

Study on the heat recovery of waste gas in printing plant

Yuhui Di^{1,a}, Linyuan Zhou^{2,b}, Hui Yin^{1,c} and Lijuan Wang^{1,d}

¹Xi'an Polytechnic University, Xi'an, China

²Fushan District, Yantai City Yongda Street No. 720, Shandong, China

^a470836165@qq.com, ^b735310759@qq.com, ^c865857214@qq.com

^d643547601@qq.com

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Abstract. The purpose of this study is to recycle the heat of waste gas in printing plant. Several heat recovery equipments are presented and analyzed. After comparing, the heat-pipe heat recovery equipment is found as the most effective equipment for the organic exhaust gas on the basis of its temperature. The mathematical model of heat recovery is provided and discussed. The conclusions are useful to increase the efficiency of heat recovery and save energy.

Introduction

The organic waste gas emitted by printing process causes great threat not only to the quality of printing production, but also to the work-men's health [1]. In addition, if the waste heat carried by the gas is emitted directly, the energy will be wasted and the air will be polluted. In this paper, taking the printing plant in the Xi'an as the example, the heat recovery technologies are used for the organic exhaust gas.

Introduction of printing plant

The printing plant is located in Xi'an, China. Its area is $72 \times 9 \text{ m}^2$, and the height of lower chord is 5 m. There are 9 printing machines inside, and whose sizes are $3.2 \times 2.6 \times 2.6 \text{ m}^3$.

Since the dew-point temperature in Xi'an is very low, when the temperature of fresh air gets close to this value, the characteristics of paper and ink might be affected. Besides, the sensible heat of printing device is so much that it is kind of waste of energy. According to these factors, the heat recovery to compensate heating load is presented in this paper.

Treatment Strategy

Organic waste gas emitted by printing is collected by local exhaust hood [2], and then it is collected to exhaust duct through exhaust branch pipe. The organic gas distributes in the upper space with the aid of the rising heat flux. In order to collect the gas effectively, a negative pressure and upward exhaust hood are used. The size of the exhaust hood is $3.2 \times 3 \text{ m}^2$, and it is made of galvanized steel plates. According to the height and the limited space in the printing plant, the distance between the hood face and the top of equipment is 0.4m, and the distance between the hood face and the exhaust gas source is about 1m. The vent size of the plant is $1.48 \times 1.55 \text{ m}^2$, with the total exhaust air capacity of $63000 \text{ m}^3/\text{h}$. The emission concentration of the organic waste gas can not meet the second level emission standards of the "Comprehensive Discharge Standard of

Atmospheric Pollutants” [3]. So it cannot be released to atmosphere without any treatment. If the catalytic oxidation is used to treat the exhaust air, the bottleneck will be wasted energy because of the huge quantity of exhaust air with low concentration organic gas [4]. In this paper, the technology of adsorption concentration combined with catalytic oxidation [5] is adopted to treat the exhaust air. Its technological process is shown in Figure 1.

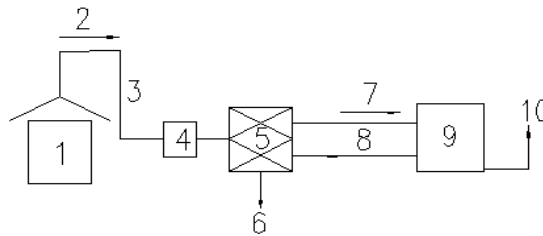


Figure 1. Treatment process about printing organic waste gas.

1-printing device, 2-low concentration VOCs, 3-exhaust manifold, 4-prefilter, 5-adsorption bed, 6-clean air, 7-high concentration VOCs, 8-hot flue for desorption, 9-equipment for catalytic oxidation, and 10-emission gas

Compared with the direct catalytic oxidation, the technology of adsorption concentration combined with catalytic oxidation is more efficient. However, the high temperature of emission gas still leads to a huge waste of latent heat and sensible heat. If the heat is directly discharged into the atmosphere, the thermal pollution will happen. So the technology of heat recovery should be introduced in next chapter.

Technologies of Heat Recovery

General plan of heat recovery. According to the related research results, the temperature of treated organic waste gas can reach 400~500 °C [6]. Combined with the organic waste gas treatment process of the printing plant, the residual heat of the emission gas will be used for heating or reheating. In this way, the temperature of the emission gas will be reduced, and the heating energy consumption will be cut down dramatically [7]. The principle of the heat recovery is shown in Figure 2.

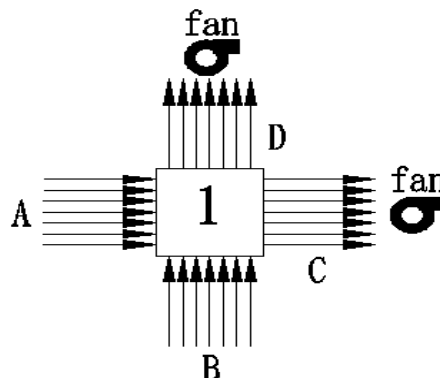


Figure 2. The principle of heat recovery.

1-heat recovery unit; A-new air with low temperature, B-high temperature emission gas, C- supply air with middle temperature, and D-middle temperature exhaust air.

