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Saving Study on a Large Steel Plant by Total Site Based Pinch Technology

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We applied the total site approach of "Site Source Sink Profile (SSSP) analysis", based on pinch technology, to a large scale steel plant. Despite the very high efficiency of the individual processes, there is still a huge energy saving potential by adopting this approach. We found that the available pinch technology tools and techniques lend themselves very well to the analysis of a steel plant. The heat under 300°C is not utilized in a steel plant and we were able to identify the distribution and the quantity of such heat and proposed plans to utilize it for energy saving.

1. Introduction

A steel plant consumes a huge amount of energy and energy saving has been studied within the steel industry for long years by many well-respected, professional engineers and a great deal of equipment has been introduced to significantly improve energy efficiency (Bisio and Rubatto, 2000, Chan et al., 2010, Xu and Cang, 2010). The approach of these engineers concentrated on the study of individual process systems (Worrell et al., 2001) but a total site approach has not previously been considered.

However pinch technology (Kemp, 2007), an analytical methodology, has been applied in heavy chemical complexes, such as refineries and petrochemical plants, to analyze the heat-recovery system with the objective of reducing energy consumption in a plant or a complex of plants. It is well known that engineers in heavy chemical complexes study energy saving by using not only a single process system approach but also by a total site approach of SSSP analysis based on pinch technology.

Pinch technology needs and makes use of the data obtained from many heat exchangers in the pressurized system of a heavy chemical complex. However, most of the process systems in a steel plant are operated under atmospheric pressure and, despite improved heat recovery systems, heat exchangers are not used as much as they are in a chemical complex. In order to apply pinch technology to a steel plant, we first confirmed and analyzed how the heat is utilized in each process system and developed a procedure to extract adequate heat data for pinch technology analysis. We then, with the extracted heat data, studied a large steel plant by using the total site approach of SSSP analysis.

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2. SSSP analysis and data

2.1 SSSP analysis

In the context of the total site consisting of a number of process plants, the utility system must be understood and optimized. A graphical method, so called site profiles, was first introduced by Dhole and Linnhoff (1993). Klemeš et al. (1997) considerably extended this methodology to site-wide applications. Heat recovery data for individual process are first converted to grand composite curves (GCCs). GCCs are combined to form a site heat source profile and a site sink profile. These two profiles form total site profiles (SSSP) analogous to the composite curves for the individual processes. SSSP shows the energy and heat utilization profile of the whole plant. SSSP analysis can identify the opportunities for inter-process integration via the utility system and the preparation of the appropriate integration strategy. Perry et al. (2008) extended the site utility grand composite curve (SGCC). Bandyopadhyay et al. (2010) developed the methodology to estimate the cogeneration potential of an overall site through SGCC.

2.2 Steel plant

A large scale steel plant was studied, with production capacity of 8 Mt/y crude steel, which consisted of a raw material preparation process (coke oven and sintering), an iron making process (blast furnace), a steel making process (converter and continuous casting machine), and a rolling and finishing process (hot and cold strip mill).

2.3 Data for analysis

Most of the process systems in a steel plant are operated under atmospheric pressure and heat exchangers are not much used despite improved heat recovery systems. We confirmed how the heat was utilized in each process. Fig.1 shows the coke dry quench (CDQ) unit, one of the most effective heat recovery systems, that is equipped with the coke oven process. This unit cools the red hot coke from the coke oven process and recovers its heat. The hot coke (1,000 °C) in the heat recovery system is initially charged into the CDQ chambers (sealed vessels) and heat-exchanged with the inert gas (nitrogen). The nitrogen is heated to about 800 °C and then the hot nitrogen is routed into the CDQ boiler (waste heat boiler) to produce the steam. Finally the very high temperature heat of the hot coke is recovered to produce the high pressure steam (HPS) from the nitrogen. From the point of view of heat recovery, there are two heat exchangers in CDQ unit. The first exchanger, the CDQ chambers, treats the heat of the hot coke and the nitrogen and the second one, the CDQ boiler, treats the heat of the nitrogen and steam. SSSP analysis uses the data of the utility/process fluids in the heat exchangers, such as heaters and coolers. In the first exchanger, it seems that the nitrogen is a utility fluid, but its operating condition is fixed like a process fluid. We considered that the first heat exchanger treated a process/process fluids and the data from such exchanger was not suitable for SSSP analysis.

