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Analysis on the Performance Degradation for Residential Air-conditioner

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ABSTRACT

The performance of residential air-conditioner will be degraded when outdoor temperature increases for cooling and decreases for heating. In this study, the cooling and heating performances of a residential air-conditioner system were experimentally investigated by varying outdoor temperature. The experimental results showed that the cooling capacity decreased and the heating capacity increased with the increase of outdoor temperature. For cooling, when the outdoor temperature rose from 35°CDB/24°CWB to 48°CDB/30°CWB, the cooling capacity decreased by 17.81%. For heating, when the outdoor temperature dropped from 7°CDB /6°CWB to -15°CDB/RH75%, the heating capacity decreased by 50.93%. These were mainly due to the cooling capacity per unit quality, i.e. the enthalpy difference, decreased with the increase of outdoor temperature and the mass displacement of compressor decreased with the decrease of outdoor temperature.

1. INTRODUCTION

China has been becoming the biggest producing and consuming air-conditioners country all over the world. Since the first air-conditioner was produced, research on air-conditioners has never been stopped. The previous research on air-conditioner mainly focused on the performance of system and related components. Little research on the performance degradation with varying work conditions was published.

The performance of air-conditioner is designed and tested under the rated conditions. However, air-conditioners often work under off-design conditions most of the time in practice. And under off-design conditions, the system performance is different from that under the rated conditions. In this study, the difference of system performance between off-design conditions and the rated conditions was experimentally investigated.

A residential heat pump air-conditioner was tested under the rated conditions and off-design conditions. The experimental results about the performance degradation were analyzed. The reasons for the performance of residential air-conditioner decreasing under off-design condition were discussed.

2. EXPERIMENTS

In this study, a heat pump air-conditioner is chosen for system performance test under various working conditions. The performance parameters of tested air-conditioner were tested under rated conditions. In the experiment, the temperature in outdoor chamber is varied from 27°C to 48°C for cooling modes and from -15°C to 21°C for heating modes. The temperature in indoor chamber maintains 27°C for cooling modes and 20°C for heating modes. The detailed test conditions are listed in table 2. Thereinto, the rated conditions are 27°CDB/19°CWB indoor and 35°CDB /24°CWB outdoor for cooling, and 20°CDB/15°CWB indoor and 7°CDB /6°CWB outdoor for heating. The experiments are carried out in an air-enthalpy laboratory, which includes outdoor chamber, indoor chamber and control room. The laboratory consists of insulated wall, air-sampling equipments, air-handling equipments,

temperature and humidity acquisition equipments, air volume testing equipments, electrical control equipments and computer unit. The cooling and heating capacity can be tested and automatic calculated. The dry bulb and wet bulb temperatures, as well as humidity can be automatic controlled by the air-handling equipments installed in the test chambers. The indoor unit of the air conditioner is placed in indoor chamber, and the outdoor unit is placed in outdoor chamber. T-type thermocouples are used to test temperature of outdoor unit heat exchanger and suction and discharge temperature of compressor. The compressor suction and discharge pressures are tested by the pressure sensors. All the testing data can be collected and displayed by the computer unit.

Table 1: Performance Parameters

Items	Parameters
Cooling Capacity	3380W
Heating Capacity	3720W
Cooling Power	1060W
Heating Power	1050W
E.E.R	3.19
C.O.P	3.54

Table 2: Experiment conditions

Operating Modes	Indoor Chamber	Outdoor Chamber
	Dry/Wet Bulb Temperature °C	Dry/Wet Bulb Temperature °C
Cooling	27/19	27/-
		35/24
		43/26
Heating	20/15	48/30
		21/15
		7/6
		2/1
		-7/RH 80%
		-15/RH 75%

3. RESULTS AND DISCUSSIONS

3.1 Cooling Capacity

The change curves of the cooling capacity and power with outdoor temperature are shown in figure 1. It can be seen from figure 1 that the cooling capacity decreases with the rising of outdoor temperature. Comparing with the rated cooling capacity (the cooling capacity under the rated condition), the cooling capacity is about 89.8% of the rated cooling capacity when outdoor temperature is 43°CDB/26°CWB, viz. the cooling capacity decreases by 10.2% comparing with the rated cooling capacity. The cooling capacity decreases by 17.8% comparing with the rated cooling capacity when outdoor temperature is 48°CDB/30°CWB. However, the cooling capacity increases by 7% comparing with the rated cooling capacity when outdoor temperature is 27°CDB.

