Study on Performance Factors of Variable Frequency Heat Pump Water Heater

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Abstracts: The performance factors of a R290 variable frequency heat pump water heater are experimentally studied. The performance factors including COP, heating time, consumption power , compression ratio, degree of super heat and degree of sub cooling with the frequencies changing from 40Hz to 90Hz are discussed. The results show different compressor frequency has a greater influence on the size of the heat, and heat increases with the increasing of the frequency.When the outlet water flow is increased, the heat capacity and COP are improved corresponding. In addition, the compression ratio, degree of superheat is direct ration with frequency, but the degree of subcooling is reverse with it.

1.Introduction

Freon(CFCs,HCFCs) is widely used in the refrigerating equipments and air-conditioner. Because of their depleting the ozonosphere and making the earth become warmer, the developed countries had been prohibited from producing and used CFC since 1996, and the banning schedule for R22 would be ahead from 2020 to 2030 according to the Montreal Revision[1]. R290 is a natural and environment-friendly refrigerant with its values of the ozone layer depletion and global warming coefficients (ODP and GWP) close to zero[2-4]. With the basic physical properties of approaching almost to R22, stable chemical property, low price, compatibility with material used commonly in the refrigerant equipments, no damaging the environment, R290 has a bright future as alternative for R22[5-7]. To explore the feasibility of application of R290 to the variable frequency heat pump water heater, the relationship between the COP, heating time, consumption power, compression ratio, degree of superheat and degree of subcooling with the frequencies changing from 40Hz to 90Hz were studied on variable frequency R290 heat pump water heater bench. It will be helpful to understand R290 variable frequency heat pump performance on load change .

2. Experimental system

The whole experimental system is divided into 3 parts by using R290 refrigerant. (1)Refrigerant cycle system mainly includes DC inverter compressor (rated power is 2.2kW), condensing heat exchange system, evaporation heat exchange system, frequency converter (rated power is11.5kW), external balanced thermal expansion valve.(2)Water system includes water tank, electromagnetic flowmeter (measuring accuracy is 0.06m^3/h and measure is ranged from 0.06m^3/h to 9.54m^3/h), water pumps, valves, etc.(3)Data acquisition system includes Agilent data acquisition instrument model 34970A, temperature sensor using PT100 thermal resistance, pressure sensor measurement ranged from 0MPa to 6MPa and the accuracy of 0.25%. Temperature, pressure, mass flow and current signal are automatically measured by industrial computer with data acquisition instruments.The experimental system and arrangement of measuring points are shown in the Fig.1.

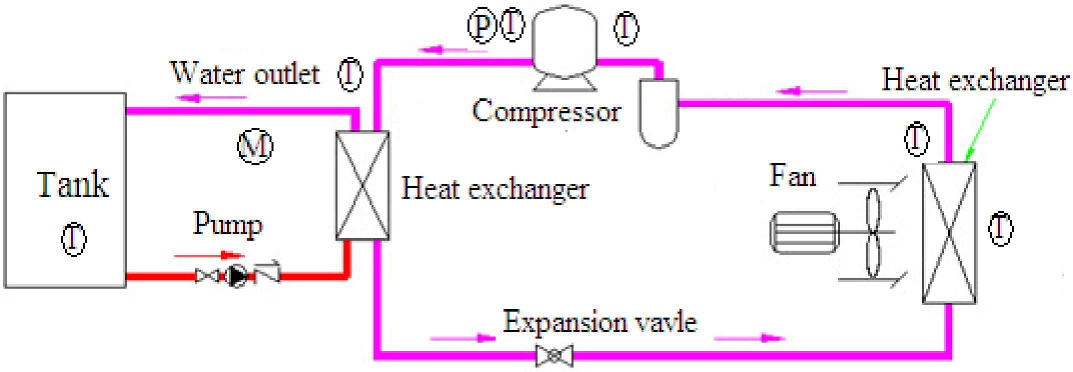

Fig. 1 Schematic of the experimental system and arrangement of measuring points

3. Results and discussion

Fig.2 shows the relationship between COP, frequency and water mass flow. When the frequency of the compressor is decreased from 90Hz to 40Hz, the COP is increased linearly.On the one hand, when the frequency is reduced, the flow velocity of the refrigerant in the heat exchanger is small, and the heat transfer time of the other side of the heat exchanger is prolonged, so the heat exchange heat transfer efficiency is improved greatly. On the other hand, the temperature difference is decreased, so the condensation temperature is also decreased and the evaporation temperature is increased gradually. In addition, when the flow rate is increased from 100kg/h to 160kg/h, the COP is gradually increased. With the increase of the cooling water flow, when the condensation temperature is decreased, it will lead to the reduction of the pressure ratio and the COP.

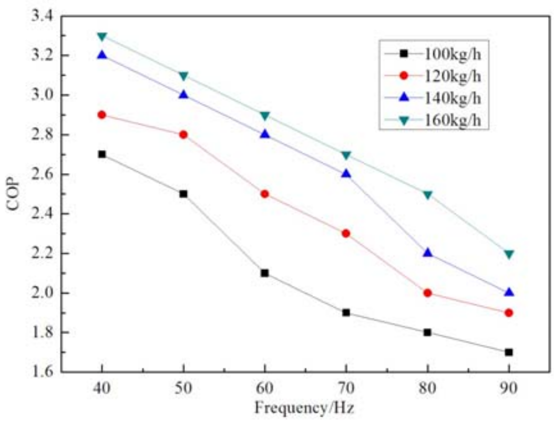

Fig.2 The relationship between COP, frequency and water mass flow

Fig.3 shows the relationship between frequency, heating time and water temperature . When the water temperature is raised from 20°C to 30°C, the compressor with 80Hz operation of the heating time is about 9min and the compressor with 70Hz running time is about 10min, the compressor with a higher frequency of heating time is shorter than the lower frequency, mainly because the higher frequency of the compressor, the more number of thermal cycles, the more heat exchange.
As shown in figure 4, when the water temperature is raised from 20°C to 30°C, the compressor with the power consumption at 80Hz is 0.38 kW.h, and the power consumption at70Hz is 0.42kW.h. When the water temperature rise of the same time, the general compressor power consumption is slightly lower than the low frequency operation, mainly because the compressor is working at high frequency, but the shorter heating time, the total power consumption is lower.

