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Experiment Study on Heating Performance of Solar-Air Source Heat Pump Unit

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Abstract

Ambient temperature has a great impact on heating performance of air source heat pump. Outdoor fin-tube heat exchanger of air source heat pump usually frost on low temperature conditions, which results low operation efficiency and further deterioration. A solar-air heat pump unit was established and outdoor fin-tube heat exchanger of air source heat pump is used jointly by the refrigerant and solar hot water. Running parameters such as outlet temperature of refrigerant, heat capacity and COP of air source heat pumps of composite heat pump units were tested respectively under the standard working conditions and low temperature conditions. The results showed that the performance of solar-heat pump is significantly improved, compared with the single air source heat pump. The effect is more obvious with increasing of the temperature of the solar hot water temperature. Under standard working conditions (ambient temperature 7°C), the unit heat capacity reached 60.9kW、62.9kW 和 64.5 kW, increased 13.4%、17.1%、20.1% respectively and the coefficient of performance also increased 13.9%、17.4%、20% respectively. Under low temperature conditions (ambient temperature -5°C), the unit heat capacity increased 16%、23.3% and 27.6% respectively, up to 49.52kW、52.67kW、54.5kW, and COP also increased 31.2%、38.6%、45.5% with different solar hot water temperature 20°C、25°C and 30°C.

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1. Introduction

When the air source heat pump is used in cold conditions in the cold regions of the north, the heating efficiency of the unit is low[1]. With the decrease of the outdoor environment, there will be a series of problems, such as the compression ratio increases, the volumetric efficiency reduction, and refrigerant mass flow reduction, high compressor exhaust temperature, operating efficiency decreased, and even can not start properly, which greatly limits the application of air source heat pumps in cold and humid areas. Therefore, the frost mechanism, defrosting method have always been the focus and difficulty of air source heat pump research and application[2].

At home and abroad, most of the researches on defrosting are focused on preventing the frost and timely defrosting of air source heat pump[3]. However, these technologies will be limited by investment, processing requirements, and cannot solve the problem of low efficiency fundamentally in winter.

A new type of solar-air source heat pump was established in this paper, which combines air source heat pump and vacuum tube solar water heating system. Solar and air two low energy as a composite heat source, can be used as a composite heat source to solve the problem of performance degradation and frosting at low temperature of air source heat pump. It can effectively improve the air source heat pump in the low temperature performance; improve the reliability of air source heat pump utilization[4,5]. The new heat pump can be used to solve the problem of low performance and frosting of air source heat pump at low temperature, which can improve the performance of air source heat pump and improve the reliability of air source heat pump.

2. System composition and operation conditions

The heat exchanger of solar-air heat pump is a composite fin-tube exchanger for refrigerant and solar hot water, which is the organic combination of air source heat pump and vacuum tube solar water heating system. The composite heat exchanger is a base of a conventional air source heat pump system with a row of solar lines in the windward side of heat exchanger. The composite heat pump can achieve the advantages of air source heat pump and solar heat collection system. The structure of solar heat pump system processes and heat exchanger are shown in fig. 1.

