INVESTIGATION OF AIR CONDITIONING SYSTEM FOR ELECTRIC VEHICLES

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Abstract- the electric vehicles are an automobile propelled by electric power and has the advantage of zero emission on the road. With its energy-saving, low pollution, and efficient mobility benefits, the electric vehicles are the rising star in the future of automobile industry. The electric vehicles comprises many mechanical parts. As the air-conditioning system consumes large amounts of energy (approximately 30 ~ 40 %), how all components of the air-conditioning system in an electric vehicles are designed in order to raise the COP of the system, to reduce energy consumption, and to increase durability becomes a crucial topic. This study established anair conditioning system that consists of an electric compressor, an electric expansion valve, the evaporator and the condenser, to meet the cooling, heating and dehumidification demand of the electric vehicles. This study investigated the compressor rotationalspeed, temperatures of air flowing into the condenser, and different volumetric flow rate of air flowing into evaporator, respectively. The results show under cooling mode, the compressor speed from 2000 ~ 5000RPM, cooling capacity of the system can provide 2.1 ~ 5.8 kW, COP can be maintained above 4.

Index Terms- electric vehicles, air-conditioning, COP

I. INTRODUCTION

An electric *vehicles* is an automobile propelled by electric power and has the advantage of zero emission on the road. With its energy-saving, low pollution, and efficient mobility benefits, the electric *vehicles* is the rising star in the future of automobile industry. An electric *vehicles* comprises many mechanical parts. As the air-conditioning system consumes large amounts of energy (approximately 30 ~ 40 %), The air conditioning system need to meet the cooling demand, heating demand, constant temperature control and a matter of life and death function, makes passenger located in a comfortable place, and promote the safety of driving in low temperature environment.

The statistic of internal combustion engine consumption gas by JARI(Japan Automobile Research Institute)shows that electric vehicle drive in every 1 kilometer expense the energy only 30% as gas vehicle, and the CO_2 emission decrease 75% than the gas vehicle. To makes electric vehicle to popularize, it must to pair up an air conditioner system. Surampudi et al. [1] traditional air conditioning except compressor will cause engine power burden, the fan of external heat converter power consumption cannot be ignore, it's development electric air conditioner system, at cooling fan and compressor power supply system enhance control device, reduce spare battery burden.Wei[2]to solid electric air conditioning and common air conditioning build system model, use MATLAB/Simulink build simulation program, put many of heated burden difference to calculate it is numerical value, and simulation when the maximum temperature inside the car reach 60-70℃in summer. When lower temperature to goal need time and burden work inside the car, the result about 8 minute can be lower to body comfortable temperature, compressor rotational speed about 1900RPM, save 13% than car traditional air conditioning. Thus, how all components of the air-conditioning system in an electric vehicles are designed in order to raise the COP of the system, to reduce energy consumption, and to increase durability becomes a crucial topic.

II. PROCEDURE FOR PAPER SUBMISSION

In this study, an air conditioning system experimental platform of the electric vehicle was setup as shown in Fig.1. It main including compressor、condenser、expansion valve and evaporator,the R134-a are used as working fluid in this study. Experiment parameter are aimed under various conditions including different compressor rotational speed (2000 rpm、3000 rpm、4000 rpm、5000 rpm), different temperatures of air flowing into the condenser (30℃、40℃), and different volumetric flow rate of air flowing into evaporator(0.15m^3/s 、 0.22 m^3/s), the experiment parameter are listed in Table 1. The compressor rotation speed is controlled by a 300V DC power supply which is connected with programmable logic controller（PLC）.

Temperature, pressure are major components were measured for evaluating performance of the refrigeration cycle, the measuring point of the system are shown in Fig.1. The temperature and pressure of accuracy are ±0.08% and ±0.03% in the full scale of measurement, respective. The power consumed for driving the compressor rotational speed was varied up to 1000-5000 rpm for performance evaluation of the system under the various operation condition. The experimental results are analyzed regarding the system's operating temperature, operating pressure, cooling capacity, compressor power consumption, and COP. It was made to investigate cooling performance

characteristics in order to analyze automotive refrigeration cycle for R134a.

