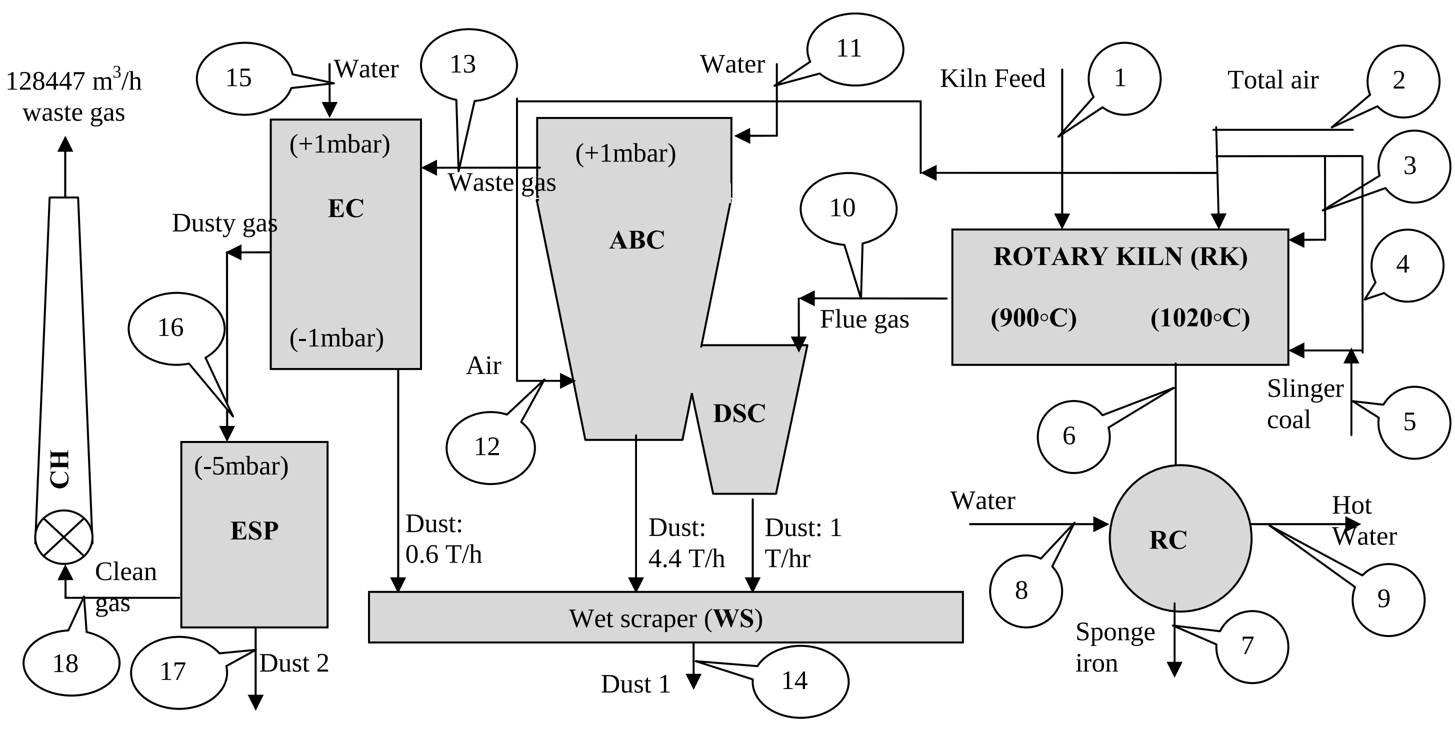
CASE STUDY ON THRESHOLD PROBLEM

Sponge Iron Production Process

Process description

This is the case study of typical coal based sponge iron plant of 500 tonne per day capacity. The process flow diagram (PFD) of the sponge iron process is shown in Fig. 1. Different streams in the PFD are assigned individual number and henceforth each stream will be referred through its respective number. Detailed operation of this plant is discussed in the work of Prasad et al. [2011]. The operating parameters for this process are shown in Table 1.



