# Application Of Pinch Technology In Heat Recovery System Optimization Of Coated Paper Machine


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### ABSTRACT

Pinch technology provides a systematic methodology for energy saving in process and total sites. The methodology can be based on thermodynamic principles, and it is a static, optimum method for heat exchanger networks. Pinch analysis is used to identify energy cost of heat exchanger network and recognize the pinch point. The heat recovery system of coated paper machine is actual a heat exchanger network. The main function of the system is recovering the energy of the hot, moist exhaust air from the hood. The supply air that from the hall for hood and pocket ventilation is heated, and the process water is heated too.

In this paper, pinch technology is applied to diagnose and analyze heat exchange networks in the dryer section of coated paper machine. Some parameters used for pinch analysis are obtained after months of investigation in the paper mill. For example, the humidity, temperature of the supply and exhaust air. Other data are measured by some special instrument. Problem table algorithm and grand composite curve are used in the analysis. The result showed that there is a big energy-saving potential in the existing heat exchange networks and the quantity of heat-saving in new heat exchange networks after reforming increased from 4821.6 kJ/s to 9973.1kJ/s, 2.3% fresh steam of dryer section is saved.



***Keywords:*** *coated paper machine; heat exchange networks; pinch technology; optimum analysis.*


## Introduction

Pinch technology is introduced by Prof. Linnhoff of UMIST in 1970s[1]. It presents a simple methodology for systematically analyzing chemical process and the surrounding utility systems with the help of the first and second laws of thermodynamics. For energy analysis researchers, pinch analysis has now become a routine tool and incursions have been made in extensions of the technique to specific cases. The object of pinch is to identify energy cost and heat exchanger network capital cost targets for a process and recognizing the pinch point. It can be used in heat exchanger network design, retrofit and optimization[2]. For the last decades, pinch technology is widely used in chemical plant, such as petrochemical and alcohol distillery plants. Pinch technology is also used widely in paper mills [3-5]. C. Bentasson's group applied the pinch technology and MINP in a Sweden paper mill, and got a good energy saving result[6]. Ian C. Kemp used process integration and pinch analysis together to optimize the energy use and cost in dryers[7]. A.Isafiade and D. Fraser examines the benefits that plant it was also used in paper and board industry[8]. In China, Zhong Hong etc. analyzed the Kamyr Continuous Digester mass and heat transfer process using pinch technology, and got a good result in energy saving[9].

Paper machine dryer section heat recovery system plays an important role in energy recovery and energy saving in paper industry. For a typical newsprint machine, more than 60% of the exhaust energy from the dryer section can be recovered, resulting typically in a regain of about 30MW[10]. In order to recover the most energy in the humid hot exhaust air from the hood, the heat recovery system always consists of two parts. In the first part, the heat is recovered by the dry supply air which is going to the hood after heated, which is called conventional heat recovery (CHR). In the second part, heat is reused by heating cool water, such as white water, process water etc. The process is called aqua heat recovery (AHR)[11]. For an online coated paper machine, the dryer section is divided into two parts: the Pre-drying and After-drying. The base paper is dried in the pre-drying process, which is similar to the newsprint drying process. When the paper is coated by paint, such as calcium carbonate, the coated paper is dried by the hot blow air and infrared radiation, which are produced by burning the natural gas and liquefied petroleum gas. Then, more heat energy will be recovered.

Many researchers did lots of work in optimizing the heat recovery system of paper machine. New models and methods are used in different research articles. In this paper, the pinch analysis is used to analyze the heat recovery system of online coated paper machine. The analysis result shows that more heat energy can be recovered in the dryer section, which leads to higher energy utilization efficiency and less steam consumption.

## Steps of pinch analysis

### Identification of hot, cold, and utility streams in the process

Hot streams are those that with higher temperature. Heat transfers from them to cool streams. Cold stream are those that must be heated. Utility streams are provided by boiler or refrigerator which is different from those two kinds of streams, such as steam in the paper machine dryer section.