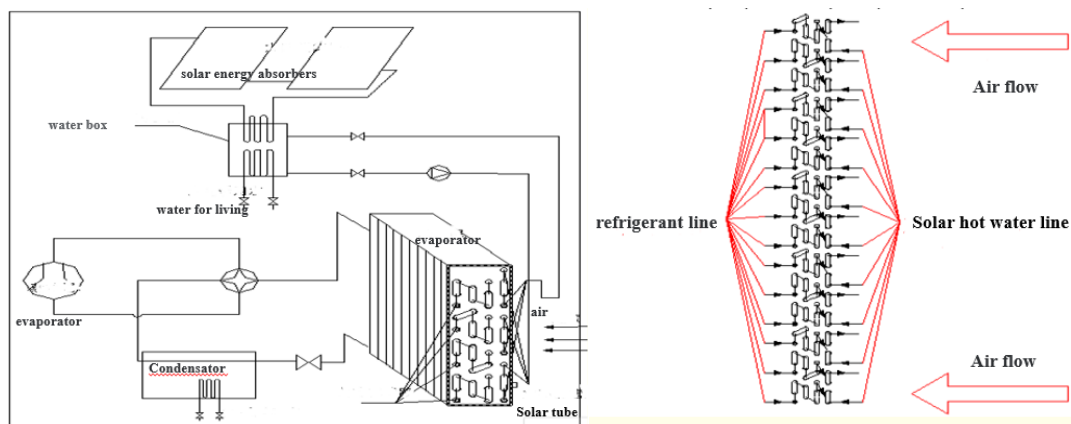


Fig. 1. Solar-air source heat pump system and the composite heat exchanger

The solar collector plate heats the water in the storage tank by heat exchange. In cold winter, the valve of domestic hot water closed in the hot water storage tank and the hot water flow over the solar pipeline which is the outermost of the evaporator. When the air flows through the hot water tubes, the temperature rises and then the hot air flows through the refrigerant line for heat exchanging. And then, the heat of the hot water passes through the fins

to the refrigerant in the inner coil. Through these two functions, the evaporation temperature of the refrigerant can be improved, which can effectively avoid frosting of the outdoor heat exchanger. In hot summer, closing the valve for evaporator, and providing domestic hot water by storage tank. This system has two advantages. First, the temperature of cold air can be increased, and heat transfer temperature difference between the refrigerant and the heat pump evaporator can be reduced. Second, the operating conditions of air source heat pump can be effectively improved in winter, and the frosting problem of air source heat pump can also be reduced or avoided.

3. Experiment process and result analysis

3.1 Experiment process

The experiment was carried out in the enthalpy difference lab, and the experimental conditions were also simulated by enthalpy difference lab. The inlet air temperature, unit input power, COP and so on were monitored and recorded by the software testar[6]. The outlet temperature of evaporator and fan, solar supply and return water temperature were measured using thermocouples, and the data were transmitted to the testar program for recording.

The unit rated heating capacity is 60KW, and setting the fan flow for 9000m³/h. The hot water temperature that provided from water tank to solar energy pipeline was 20°C, 25°C, 30°C. And the water flow was 4.6 m³/h. Heating water inlet and outlet water temperature were 40/45°C, and the unit flow was automatically adjusted according to the load change.

The experiment was carried out in two kinds of working conditions: the nominal operating condition of the unit tested by GB/T18430.1-2007[7,8], whose dry bulb temperature was 7°C, and the wet bulb temperature was about 6°C. In addition, in order to test the applicability of the new solar-air source heat pump in the low temperature condition, the performance of the unit in the environment temperature of -5°C was tested.

3.2 Experimental results and analysis

- Frosting and defrosting time without solar water

Without solar water, the new solar-air source heat pump unit is equivalent to the traditional air source heat pump unit. Under the two different working conditions, automatic defrosting will occur in the operation of the unit. Normal operating and defrosting time were shown in table 1:

Table 1. Defrosting time of air source heat pump

	Operation cycle (min)	Defrost time (min)	Normal heating time(mm)	Defrost time ratio
Nominal operating condition (7°C)	40	8	32	20%
Low temperature condition (- 5°C)	35	12	23	34%
Difference	12.5%	50%	28.1%	—

We can see from table 1, in the nominal operating condition, the defrost process takes 8 minutes, while the entire operating cycle for 40 minutes(defrost time + normal heating time), and defrost time accounted for 20%; When the ambient temperature is -5°C, the defrosting time ratio is increased to 34%; Under the condition of -5°C, the operating cycle is shortened by 12.5% compared with the temperature of 7°C, the normal heating time is shortened by 28.1%, and the defrosting time is increased by 50%. It can be seen that when the air source heat pump unit is running in winter, the defrosting time accounts for a large proportion of the whole operation cycle. And with the decrease of the environment temperature, the proportion of defrosting time is increasing, and the defrosting period is shortened, the frosting condition is further deteriorated, which will cut down the thermal efficiency of the unit and even can not start. When the defrosting condition of the unit is over, the compressor suction temperature will

increase, which will lead to the high pressure of the compressor suction inlet, so that the operating load of compressor will increase and even burn down. During this process, the heating capacity, COP and the evaporator surface temperature fluctuate greatly. With the decrease of the ambient temperature, the frosting phenomenon is more serious, and the impact on the efficiency and service life of the unit is also more serious[9].