Analysis about the performance degradation is carried out according to the curves in figure 2 to figure 5. The change curves in figure 2 to figure 5 are the temperature of condenser with outdoor temperature, the cooling capacity and enthalpy difference with outdoor temperature, the outlet temperature of evaporator and the refrigerant mass flow with outdoor temperature, and the cooling power with pressure ratio, respectively. It can be seen from the figures that the temperature of condenser (the outdoor heat exchanger) raises with the rising of outdoor temperature. Then the temperature of refrigerant at the outlet of the outdoor exchanger rises. So, the enthalpy of refrigerant at the exit of the outdoor exchanger rises, accordingly. However, the temperature of refrigerant at the outlet of evaporator (the indoor exchanger) remains nearly constant when outdoor temperature rises. The refrigerant enthalpy at the outlet of the indoor exchanger keeps constant. So, the enthalpy difference of refrigerant (i.e. the difference of the refrigerant enthalpy at the outlet of the outdoor exchanger and the refrigerant enthalpy at the outlet of the indoor exchanger) decreases, viz. the cooling capacity per unit quality (i.e. the enthalpy difference) decreases.

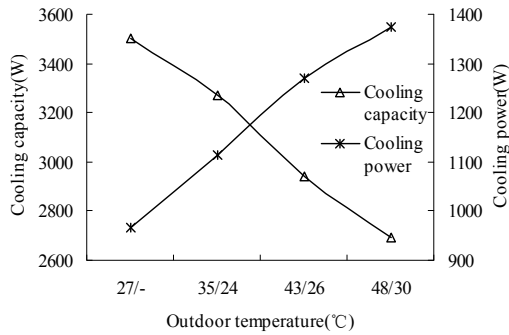


Figure 1: Changes of cooling capacity and power with outdoor temperature

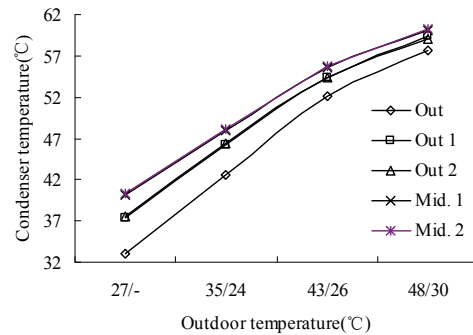


Figure 2: Changes of temperature of condenser with outdoor temperature

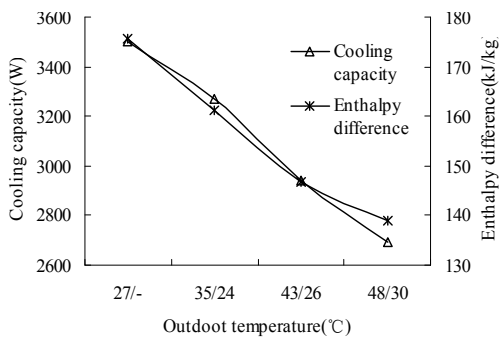


Figure 3: Changes of cooling capacity and enthalpy difference with outdoor temperature

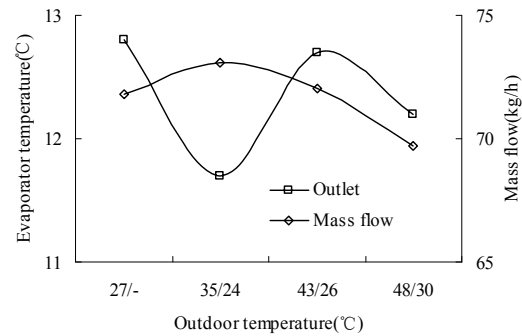


Figure 4: Changes of outlet temperature of evaporator and mass flow with outdoor temperature

On the other hand, it can be seen from figure 3 that the trends of the cooling capacity and the enthalpy difference decrease consistently with outdoor temperature. From figure 4, the refrigerant mass flow keeps nearly constant when outdoor temperature rises. Hence, the decrease of the cooling capacity is mainly due to the decrease of the enthalpy difference of refrigerant with the rising of outdoor temperature. From figure 5, it can be seen that with the rising of outdoor temperature, the pressure ratio of the high pressure and the low pressure increases. Hence, the cooling power rises.

3.2 Heating Capacity

The change curves of the heating capacity and power with outdoor temperature are shown in figure 6. It can be seen from figure 6 that the heating capacity decreases with the falling of outdoor temperature. Comparing with the rated heating capacity (the heating capacity under the rated condition), when outdoor temperature is 2°CDB/1°CWB, the heating capacity (without defrosting) is about 72.65% of the rated heating capacity, viz. the heating capacity decreases by 27.35% comparing with the rated heating capacity. The heating capacity decreases by 41.51% comparing with the rated heating capacity when outdoor

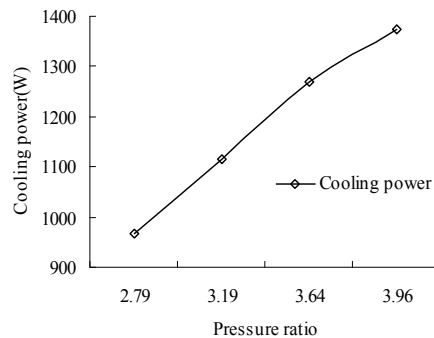


Figure 5: Changes of cooling power with pressure ratio

temperature is $-7^{\circ}\text{CDB/RH80\%WB}$. However, when outdoor temperature is $21^{\circ}\text{CDB}/15^{\circ}\text{CWB}$, the heating capacity increases by 23% comparing with the rated heating capacity.