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### Thermal data extraction for process and utility streams for each stream

Thermal data which is extracted from the process material includes

(1) Supply temperature: the temperature at which the stream is available

(2) Target temperature: the temperature the stream must be taken to

(3) Heat capacity flow rate (CP: kW/°C): the product flow rate in kg/s and specific heat (Cp kJ/kg·°C), which is calculated by:

$$CP = m * Cp \quad (1)$$

### Subsystem of the heat exchanger network and energy load calculation

The subnet-work is a simple description of heat exchanger network. The minimum temperature difference (DTmin) in the sub work-net is determined by different process. Typical DTmin values based on experience are available in literature for reference. For example, the DTmin chemical heat exchanger process is 10~20°C.

### Pinch point identifying- using problem table algorithm

As the subnet-work is figured and the DTmin is known, the energy balance of the heat exchanger system will be shown in a problem table algorithm. Then the pinch point is the point where the energy flow is zero.

**Construction of grand composite curve**

The Grand composite curve is one of the most basic tools used in pinch analysis. It shows the heat supply and demand with in the process. Using the diagram the designer can find which and how much utilities are to be used. The designer aims to maximize the use of cheaper utility levels and minimize the use of the expensive utility levels. By the help of GCC, cheaper utility and less expensive utility levels will be used.

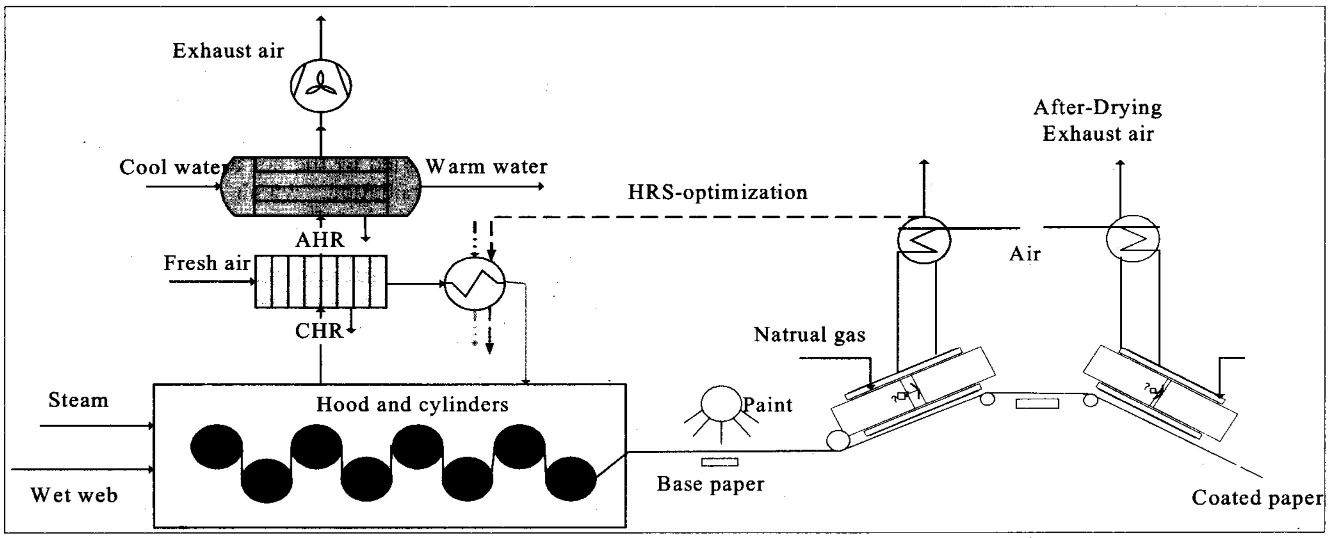
### A case study Of Pinch technology In coated paper Machine heat recovery system

As lots of research and survey were taken in a paper mill, the coated paper machine heat recovery system (HRS) just recovers the heat energy of pre-drying exhaust air currently. The after-drying air was exhausted out of the system openly. Pinch technology is used to analyze and optimize the heat recovery of a coated paper machine. The designed parameters of the paper machine are: machine speed: 1800m/min, basis weight of the product: 80~120g/m$^2$, production yield: 1500ton/d. the heat recovery system of the paper machine is showed in figure1.

