Study on Influence of Air Supply Technology on Performance of Low Temperature Air Source Heat Pump Water Heater

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Abstract: the Technology of Replenishing Gas Can Increase the Heating Capacity and Reduce the Exhaust Temperature of Compressor. Based on the Basic Principle of the Compressed Heat Pump System, This Paper Carried out Repeated Experiments in the Same Air Source Heat Pump System to Test the Specific Impact of the Air Replenishment Technology on the Performance of the Low-Temperature Air Source Heat Pump Water Heater. the Results Show That the Air Supply Technology Has a Significant Impact on the Performance of the Low-Temperature Air Source Heat Pump Water Heater. When the Relative Air Supply Increases by 12.73%, the Heating Capacity Will Increase by 9.28kw and the Heating Capacity of the System Will Be Improved. When the Vent Hole Diameter of the Make-Up Hole of the Compressor is Fixed, the Maximum Make-Up Pressure Will Appear, and the Heating Efficiency of the System Will Reach the Maximum At This Time. When the Temperature of the Refrigerant is Well Regulated, the Safe Operation of the Expansion Valve Can Be Ensured.

1. Introduction

1.1 Literature Review

Qi Yaru and others explored the low-temperature heating performance of air source heat pump, analyzed the performance change of heat pump under low-temperature condition through the enhanced air replenishment (EVI) technology of quasi two-stage compression cycle, and compared the difference between the air replenishment system and other air replenishment systems. Through three aspects of model building, experiment and innovation optimization, the effect of enhanced air supply technology on low temperature air source heat pump is studied. It is concluded that in the environment of-15℃, enhanced air supply system can still increase COP by 7.7% - 25.0%, and reduce exhaust temperature by 6.37-20.36 ℃ (Qi et al., 2015). Cui Siqi and others pointed out the problems of high exhaust temperature, high compression ratio, low system performance and low volume efficiency in the low temperature environment. At the same time, it puts forward to use the medium pressure air supply technology to improve the existing problems, which is proved by experiments to be able to significantly improve most of the problems of heat pump air conditioning in low temperature environment. Compared with heat pump air conditioning without air supply, it has higher safety and feasibility (Cui et al., 2018). Dai Yuande and others developed a prototype of low-temperature air source heat pump based on the air replenishment technology of scroll compressor. After reasonable experiments, it was found that the heat and the heating coefficient of the air replenishment sample mechanism of scroll compressor were effectively improved (Dai et al., 2014). Lei Mingjing and others analyzed the working principle and theoretical coupling of the hot water system of variable frequency heat pump with hot air source, and proposed that when the heat pump is running, the compressor exhaust is lower and more stable than the water heater with circulating heating mode in terms of exhaust and pressure (Lei et al., 2015). Ran Xiaopeng and others set up the simulation model of evi air source heat pump, and verified the specific effect of simulation experimental data on the air supply operation characteristics of the air source heat pump system with evi. It was found that when the optimal air supply quantity was achieved, the maximum

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heating capacity was increased by 33%, and the maximum energy efficiency was increased by 31% (ran et al., 2019).

1.2 Purpose of Research

Air source heat pump system has a variety of features, such as the integration of cold and heat sources, reducing the setting of boiler room and refrigerator room, compact and convenient, and can be placed anywhere at will. The system does not need cooling water system, which means the consumption of power and cooling water is reduced. Air source heat pump system does not form a lot of bacteria, the overall system is safe and pollution-free, very environmental health. However, when a large amount of heat is needed, the air source heat pump can not provide enough heat. When running in a cold place, the energy efficiency drops rapidly. Therefore, this paper studies the low-temperature air source heat pump water heater to reduce the impact of cold factors on the test, and only tests whether the air replenishment technology has an impact on the performance of the low-temperature air source heat pump water heater, which is of great significance for improving the low-temperature air source heat pump water heater.

