

Study of a Solar Energy Assisted Air Source Heat Pump Integrated With Building

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Abstract. In this paper a solar air preheater is installed in front of the evaporator of air source heat pump in order to solve frost and liquid strike of the evaporator operating in the cold regions. The analysis shows that the new system can increase the air side temperature of the heat pump evaporator effectively, and improve the operation stability of heat pump. It provides a reference for the popularization and application of air source heat pump technology in cold area.

Introduction

The air source heat pump has been widely used in recent year, because it can save energy, reduce environment pollution. However under the condition of low temperature it is easy to frost on the surface of the heat pump evaporator, it increase the heat transfer resistance between refrigerant and the air, make the heat transfer effect worsen. Along with the growth of frost layer, the air flow resistance is greatly increased; resulting in the fan power consumption increase. Furthermore the compressor continued to work under frosting condition, it occurs liquid impact which causes the air source heat pump performance variation [1].

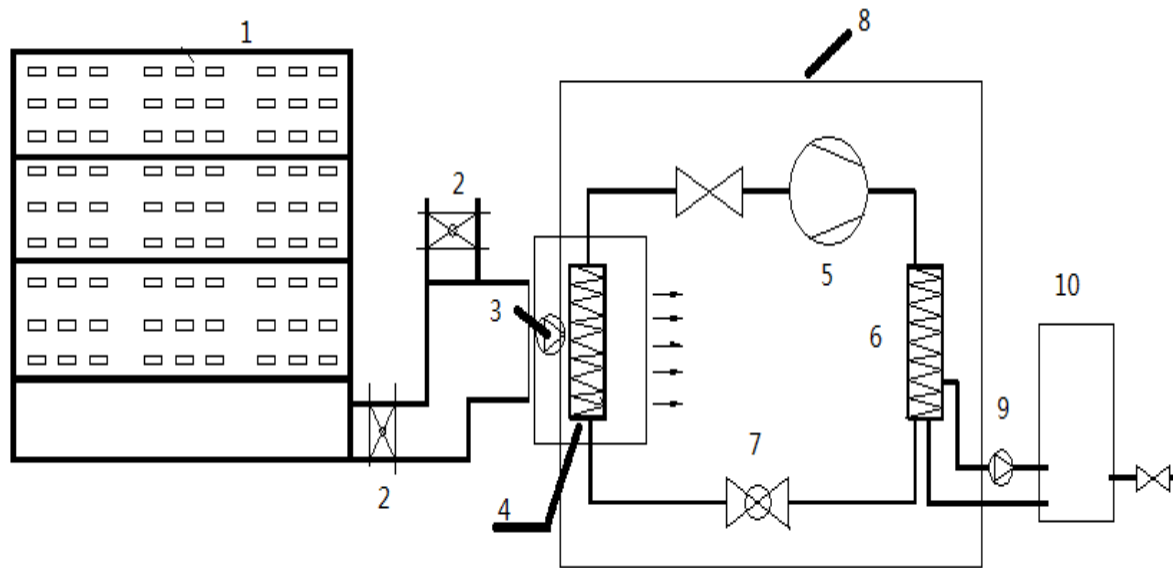
At present, the most commonly used air source heat pump defrosting way is to reverse cycle defrost and hot gas bypass defrosting. Reverse cycle defrost faster, but in the process of defrosting needs to absorb heat from the interior side, at the same time, four-way valve frequent commutation will affect its reliability and lifetime; In the process of the hot gas bypass defrosting, defrost energy mainly comes from the compressor power consumption, therefore, defrosting slower, and easy to cause compressor suction liquid defrosting process[2]. Furthermore in recent years the air conditioner manufacturers have developed increasing enthalpy by replenish gas, multistage compression techniques to improve the performance of the heat pump under low temperature conditions, but the effect is not obvious, equipment costs increased significantly.

In order to improve the efficiency of air source heat pump under low temperature condition, many scholars put forward the new system types which combined low temperature solar energy system with air source heat pump system for composite utilization [3-6]. One kind of composite system take the solar heating system as the main body, and the heat pump is auxiliary heat source, only used when the heating supplied by solar heating system is not enough. Another kind is solar assisted heat pump system, also known as the solar energy heat pump; the solar heating system is assistive technology to hoist the system performance of the heat pump. The structure of solar assisted heat pump hot water system is complex and the water leak proof and winter antifreeze problems pose a threat to persistent operation of the system; moreover, the cost of solar hot water collector is higher, not easily accepted by ordinary people. So, on the basis of the existing air source heat pump, the infiltration air heating device is combining with building to preheating the intake air of heat pump. The new system can improve air source heat pump performance and broaden the equipment using regional without major changes of investment.