EC: Evaporating Chamber, ESP: Electrostatic Precipitator, CH: Chimney, RK: Rotary kiln
ABC: After Burning Chamber, DSC: Dust Settling Chamber, WS: Wet Scrapper, RC: Rotary cooler

Fig. 1 Process flow diagram of the sponge iron process with material and energy balanced data

Table 1 Operating parameters of the process under consideration

Stream No.	T,°C	Mass Flow, t/h	Stream No.	T,°C	Mass Flow, t/h
1	30	44.59	10	900	98.93
2	30	83.913	11	30	12
3	30	13.516	12	30	13.516
4	30	2.816	13	1050	119.046
5	30	7.73	14	80	6
6	1020	23.788	15	30	45
7	110	23.788	16	250	163.446
8	30	750	17	220	5.5
9	34.74	750	18	220	157.946

Data extraction

The aim of this work is to modify the flow sheet of the existing system to reduce energy consumption used per tonne production of sponge iron. The first step to achieve this aim is to extract the required data from the process flow sheet, shown in Fig. 1. These data are summarized in Table 2. The minimum temperature difference, ΔT_{min}, for this case is 50°C.

Table 2: Stream data for the process

Steam no.	Stream name	Type	T_s (°C)	T_t (°C)	CP (kW/°C)
6+7	h1	Hot	1020	110	4.545
14	h2	Hot	80	30	1.461
17	h3	Hot	220	30	1.386
18	h4	Hot	220	152.63	50.016
2	c1	Cold	30	170	24.069
18	c2	Cold	60	142.7	50.016

+ used for streams which are considered together for heat integration

The data shown in Table 2 is extracted with a purpose to utilize the heat available with waste gas (Stream No. 18). In this data waste gas is used for air preheating from 30°C to 170°C and then cold gas is used to cool kiln outlet stream (Stream No. 6+7). Therefore, in Table 2 waste gas (Stream No. 18) is considered twice: initially as hot stream and then as cold stream.

Targeting

The composite curve for this case is shown in Fig. 2 where hot and cold utilties are 0 and 336 kW, respectively. As one utility is zero it is the case of threshold problem. It indicates that possible recovery of heat within the process is 7506 kW.

