Heat Integration of a Continuous Reforming Process

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The continuous reforming process is an energy-intensive process. Therefore, it is worthy to perform heat integration on its heat exchanger network (HEN) to reduce energy consumption and gain economic benefit. In this paper, pinch technology is utilized to analyze and optimize the HEN of a certain continuous reforming process. The pinch calculation shows that the energy saving potential for the HEN is 8050 kW which accounts for 15.5 % of the heating utility. The unreasonable heat exchanges are identified，which are mainly the heat transfer across the pinch. The retrofit is then undertaken on existing network by removing the unreasonable heat exchanges with larger heat duty. Eleven new heat exchangers should be installed. Finally, the economic analysis of the retrofit gives the payback period of the investment as 0.78 y.

1. Introduction

With the fast development of the industry, the energy consumption escalates recently. In 2009, China's oil consumption reaches 39.3 Mt and 20.4 Mt of oil is imported, which indicates that the situation of energy use becomes significantly severer (Xiong, 2010). Process integration is considered to be an efficient tool to achieve energy recovery and improve energy efficiency.

Pinch analysis is the core of process integration (Gundersen et al., 2009). Based on thermodynamics analysis, pinch technology can locate the energy bottleneck of a system and provide a solution for de-bottleneck. Significant energy recovery and economic benefit can be obtained (Ahmad et al., 1990; Linnhoff, 1984; Matsuda, 2007; Silva et al., 2010).

The continuous reforming process produces high octane gasoline components with rich aromatic hydrocarbon. In the process, the reforming reaction is a strong endothermic reaction. The severer the reaction is, the more heat is needed, so that the more fuel is consumed (Zhang, 2009). Hence, the energy consumption of the continuous reforming process has great impact on that of the whole process.

Although pinch technology has been widely applied in many petrochemical facilities, there is no report on analyzing and optimizing the heat exchanger network (HEN) of continuous reforming process. In this paper, pinch technology is utilized to analyze and optimize the HEN of a certain continuous reforming process in a petrochemical

company. The unreasonable heat exchange in the current HEN is identified and the retrofitted HEN is constructed whilst achieving the energy saving benefits.

2. Process description

The continuous reforming process is designed by UOP and yields 0.6 Mt products every year. The process converts low-octane naphtha to high-octane gasoline with rich aromatic components. The process is composed of four sections: the pretreatment, reforming, catalyst regeneration and utility. The simplified process flow chart is shown in Fig.1.
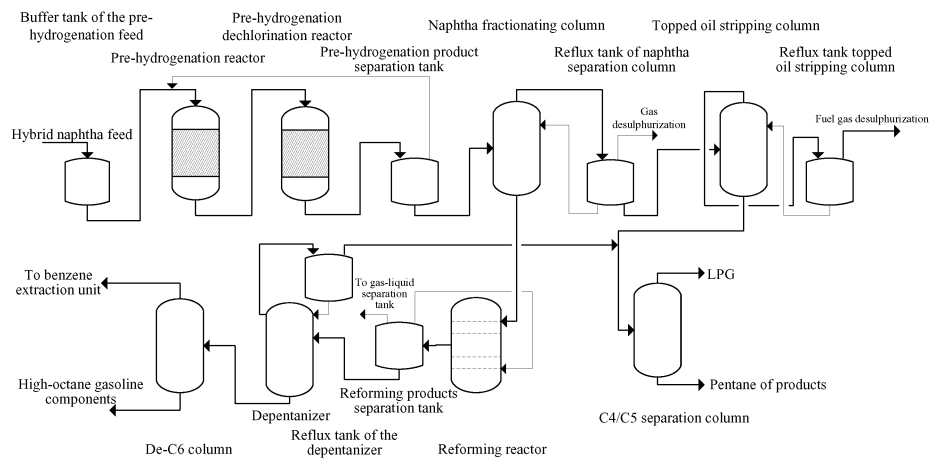

Fig.1: Simplified process flow diagram of a continuous reforming unit.

3. Analysis for current HEN

The existing HEN is shown in Fig.2 and the value in the bracket corresponds to the heat duty of the heat exchanger and the unit is kW. Totally, there are 22 hot streams and 21 cold streams extracted from the process. The distribution of the heaters, coolers and heat exchangers in the existing HEN is clearly depicted in the figure.