- Variation of evaporator outlet refrigerant temperature with different solar water temperature

The variation of outlet refrigerant temperature of evaporator without or with solar water t on nominal condition and low temperature condition was shown in fig. 2.

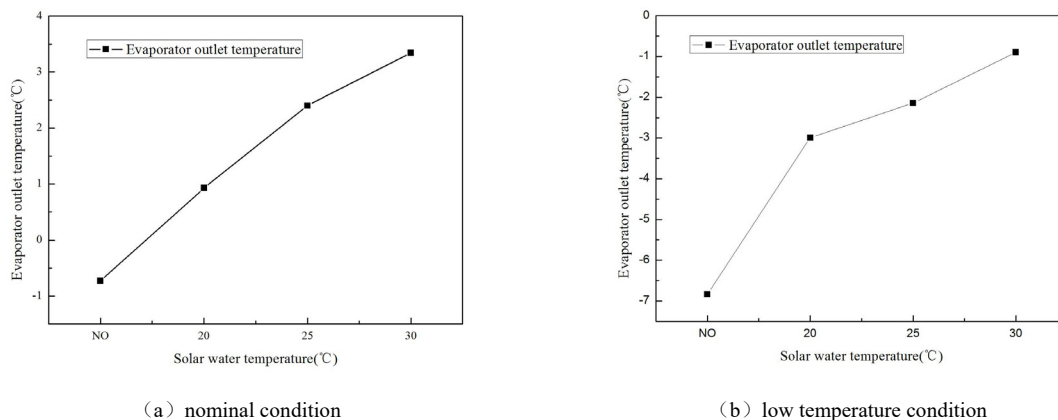


Fig. 2. Variation of outlet refrigerant temperature of evaporator on two conditions

Fig. 2 shows that, on nominal condition, evaporator outlet refrigerant temperature is -0.73°C without solar heat water, and the frosting phenomenon of the unit fins-tube heat exchange is slight. The evaporator outlet refrigerant temperature increases with increasing solar water temperature, and the unit fins-tube heat exchange does not appear frost phenomenon from 20°C solar heat water. With the increase of the outlet temperature of the evaporator, the superheat of the refrigerant outlet is increased, which increases the suction temperature of the compressor and improves the performance of the unit.

On -5°C condition, without solar water evaporator outlet refrigerant temperature is -6.83°C , which results the serious frosting phenomenon of fins and heat exchanger. The frost on fin-tube and gas collector is show in figure 3.

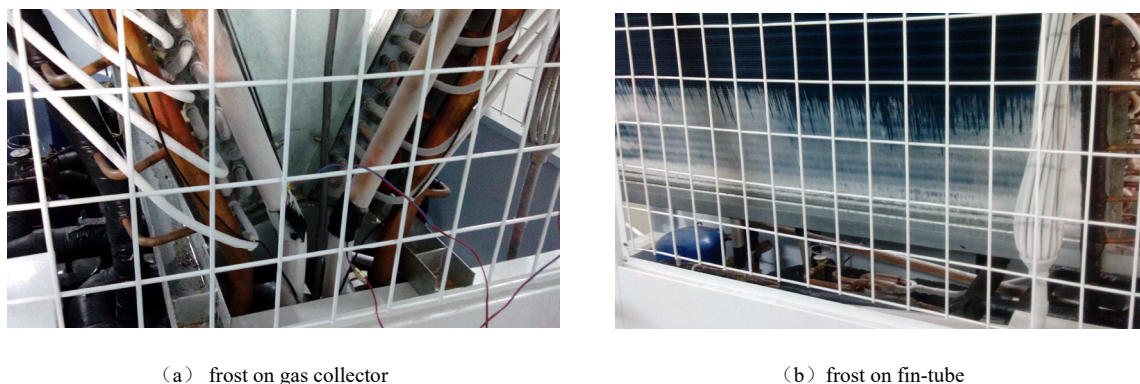


Fig. 3. The frost on fin-tube and gas collector of heat exchanger

Frost result the deterioration of heat transfer of fins-tube heat exchange. The long automatic defrosting time will affect the performance of the unit, and even lead to the abnormal operation. With solar heat water, the evaporator outlet refrigerant temperature has been greatly improved, and the unit frosting phenomenon has been significantly

reduced. Meanwhile, the defrosting period is prolonged and the defrosting time is shortened greatly, which greatly improves the performance of the unit under low temperature.