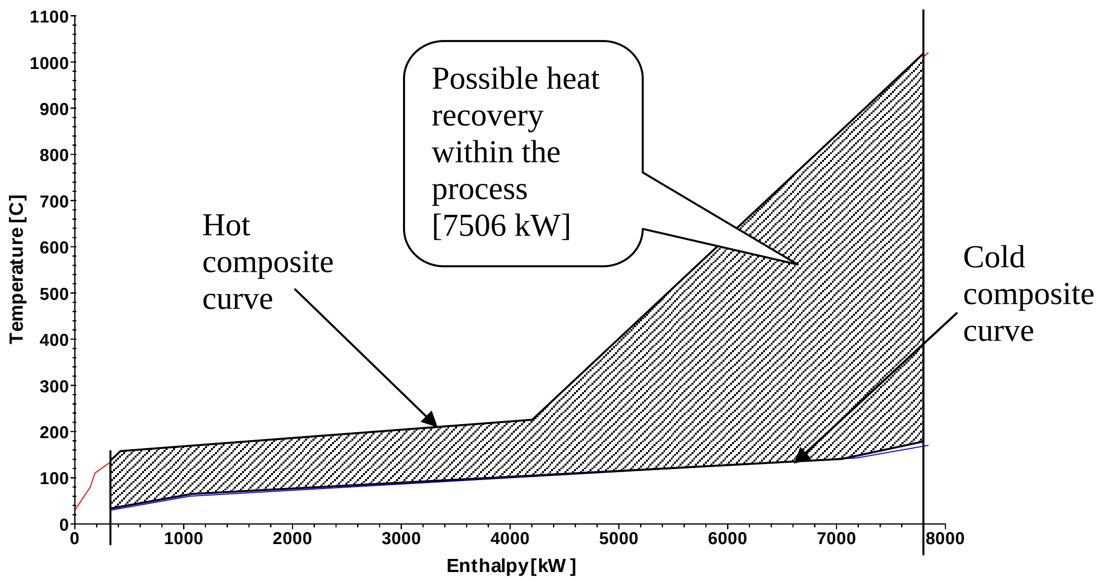


Fig. 2 Composite curve

Designing

The heat exchanger network (HEN) is designed for this case and shown in Fig. 3. While designing the HEN streams h2 and h3 are not considered as these are dust streams and may foul the surface of heat exchanger considerably and make it inoperable in a short span of time. Fig. 3 shows that only two heat exchangers are required in the HEN. Exchanger-1 of load of 2951.6 kW is used to preheat air (Stream c2) from 30°C to 170°C using waste gas (Stream h4) and exchanger-2 of load of 4136.2 kW is employed to cool kiln outlet (Stream h1) using waste gas (Stream h2). Fig. 3 does not include any heater due to zero hot utility. Moreover, cooler is also not used in the design as cooling is required by streams h2 and h3 which are already excluded from design.

It is should be noted from Fig. 3 that total recovery of heat in the process is only 7087.8 kW instead of 7506 kW shown in Fig. 2. This fact is illustrated as: due to the preheating of air by waste gas the coal consumption has dropped down to 20.239 t/h. It should be noted that earlier (in existing system) the heat required for air preheating was taken from coal itself. In fact, the coal consumption figure reported above is computed based on the primary amount of air which is 83.913 t/h, as shown in Table 1. However, when the consumption of coal drops the quantity of air required to burn it also drops. So the solution of this problem requires trial and error approach. Based on the trial and error method the final amount of coal required is estimated to be 19.195 t/h and the corresponding air requirement comes out to be 74.158 t/h. Further, due to decrease in the amount of air the waste gas amount will also decrease to 145.665 t/h in comparison to earlier figure of 157.946 t/h as shown in Table 1. A fresh computation shows that with the revised amount of air as well as waste gas, value of CP for air and waste gas also decreases. Consequently, total load of exchanger-1 also drops down; however, that for exchanger-2 remains unchanged. Thus, after designing recovery of heat in the process is decreased than that has been targeted through composite curve shown in Fig. 2.

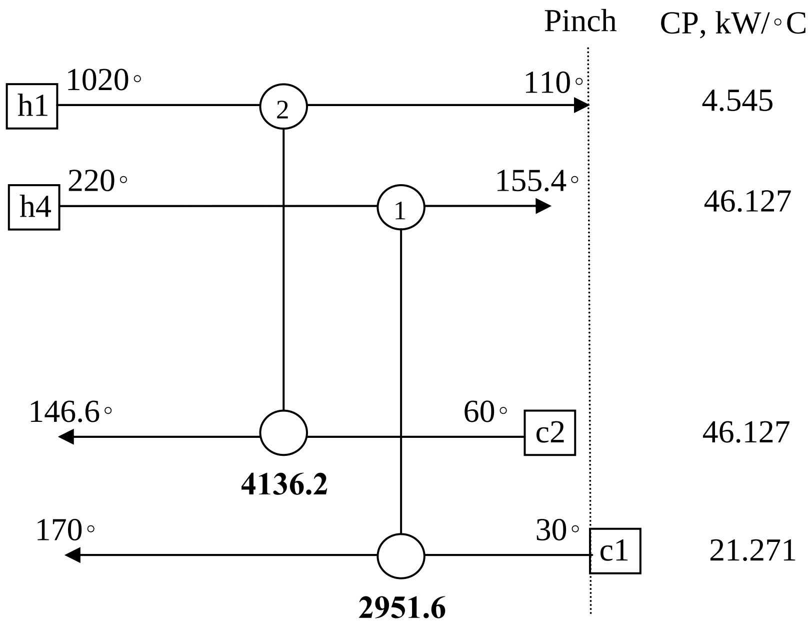


Fig. 3 Designing of HEN

Modified process flow diagram

The modified PFD for sponge iron process based on HEN is shown in Fig. 4 where grey lines shows the ducts to carry waste gas from chimney to exchanger-1 (shown through G-G HX in Fig. 4), from exchanger-1 to exchanger-2 (shown through G-S HX in Fig. 4) and from exchanger-2 to chimney. This heat integration based modification causes coal consumption to be reduced by 11.6% in comparison to the existing system.