The cooling capacity, compressor consumption power, system COP and refrigerant mass flow rate were calculated by equations (1)-(4). The power consumptions of compressor are monitored by the control panel. Temperature and pressure of refrigerant at compressor inlet and outlet are measured to evaluate the enthalpy of refrigerant. The mass flow rate of refrigerant is calculated by equations (1):

$$\dot{m}_r = \frac{W_{comp}}{R,2 - R,1} \quad (1)$$

Where $\dot{m}_r$ is the mass flow rate of refrigerant (kg/s) ; W_{comp} is compressor consumption power (kW) ; $_{R,1}$ is the enthalpy of refrigerant at compressor inlet (kJ/kg) ; $_{R,2}$ is the enthalpy of refrigerant at compressor outlet (kJ/kg).

The cooling capacities on the air side and on the refrigerant side were measured and compared in order to find exactly the cooling capacity on the evaporator. The following Equation (2) was used to find the cooling capacity on the refrigerant side by measuring the temperature and the pressure of the refrigerant at the evaporator inlet or outlet. The cooling capacity of the refrigerant side was calculated by the enthalpy difference between inlet and outlet at the evaporator.

$$Q_{evap,R} = \dot{m}_R(_{R,1} - _{R,4}) \quad (2)$$

Where $_{R,4}$ is the enthalpy of refrigerant at evaporator inlet (kJ/kg) ; $_{R,1}$ is the enthalpy of refrigerant at evaporator outlet (kJ/kg).

The cooling capacity on the air side was airflow and the specific volume were measured by means of the enthalpy difference resulting from the dry-bulb temperature and the relative humidity at the indoor air inlet and the outlet. The following Equation (3) was used to calculate the cooling capacity for air side.

$$Q_{evap,a} = \frac{\dot{V}_a}{v}(_{a,out} - _{a,in}) \quad (3)$$

Where $\dot{V}_a$ is the volumetric flow rate of air at evaporator inlet (m^3/s) ; $_{a,out}$ is the enthalpy of air at evaporator outlet (kJ/kg) ; $_{a,in}$ is the enthalpy of air at evaporator inlet (kJ/kg).

Equations (2) and (3) were used to compare the cooling capacities on the air side and on the refrigerant side. The following Equation (4) was then used to compare the energy balance to check the test results. In this study, the measured experiment results were used, the energy balance deviation is distributed within approximately 5% under the various operation conditions.

$$Q_{evap,diff} = \frac{(Q_{evap,R} - Q_{evap,a})}{Q_{evap,R}} \times 100\% \quad (4)$$

In this study, the system coefficient of Performance (COP) is defined as a ratio of cooling capacity to the compressor consumption power and calculated with Equation (5).

$$COP = Q_{evap,R} / W_{total} \quad (5)$$

Where the W_{total} is the consumption power of the system (include the consumption power of the condenser fan and the evaporator fan) (kW).

III. RESULTS AND DISCUSSION

Figure.2 presents the cooling capacity r at the different experiment parameter. It is noted the cooling capacity increase with increasing value of the compressor rotational speed and decreasing values of the condensation temperature. When the compressor rotational speed from 2000RPM to 5000RPM, the value of the cooling capacity increased from 3.7kW to 5.8 kW at condenser temperature 30℃, and increased from 3.3kW to 5.4 kW at condenser temperature 40℃, respective.

Figure.3 presents the compressor power consumption at the different experiment parameter. It is noted the compressor power consumption increase with increasing value of the compressor rotational speed and increasing values of the condensation temperature. When the compressor rotational speed from 2000RPM to 5000RPM, the value of the compressor power consumption increased from 0.35kW to 1.21 kW at condenser temperature 30℃, and increased from 0.37kW to 1.25 kW at condenser temperature 40℃, respective.

