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Application of the Self-Heat Recuperation Technology to Crude Oil Distillation

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Crude oil distillation (atmospheric distillation column with furnace) consumes about 50% of the energy required in oil refinery plant. To achieve further reduction of the energy required in oil refinery plants, it is required to investigate the crude oil distillation and to retrofit it for energy saving process. Recently, authors developed an innovative process design technology, self-heat recuperation technology for energy saving. In this research, the crude oil distillation with exergy analysis and the feasibility for application of the self-heat recuperation technology have been investigated, and develop the self-heat recuperative crude oil distillation

1. Introduction

In our ordinary lives, we can find out many products origin from oil. It can be said that not only products but also economy has been relied on petroleum. In fact, amount of an annual crude oil importation in Japan is about 230 GL/year. This value is about 5% of an annual world crude oil production (PAJ website, 2010). It is reported that about 5% of this amount is used as a fuel in oil refinery plants. Although many heat integration techniques have been applied to oil refinery plants from 1970s, oil refinery plants still consume large amount of energy as compared to the values based on exergy analysis for separation processes. Especially, it is reported that about 50% of the total amount of fuel in an oil refinery plant is consumed in crude oil distillation (atmospheric distillation column with furnace) in Japan. Thus, it can be said that we can achieve a drastic reduction of CO_2 emission and energy consumption in the oil refinery plant if we reduce the energy consumption of the crude oil distillation.

Several energy saving technologies for the crude oil distillation based on heat cascading utilization have been developed and applied (Liau et al. 2004, Motlaghi et al. 2008, Errico et al. 2009). One of the representative examples is that heat of pump around is recovered and fed into furnace of crude oil distillation by designing heat exchanger networks (Promvitak et al. 2009a, b, Varga et al. 2010). Although furnace duty can be decreased to apply this technology, only a part of heat is recovered and it requires a large amount of additional heat by fuel combustion. In contrast, authors have developed self-heat recuperation technology based on exergy recuperation, in which a whole process heat is utilized without additional heat, leading to the reduction of process

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energy required, and applied this technology to chemical processes in previous studies. (Kansha et al. 2009, 2010a, b, Matsuda et al. 2010)

The crude oil distillation is one kind of distillation process. However, it uses many techniques, which are not used in ordinal distillation, such as a pump around and a steam distillation. Thus, we investigate that the crude oil distillation with exergy analysis and the feasibility for application of the self-heat recuperation technology, and develop the self-heat recuperative crude oil distillation in this research.

2. Configuration of Crude Oil Distillation

Figure 1 shows a schematic flow diagram of a conventional crude oil distillation. To make it simple, this crude oil distillation has one feed which consists of crude oil and representative five separated products; naphtha, kerosene, diesel, atmospheric gas oil (AGO) and residue in this figure followed by workshop text book (Invensys Scimsci, 2007). These products are mixtures of several components and separated by the boiling temperatures. This crude oil distillation has three pump arounds, three side columns and a preheater. The number of stages in the column is 20. The numbers of column in Figure 1 mean the stage numbers from top, which include condenser. For steam distillation purpose, steam is installed into the column.