In the existing HEN, the minimum approach temperature difference is 7.4°C. Considering energy recovery, heat transfer area, retrofit cost of the network and operation stability, the minimum approach temperature difference is taken as 10°C (Yoon et al., 2007) in the following analysis.

Based on pinch calculation, the average pinch temperature is determined as 146.3°C. The minimum heating and cooling utilities are 43508 kW and 25402 kW, respectively. However, the current heating and cooling utilities are 52116 kW and 34010 kW, respectively. Thus the energy saving potential of the process is obtained as 8608 kW, accounting for 16.5 % of the current heating utility and 25.3 % of the cooling one.

According to the principles of pinch technology (no heat dissipation above the pinch, no heat supply below the pinch, no heat transport across the pinch (Geldermann et al., 2006), the unreasonable stream matches in the existing HEN can be identified as listed in Table 1.
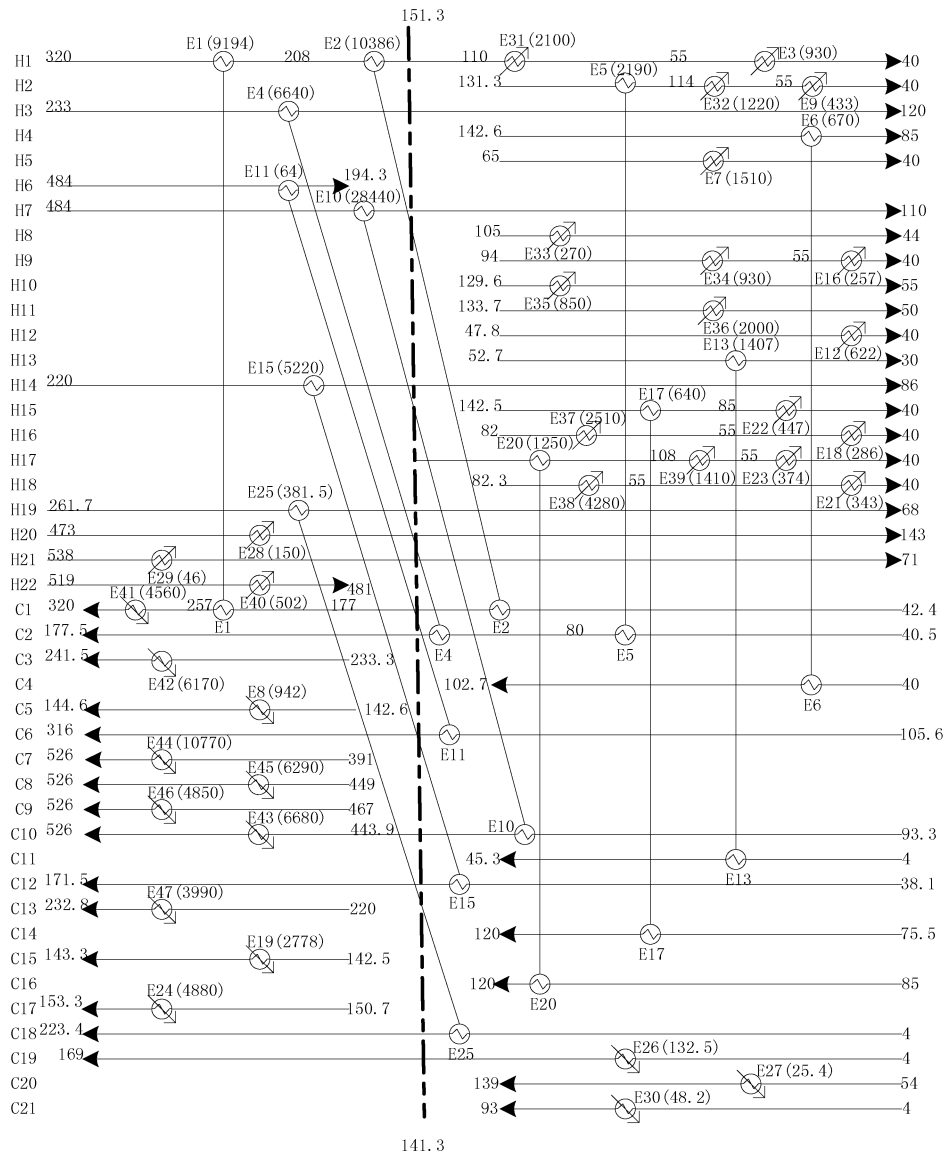
Fig.2: The current heat exchanger network.