**The process data collection and stream data calculation**

Process data is measured by portable instrument and online sensors. Humidity, temperature and flow of air are measured by the TESTO400 (made in Germany) and FLUKE454 (made in America). The parameters of steam and water are measured by the online sensors. The stream data is showed in table 1.

**Fig.1 heat recovery system**




Of the coating paper machine

TABLE-1 TYPICAL STREAM DATA OF HEAT RECOVERY SYSTEM

| Stream Flow | | Heat Cap. /kJ· ( s·°C ) $^{-1}$ | TS /°C | TT /°C | Heat flow /kJ·s$^{-1}$ |
|---|---|---|---|---|---|
| Cold | Fresh air | 152.30 | 20 | 102 | 12488.69 |
| Stream | Cold water | 1098.53 | 20 | 50 | 32955.90 |
| Hot | Hood air | 309.81 | 110 | 48 | 19208. 22 |
| Stream | Saturated air | 942.7 | 70 | 48 | 20739.4 |

### Energy balance of the subnet-works

According to the stream data, the grid diagram of HRS can be figured out. The DTmin we choose is 200. The grim diagram is divided into for subnet-works as showed in figure2.

The energy balance in each subnet-work was calculated by the following equations:

$$O_K = I_K - D_K \quad (2)$$

$$D_K = (\Sigma CP_{cold} - \Sigma CP_{hot}) * (T_K - T_K + 1)\ k = 1,2 \ldots\ldots\ldots K \quad (3)$$

Where:

$O_K$ --energy from the subnet-work;

$I_K$ --energy supplied for subnet-work;
$D_K$--the deficit of subnet-work k (+: energy in;-: energy out);
$\Sigma CP_{cold}$ --the heat flow rate of total hot stream flow;
$\Sigma CP_{hot}$ --the heat flow rate of total cold stream flow;
$T_K - T_K+1$ --temperature difference of a subnet-works;

Following the equations, the result of the energy balance for the grid diagram is shown in table2.

We can see that: in table2, energy in and out of some of the subnet-work is negative. As the energy cannot transfer from cold to hot, when the energy of the subnet-work is negative, more energy should be supplied by the utility stream. The hot utility stream is fresh steam in the heat recovery system. When the energy of the fresh steam reaches 5185.08kJ/s, the subnet-work turns to be positive.