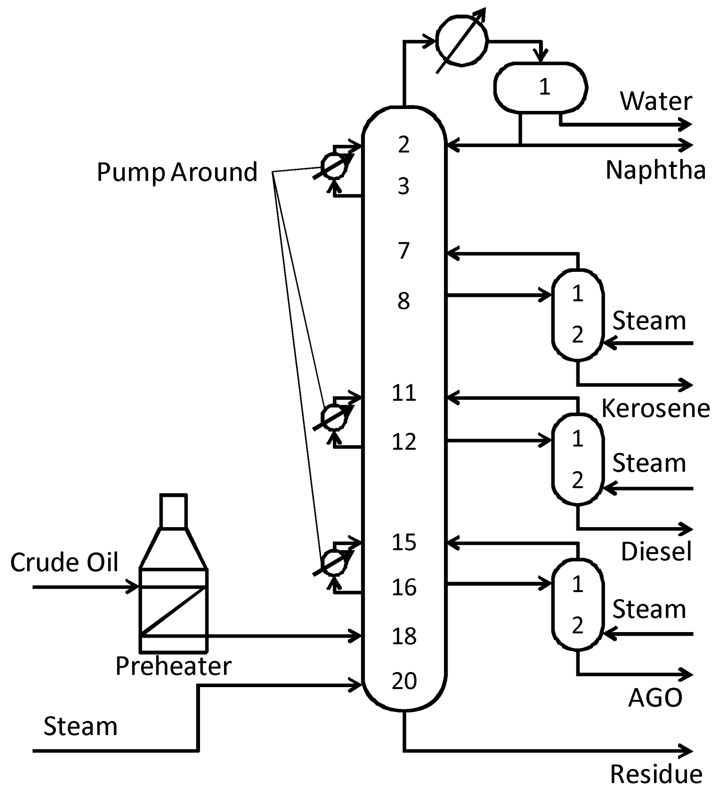

Figure 1: A schematic flow diagram of crude oil distillation

3. Process Analysis and Simulation

The heat energy analysis was conducted by following the self-heat recuperation technology. The simulation was conducted by PRO/II Ver. 8.1(Invensys, Simsci) to calculate the energy required. In this simulation Grayson-Streed was selected as the thermodynamics data.

3.1 Analysis of heat input/output

To analyze the heat input/output of the process, we defined feed condition as a base condition as shown in Table 1. Then all of heat input/output to the process were pointed out and examined the heat duties; preheater, pump arounds, condenser and products, and energy and exergy of heats are examined. For additional information of this crude oil distillation, Tables 2, 3, 4 and 5 show stripping steam data, products flow rates, column pressure and operating conditions, respectively.

Table 1: Crude column feed data

TBP Data (760 mmHg)		Light Ends	
Lv%	°C	COMP	Liq Vol%
3	36.1	C2	0.1
5	65.0	C3	0.2
10	97.8	IC4	0.3
20	165.5	NC4	0.7
30	237.2	IC5	0.5
40	310.0	NC5	1.2
50	365.6		
60	410.0	Total=3% LV of Assay	
70	462.8		
80	526.7		
100	871.1		
Avg. density	0.88052	SPGR	
Flow rate	795	m^3/h	
Temperature	232	°C	
Pressure	2.0175	kg/cm^2A	

Table2: Stripping stream data

To Main Column	4536	kg/h
To Kerosene Stripper	1814	kg/h
To Diesel Stripper	2041	kg/h
To Gas Oil Stripper	681	kg/h
Total Steam	9072	kg/h
Pressure	5.2515	kg/cm^2A
Temperature	Dew Point	

Table3: Product rates

Decant	8750	kg/h
Naphtha	170	std m^3/h
Kerosene	115	std m^3/h
Diesel	95	std m^3/h
Gas Oil (AGO)	150	std m^3/h
Residue	Unknown	

Table 4: Column pressure

Condenser	1.4062	kg/cm^2A
Top Tray (stage 2)	1.6315	kg/cm^2A
Flash Zone (stage 18)	1.9120	kg/cm^2A
Bottom Stage	1.9477	kg/cm^2A
Kerosene Side Stripper	1.8620	kg/cm^2A
Diesel Side Stripper	1.9120	kg/cm^2A
Gas Oil Side Stripper	1.9681	kg/cm^2A

Table 5: Operating Conditions

Operating Estimate	
Condenser Temperature	43.3 °C
Operating Requirements	
ASTM D86 95% Point for Naphtha	171 °C
ASTM D86 95% Point for Kerosene	271 °C
ASTM D86 95% Point for Diesel	352 °C
TBP 95% Point for Gas Oil	475 °C
Residue Yields	43%

3.2 Stripping stream

From the previous analysis, the stripping steam drew about 5% heat energy of preheating duty from the process. This means that the stripping steam works as a kind of heat sinks in the process. To confirm the enthalpy change of the process heat, all of steam should be taken out from the process. Therefore, we examined the partial pressure of oil in each stage of the column as shown in Figure 2. We put all of partial pressure of oil as pressure of stages and carried the process.

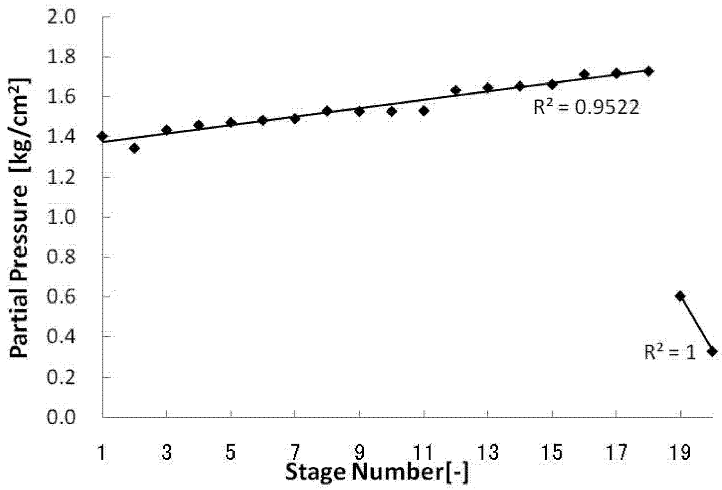

Figure 2: Partial pressure of oil in the column

3.3 Pump around

Pump around has two roles; one is a heat sink which provides the temperature differences among stages, and the other is a mixer in the middle of column to mix vapor and liquid well for separation. The condenser of the ordinal distillation column has both roles. Therefore, it can be substituted for pump around when the crude oil distillation is divided into some ordinal distillations.

