EXPERIMENTAL RESEARCH ON THE ELECTRIC VEHICLE HEAT PUMP SYSTEM BASED ON R744 REFRIGERANT

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ABSTRACT

According to the Montreal Protocol, refrigerant with high GWP has been subject to regulation. R134a, previously used in vehicles, also has been subject to regulation because of its high GWP. As a substitute for R134a, R1234yf is commonly used in electric vehicles because of its similar performance with R134a. However, due to PFAS (per- and polyfluoroalkyl substances) regulations, R1234yf also will be subject to regulation. So, the heat pump system using other refrigerants needs to be developed. In this study, the performance of electric vehicle heat pump system using R744 is studied. As a result, compressor speed has higher effect on performance in all modes while fan speed has lower effects on performance.

KEY WORDS

Electric Vehicle, Air Conditioning System, Natural Refrigerants, Experimental study, Thermodynamics

1. INTRODUCTION

According to the 2050 net zero milestone[1], sales of internal combustion engine vehicles will be restricted in 2035. Therefore, electric vehicles will gradually replace the current vehicles. However, electricity is used to operate heaters for electric vehicles, which has a massive impact on driving performance[2]. To minimize these problems, heat pump systems for electric vehicles are being widely applied.

The European Chemicals Agency has adopted and published the EU REACH restriction report[3], which aims to limit the use of perfluorinated compounds (PFAS) and is scheduled to enter into force from 2025. R1234yf is also subject to regulation. Therefore, research on heat pump systems for electric vehicles using natural low GWP refrigerants is conducted.

R744 has higher efficiency and non-flammable. So, research about heat pump systems using R744 is ongoing. However, research about R744 based heat pump systems is mainly conducted with prototype model[3]. So, Research about actual-size electric vehicle heat pump systems using R744 is conducted in this study.

2. EXPERIMENTAL SETUP

2.1 Experimental Setup

The test bench was consisting of three tube-fin type heat exchanger, one plate type heat exchanger, one scroll compressor for refrigerant compression, three expansion valve. Two tube-fin type heat exchangers exchanged heat with indoor air for cabin heating and cooling. The other tube-fin type heat exchanger exchanged heat with outdoor air. Plate type heat exchanger was used for battery chilling The heat capacity and COP were calculated using Equation (1)~(2).

$$Q=mC_p\Delta t \tag{1}$$

$$COP = Q/W \tag{2}$$

2.2 Test Conditions

Table 1 shows the test conditions. Ambient temperature and coolant temperature is determined based on ASHRAE J1634.

Table 1. Test conditions

Parameter	Unit	Range
Compressor Speed	RPM	4500 ~ 6000
Ambient Temperature	℃	35 ~ 45 (cooling) / -10 ~ 0 (heating) / 20 ~ 30 (battery chilling)
HVAC Fan Current	A	3 ~ 5 (cooling / heating)
COND Fan Current	A	3 ~ 8
Coolant Temperature	℃	30 ~ 40 (battery chilling)

3. RESULTS AND DISCUSSION

3.1 Refrigerant Charge Determination

Refrigerant charge amount is determined with COP in each mode. When the refrigerant charge is 0.48kg, it shows the best COP in cooling mode. When the refrigerant charge is 0.6kg, it shows the best COP in heating mode. In battery chilling mode, 0.56kg shows the best COP

3.2 Performance Analysis in Cooling/Heating/Battery Chilling Modes

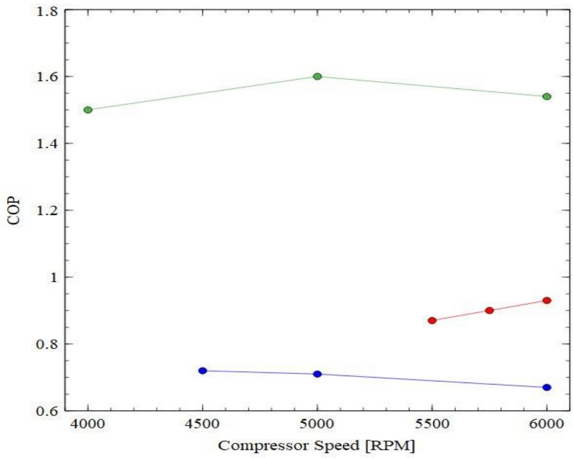

Fig. 1 COP under different compressor speed

Fig. 1 shows the changes of COP when compressor speed is changed. In cooling mode, when compressor speed increases, COP changes from 0.72 to 0.67. It is due to the decrease in compressor efficiency. In heating mode, when compressor speed increases, COP changes from 0.87 to 0.93. It is because increases in heating capacity is higher than increases in compressor work. In battery chilling mode, COP increases from 1.5 to 1.6, and decreases to 1.54. It is due to the increase of compressor work is higher than that of cooling capacity.

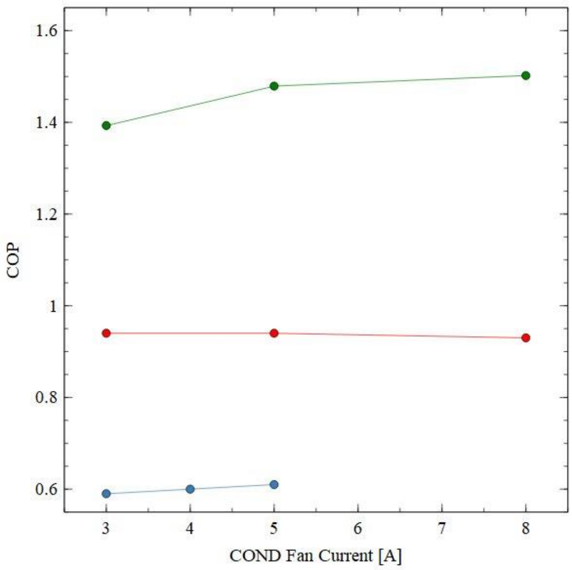

Fig. 2 COP under different COND fan current

Fig. 2 shows the changes of COP when COND Fan Current is changed. In cooling mode, when fan current increases, COP changes from 0.59 to 0.61. It is due to the increase in heating capacity and cooling capacity. In heating mode, when fan current increases, COP changes from 0.94 to 0.93. It is because increases in fan power is higher than increases in heating capacity. In battery chilling mode, COP increases from 1.39 to 1.50. It is due to the increase of cooling capacity is higher than that of system power consumption.

4. CONCLUSION

In this paper, an experimental study of electric vehicle heat pump based on R744 is conducted. Compressor speed has higher effects on system performance. Otherwise, COND fan current has the lowest effects on system performance.

ACKNOWLEDGEMENTS

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