Composition of the New Solar Energy Coupling Air Source Heat Pump System

System composition

Fig 1 shows the principle diagram of the new solar energy coupling air source heat pump system. The system mainly includes air source heat pump systems and the solar energy air preheats system. The outdoor evaporator is mounted after the preheat system and the supplied water outflow from the condenser of the air source heat pump, into the water tank. The solar energy air preheat system is made up of infiltration air collector, fan and air valve. In order to integrate with the building, the air collector can be installed on the south wall. The installation layout of the infiltration collector is displayed in Fig2.



1 infiltration air collector 2 air valve 3 fan 4 evaporator 5 compressor 6 condensor

7 expansion valve 8 air source heat pump 9 pump 10 water tank

Fig 1 The principle diagram of the new solar energy coupling air source heat pump system.

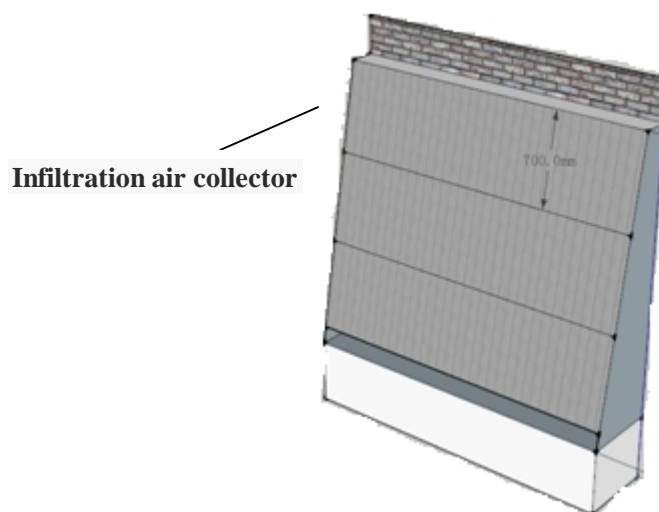


Fig2 Installation layout of infiltration air collector

System operation mode

In the heating season the compound heat pump system uses the homemade infiltration air collector to preheating the outdoor air, then the outside evaporator of air source heat pump extract the heat from

the preheated air to make the hot water. This new device can realize double effect for heating and cooling operation. By the centrifugal fan in the air duct the preheated air is introduced as the low temperature heat source of the heat pump to realize the heating condition. In the cooling season the path from infiltration air collector to outdoor exchanger heater by closing the valve, at the same time the by-pass valve is open, the heat pump outdoor unit can exhaust heating normally .

The new compound system has three kinds of operating conditions:

Mode 1: single air source heat pump heating operation mode: in winter when the irradiation is absence, air source heat pump absorbs heat from the air, for the single pump operation mode.

Mode 2: The solar assisted air source heat pump heating mode: in winter when it is a cold day with abundant irradiation. The solar air preheater is launched to improve the operation efficiency of the evaporator.

Mode 3: A single air source heat pump cooling operating mode: in summer the air source heat pump is adopt to realize cooling condition.

Design and Testing of the New Composite System

Equipment Selection

In this paper a typical rural residence in Beijing is selected as research object. Its heating area is 80m^2 , the calculation result of heating load is 32kW in accordance with the building heating load index of 40W/m^2 . According the heat load, the main equipment parameter of the compound system are confirmed and listed in the table 1.

Table 1 the parameters of the main equipment

Item	Specification	
Heating capacity	3.2KW	
Power supply	3N-380V/415V50HZ/60HZ	
Refrigeration	R22 22.7kg	
Compressor	Entire seal vortex type compressor	
Condensor	type	tube-in-tube condenser
	cooling waterconsumption	$0.3\text{m}^3/\text{h}$
Evaporator	Air volume	$1035\text{ m}^3/\text{h}$
Air collector	Area	9m^2

System testing

In order to study the affection of the solar preheated air for heat pump, the compare test is carried out under the approximate operating condition. Test items include the water side import and export temperature, the outlet air temperature of the collector, air mass flow, water side flow, system electricity power and the coefficient of performance so on. The test range and precision of the instrument are listed in the Table2.