In Figure 2, the heat recovery is an air to air heat recovery system. The heat transfers from high temperature gas to low temperature fresh air in the unit. The efficiency of heat exchange is

determined by the flow rate, flux, the construction of heat recovery equipment, etc.

Comparison of recovery equipments. The heat recovery device can be divided into full heat recovery unit and sensible heat recovery device. It also can be divided into plate type, plate-fin type, runner type and heat-pipe type according to the structure [8]. The characteristics of them are shown in Table 1.

Table 1. The characteristics of heat recovery equipments

Type	Characteristics
Plate	static type; used for sensible heat recovery; simple structure; heat recovery efficiency from 40-60%.
Plate-pin	added fin to plate device; efficiency improves with the increase of heat exchange area; used for general heat recovery with low energy consumption.
Runner	rotated device; can be used for large air flow; high efficiency; no pollution to new air; driven by electrical machine; complex structure.
Heat-pipe	suitable for heat recovery of exhaust air whose temperature is lower than 400~500°C; easy-constructed; convenient for maintaining; high efficient and no energy consumption for large pin and heat exchange area device; no pollution to new are.

Considering the temperature of organic waste gas, structure, heat recovery efficiency, operation and other factors, the heat-pipe heat recovery equipment is chosen to reheat fresh air. Figure 3 shows the structure of heat-pipe heat exchanger. The fin is installed in the outer surface of heat pipe to increase the heat exchange area. A baffle in the middle of the device is used to prevent waste gas mixing with fresh air.

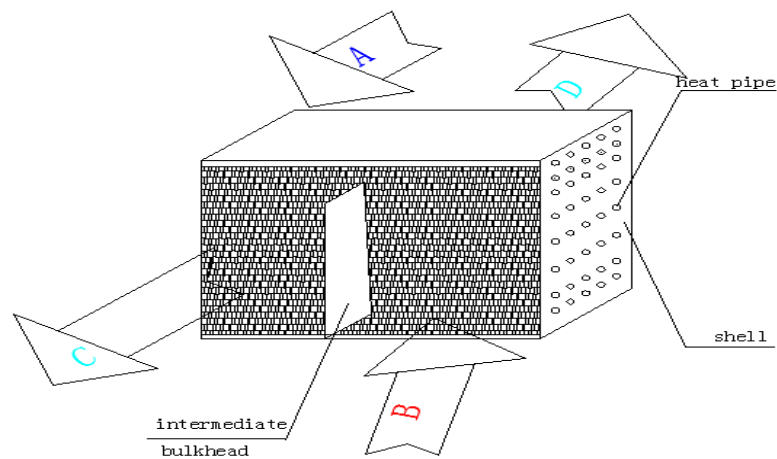


Figure 3. The heat-pipe equipment for sensible heat recovery

On the basis of heat transfer knowledge, the heat exchange between fresh air and high temperature emission gas can be presented as,

$$Q_{ex} = K \cdot A \cdot \Delta T \quad (1)$$

where K is coefficient of heat transfer, A is heat exchange area, and ΔT is logarithmic mean temperature difference [9].

$$\Delta T = \frac{(t_{wi} - t_{xo}) - (t_{wo} - t_{xi})}{\ln \frac{t_{wi} - t_{xo}}{t_{wo} - t_{xi}}} \quad (2)$$

where t_{wi} is inlet temperature of emission gas, t_{xi} is inlet temperature of fresh air, t_{wo} is outlet temperature of emission gas, and t_{xo} is outlet temperature of reheat air.

The heat balance equation is

$$Q_{ex} = M_w c_w (t_{wi} - t_{wo}) = M_x c_x (t_{xo} - t_{xi}) \quad (3)$$

where M_w is the mass flow rate of emission gas, M_x is the mass flow rate of fresh air, c_w is the specific heat capacity of emission gas, and c_x is the specific heat capacity of fresh air.

The efficiency of sensible heat recovery is

$$h = \frac{t_{xo} - t_{xi}}{t_{wi} - t_{xi}} \times 100\% \quad (4)$$

Substitute Eq. (1), Eq. (2) and Eq. (3) into Eq. (4), and the following equation can be obtained.

$$h = \frac{1 - \exp\left[(R-1) \frac{K \cdot A}{M_x c_x}\right]}{1 - R \cdot \exp\left[(R-1) \frac{K \cdot A}{M_x c_x}\right]} \times 100\% \quad (5)$$

where R is water equivalent ratio.

$$R = \frac{M_x c_x}{M_w c_w} \quad (6)$$

Eq. (5) shows that the efficiency of the heat-pipe heat recovery equipment has relationship with the heat transfer coefficient, heat transfer area, the quantity and specific heat capacity of the gas. So the heat recovery efficiency can be raised by installing fin or regulating the flow ratio.

Conclusions

In order to treat the organic waste gas in the printing plant, the characteristics of several equipments is compared. The heat-pipe heat recovery device is the best and chosen to heat fresh air. Besides, the mathematical model of heat transfer process is provided and its efficiency is analyzed.

The sensible heat recovery is analyzed in this paper. If the whole heat recovery technology can be taken into the heat recovery, it will be more significant. It needs further research is in need to explore the technology of increasing the recycled heat for full year operating mode.

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