Experimental Research of Air Source Heat Pump Frosting and Defrosting in a Double Stage-Coupling Heat Pump

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Abstract: In a double stage-coupling heat pump, comprising an air source and water loop heat pump, the 13~20 low temperature water is supplied to the water loop heat pump unit. The water loop heat pump can extract heat from the water and heat the indoor air. The most common method of air source heat pump frost removal is reverse-cycle defrost. During the defrosting operation, the heat pump runs in the cooling mode. The defrost process is accomplished by reversing the normal heating mode. In this paper, the effect of the heat storage tank to the air source heat pump defrosting is test. Owing to the existence of the heat storage tank, thermal inertia of the loop is relatively high. The frosting and defrosting course of the air source heat pump have little effect on the room temperature.

Key words: water source heat pump, double stage coupling heat pump, air source heat pump, heat storage tank

1. INTRODUCTION

Double stage coupling heat pump system is composed of air source heat pump (ASHP) and water source heat pump (WSHP) through the water loop. The system runs in double stage mode when the outdoor temperature is lower. At this time, ASHP supplies 13～20 water to WSHP as a low temperature heat source. WSHP supplies 40～50 hot water to the user. The system can improve the working condition of ASHP[1]. Air source heat pump, heating or cooling water with the coil and transfer heat from the outdoor air. The compressor inlet pressure arises with the decrease of the outdoor air temperature in heating. The designing of the air source heat pump have to consider the lowest outdoor environmental temperature. In the cold regions, double stage coupling heat pump of air source and water loop, the 10~20 low temperature water is supplied to the water-air heat pump unit. The water loop heat pump can extract heat from the water and heating the indoor air.

A Water-loop heat pump consists of individual water-source heat pumps located in each zone. The heat pumps are linked with a common circulating water loop that serves as a heat sink when cooling and a heat source when heating. Water-loop heat pump is a kind of air-conditioning system which can reclaim the excess heat of the building. If there are two kinds of water-loop heat pump of difference running modes in a same water system, when some units need cooling owing to the mass indoor heat generation, while the others need heating because of the much building thermal losses. If the ratio of the two kinds unit is proper, the water can be circulate need neither heating nor cooling. Here the heating water of the heating mode heat pump is the excess water heat from the cooling mode heat pump.

In winter, frost forms on evaporator surface when the surface temperature is below the freezing point and ambient air humidity is higher than the saturation humidity at the evaporator surface temperature. Under these conditions, the frost layer has to be melted away periodically to keep a high heat pump coefficient of performance (COP). The most common method of frost removal is reverse-cycle defrost. During the defrosting operation, the heat pump runs in the cooling mode. The defrost process is accomplished by reversing the normal heating mode. In the defrosting process, high temperature refrigerant is discharged into the air-cooled coil to melt the frost. This results in cooling of the indoor space. During the defrosting cycle, the air cooled fan is normally turned off[2,3]. In this paper, the effect of the heat storage tank to the air source heat pump defrosting is test.

2. SELECTION OF THE TEST UNIT

2.1 Climatic features of Zhejiang & Jiangsu Province

Climatic features of Zhejiang & Jiangsu Province Zone are just the same although each of the zone has some difference. Extreme summer temperature is high, hot season lasts very long. However, there is a period of low temperature in winter. Humidity is high all around a year. Product is easy to mould owing to the wet floor during the wet season of 'Meiyu'. For example of Zhejiang Province, average June temperature of Zhejiang Province is 27～30 , the warmest month temperature of 13 o'clock is 32 , January and February is the coldest month of the winter. Average temperature is 2～7 , the whole day temperature below 10 , in the south area is about 120～130d, in the north area is about 100d, Average whole year temperature is 80% or so[4]. The outdoor climatic parameter of the main city of Zhejiang & Jiangsu Province and Shanghai City is shown in table1.

Evaporator frosting of the air source heat pump depends on the outdoor air temperature and relative humidity. Frosting is most severe under the same relative humidity (above 70%) the temperature range 3～5 . The influence of relative humidity to frost is much than the air temperature. The frosting quantity decreases greatly when the outdoor air relative humidity is less than 65%. There is no frosting when the outdoor air relative humidity is less than 65%. The winter outdoor air humidity is great in Zhejiang & Jiangsu Province Zone. Air source heat pump is severe frosting and running in unsteady state. Defrosting is necessary to the unit.

2.2 Selection of the ASHP

Water source heat pump of the peripheral building absorbs heat from the water loop heating in winter. When the inner unit heat rejection is less than the peripheral building absorbs. The temperature of the water loop will fall down, when it reaches to 13 , the heating equipment must start to heat the water loop. Thus the heating equipment must be correctly selected in the water source heat pump system.