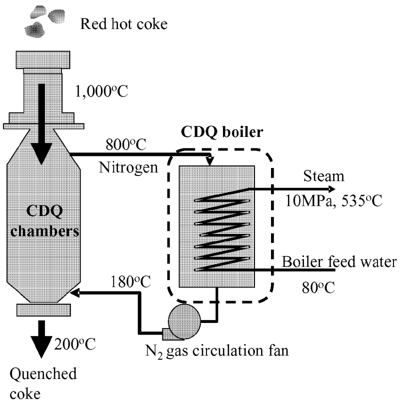

Fig.1: Coke dry quench (CDQ) unit

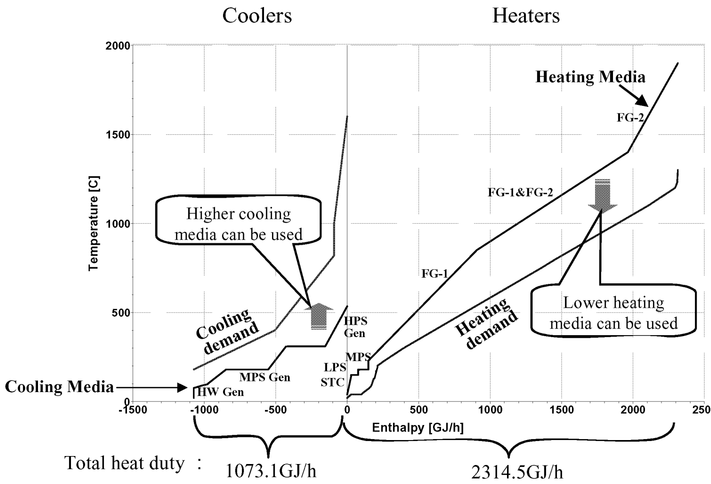

Fig.2: SSSP chart in current case

Eventually we determined to use the data of the second exchanger. In this way, we confirmed all the heat exchanging systems in the steel plant and decided to use the input data of heat exchangers (heaters and coolers) for SSSP analysis.

2.4 Utility conditions

The "current" column in Table 1 summarizes the utility conditions of heaters and coolers for the current operation case after determination of the appropriate heat exchangers data for SSSP analysis. There are five utilities for heaters (Table 1a) and three utilities for coolers (Table 1b). The data zero for IPS indicates that IPS is not used.

Table 1: Utility conditions for heaters and coolers in current and targeting cases

a

Utilities for Heaters		Current (GJ/H)	Targeting (GJ/H)	Difference (GJ/H)
FG-2 (1900-850°C)	Flue gas at steel material heating	734.4	0.0	-734.4
FG-1 (1400-230°C)	Flue gas at Blast Furnace	1431.9	2070.7	638.8
IPS (235°C)	Middle high pressure steam (3MPa)	0.0	42.4	42.4
MPS (180°C)	Middle pressure steam (1MPa)	71.2	11.6	-59.6
LPS (151°C)	Low pressure steam (0.5MPa)	49.4	162.2	112.8
STC (140°C)	Steam condensate	27.6	27.6	0.0
	Total	2314.5	2314.5	0.0

b

Utilities for Coolers		Current (GJ/H)	Targeting (GJ/H)	Difference (GJ/H)
VHPS Gen (100-535°C)	Very high pressure steam (12MPa)	0.0	1041.5	1041.5
HPS Gen (100-535°C)	High pressure steam (10MPa)	630.1	0.0	-630.1
IPS Gen (80-235°C)	Middle high pressure steam (3MPa)	0.0	31.6	31.6
MPS Gen (90-180°C)	Middle pressure steam (1MPa)	350.9	0.0	-350.9
LPS Gen (80-151°C)	Low pressure steam (0.5MPa)	0.0	0.0	0.0
HW Gen (76-98°C)	Hot water	92.1	0.0	-92.1
	Total	1073.1	1073.1	0.0