2. Basic Principle of Compressed Heat Pump System

2.1 It Can Promote the Mental Health of College Students in Time and Improve the Effect of Ideological and Political Education

According to the schematic diagram (Fig. 1) and pressure enthalpy diagram (Fig. 2) of the air supply technology compressed low-temperature air source heat pump system, the main components involved in this system are condenser, economizer, compressor, evaporator, expansion valve A and expansion valve B. The refrigerant mainly circulates according to the 4-5-5'-1-2-2'-3-4 route, and runs the 4-4'-6-2'-3-4 auxiliary circuit to circulate and flow at the same time. When the condenser participates in the heat pump cycle, the working medium enters the economizer from two ways to exchange heat. Most of the working medium becomes supercooled liquid (4-5) after heat release, flows through expansion valve a to reduce the evaporation pressure (5-5') to PS, then absorbs heat from the evaporator to become refrigerant gas (5'-1), and finally enters the compression stage (1-2) in the suction. In addition, a small part of the working medium first reduces the pressure (4-4') to the intermediate pressure PM through the expansion valve B, flows into the economizer and inhales the liquid heat of the previous path, and becomes superheated gas (4'-6), flows into the compression chamber and mixes with the gas at point 2 in the compression state (6-2'-2). The mixed gas is compressed together to the exhaust pressure PD, and the heat is released from the compressor (2'-3) to the condenser, which is condensed into cold liquid (3-4), and then divided into two ways to form a cycle for cold air heating.

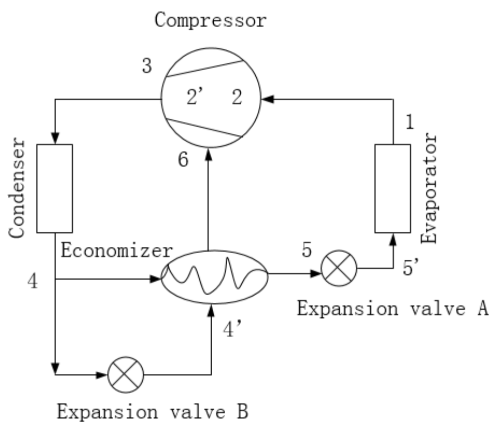

Fig.1 Schematic Diagram of Compressed Heat Pump System with Air Replenishing Technology

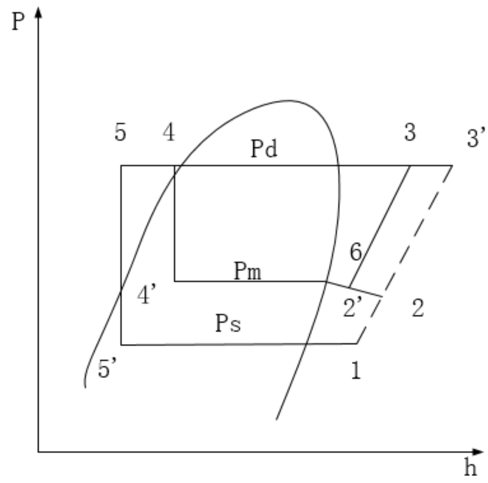

Fig.2 Pressure Enthalpy Diagram

3. Experimental analysis of the influence of air supply technology on the performance of low temperature air source heat pump water heater

3.1 Test Bench

The system components of air source heat pump water heater are as follows: BSR model 335m^3/h screw compressor, shell tube heat exchanger of 32.4 m^2 as condenser, needle valve as throttle valve of air replenishing circuit, and electronic expansion valve of I21 and Alco EX8 as throttle valve of main circuit.The plate heat exchanger with SWEP model parameter of 14.1 m^2 is selected as the economizer. 50 m^2 shell and tube heat exchanger for evaporator. Refrigerant R124 is used. The refrigerant pressure and temperature at the inlet and outlet of the economizer are measured. There are four inlets and outlets in total. The refrigerant enthalpy value and relative air replenishment amount are calculated.

