ANALYSIS OF ENERGY-SAVING EFFECT OF FRESH AIR HEAT RECOVERY SYSTEM FOR RESIDENTIAL BUILDINGS IN SEVERE COLD AREA

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1 Introduction

For the northern cold regions, in order to achieve the purpose of keeping warm in winter and cold in summer, the indoor heat and cold are usually kept in the room by increasing the indoor air tightness. As a result, the indoor air does not flow, and the harmful gases cannot be discharged in time and effectively. This phenomenon affects people's health, and an effective way to solve indoor quality problems is to introduce fresh air.

The two major drawbacks of the traditional fresh air system are: 1) The fresh air temperature is low in cold areas in winter, which leads to condensation on the condensate pipes. 2) The introduction of fresh air will increase the load of indoor heating and other equipment, resulting in large fluctuations in indoor temperature and affecting comfort.

By analyzing many domestic and foreign related literatures [1-3], it is found that the energy saving effect of the system with heat recovery is better. It can not only overcome the disadvantage of low fresh air inlet temperature in winter, but also fully recover the exhaust air heat and improve the COP value of the heat pump system. Under the same outdoor air temperature conditions, the heat capacity and energy efficiency ratio of the dual heat source composite heat pump system are higher than single air source heat pump. The lower the air temperature, the greater the increase in heating capacity and energy efficiency ratio [4]. In the case of low ambient temperature in winter, solar-assisted heat pump has obvious advantages [5].

In summary, the introduction of fresh air will inevitably improve the indoor air quality, and also introduce fresh air load, increasing heating pressure and air conditioning load. The combination of fresh air and exhaust air heat recovery equipment not only recovers the waste heat, but also solves the problem of fresh air load, and the energy saving effect is also obvious. In this paper, the TRNSYS transient simulation software is used to compare and analyze the performance coefficient of the air source heat pump and the hot water outlet temperature on the load side under the conditions of single heat source and double heat source.

2 Model

The winter measured data of the CHP-80Y heat pump unit is used as the basis for compiling the external files of the air source heat pump in TRNSYS. The measured data is shown in Table 1. The main modules and functions of the simulation are shown in Table 2.

| Temperature/°C | Inlet temperature/°C | Heating capacity/kW | Power/kW |
|----------------|-----------------------|---------------------|----------|
| −30            | 5                     | 36.2                | 18.1     |
| −25            | 5                     | 40.8                | 19.4     |
| −20            | 5                     | 45.0                | 20.1     |
| −15            | 5                     | 50.0                | 20.7     |
| −10            | 5                     | 55.0                | 21.2     |
| −5             | 5                     | 55.5                | 22.0     |
| 0              | 5                     | 55.7                | 22.1     |
| 2              | 5                     | 55.8                | 19.8     |
| 7              | 9                     | 60.0                | 16.2     |
| 10             | 11                    | 62.0                | 15.6     |
| 16             | 17                    | 67.5                | 16.1     |
| 20             | 19                    | 65.0                | 15.1     |
| 25             | 24                    | 65.0                | 14.8     |
| 30             | 27                    | 65.0                | 14.4     |
| 35             | 29                    | 65.0                | 14.8     |
| 43             | 38                    | 62.0                | 14.1     |

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Table 2. Main modules and functions

| Module     | Function             |
|------------|----------------------|
| Type9      | Data reader          |
| Type3      | Water pump           |
| Type668    | Air-Water Source heat pump |
| Type65a    | Plotter              |
| Type25c    | Data output          |
| Equatio    | Calculator           |

2.1 Simulation of single heat source air source heat pump

Single heat source parameter setting: The time in simulation is the heating season from November to March of the next year. The outdoor weather parameters are obtained by reading the typical winter weather data in Shenyang and use them as the single heat source. The flow rate is 1494Kg/h through actual measurement. Each module in Figure 1 constitutes a flow chart for preparing domestic hot water by taking heat from outdoor air by an air source heat pump.

![Fig. 1. Condition 1 (single heat source condition)](image)

2.2 Simulation of dual heat source air source heat pump

Dual heat source parameter setting: The air temperature of the air source heat pump on the source side mix the outdoor air temperature and the indoor exhaust air temperature according to 1:1, and the indoor exhaust air temperature is set to 18°C. Other settings are the same as the settings of single heat source air source heat pump.

![Fig. 2. Condition 2(dual heat source condition)](image)

3 Equations and mathematics

The output COP and the outlet water temperature on the load side were compared and analyzed after the two operating conditions were operated in the heating season. Under the condition of single heat source (the air source heat pump only takes heat from the outdoor air to provide domestic hot water), the average COP value of the heat pump in the heating season is 2.78, and the temperature of the outlet water on the load side ranges from 32.35 to 54.04°C. Under the condition of dual heat sources (that is, the air source heat pump only takes heat from the outdoor air preheated by the exhaust air to provide domestic hot water), the average COP value of the heat pump in the heating season is 3.24, and the outlet water temperature range on the load side is 46.03 to 54.65°C. When the exhaust air heat is recovered to preheat the outdoor air temperature, the source side temperature entering the heat pump is increased.

The COP values under the two working conditions are shown in Figure 3. It can be seen from Figure 3 that the COP value under the dual heat source condition tends to be gentler than that under the single heat source condition, and the fluctuation is small, and the performance coefficient of the heat pump is increased by 17%. After 1500 hours of heating (around the middle and late January of the following year), the performance coefficient of the single heat source heat pump reaches the minimum value of 2.18, and the outlet water temperature on the load side of the heat pump is about 32°C, which is difficult to reach the comfort level of people's domestic hot water. After the outdoor air is preheated with indoor exhaust air, the heating capacity of the heat pump increases and tends to be the same which can increase the service life of the heat pump.

![Fig. 3. COP value under 2 conditions](image)

The water temperature on the load side under the two working conditions is shown in Figure 4. It can be seen from Figure 4 that the maximum outlet water temperature on the load side has no significant change compared with the single heat source condition. When the air source heat pump only takes heat from the outdoor air, the outlet water temperature on the load side fluctuates violently. After the fresh air is preheated, the outlet water temperature on the load side fluctuates around 48°C, which can meet people's 24-hour demand for hot water.
By simulating the working conditions in Table 3 through TRNSYS, when the indoor exhaust air temperature is increased, the COP of the air source heat pump and the outlet water temperature on the load side are increasing. The minimum outlet water temperature on the load side increased significantly, but the fluctuation range of the maximum outlet water temperature was small, and the average outlet water temperature increased by about 0.8%. It can be seen that the dual heat source condition (the source side air temperature is preheated with exhaust air) can increase the minimum outlet water temperature on the load side, but the maximum outlet water temperature does not change much.

4 Conclusion

The fresh air mixed with the indoor exhaust air and the outdoor fresh air according to the air volume of 1:1 is used as the air supply side of the air source heat pump, which not only improves the performance coefficient of the air source heat pump, but also can provide stable domestic hot water. The air source heat pump operates under the condition of dual heat sources. When the exhaust air temperature is 18°C, the average COP value reaches 3.24, which is 17% higher than the performance coefficient of the air source heat pump with a single heat source, and the temperature of the domestic hot water is stable at 46.03°C to 54.56°C, meeting people's demand for hot water. When the indoor exhaust air temperature is increased, the coefficient of performance of the air source heat pump and the outlet water temperature on the load side are increasing, and the average outlet water temperature increases by about 0.8%.

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