In Table 1b, we have used the words ‘HPS Gen’ and ‘MPS Gen’, which are different from mere high and middle pressure steam conditions. For example, HPS Gen means the range from supplied cold boiler feed water (100 °C) up to superheated high pressure steam (10 MPa, 535 °C).

3. Results

3.1 SSSP analysis

Fig.2 shows the SSSP chart based on the current data for heaters and coolers in Table 1. The right side of Fig.2 shows the information of the heaters and the left side shows that of the coolers. It is acknowledged that the heaters duty (2314.5 GJ/h) is almost twice as large as the coolers (1073.1GJ/H). A large scale steel plant consumes a huge amount of energy but only half of the consumed heat is recovered, which means that, despite the very high efficiency of the individual processes in a steel plant, there is a huge energy saving potential. And there is a large space between two composite curves for heaters (heating media and heating demand) as shown in the right side of Fig. 2, which suggests that the lower temperature heating media can be used instead of the present heating media. Correspondingly, due to the large space between two composite curves as shown in the left side of Fig. 2, the higher temperature cooling media for coolers can be used instead of the present cooling media.

3.2 Targeting

We studied the targeting case for energy saving by changing the utility for heating and cooling as shown in Fig. 3. For heaters, the present FG-2 (1,900-850 °C) can be substituted for FG-1 (1,400-230 °C) because the heating demand level is adequately satisfied by the lower level utility, FG-1. The present HPS Gen condition for coolers causes the large space from the cooling demand composite curve. It is therefore possible to produce a new utility such as VHPS (very high pressure steam) Gen. The result of the targeting case study are summarized in the “targeting” column of Table 1.

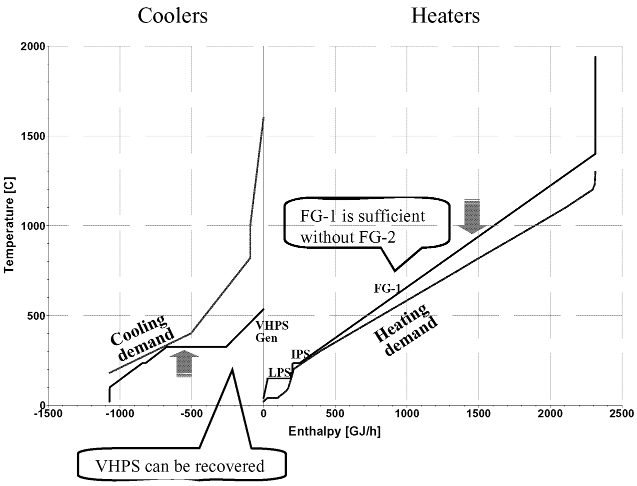

Fig.3: SSSP chart in targeting case

4. Discussion

4.1 Heater side

In Table 1a, it can be seen that FG-2 can be substituted totally for FG-1 and the lower level heating demand can be satisfied with several kinds of steam, IPS (newly installed), MPS and LPS. The excess FG-2 could be reused in the adjacent power plant to increase the power and heat generation. A steel plant uses the very high temperature heat in large quantities. The heating demand about 1,600 GJ/h above 500 °C (Fig.2) amounts to70% of the total demand (2,314.5 GJ/h). Fig.4 shows the enlarged view of the heaters on the right side of Fig.2. Looking at the heat demand under 100°C, three utilities (MPS, LPS and steam condensate) are used. Their duties (71.2, 49.4, 27.6 GJ/H) are small share of the total heat duty (2,314.5 GJ/H) in Table 1, but the MPS supply could be substituted for LPS, resulting in increasing power generation by 0.6 MW.

