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Experimental Investigation on Heating Performance of Heat Pump for Electric Vehicles in Low Ambient Temperature.

Fei QIN[a,b], Shuangquan SHAO[a], Changqing TIAN[a]*, Hongxing YANG[c]

[a]Technical Institute of Physics and Chemistry,CAS, Beijing 100190, China
[b]University of Chinese Academy of Sciences, Beijing,China
[c] Renewable Energy Research Group, The Hong Kong Polytechnic University, Hong Kong, China

Abstract

In comparison with the traditional cars, Electric Vehicles (EVs) cannot utilize the waste heat of the engines to keep warm inside the car in winter. As a potential heat source, air source heat pump (ASHP) for EVs with scroll compressor and test bench has been built to investigate the heating performances on heat pump system in low ambient temperature. Based on the demand of moisture condensation control on the window screen of EVs, the heating performances are tested on both all fresh air supply and various indoor air inlet temperature conditions, under low environmental temperature -10°C, -15°C and -20°C. The experimental results show that ASHP for EVs has big differences to buildings or household ACs due to its big ratio of fresh air, even at -20°C, the system's COP under the largest heat capacity is over 1.7.

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Keywords: electic vehicles, heat pump, cold regions, experimental investigation

1. Introduction

For Electric Vehicles (EVs), the air-conditioning system plays a significant role[1], for providing comfortable and safe driving conditions[2].

Unlike the traditional cars with internal combustion engines (ICE), EVs cannot utilize the waste heat of the ICE to keep warm inside car in winter. Therefore, it is essential to develop high efficiency air conditioning system. The most commonly methods are PTC electrical heating and heat pump system. If it is heated by electricity alone, the driving range will decrease up to 50%[3]. It is a promising way to apply the air source heat pump (ASHP) for heating in winter[4] besides for cooling in summer with a sole system. Based on the demand of moisture condensation control on the window screen of EVs, big ratio of

* Changqing Tian. Tel.: +0-000-000-0000 ; fax: +0-000-000-0000 .
E-mail address: chqtian@mail.ipc.ac.cn.

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fresh air supply, even all fresh air, is necessary, which means the indoor inlet air temperature is lower, and the heat transfer temperature difference is higher than the traditional HP. It is rare in buildings or household ACs, and little research has been presented the operation condition of this kind of system.

Aiming at the cold region, an ASHP system for EVs and test bench has been built to investigate the performance in the present work. To meet the demand of EVs, the heating performances are tested on both all fresh air supply and various indoor air inlet temperature conditions, under low environmental temperature -10^{o}C, -15^{o}C and -20^{o}C.

The investigation shows that HP for EVs has big difference to buildings or household ACs, owing to its big ratio of fresh air. The development of ASHP will also promote the industrialization and practicability of EVs.

2. Experimental Setup and Procedure

A test bench of ASHP for EVs with scroll compressor has been built to investigate the heating performance on the heat pump system. Fig. 1 illustrates the schematic diagram of test system.

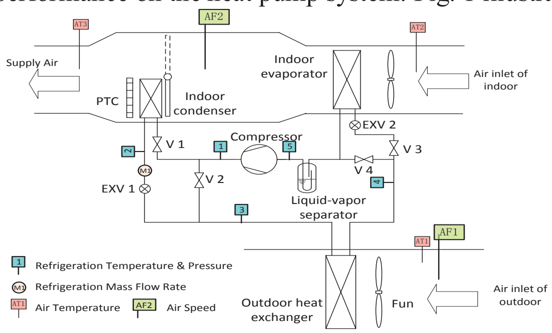


Fig. 1. Schematic diagram of ASHP

Table 1. Measurement devices

Parameter	Type	Rang	Error
Temperature	Thermocouple	-30 to 220°C	±0.5°C
Pressure	Diaphragm	0-30bar	±0.5%
Air speed	Hot bulb	0-40m/s	±3%
Mass flow rate of Ref.	Coriolis	<370kg/h	±0.1%

The indoor heat exchangers (indoor condenser and indoor evaporator) and outdoor exchanger are placed in two air ducts located in two environment chambers with different set conditions respectively.

The inlet air parameters of two ducts and compressor speed are set, based on the test condition. The measurement devices are shown in Table 1, and the test points are shown in Fig. 1. The operation performances of system are tested under low environmental temperature.

The face velocity of outdoor heat exchanger is around 3.5m/s, and the air volume (calculated form air speed and sectional area of duct) of indoor duct is 350m^3/h. The speed of inverter compressor is from 2000r/min to 8500r/min. The environmental temperatures in the test are -10 ^{o}C,-15 ^{o}C, and -20 ^{o}C, and the different ratio of fresh air tests are based on -20 ^{o}C.

3. Result and Analysis

3.1. All fresh air condition

Fig. 2 is the experimental results of all fresh air. All fresh air condition means the inlet air temperature of indoor and outdoor are the same.

Fig. 2 shows that the condensing temperature, air temperature, and heating capacity increase with the rising of compressor speed, due to the growing up in refrigerant mass flow rate. Being different from traditional ACs in buildings, the changing scope of condenser temperature is large with the changing of heat capacity in EVs. COP of the system decreases obviously with the rising of compressor speed, which can enlarge the temperature difference between condenser and evaporator to a great extent.

