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Application of the self-heat recuperation technology to crude oil distillation

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ABSTRACT

Crude oil distillation is an atmospheric distillation column using a furnace. It consumes about 50% of the energy required in an oil refinery plant. To reduce energy requirements, it is necessary to investigate crude oil distillation and to retrofit it with energy saving processes. Recently, the authors developed an innovative process design technology, termed self-heat recuperation technology for saving energy. To apply this technology, whole-process heat is recirculated within the process without heat addition, leading to large energy savings. In this paper, crude oil distillation is analyzed and a crude oil distillation model for an energy saving design is developed. Furthermore, the feasibility of application of self-heat recuperation technology is investigated and self-heat recuperative crude oil distillation is proposed.

1. Introduction

In our daily lives, we use many products that originate from oil, such as fuel and plastics. In fact, not only consumer products but also whole modern economies rely on petroleum. Currently, the amount of annual crude oil imports to Japan amounts to about 230 GL/y or about 5% of annual world crude oil production [1]. It is reported that about 5% of this amount is used as fuel in oil refinery plants. Recently, energy saving has attracted increased interest in many countries to minimize global warming, caused mainly by the consumption of fossil fuels. Although many heat integration techniques for process energy saving have been applied to oil refinery plants since the 1970s [2], oil refinery plants still consume large amounts of energy compared to the required values based on an exergy analysis for separation processes [3–5]. In particular, it has been reported that about 50% of the total amount of fuel in an oil refinery plant is consumed in the crude oil distillation unit (atmospheric distillation columns using a furnace) [6]. Thus, it can be said that we could achieve a marked reduction in CO_2 emissions [7] and energy consumption [5,8] in oil refinery plants if we could reduce the energy consumption of crude oil distillation.

Crude oil distillation is classified as a distillation process. However, it uses many techniques that are not used in a typical distillation column, such as a pump-around and a steam injection to the column [9]. Thus, many researchers have proposed the correct modeling method for crude oil distillation units is to understand it [10–12] and to optimize the conditions for fitting its parameters [13,14]. These models using numerical calculation strongly contribute to design of control system and optimization for the processes. However, these are not suitable for energy saving of the process because of the lack of physical knowledge. Simultaneously, to reduce the energy consumption of this process, several energy saving technologies for crude oil distillation based on heat cascading utilization have been developed and applied. One representative example is to recover the heat of pump-arounds and feed this into the crude oil distillation furnace by designing heat exchanger networks [15–18]. Moreover, the operating system of the heat exchanger networks has been investigated [19,20]. In other heat integration technologies, the crude oil distillation unit is divided into two or more columns and reconfigured into a heat integrated process. These columns are thermally coupled and the heat-integrated crude oil distillation unit is designed as a multi-effect distillation or the column feed conditions are modified for energy saving [6,21–24]. Although furnace duty can be decreased to implement these technologies, only a part of the heat is recovered and it requires a large amount of additional heat to be supplied by fuel combustion.

In contrast, the authors have developed self-heat recuperation technology based on exergy recuperation, in which whole-process heat is utilized without additional heat, leading to the reduction of process energy required, and they have applied this technology to distillation and petrochemical processes in previous studies [25–30]. Here, we investigate crude oil distillation units with energy and exergy analysis and the feasibility of applying self-heat recuperation technology and thus develop self-heat recuperative crude oil distillation.

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