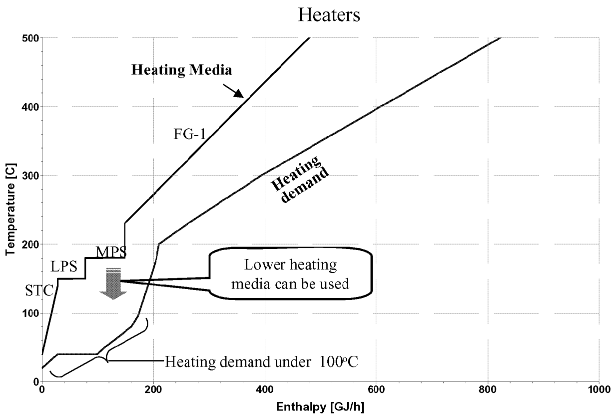

Fig.4: SSSP chart with enlarged view of heaters in current case

4.2 Cooler side

Fig.5 shows the enlarged view of the coolers from Fig. 2. The new VHPS Gen could be generated in the cooler side, as shown in Table 1b, instead of the present HPS Gen and MPS Gen. The generated VHPS Gen shifted from MPS Gen would be able to produce power generation of 21.1 MW. But the VHPS Gen shifted from HPS Gen would generate little power because the operating conditions are close each other. The use of the heat for the HW Gen was changed for pre-heating of the IPS Gen.

4.3 Utilization of un-utilized heat

The heat under 300 °C (Fig. 5) is about 300 GJ/h. It can be used to produce only HW Gen and a little MPS Gen, but this is not considered to be the optimum way to utilize this heat as it means that there would be a large amount of un-utilized heat in the steel plant. A potential for energy saving was identified and we developed a

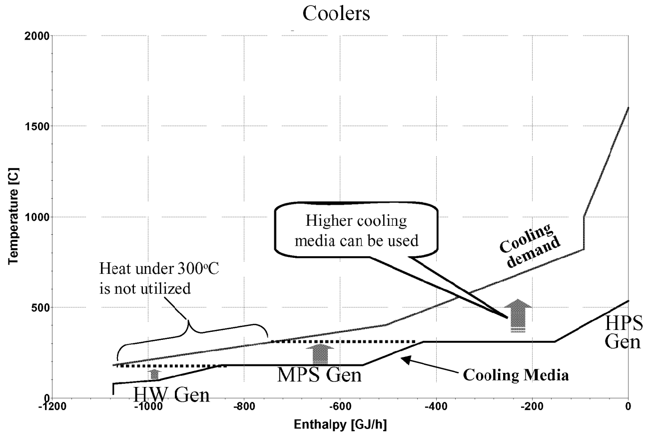

Fig.5: SSSP chart with enlarged view of coolers in current case

utilization plan combining the power generation and heat utilization. First was the power generation system (6.2 MW) using recovery steam (around 200 ^{o}C), secondly supplying the exhaust steam from the power generation system to the reboiler in the CO_2 removal system (capacity: 2 Mt CO_2/y) and, finally, low heat power generation (12.3 MW) using highly concentrated NH_3 solution as an operating fluid, exchanged with the hot condensate heat from the reboiler.

5. Conclusions

It was generally believed that there was no further potential for energy saving in a steel plant because almost all energy saving measures thought to be possible had already been developed and introduced. As it became clear, the concept for energy saving studies had been limited only to the individual processes in the plant. SSSP analysis based on the total site approach was able to identify that there was a large energy saving potential of 21.1 MW, especially in cooler side. Furthermore the quantity of the heat under 300 ^{o}C showed the possibility for developing the combined system of two power generation systems (18.5 MW) and heat utilization system for the removal of CO_2.

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