4. HEN retrofit

4.1 Retrofit design

To retrofit an existing HEN, fewer changes with obvious heat recovery are preferred. Therefore, the main consideration is to eliminate the unreasonable heat exchange with larger heat duty (Li and Chang, 2010). Five heat exchangers, heat exchanger E2, E4, E10, E15 and the air cooler E40, should be retrofitted, which is expressed as follows and shown in Fig. 3.

Table 1: Unreasonable stream matches

	Heat exchanger	Unreasonable heat transport (kW)
Cooler above the pinch	E28	146.23
	E29	38.09
	E40	502
Heat transfer across the pinch	E2	3254.54
	E4	1945.2
	E10	419.4
	E11	10.86
	E15	1474.66
	E25	74.68
Heater below the pinch	E26	110.26
	E27	25.4
	E30	48.2

(1) The heat duty of E2 is reduced to 7131.5 kW which is the reasonable heat exchange between H1 and C1. To recover the heat of H1 above the pinch, EN2 is added to transfer heat between H1 and C17, which gives 3254.5kW of energy saving for heating utility. In order to supply heat to C1 below the pinch, EN9 and EN10 are installed. EN9 is used to exchange heat between H11 and C1, which leads to 1354.1 kW of saving for cooling utility. EN10 is used to exchange heat between H18 and C1 and it saves 1900.5kW of cooling utility.

(2) The heat duty of E4 is reduced to 4695 kW which is the reasonable heat exchange between H3 and C2. To recover the heat of H3 above the pinch, EN4 is added to exchange heat between H3 and C15, which saves 1945kW of heating utility. The higher temperature section on H2 is kept for heating C10 and the heat duty of E5 for H2-C2 match is increased to 266.7 kW. In order to supply heat for C2 below the pinch, EN11 is added to exchange heat between H18 and C2 which saves cooling utility 1678.3 kW.

(3) The heat duty of E10 is reduced to 28020.6 kW which is the reasonable heat exchange between H7 and C10. To recover the heat of H7 above the pinch, the heat duty of E10 between H7 and C10 is increased and it leads to save 419.4kW of heating utility. In order to supply heat for C10 below the pinch, EN12 is installed to exchange heat between H2 and C10, which saves 419.4 kW of cooling utility.

(4) The heat duty of E15 is reduced to 3745 kW which is the reasonable heat transfer between H14 and C12. To recover the heat of H14 above the pinch, EN7 is installed to exchange heat between H14 and C17 and it saves 1475 kW of heating utility. The heater E24 on C17 can be removed. In order to supply heat for C12 below the pinch, EN13 is implemented to exchange heat between H1 and C12, which leads to 1474.7 kW of cooling utility saving.

