Experimental study on combined defrosting performance of heat pump air conditioning system for pure electric vehicle in low temperature

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Abstract: The development of defrosting technology is a crucial technical barrier to the application of ~~-~~the heat pump air conditioning system for the pure electric vehicle. The frosting on the air conditioning system significantly affects systematic performance and reliable operation especially in low temperature and high humidity climate condition. Therefore, in this paper, an experimental study of ~~low~~ low-temperature heat pump air conditioning system with the combined defrost technology of increasing enthalpy and temperature is carried out ~~in order~~ to find proper thermal management solutions. Based on the reverse-cycle methods, the combined defrost technology makes full use of the compressor air-supplying enthalpy-adding, air-cooled heat exchanger inside the vehicle preheating, temperature-raising, enthalpy-adding and the external heat exchanger condensation temperature-increasing technologies. The fast defrosting process can be realized by means of releasing the condensation heat and volume significantly while the ~~external~~ outer heat exchanger is conducting a defrosting operation. Meanwhile, the cold cabin ~~cold~~ sensitivity can be reduced ~~correspondingly~~ while defrosting process taking place correspondingly. Experimental results show~~s~~ that under the operating condition of -20℃ outside environment temperature and 80% relative humidity, ~~rapid~~ instant defrosting time at fully defrosted air-cooled heat exchanger outside the vehicle can be controlled within 100 seconds.

Keywords: Heat pump, Pure electric vehicle, Air conditioning, Defrosting, Thermal management

1. Introduction

With the intensifying energy crisis and the increasing environmental problems, it is imperative to take actions for energy saving and environmental protections on automotive industries. Pure electric vehicle (PEV) as disruptive technology provide an alternative way to replace traditional automotive industry ~~in order~~ to achieve sustainable development ~~in near future~~shortly. To maintain the PEV working at proper temperature and humidity condition, vehicular air conditioning system becomes an indispensable sub-system that it not only provides the thermal comfort in the cabin but also contributes to the safeties of traction batteries and power ~~electronics[~~electronics [1, 2]. The wide-ranging features of the ~~constantly changing~~evolving environment outside the car has also raised the requests on the air conditioning system performance in the PEV. And the heat pump air conditioning system has such advantages as high efficiency, energy saving, environmental protection that it is becoming the priority of vehicular air conditioning in the PEV[3-6]. There are, in spite of

~~aforementioned~~ merits mentioned above, still some issues of itself especially in low temperature and high humidity ambient. The exterior heat exchanger of the heat pump prone to frost while the system is in heating mode. It not only causes both blockages of air channels and increase of ventilation resistance~~,~~ but also the overall thermal resistance of exterior heat exchanger. Consequently, the frost will be accumulated and thickened resulting in ~~serious~~ severe deterioration of working performance and reliability of vehicular conditioning ~~system[~~system [7-9]. Therefore, it is important to find out the main factors of influencing defrost in the exterior heat exchanger ~~in order~~ to reduce defrosting time through reasonable and effective control strategies.

An e~~E~~vaporator is a unit where it is easy to frost, so to analyze operating characteristics of the evaporator in the case of defrosting is the key to studying the defrosting of the heat pump system. In the 1970s, Sanders, a Dutch[10] began the study on defrosting of air-conditioning evaporators, who created a model of evaporator defrosting of the air-conditioning system in his doctoral thesis, and recorded the whole course of defrosting through experiments and analyzed the distribution of energy consumption in the system during the defrosting. In the 1980s, E.N.АНДРАЧНИКОВ, a scholar of the former Soviet Union[11] proposed an ~~effective~~ efficient way of automatic evaporator defrosting, and the system was designed with main and secondary evaporators, and a 2_PM time relay was used for control over the two evaporators defrosting alternately. D. L O'Neal and Payne[12] studied the effect of the air volume of the evaporator fan on the defrosting performance. Based on the basic air volume of $72m^3$/min, experiments were conducted at a low air volume of $40m^3$/min and a high air volume of $88m^3$/min respectively. The results showed that compared with the basic air volume, the defrosting time and water accumulation after defrosting were ~~greatly~~ significantly reduced ~~under~~ in the low air volume, yet it lowered the evaporating temperature of the system and increased the frosting rate of heat exchanger; under the high air volume, the heat exchange of the system was increased, meanwhile, the defrosting time was prolonged, yet it increased the evaporating temperature of the system which lowered the frosting rate of the heat exchanger. Padhmanabhan[13] compared the performance difference between finned evaporator and micro-channel evaporator during defrosting~~,~~ and found that the defrosting time of the finned evaporator was about twice of that of micro-channel evaporator, but the frosting rate of the micro-channel was ~~obviously~~ apparently higher than that of the finned evaporator.