Table 2 Test range and precision of the instrument

No	Instrument Name	specifications	Test ranges	Test precision
1	Temperature data logger	RHLOG-T-H	$-25^{\circ}\text{C}\sim 55^{\circ}\text{C}$	$\pm 0.3^{\circ}\text{C}$
2	Hot bulb anemometer	QDF-2A	$0\sim 10\text{m/s}$	$\pm 5\%$
3	Temperature sensor	PT100	$0\sim 100^{\circ}\text{C}$	$\pm 0.1^{\circ}\text{C}$
4	Pyranometer	CM11	$0\sim 2000\text{W/m}^2$	$5.15\mu\text{V}\cdot\text{W}\cdot\text{m}^{-2}$
5	Turbine flow meter	DN20	$4\sim 20\text{kg/min}$	$\pm 0.5\%$
6	Clip-on digital power meter	MS2203	600V、1000A	0.002
7	Handheld hot wire anemometer	TSI 9565	$0\sim 50\text{m/s}$	0.01m/s

In this paper parts of experiment data of two heating operation mode are showed in the Table 3 and Table 4. The experimental data in Table 3 are tested when the evaporator of heat pump exact heat from outdoor air. The experimental data in Table 4 are tested when the evaporator of heat pump absorb the heat from the preheated air by the infiltration air collector.

Table 3 the test result of single air source heat pump heating operation mode

Test time	Water flow /m ³ /h	environment temperature/°C	Inlet temperature of evaporator/°C	Temperature of water tank/°C	Power /W
10:00	3.23	1.2	2.8	13.0	1221
10:10	3.21	0.9	1.4	14.4	1330
10:20	3.23	1.3	1.8	16.4	1210
10:30	3.25	1.3	1.8	22.1	1268
10:40	3.26	1.5	2.1	25.1	1307
10:50	3.26	1.6	1.1	29.3	1311
11:00	3.28	2.1	1.5	35.1	1424

Table 4 the test result of solar assisted air source heat pump heating mode

Test time	Water flow /m ³ /h	environment temperature/°C	Inlet temperature of evaporator/°C	Temperature of water tank/°C	Power /W
11:33	3.34	2.7	7.8	13.5	1136
11:39	3.35	2.3	9.1	18.1	1362
11:45	3.35	2.4	8.2	20.7	1398
11:51	3.35	2.2	7.4	22.8	1423
11:57	3.35	1.8	7.3	25.1	1440
12:03	3.35	1.3	6.1	29.1	1478
12:09	3.35	1.7	6.9	33.3	1510
12:15	3.35	1.4	6.1	35.1	1500

Calculation formula of test evaluation index

The calculation method of tested coefficient of performance

$$COP_{sys} = \frac{Q_o}{\sum N_i} \quad (1)$$

Where the Q_o stand for total heat supply and $\sum N_i$ is total power consumption of the system

The Q_o is calculated by Eq(2)

$$Q_o = r_w c_{pw} V_s (t_e - t_b) \quad (2)$$

Where r_w is the density of water, kg/m³; c_{pw} is the specific heat capacity of water, J/(kg·K); V_s is the water tank capacity, m³; t_b is the beginning water temperature, °C. t_e is the ending water temperature.

It can be found that the mean electricity power of the system is 1303W when the new compound system operated under Mode 1. It need about 1 hour to rise water temperature from 13°C to 35.1°C. According to the data of Table 3, the total heat supply is 9420KJ; the total power consumption in 1hour is 4690.8kJ. So the calculation result of coefficient of performance is 2. From the Table 4 it can be found that the time required to rise the same water temperature decreased. It only needs 45minute to rise water temperature from 13.5°C to 35.1°C. Therefore the total heat supply is 8899KJ;

the total power consumption in 1hour is 3542.5kJ. So the calculation result of coefficient of performance is 2.51. Comparing two kind of operating mode, the tested results show that Mode 2 preheating the outdoor air by solar infiltration collector can improve the coefficient of performance about 25.5%.

Conclusions

In this paper a new solar energy combined with air source heat pump system is presented. The solar air preheating system can restrain the frost layer and make the air source heat pump run under the condition of frost-free completely. It can effectively increase the coefficient of performance. Furthermore as a low grade energy the solar energy can be used to preheat the cold air into the outside evaporator, it will be raise the utilization ratio of solar energy and realize the reasonable energy level matching.

Acknowledgements

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