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Energy saving study on a large steel plant by total site based pinch technology

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A B S T R A C T

The total site approach using a "Total Site Profile (TSP) analysis" (based on pinch technology) was applied to a large scale steel plant. And it was confirmed, despite the very high efficiency of the individual process systems of the plant, that there would be a huge energy saving potential by adopting this approach. It became apparent that the available pinch technology tools and techniques lend themselves very well to the analysis of a steel plant. The heat (thermal energy) under 300 °C has previously not been well utilized in steel plants. But TSP analysis was able to identify the distribution and the quantity of such heat, from which energy saving plans could be developed.

1. Introduction

A steel plant consumes a huge amount of energy. Energy saving has been studied for long years by many well-respected, professional engineers and a great deal of equipment has also been introduced to significantly improve energy efficiency (Bisio and Rubatto [1], Chan et al. [2], XU and Cang [3]). These approaches concentrated on the study of individual process systems (Worrell et al. [4]) but a total site approach has previously not been considered.

Pinch technology (Kemp [5]), an analytical methodology, has however 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, not only by using a single process system approach but also by a total site approach of TSP analysis based on pinch technology. Tian et al. [6] studied the integration approach in a steel plant from the aspect of industrial water saving.

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 originally the concept of using heat exchangers for heat recovery in the steel plant was hardly recognized, despite improved heat recovery systems. On the contrary pinch technology is based on the data obtained from heat exchangers. In order to analyze the heat recovery systems in a steel plant by total site approach, the data equivalent to that obtained for heat exchangers was essentially required. A procedure for the preparation of such data was newly established. It was important for the procedure to analyze and understand how the heat was utilized in each process system. Firstly all the process systems that consumed and recovered the heat were extracted. And then it was confirmed how the heat was transferred to heat and cool the process streams, even without any heat exchanger. After confirmation of the heat balance, each fluid was identified as to whether it was a utility fluid or a process fluid. For TSP analysis, the data of the utility/process fluids in heat exchanging are used, but not the process/process fluids. Thus the procedure was developed to extract adequate heat data for pinch technology analysis. A large steel plant was then studied with the extracted heat data by using the total site approach of TSP analysis.

2. TSP analysis and data

2.1. TSP analysis

In the context of a 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 [7] and later Raissi [8]. Klemes et al. [9] considerably extended this methodology to site-wide applications. Heat recovery data for individual processes are firstly 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 (TSP) analogous to the composite

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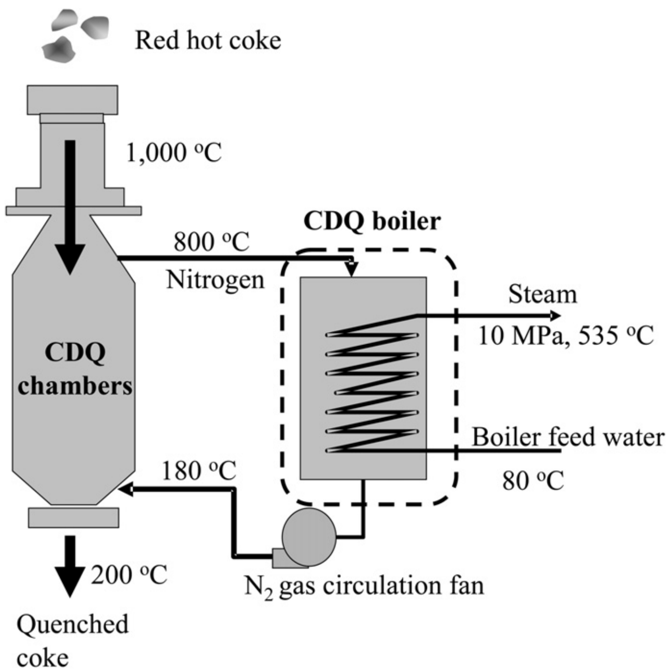

Fig. 1. Coke dry quench (CDQ) unit.

curves for the individual processes. TSP shows the energy and heat utilization profile of the whole plant. TSP analysis can identify the opportunities for inter-process integration via the utility system and the preparation of the appropriate integration strategy. Perry et al. [10] extended the site utility grand composite curve (SGCC). Bandyopadhyay et al. [11] 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 an annual production capacity of 8,000,000 tons of crude steel. The plant 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). An adjacent thermal power plant received fuel gas that was a by-product of the steel plant, and generated electricity and heat which were then sent back to the steel plant.

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.

It was confirmed how the heat was utilized in each process. Fig. 1 shows a coke dry quench (CDQ) unit, one of the most effective heat recovery systems equipped with a coke oven process. This unit cools the red hot coke from the coke oven process and recovers the heat of the red hot coke. The red hot coke (1000 °C) in the heat recovery system is initially charged into the CDQ chambers (sealed vessels) and the heat is recovered by inert gas (nitrogen), which is heated to about 800 °C. The hot nitrogen is then introduced into the CDQ boiler (waste heat boiler) to produce high pressure steam (HPS). Finally the very high temperature hot coke produces HPS through the nitrogen. There are two heat exchanging systems (Fig. 2) in the CDQ unit. One, the CDQ chambers, treats the heat of the red hot coke and the nitrogen. And the other, the CDQ boiler, treats the heat of the nitrogen and the steam. TSP analysis uses the data of the utility/process fluids in the heat exchangers. In the first exchanger (CDQ chambers), it appeared that the nitrogen is a utility fluid but its operating condition is fixed like that of a process fluid. It was considered that the first heat exchanger treated a process/process fluid and that the data from such exchanger was not suitable for TSP analysis. It was eventually decided to use the data of the second exchanger (CDQ boiler). In this way, all the heat exchanging systems in the steel plant were checked and the input data of the heat exchangers (heaters and coolers) was chosen for TSP analysis.

2.4. Utility conditions

Five utility conditions are used for heaters and three are used for coolers. Utilities for heaters are two kinds of flue gases (FG-H and FG-L), two pressure levels of steam and a steam condensate. FG-H and FG-L are the flue gases at the heating unit and furnaces, which are combusted gases of the by-product gases from the steel plant. Utilities for coolers are two pressure levels of generated steam and a hot water.

3. Results

The "current" column in Table 1 summarizes the utility conditions of heaters and coolers for the current operation case ("current case") after determination of the appropriate data from the heat exchangers for TSP analysis. There are five utilities for heaters (Table 1a) and three utilities for coolers (Table 1b). The data zero for IPS (intermediate pressure steam) indicates that IPS is not used. In Table 1b, the terms 'HPS Gen' and 'MPS Gen' were used to differentiate them 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).

3.1. Current case

Fig. 3 shows the TSP chart which is based on the current data for heaters and coolers as shown in Table 1. The right side of Fig. 3

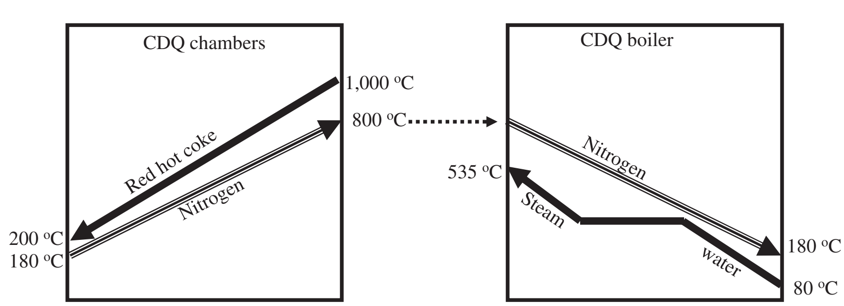

Fig. 2. Temperature–heat diagram of CDQ unit.