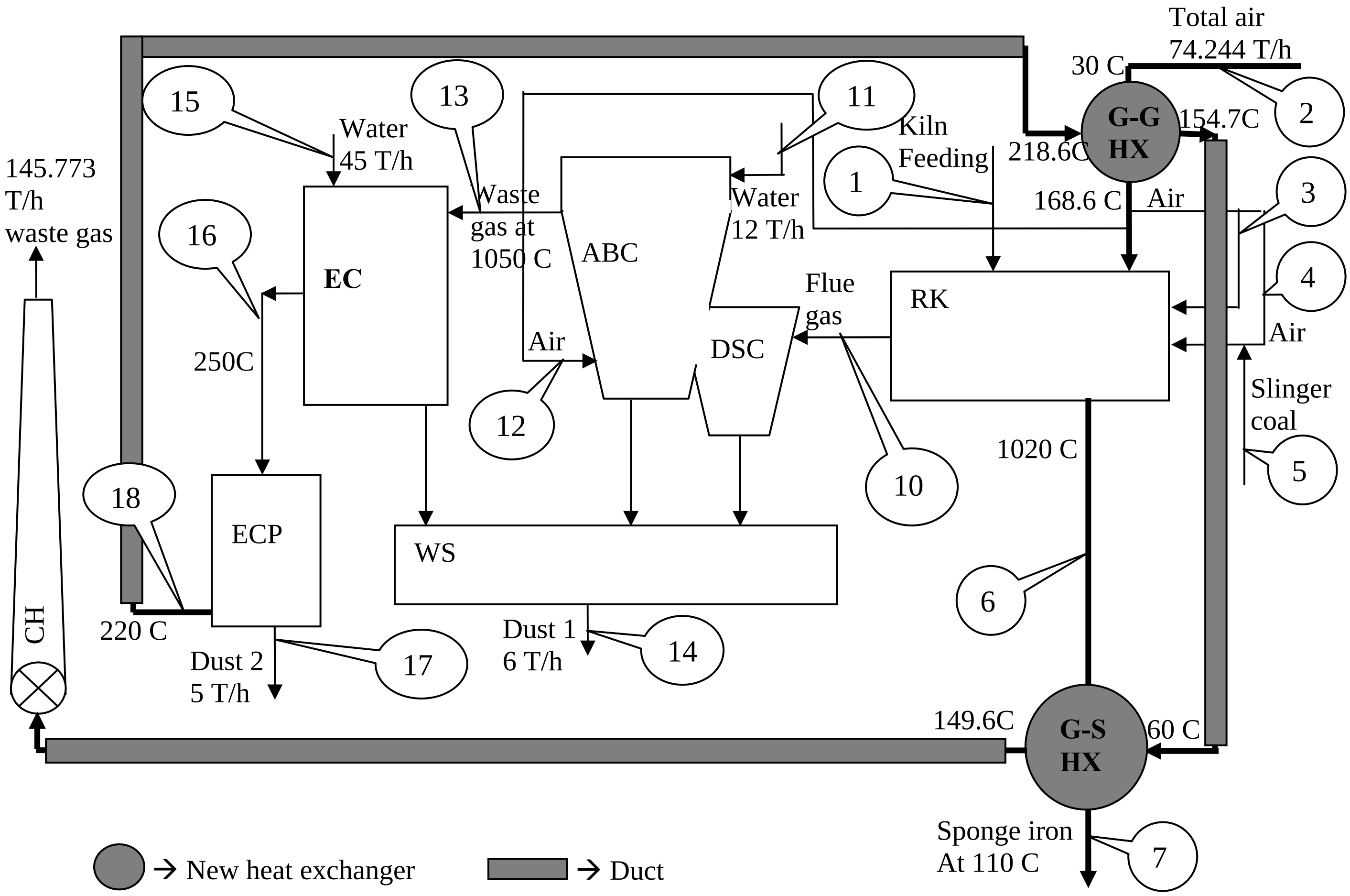


Fig. 4 Modified PFD for sponge iron process

References

1. Prasad A.K., Prasad R.K., Khanam S., Design modifications for energy conservation of sponge iron plants. J. Thermal Sci. Eng. Appl. 3, 015001-1-015001-11 (2011).