The change curves in figure 7 to figure 9 are the suction and discharge temperature with outdoor temperature, the heating capacity and the enthalpy difference with outdoor temperature, and the heating power with pressure ratio, respectively. It can be seen from the figures that the suction temperature of compressor drops with the falling of outdoor temperature. The suction specific volume increases with the falling of suction temperature. And this results in the decrease of mass displacement of compressor.

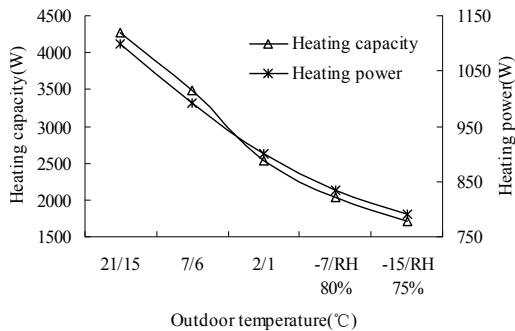


Figure 6: Changes of heating capacity and power with outdoor temperature

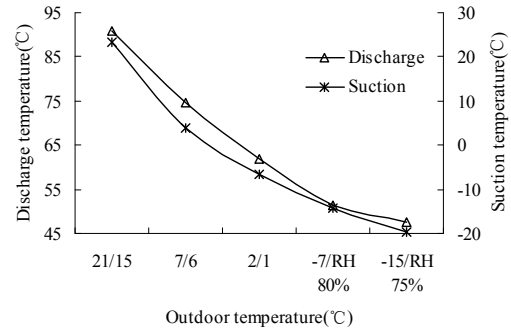


Figure 7: Changes of suction and discharge temperature with outdoor temperature

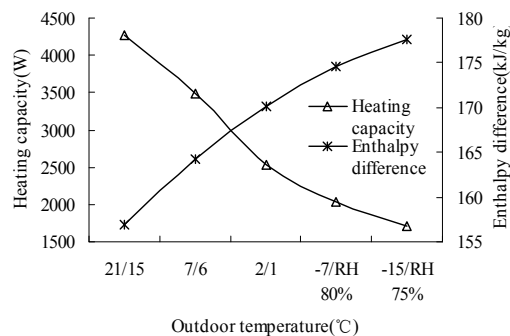


Figure 8: Changes of heating capacity and enthalpy difference with outdoor temperature

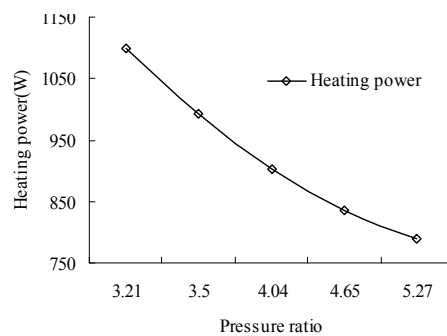


Figure 9: Changes of heating power with pressure ratio

On the other hand, from figure 8, the enthalpy difference of refrigerant at the inlet and outlet of condenser (the indoor exchanger) rises with the falling of outdoor temperature. This indicates that the decrease of the heating capacity is mainly due to the decrease of the mass displacement of compressor with the falling of outdoor temperature but not the enthalpy difference of refrigerant. It can be seen from figure 9 that the heating power decreases with the rising of pressure ratio. And this indicates that due to the decrease of the mass displacement of compressor, the heating power decreases.

4. CONCLUSIONS

The effects of outdoor temperature on the cooling and heating performance of a residential heat pump air-conditioner were tested under the rated condition and some off-design conditions. The analysis on the experimental data shows that:

- (1) The enthalpy difference of refrigerant at the inlet and outlet of indoor exchanger decreases when outdoor temperature rises. The cooling capacity decreasing with the rising of outdoor temperature is mainly due to the decrease of enthalpy difference of refrigerant. And the rise of the cooling power can be mainly due to the rise of pressure ratio when outdoor temperature rises.
- (2) The mass displacement of compressor decreases when outdoor temperature drops. And this results in the heating capacity and power decrease with the falling of outdoor temperature.
- (3) The capacity degradation is inevitable for the characteristics itself.

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