The present water heating equipment is electrical boiler, gas or oil boiler, water-water heat exchange, steam-water heat exchange, solar energy collector etc. Determining conditions of the heating equipment are: outdoor temperature is the winter calculating dry-bulb temperature for heating; there is

Tab. 1 Winter outdoor climatic parameter of the main city of Zhejiang & Jiangsu Province

City	Calculating dry-bulb temperature for heating ( )	Calculating dry-bulb temperature for air conditioning ( )	Average calculating dry-bulb temperature for the lowest day ( )	Humidity (%)
Lianyungang	-5	-8	-11.4	66
Xuzhou	-5	-8	-12.1	64
Nantong	-2	-5	-8.2	76
Nanjing	-3	-6	-9	73
Shanghai	-2	-4	-6.9	75
Hangzhou	-2	-4	-6	77
Ningbo	0	-3	-4.3	78
Wenzhou	3	1	-8	84

no occupant in the room; other heat source as lighting or solar radiation or human are neglected; the room temperature is the designing temperature. But whether there is a night low temperature of the room, morning preheat or heat storage tank are considered when deciding the heating equipment.

According to the load calculation of the test room, HL（R）（S）series HLR10 is adopted of ASHP. Nominal cooling capacity is 10kW, nominal heating capacity is 11kW. Some control strategies are used to providing the hot temperature of 13～20 . The heat is supplied to the indoor water source heat pump by the water loop. The water source heat pump can absorb heat from the water and heating the indoor air directly.

2.3. Determination of the heat storage tank

There is always a heat storage tank in the water-loop heat pump to improve the system running feature. It is well known that the typical water-loop heat pump system can transfer the heat by the water loop from the inner zone to the peripheral zone. However, it is difficult to meet with the balance of the peripheral zone and the demanding of the inner zone. Thus a heat storage tank is necessary in order to realize the heat transfer of time. That is to say, condensing heat rejecting to the water loop of the inner zone of cooling condition can meet with the evaporating heat peripheral zone of heating condition in a day or even a long cycle. Thus the cooling tower and the water heater capacity can be greatly reduced.

Heat storage tank is in series of the water loop to enlarge the system water storage. It is obviously that system has a stronger ability of the recovery of the surplus heat with more water storage and less starting cooling tower or water heater.

The size determination of the heat storage tank is according to the balance of a whole day of cooling and heating load in general, it is to say, utilization of the day surplus heat to the night and morning temperature lifting. Capacity of the heat storage tank is between 100L~200L by calculation. Size: Length×Width×Height=0.6m×0.6m×0.6m. It is insulation outside. Water height is 0.5m during test, the practical capacity is 180L.

2.4 Selecting of the WSHP and the test system

Split water source heat pump SR88PW is chosen for the test, rated cooling capacity is 8.8 kW, rated heating capacity is 10 kW. The condenser is high efficiency double pipes heat exchanger. ASHP is a heat source for it. The test diagram is shown in Fig.1. Test carries in the artificial climatic room. The surplus heat is consumed by a chiller to keep the return temperature of 15 .

Tab.2 Unit pressure and discharge temperature of different environmental temperature

Environmental temperature（ ）	Condensing pressure Pe（MPa）	Evaporating pressure Pc（MPa）	Pressure ratio Pc/Pe	Discharge temperature（ ）t
－3	0.91	0.23	3.96	58
－4	0.90	0.22	4.09	57
－5	0.88	0.21	4.19	54
－6	0.87	0.21	4.14	51
－7	0.86	0.20	4.3	48
－**8**	0.86	0.19	4.53	46

.3 TEST RESULTS AND DISCUSSION

3.1 Running parameters of ASHP

Unit pressure and discharge temperature of different environmental temperature are measured by the pressure transducer and thermo-couple as shown in Tab.2.

From Pe, Pc, Pc/Pe and discharge temperature variation with the environmental temperature, some conclusion can be gotten:

(1) Pressure ratio of the unit is only about 4.53 at maximum. It is far below the compressor single critical pressure ratio, for example, piston compressor: $P_c/P_e \le 8$.

(2) The discharge temperature is quite low, maximum value is not exceed 60 , far below the demand of no less than the 150 of the compressor discharge temperature.

(3) Evaporating pressure is about 0.2MPa.

(4) Maximum condensing pressure is not exceed 1MPa, far below critical pressure 2.5MPa of the compressor discharge temperature.

Running in the cold and wet region like Jiangsu and Zhejiang Province of the double stage coupling heat pump system, the compressor ratio, discharge pressure, condensing pressure and evaporating pressure of ASHP are both satisfactory. ASHP is of no problem in running and better COP value supplying hot water of 20 .

3.2 Defrosting running parameters of the double stage coupling heat pump

The environmental dry bulb temperature is -7.61 , relative humidity is 83.65% when frosting.

At this time, although pressure of ASHP varies greatly as shown in Fig.2, the suction and discharge pressure are 0.36 and 1.41MPa respectively. The supply air temperature is 33.8 , return air temperature is 21.2 with no fluctuation. The indoor air temperature is 20 . The time from defrosting to heating is 4 minutes or so (as shown in Fig. 3). The water supply and return temperature is 16.5 and 13.5 at minimum. They agree with the temperature of water loop heat pump. After 25 minutes, water supply and return temperature are back to normal as shown in Fig.3.