- The unit parameters change with the different solar water temperature

Fig. 4 shows the variation of the heat capacity and COP on two conditions.

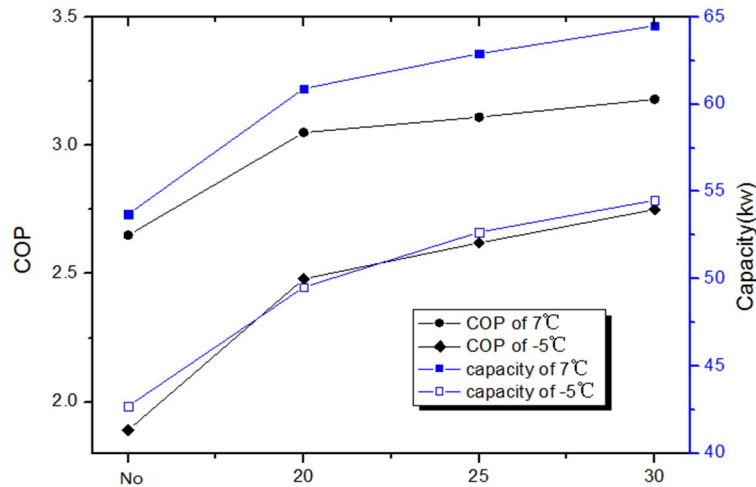


Fig. 4. Variation of unit performance with difference solar water temperature

From fig. 4 we can see, source heat pump unit is equivalent to the traditional air source heat pump unit in nominal condition without solar water, and the capacity is 53.7 kW, the COP just 2.65. When the solar heat water temperature is 20°C, 25°C, 30°C respectively, the unit heat capacity reached 60.9kW、62.9kW 和 64.5 kW, increased 13.4%、17.1%、20.1% respectively and the coefficient of performance also increased 13.9%、17.4%、20% respectively. When the water temperature is 30°C, the experimental prototype COP is 3.18, close to the national second energy efficiency level.

When the ambient temperature is -5°C, and the heat capacity is 42.7kW, COP is only 1.89 without solar heat water. When solar heat water temperature is 20°C, 25°C, 30°C respectively, the capacity respectively increased by 16%、23.3%、27.6%, reaching to 49.52KW, 52.67KW, 54.5KW, and COP correspondingly increased by 31.2%、38.6%、45.5%, reaching to 2.48, 2.62, 2.75.

It can be seen that the new solar-air source heat pump system can significantly increase the unit's COP and capacity. The higher proportion increase in the low temperature conditions, what means that the lower ambient temperature, the more obvious the advantages of the new solar-air source heat pump unit.

4. Conclusion

The new solar-air source heat pump unit can effectively improve the frosting phenomenon, and not only can avoid the energy losing caused by the automatic defrosting of the Unit, but also effectively improve the heat pump unit heat and COP. With the decrease of ambient temperature, the advantages of solar-air dual heat source composite heat pump are more obvious than that of single air source heat pump in heating performance. Under standard working conditions (ambient temperature 7°C), the unit heat capacity reached 60.9kW、62.9kW 和 64.5 kW, increased 13.4%、17.1%、20.1% respectively and the coefficient of performance also increased 13.9%、17.4%、20% respectively. Under low temperature conditions (ambient temperature -5°C), the unit heat capacity increased 16%、23.3% and 27.6% respectively, up to 49.52kW、52.67kW、54.5kW, and COP also increased 31.2%、38.6%、45.5%. With different solar hot water temperature 20°C、25°C and 30°C.

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