3.4 Development of Self-Heat Recuperative Process

According to the previous analysis, the crude oil distillation can be carried by the integrated process which consists of 4 ordinal distillation columns, in which column pressures were partial pressure observed in Sec. 3.2 and the products temperatures and flow rates were satisfied by Tables 2-5. To apply the self-heat recuperation technology to the crude oil distillation, each distillation column was modified to the self-heat recuperative distillation columns by following the previous paper (Kansha et al. 2010a, b). Then they were integrated by following hot charge method as shown in Figure 3.

4. Discussion

From this study, it can be said that the crude oil distillation is a kind of multi-effective distillation which has integrated multi-columns into a column. Pump around works partial condenser in the middle of column and steam works vacuum distillation. Therefore, we can divide the crude oil distillation column into the ordinal distillation columns. In authors' previous studies, the self-heat recuperative distillation column has been developed. The self-heat recuperative distillation column achieves about 80% reduction of energy consumption as compared with conventional distillation process in the previous study. Therefore, the feasibility of the self-heat recuperation technology to the crude oil distillation column can be understood. However, to apply self-heat recuperation technology to the first distillation column from feed in Figure 3, it requires compressor which can work high temperature and heavy oil vapor. And if the hot charge method was applied like Figure 3, the compression ratio becomes quite high. Therefore, this design still requires modification, such as a self-heat exchange and an additional furnace heater for the first distillation column, and no integration for hot charge method.

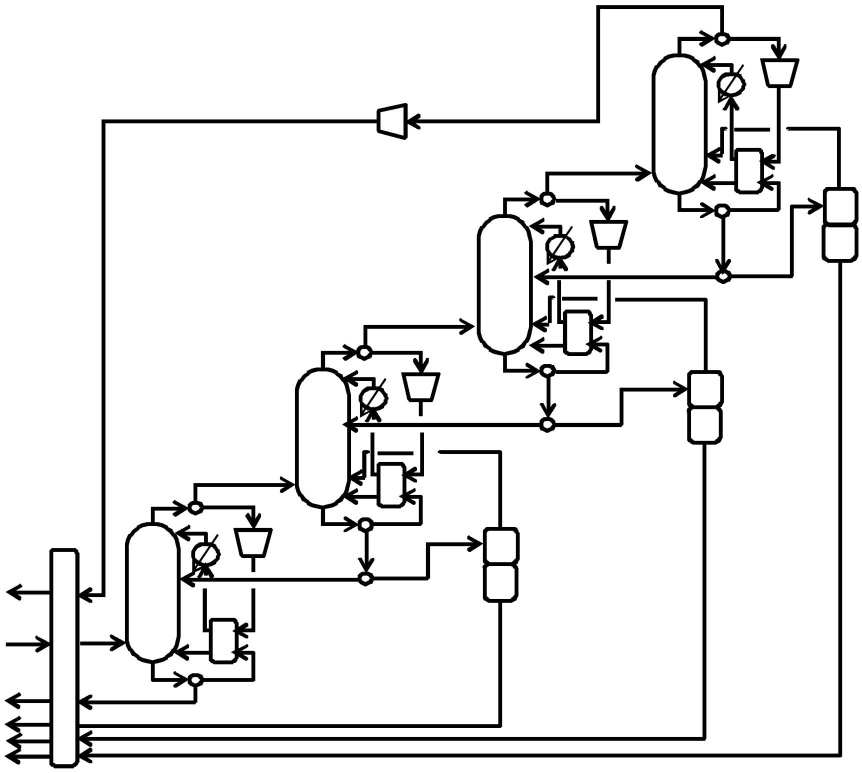

Figure 3: A schematic flow diagram of self-heat recuperative crude oil distillation which consists of 4 distillation columns

5. Conclusion

In this research, the possibility of further energy reduction of the crude oil distillation based on self-heat recuperation technology was investigated. By following the self-heat recuperation technology, each function of the crude oil distillation devices was pointed and the heat input/output of these devices by energy and exergy analysis was calculated. The feasibility for application of the self-heat recuperation technology from these analyses was investigated and an example of self-heat recuperative crude oil distillation was developed. This developed process can achieve further energy saving with development of compressor working at high temperature.

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