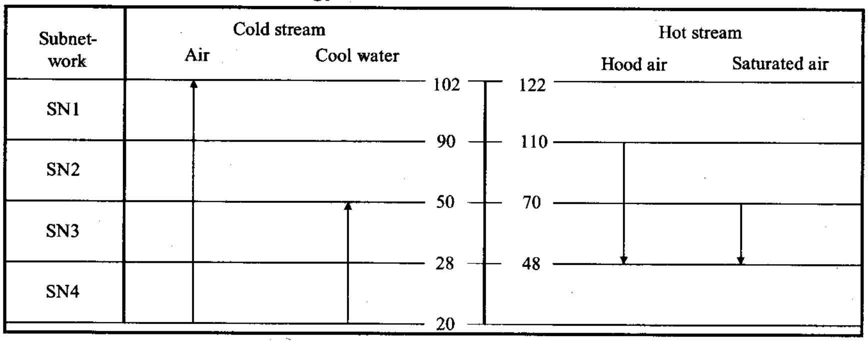



**Fig.2 Grid diagram for piNch analysis (before optimization)**

| TABLE 2 ENERGY BALANCE FOR EACH SUBNET-WORK kJ/s | | | | | |
|---|---|---|---|---|---|
| Number | $D_k$ | No Utility stream energy | | Minimum Utility stream energy | |
| | | $I_k$ | $O_k$ | $I_k$ | $O_k$ |
| SN1 | 1827.60 | 0 | -1827.60 | 5185.08 | 3357.46 |
| SN2 | -6615.53 | -1827.60 | 4787.92 | 3357.46 | 9972.99 |
| SN3 | -33.68 | 4787.92 | 4821.60 | 9972.99 | 10006.68 |
| SN4 | 10006.68 | 4821.60 | -5185.08 | 10006.68 | 0 |

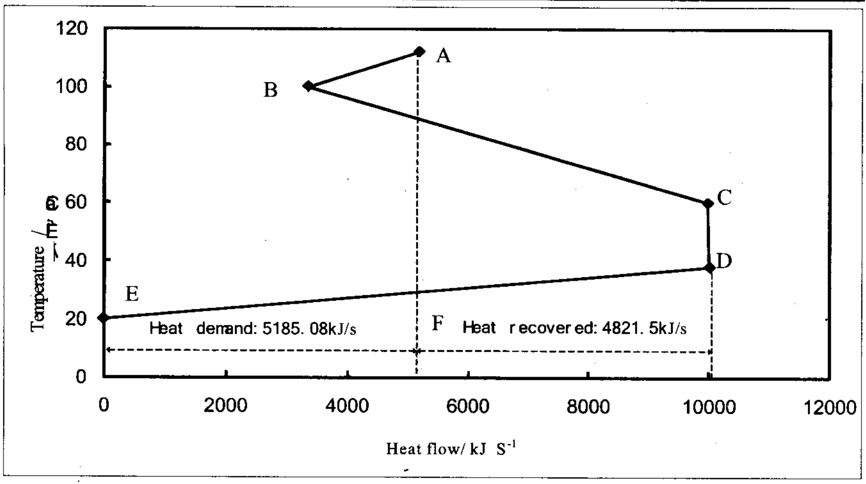



**Figure 3 GCC of heat recovery system (before optimization)**

TABLE 3 STREAM DATA OF AFTER-DRYING EXHAUST AIR

| Stream Flow | Heat Cap. /kJ·(s·°C)$^{-1}$ | TS /°C | TT /°C | Heat flow /kJ·s$^{-1}$ |
|---|---|---|---|---|
| Exhaust air | 224.37 | 220 | 110 | 24680.7 |

## Grand composite curve

GCC is base on the energy balance of the grid diagram, and the GCC of heat recovery system is shown in figure3.

The GCC shows the temperature and Heat flow of each heat exchange interface. For example, at point A, the temperature and energy flow is 600 and 9972.99kJ/s. We can see from fig.3 that the energy requirement of SN4 is 10006.68kJ/s. but the energy from other subnet-works is only 4821.60kJ/s, which is recovered from the system. The additional energy is 5185.05kJ/s which can only be supplied by the fresh steam.

## Optimization of the heat recovery sYstem

Online coated paper machine is joined into a single entity by the paper web, so the heat recovery system can be integrated. As we measured, heat energy of exhaust air from after-drying process is very significant. So it can be used to heat the fresh air instead of low pressure steam. The stream data of the after-drying exhaust air is showed in table3.

As the temperature of the exhaust air is very high, when it is recovered, the structure of the grid diagram varies considerably. The new diagram is shown in figure 4.

## Energy balance and GCC for the subnet-work after optimization

Energy balance of the subnet-work is showed in table 4

As we can see from table4, the air temperature can reach the target without the utility stream. What is more, the energy even has a surplus of 6695.17 kJ/s.

## GCC of the new heat recovery system (after optimization)

The new GCC of heat recovery system is shown in figure5.