3.2 Test Conditions

In the actual operation of air source heating, the water inlet temperature of condenser reaches 82℃, and the water outlet temperature reaches 88℃. The water inlet temperature of evaporator reaches 46℃ and the water outlet temperature reaches 43℃. During this period, the performance of the heat pump water heater system is tested. The condensing pressure of condenser is 1.88mpa, and the evaporating pressure of evaporator is 0.49 MPa The pressure regulation range of air replenishing technology is 0.84 MPa to 0.98 MPa. The specific operating parameters of the heat pump are shown in Table 1.

Table 1 Operating Condition Of Heat Pump and Regulation Range of Air Supply Pressure

Equipment	Parameter
Condenser	Inlet water temperature is 82℃
	The outlet water temperature is 88℃
	The condensation pressure is 1.88MPa
Evaporator	The inlet water temperature is 46℃
	The outlet water temperature is 43℃
	The evaporation pressure is 0.49MPa
Regulation range of air supply pressure	0.84~0.98MPa

3.3 Error Analysis of Test Equipment

The platinum resistance temperature sensor with an accuracy of ±0.1℃ is selected for temperature measurement. The accuracy is ±1%. Pressure sensor with range of 4MPa. An electromagnetic flow sensor with an accuracy of ±0.01m^2 is used to measure the flow of water. Use digital power meter with accuracy of ±(0.1% to 0.05%) to measure unit power. The recording data adopts data information collection and display system, and records are made in groups of five times. The error of test data is calculated by Kline and McClintock formula as follows:

$$\omega_R = \left[\left(\frac{\partial R}{\partial x_1} \omega_1 \right)^2 + \left(\frac{\partial R}{\partial x_2} \omega_2 \right)^2 + \cdots + \left(\frac{\partial R}{\partial x_n} \omega_n \right)^2 \right]^{1/2} \quad (1)$$

Formula: ω_R refers to the system error; $\omega_1, \cdots \omega_n$ refers to the error of a single variable; R is a function of X. According to formula (1), the maximum error of heating capacity and cop is 2.89% and 3.12%, respectively.

4. Results and Discussion

4.1 Relative Air Supply

During the test, in order to control the temperature in front of the expansion valve, continue to use the economizer to replenish air, and control the pressure adjustment range to 2.84-0.98 MPa, and the relative replenishment pressure range to 0.88-1.02 MPa. In the test range, the opening of the air make-up valve gradually increases, and the inflation pressure increases by 0.14 MPa. The relative air make-up volume increases from 9.88% to 22.61%, a total increase of 12.73% (Fig. 3). When the pore diameter of the filling hole is fixed and the filling pressure changes within a certain range, the relative filling volume will increase with the increase of the filling pressure.