4. CONCLUSION

In winter, frost forms on evaporator surface when the surface temperature is below the freezing point and the ambient air humidity is higher than the saturation humidity at the evaporator surface temperature. Under these conditions, the frost layer has to be melted away periodically to keep a high heat pump coefficient of performance (COP).

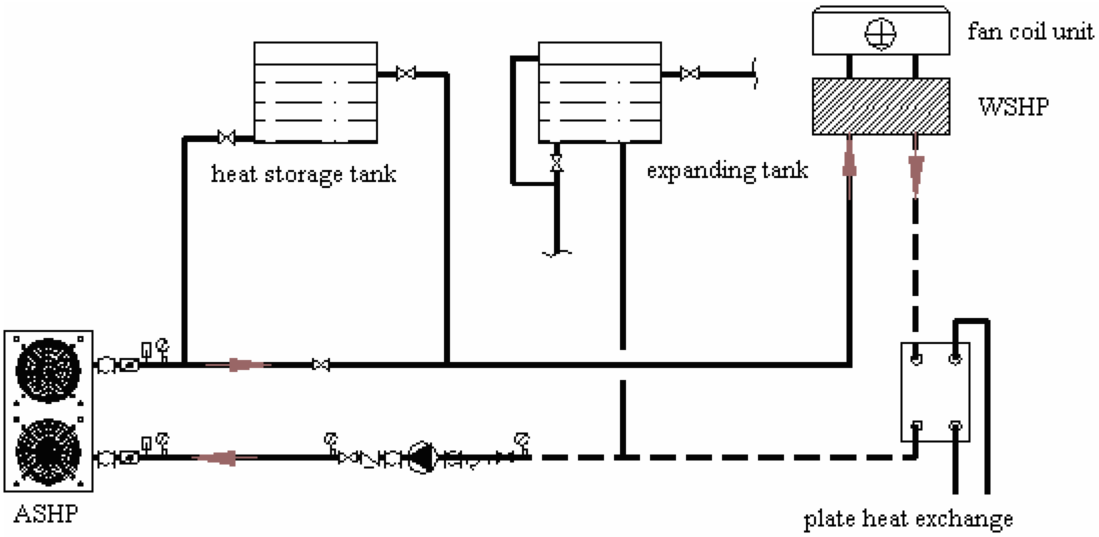

Fig.1 Experimental diagram of defrosting in double stage coupling heat pump

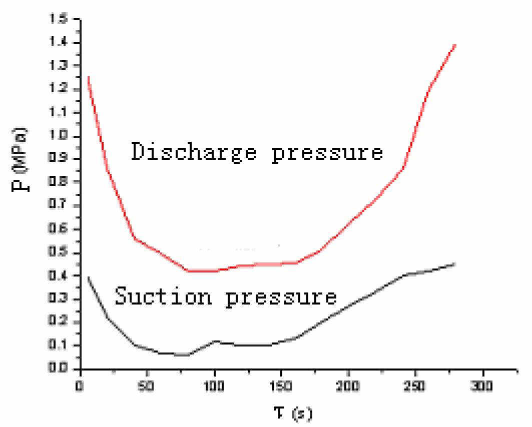

Fig.2 Variation of the ASHP defrosting

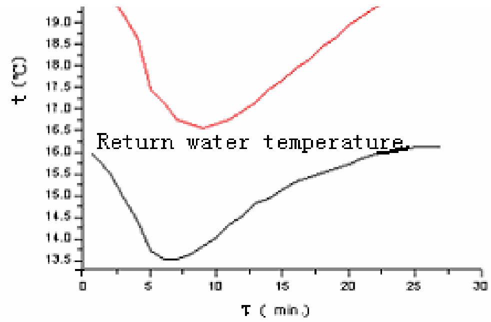

Fig.3 Variation of the ASHP defrosting temperature

The most common method of frost removal is reverse-cycle defrost. During the defrosting operation, the heat pump runs in the cooling mode. The defrost process is accomplished by reversing

the normal heating mode. In the defrosting process, high temperature refrigerant is discharged into the air-cooled coil to melt the frost. This result is of the cooling indoor space. During the defrosting cycle, the air cooled fan is normally turned off. Once the reverse-cycle defrost was terminated, the heat pump is immediately switched back to normal heating operation and the coil fan is turned on again. In this paper, the effect of the heat storage tank to the air source heat pump defrosting is test. Owing to the existence of the heat storage tank, thermal inertia of the loop is relatively high. The frosting and defrosting course of the air source heat pump have little effect on the room temperature.

The application situation of water source heat pump is plenty of excess heat in the building, a well energy efficiency result could be gotten. However, building of China present has small inner zone with little inner load. The utilization of water source heat pump has some difficult in the cold and wet zones. The presented heating system of the combination of ASHP and WSHP can improve the utilization well.

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