GCC after optimization is different from the one shown in figure 3. The point where the heat flow is zero appears on the top of the GCC. When then zero point is on the top, the analysis results show that the heat recovery system has an energy surplus. By contrast of fig.3 and fig.5, we can see that more energy is recovered by reuse the exhaust air from the after-drying process. The surplus energy is 6695.17kJ/s. however, the temperature of the air after heat exchanger is low, and so it cannot be used again and

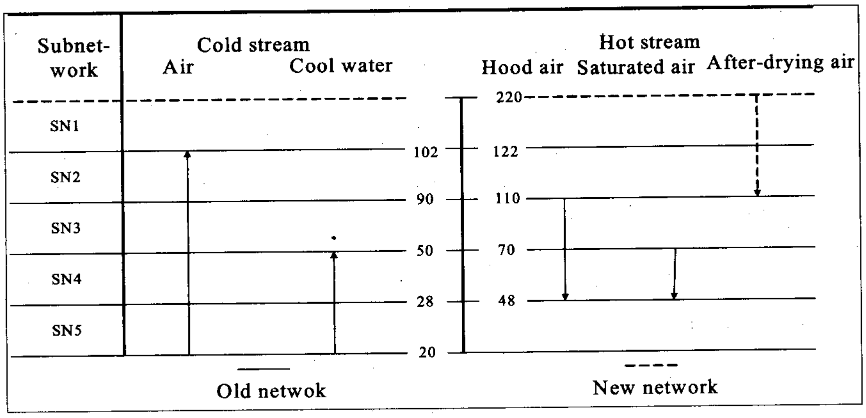
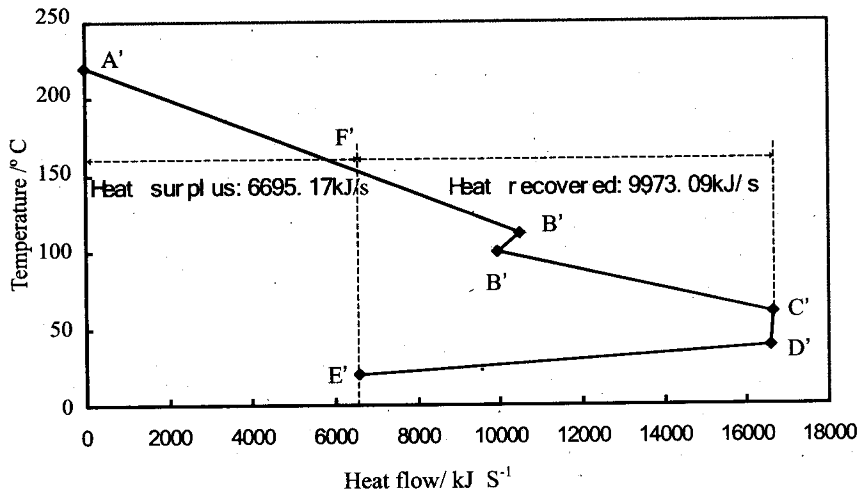



**Figure 4 Grid diagram for pinch analysis (after optimization)**

**Table4 energy balance for each subnet-work (after optimization)**

| number | $D_k$ | Heat flow $I_k$ | Heat flow $O_k$ |
|---|---|---|---|
| SN1 | -10495.1 | 0 | 10495.13 |
| SN2 | 542.50 | 10495.13 | 9952.63 |
| SN3 | -6615.53 | 9952.63 | 16568.16 |
| SN4 | -33.68 | 16568.16 | 16601.84 |
| SN5 | 10006.68 | 16601.84 | 6595.17 |




should be exhausted.

## Conclusion

(1) Pinch technology can be used in static optimization problem. It is also feasible to solve the problem in paper machine heat recovery system.

(2) Pinch analysis used in coated paper machine heat recovery system shows that more energy can be recovered to save about 2.3% fresh steam.

(3) The pinch point is changed after the system optimization, the recovery energy reaches 9973.09kJ/s, which is enough to pre-heat the supply air, and no low pressure steam will be used.

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