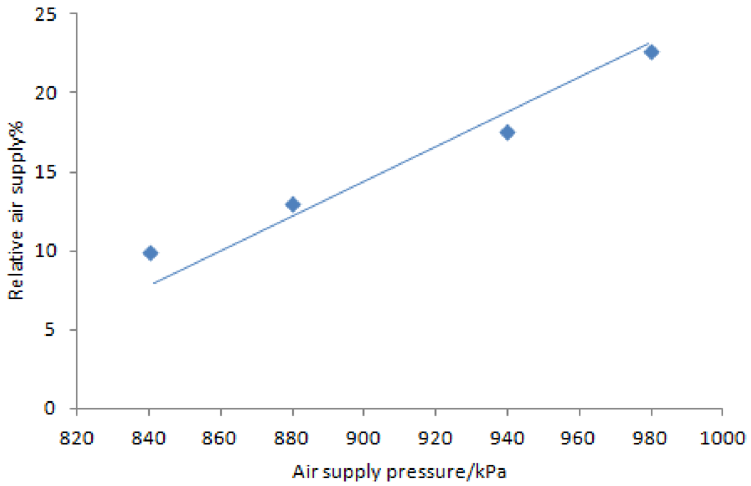

Fig.3 Relation Curve between Relative Air Supply Volume and Air Supply Pressure

4.2 Performance of Heat Pump

The relationship between heating capacity and power consumption of the system under different air supply pressure (Fig. 4) is that the relative air supply volume increases, the circulation quality of the refrigerant increases, the refrigerant flow in the condenser and compressor increases, and the power consumption of the compressor and heating capacity increases. When the air supply pressure increases by 0.14 MPa, the power consumption of the compressor increases by 7.18 kw, and the total heating capacity of the system increases by 9.78 kw. The increasing range of heating capacity and compressor power consumption is not consistent. The cop of heating system changes with the change of relative air supply, which first increases and then decreases. When the cop of the system reaches the maximum value, the optimal range of air replenishment is 0.84-0.98 MPa, the corresponding range of relative air replenishment pressure is 0.88-0.98 MPa, and the range of relative air replenishment is 9.88% - 17.27%.

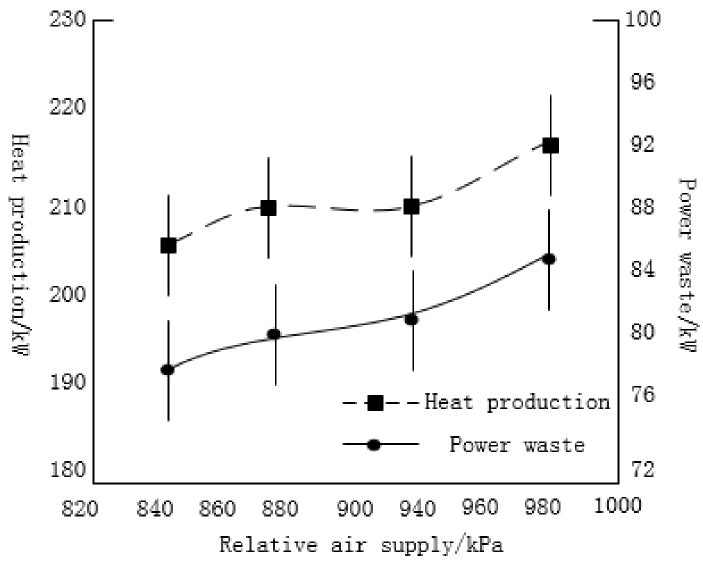

Fig.4 Change of System Heating Capacity and Compressor Power Consumption with Air Supply Pressure

4.3 Exhaust Temperature

The temperature in front of the expansion valve and the discharge temperature of the compressor will increase or decrease with the increase or decrease of the make-up pressure, and the specific change trend is shown in Fig. 5. The temperature in front of the expansion valve and the exhaust temperature of the compressor measured from the range of the air supply pressure regulation set in the test can be seen that the refrigerant temperature in front of the throttle valve decreases with the increase of the air supply pressure, while the exhaust temperature of the compressor remains basically the same. When the increase of relative air supply reaches 12.73%, the temperature in front of throttle valve will decrease by 10℃. This shows that the temperature is well regulated by refrigerant, which can ensure the safe operation of expansion valve.

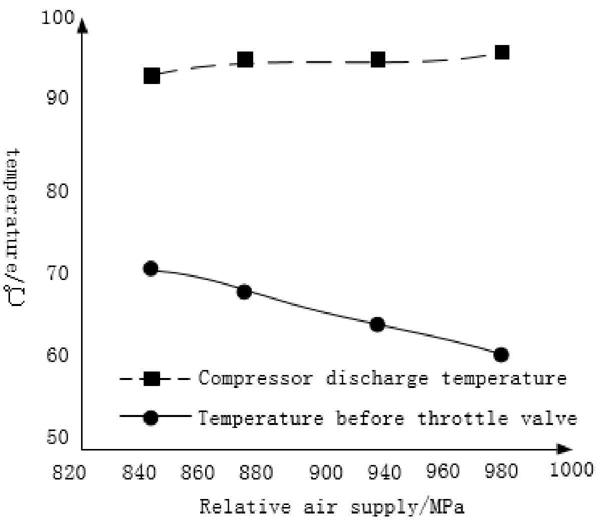

Fig.5 Change of System Heating Efficiency with Air Supply Pressure

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