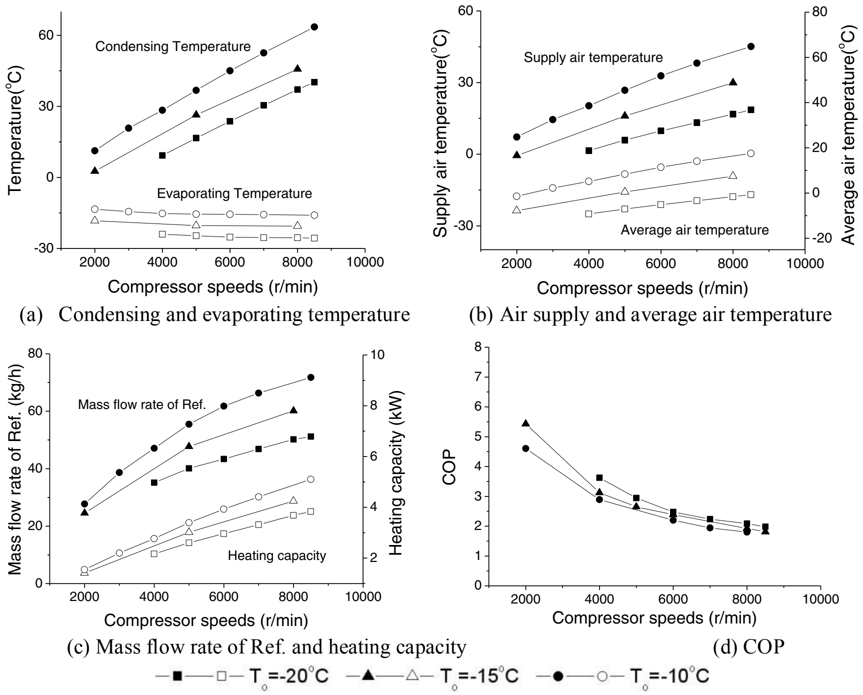


Fig. 2. Test results of all fresh air condition

Following the rising of environment temperature (T_0), the evaporation temperature is higher, while the specific volume of compressor suction is lower, which leads the increasing of refrigerant mass flow rate.

Moreover, in low environment temperature, the air supply temperature and heating capacity are not enough to meet the heating demand. At that time, the PTC is used to additional heating.

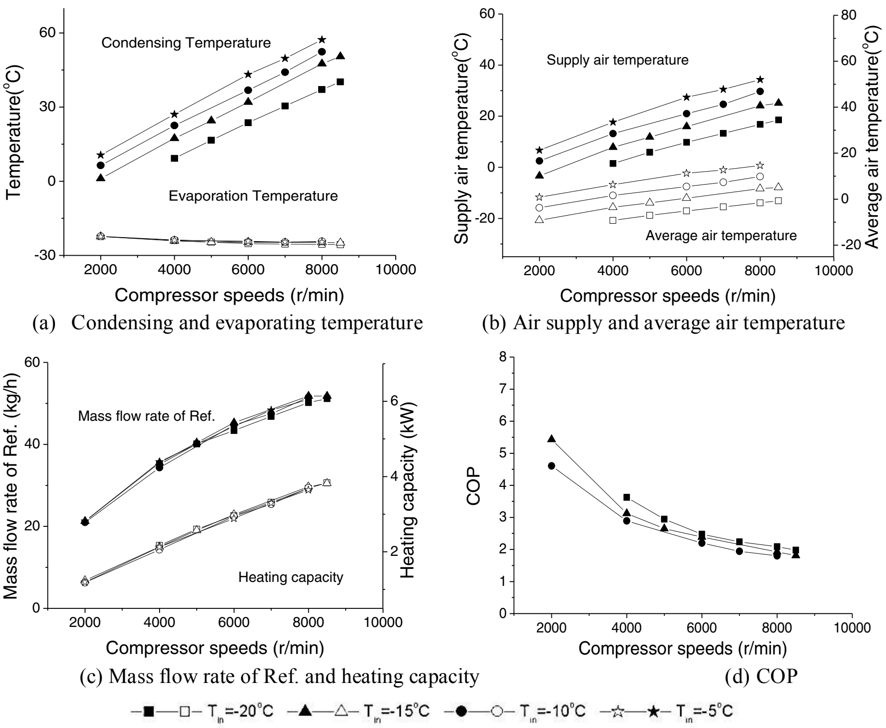
3.2. Various indoor inlet air temperature condition

Considering the low air supply temperature in low environment temperature, part of return air or another heating method may be used in further research. Different indoor inlet air temperature at -20°C are tested to simulate different ratio of return air, and Fig. 3 is the experimental results.

The changing trends of system parameters are similar to the all fresh air condition following the change of compressor speed at -20°C. Nevertheless, with the increasing of indoor inlet air temperature, the refrigeration mass flow rate and heat capacity are unchanged almost, for the changing of evaporator temperature is small. Even at -20°C, the system's COP under the largest heat capacity is over 1.7.

4. Conclusion

Aiming at the cold region, the present work builds an ASHP for EVs and test bench to investigate the performance of the system. To meet the demand of EVs, the heating performances are tested on both all fresh air supply and various indoor air inlet temperature conditions, under low environmental temperature. Even at -20°C, the system's COP under the largest heat capacity is still over 1.7, while the air supply temperature is not enough. In order to get higher air supply temperature and increase the heating capacity, raise return air ratio or heat recovery in safety region need to further research.



(a) Condensing and evaporating temperature (b) Air supply and average air temperature

(c) Mass flow rate of Ref. and heating capacity (d) COP

Fig. 3. Test results of different indoor inlet air temperature condition

Acknowledgements

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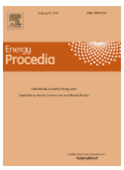

Biography

QIN Fei, Ph.D. candidate, studying in Technical Institute of Physics and Chemistry, Chinese Academy of Sciences. Research fields are Electric vehicles heat pump air conditioning system, vapor injection heat pump system, and scroll compressor simulation.