on an existing crude oil distillation unit (CDU). The energy and exergy efficiencies of the plant are low and opportunity for plant improvement was established. The methodology adopted for improving the plant performance uses process simulation techniques, and the combined exergy and traditional retrofit methods to show what the process is capable of achieving under considerable expense on the required capital investment. The process improvement carried out resulted in the increase in the overall CDU energy and exergy efficiency by 4.0 and 1.6% respectively, reduction in emissions by 14.2% and savings in utility bill by $1.61 million per annum. The required capital investment for retrofits amounted to $3.78 million with a payback time of 2.35 years.

1. Introduction

The crude oil distillation unit (CDU) is the first process unit of the petroleum refinery where raw crude oil is separated into various fractions of useful and intermediate products, each of which is then processed further in other part of the refinery to meet the market specifications. The CDU can be classified into various subunits based on the scope of production. This includes the pre-flash unit (PFU), atmospheric distillation unit (ADU), vacuum distillation unit (VDU), splitting unit (SPU), stabiliser unit (SBU) and heat exchanger network (HEN).

The operation of the CDU consumes about 35–45% of the energy used in the refinery [1], and therefore, it is one of the most crucial links in the refinery energy conservation chain. Many researchers and engineers have focused on how to improve the effectiveness of the CDU through the use of various traditional energy saving techniques that will reduce operating cost and environmental impact [2–6]. The most common techniques are the optimisation of process operating conditions and/or heat integration analysis under the specified product quality constraints and safety factors [7]. The main target is to bridge the gap between the ideal and current energy consumption of the plants [8]. However, these methods suffer from identifying the true improvement gap or capability of a system before improvements are carried out [7]. The exergy analysis provides a powerful means to understand the true improvement capability of a system [9]. The application of the aforementioned traditional methods together with the exergy concept can provide further insight into the key areas of inefficiency within a system and improvement can be implemented in the most appropriate way. With exergy analysis, the CDU can be adequately analysed to provide information regarding the location and magnitude of inefficiencies. Although, the application of exergy analysis alone to the CDU systems may also be used to propose modifications to reduce exergy losses as found in Refs. [10–13], the implementation of these proposed improvement schemes can be limited by the technological and the economic constraints of the process. However, in an improvement schemes the application of the exergy concept serve as guide in setting limits to the amount of energy losses.

Few studies exist on the combine application of exergy analysis together with other traditional improvement schemes to the CDU. Emphases have been limited to one or two subunits of the CDU. A

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holistic consideration of the entire CDU subunits are neglected in most cases due to the complex interactions of its process parts, the production scope or the limitations based on the research investigation window. For example, the exergy analysis performed by Izyan and Shuhaimi [14] on a CDU was limited to the PFU and ADU components. They showed that the furnace contributed 86% of the total exergy loss in the system. The modification carried out addressed fuel reduction by installing a heat recovery device in the furnace stack and the overall cleaning schedule of the heat exchangers. Benali et al. [15] proposed a way to improve the ADU using exergy method by visualising the energy degraded in the column. Kansha et al. [16] investigated the energy saving potential of a self-heat recuperation technology (SHRT) which was developed based on exergy recuperation for an ADU. The main advantage of SHRT is that it can be implemented on various distillation processes. However, for crude oil distillation process, the proposed technology requires a compressor which can cope with high temperature, heavy vapour oil and a relatively high compression ratio [16]. These would require further modifications and optimisation in order to trade-off between energy and cost. Since the economic feasibility of SHRT was not ascertained, it is not clear if the proposed technology can provide a system with optimal economic performance.

All the aforementioned options are promising energy saving techniques applicable for the improvement of the CDU, however, what has been failed to be done is the consideration for either the economic feasibility of the improvement and/or the inherent energy saving potential that could be embedded by analysing all subunits holistically. This study is aimed at improving the performance of a CDU by analysis its subunits holistically using exergy analysis and other traditional optimisation techniques. We build on an earlier investigation carried out on an existing CDU of a Nigerian refinery. The energy and exergy efficiencies of the plant were reported to be low due to large amount of losses, and opportunity for improvement was established [13]. This study shows what the existing CDU is inherently capable of achieving if the present plant operating conditions are well optimised and the HEN, hot and cold utility are correctly designed. It thus provides vital information that will enable the management of the industry to adopt improvement strategies based on the combined application of exergy and other traditional methods for better control of production processes and modification of areas of wastage effectively.