Figure.4 presents the coefficient of performance of the system at the different experiment parameter. It is noted the COP decrease with increasing value of the compressor rotational speed and increasing values of the condensation temperature. When the compressor rotational speed from 2000RPM to 5000RPM, the value of COP decreased from 6.5 to 4.2 at condenser temperature 30℃, and decreased from 5.7 to 3.8 at condenser temperature 40℃, respective.

CONCLUSION

This study investigated the compressor speed, temperature of outside air and volumetric flow rate of supply air under cooling mode, respectively. The results show under cooling mode, the compressor speed from 2000 ~ 5000RPM, cooling capacity of the system can provide 2.1 ~ 5.8 kW, COP can be maintained above 4.

ACKNOWLEDGEMENTS

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Table 1. The experiment parameter

Working Fluid:R134a			
CASE	Temperatures of air flowing into the condenser (℃)	Compressor rotational speed (RPM)	Volumetric flow rate of air flowing into evaporator (m^3/s)
Case1	30	2000、3000 4000、5000	0.15
Case2	40		
Case3	30		0.22
Case4	40		

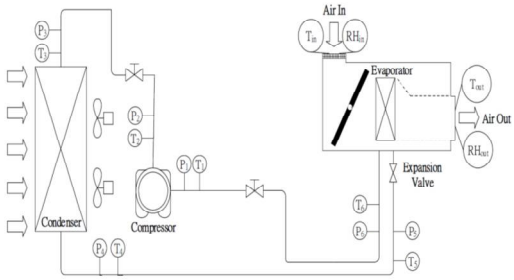


Fig. 1. Schematic diagram of experimental setup.

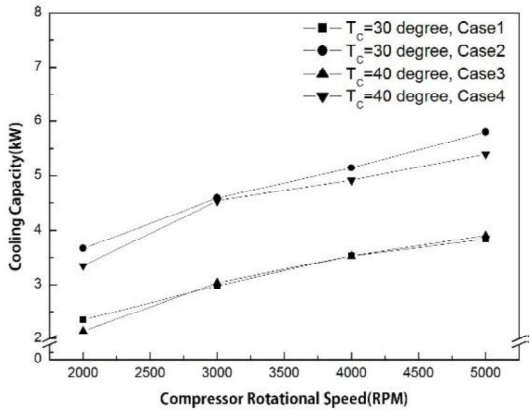


Fig. 2. Cooling Capacity for different compressor rotational speed and condenser temperature

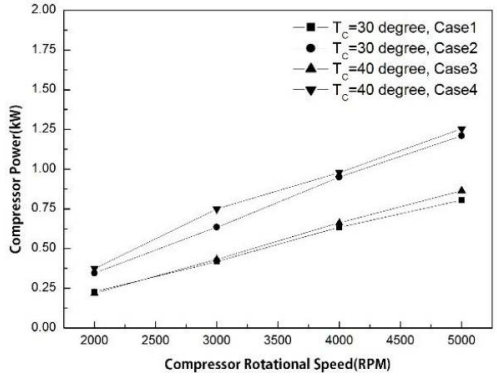


Fig. 3. Compressor power for different compressor rotational speed and condenser temperature

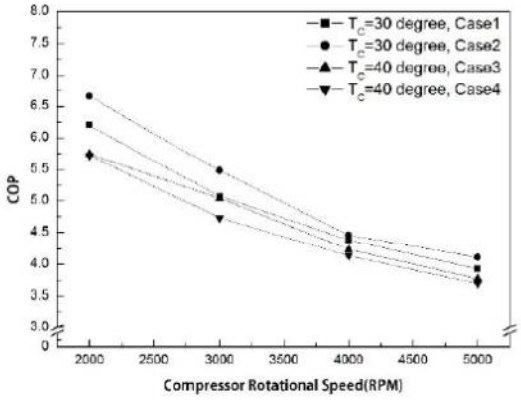


Fig. 4. COP for different compressor rotational speed and condenser temperature

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