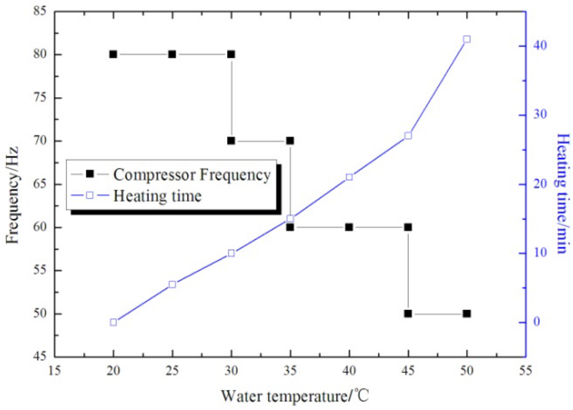

Fig.3 The relationship between frequency, heating time and water temperature

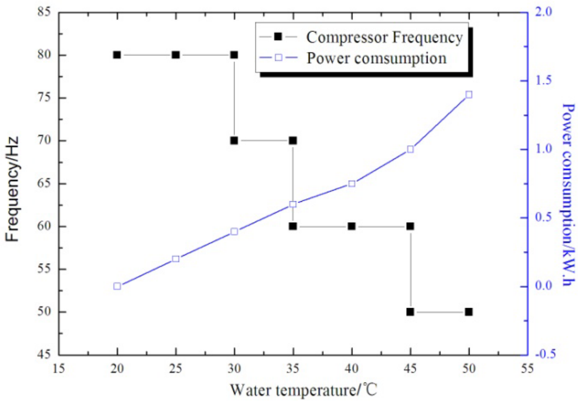

Fig.4 The relationship between frequency, power consumption and water temperature

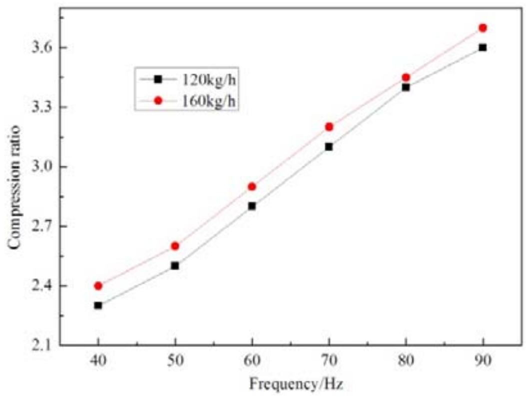

Fig.5 The relationship between compression ratio and frequency

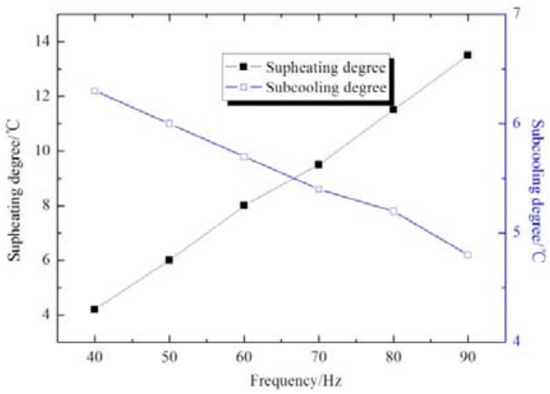

Fig.6 The relationship between supheating degree, subcooling degree and frequency

It can be seen from figure 5 that when the frequency is decreased from 90Hz to 40Hz, the pressure ratio is also decreased from 3.8 to 2.4. Because the frequency is decreased, the refrigerant flow rate is decreased and the heat transfer temperature difference is decreased, it will lead to the pressure drop and the power consumption reduce. In addition, when the cooling water flow is decreased from 160kg/h to 120kg/h, the pressure ratio is increased slowly, and the other side of the refrigerant heat transfer of water flow become smaller, it will lead to the rise of condensate pressure and discharge pressure.

Fig.6 shows the relationship between supheating degree, subcooling degree and frequency.When the frequency is raised from 40Hz to 90Hz, the degree of superheat is raised the pressure ratio is decreased from 4°Cto 14°C, the degree of subcooling is decreased from 6.5°C to 4.8°C.Because of the frequency increasing, on the one hand, the evaporation pressure is decreased and the refrigerant flow rate is increased, on the other hand, the magnitude of the decrease of the evaporation temperature is greater than that of the evaporator outlet refrigerant temperature, so the degree of super heat is gradually raised.In addition, because of the increase of the condensing pressure, the increase of the condensation temperature is less than that of the increase of the temperature of the outlet of the condenser, so the degree of the sub cooling is gradually reduced.

4.Summary

When compressor is worked at higher frequency, the shorter heating time and the less power consumption of the system can be got at the same range of water temperature rise. In order to reduce discharge pressure, compressor frequency should be reduced with water temperature increasing. When the outlet water flow is increased, the heat capacity and COP of the system are improved corresponding. In addition, the compression ratio, degree of superheat is direct ration with frequency, but the degree of subcooling is reverse with it.

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