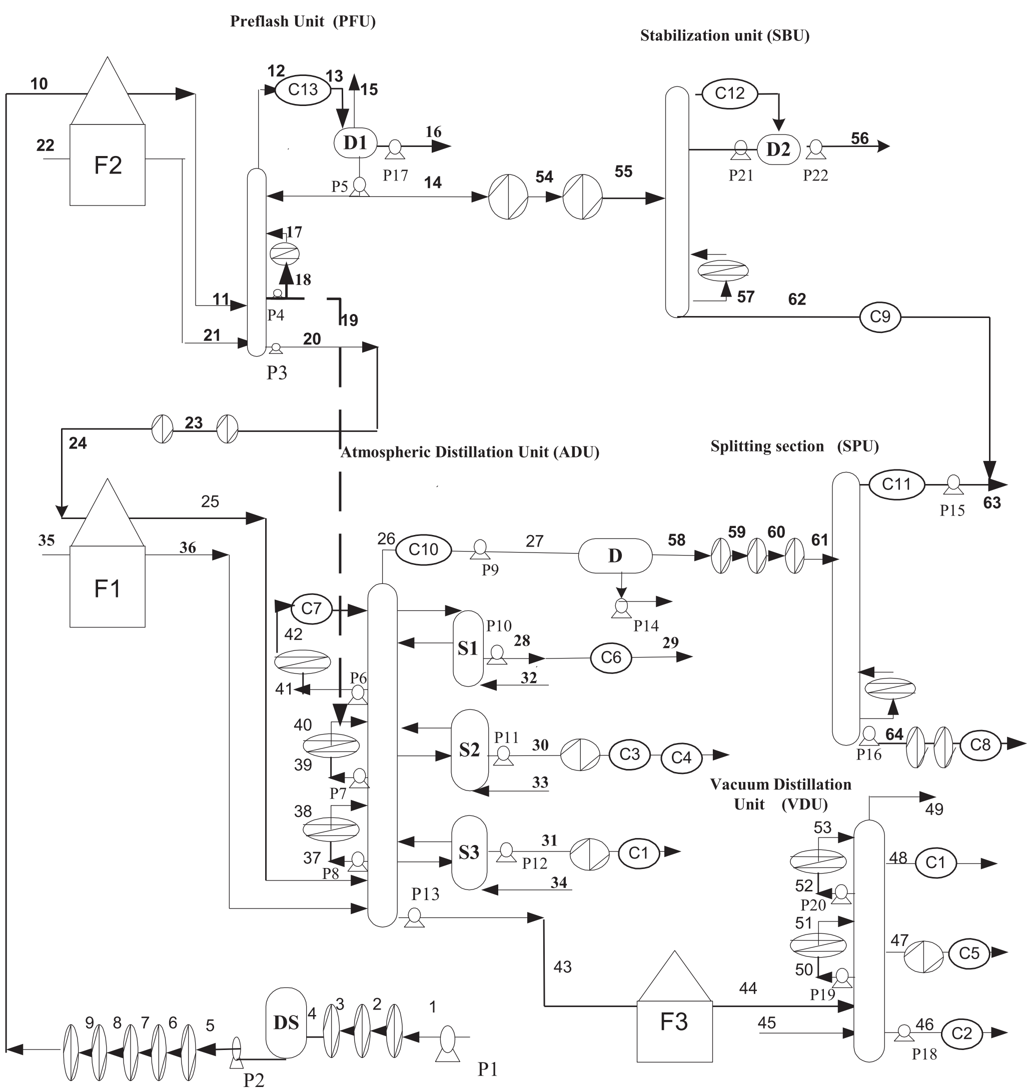

Fig. 1. Process flow diagram of a Nigerian crude oil distillation unit.