(5) E40 is removed. To recover the heat on H22, EN8 is added to exchange heat between H22 and C5 and it saves 502 kW of both cooling utility and heating utility.
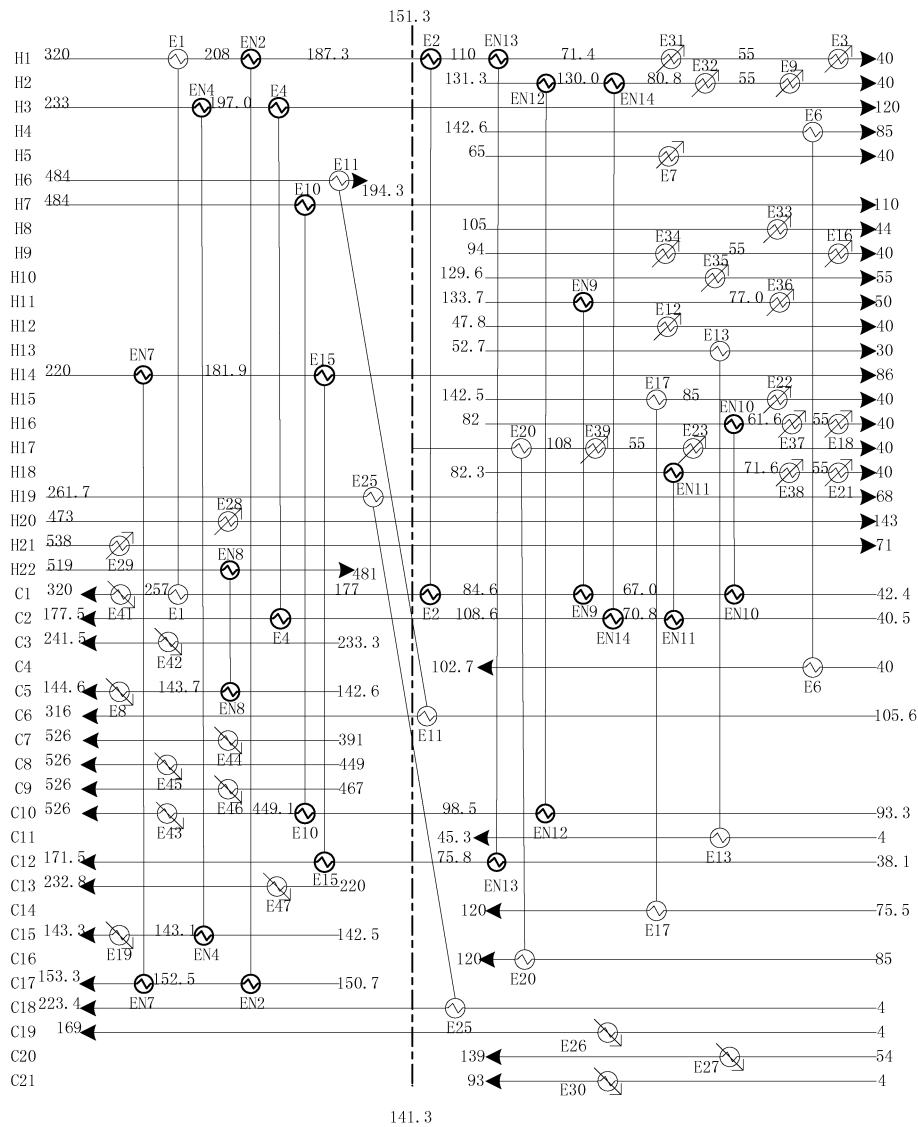
Fig.3: The heat exchanger network after retrofit

4.2 Economic analysis

After the suggested retrofit, 7595.4 kW of heating utility can be conserved, which includes 419.4 kW of fuel gas and 7176 kW of low pressure steam. The costs of fuel gas and the steam are 3487 RMB/t and 160 RMB/t, respectively. Thus the economic benefit for the saved heating utility is 17.16 M RMB/y. After the retrofit, 7595.7 kW of cooling utility can be saved, which are all from the air coolers. The operation cost of the air coolers is 0.006 RMB/ (kWh). The saved operation cost for the air cooler is 0.37 M RMB/y. In summary, the annual economic benefit from energy saving is 17.53 M RMB/y.

Besides, there are 11 new heat exchangers installed. The total capital cost of the heat exchangers is 13.72 M RMB. Thus the payback period of the investment is determined as 0.78 y.

5. Conclusion

In this paper, pinch technology is adopted to analyze the HEN of a continuous reforming process. The energy saving potential is firstly determined and it accounts for 16.5 % of the current heating utility. Next, the unreasonable heat exchanges are identified. The retrofit scheme is performed aiming at removing the unreasonable heat exchanges with larger heat duty. Moreover, eleven new heat exchangers are installed to fulfill the requirement. It saves 7595 kW of both heating and cooling utilities which accounts 14.6 % of the current heating utility and 22.3 % of the cooling one. Based on the economic analysis, the simple payback period of the investment is determined as 0.78 y.

Acknowledgements

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