In recent years, computers are used to simulate and analyze the defrosting performance of the heat pump system, which ha~~ve~~s made rapid progress. Liu[14], based on the energy conservation equation, created a hot air defrosting dynamic cycle ~~dynamic~~ model, aiming to simulate the performances of evaporator and condenser at reverse cycle defrosting~~,~~ .~~besides,~~ ~~t~~Through experiments, the model proved that it could not only simulate characteristics of defrosting of the system, but also ~~simulate~~ affect the whole defrosting course. Dopazo[15] created a heat pump evaporator defrosting model on the basis of hot air, the model divided the defrosting process into six stages: preheating, defrosting outside tubes, defrosting of fins, induced air, water film formed on fins surfaces, drying and heating, the control volume in each stage was represented by a node in the system model. A finite difference method is used to solve the equation, and the results included time needed for defrosting, energy distribution during defrosting, characteristics of instantaneous refrigerant and temperature distribution of finned tubes. Qu[16, 17] firstly studied ~~characteristics~~ features of the multi-tube heat exchanger in defrosting, and the results showed that the defrosting time of upper layers of tubes was faster than that of the lower ones, the defrosting efficiency was estimated to be 34.5%. In order to quantitatively analyze the effect of ~~different~~ various layers of tubes on defrosting, he created a semi-empirical mathematical model and the defrosting time trend calculated for different layers from top to bottom was the same as the conclusion of the experiment, and pointed out that the frosting time of lower layers of tubes reduced the defrosting efficiency of the system.

At present, it is still at the preliminary stage that there are few researches on defrosting of heat pump PEV air conditioning system. Zhong Hua and others make defrosting control ~~in terms of~~regarding traditional vehicle design in combination with the electronic expansion valve, and enhance air volume of the evaporator while increasing the electronic expansion valve ~~opening[~~opening [18]. Wu et al. find out through experiment that while the heat pump air conditioning system for PEV is supplying heat at~~in~~ low temperature, the outdoor micro channel heat exchanger was frosted severely, which influences the heating capacity of the system and the coefficient of performance, but the defrosting solution is not proposed[19]. Therefore, the ~~experimental~~ temporary tables of ~~- low -~~low-temperature heat pump air conditioning system for PEV is designed[9], and the condensation temperature and defrosting speed under different working conditions are tested. In addition, the variants are analysed such as system cooling capacity, exhaust temperature, outlet air temperature and the import and export temperature of exterior heat exchanger along with the changes of system defrost operating time. The influence on exterior heat exchanger defrosting performance by different factors is~~are~~ also studied in order to determine the fast and reliable defrosting method~~,~~ and provide an experimental basis for further improvement of the performance of PEV air conditioning system.

2. Heat pump type air conditioning system for PEV

The test rig of a low-temperature heat pump air conditioning system for PEV is designed and established using the quasi-two-stages compression principle. It combines with both the characteristics of low-~~-~~temperature heat pump technology and automotive air conditioning conditions as shown in Fig.1. This test rig consists of a compressor, four-way valve, air-cooled heat exchanger outside the vehicle, one-way valve, liquid storage drier, main expansion valve, air-cooled heat exchanger inside the vehicle, air-supplying expansion valve, and intermediate heat exchanger as well as other auxiliary parts.

The system can achieve multiple basic working modes of electric vehicle cooling, battery electric heating, and air-cooled heat exchanger outside the vehicle defrosting under different working conditions. In cooling mode, the four-way valve switches into the cooling channel which is the same as ~~ordinary~~ conventional car air conditioning cooling processes. The circulating refrigerant is discharged through compressor with high pressure and subsequently flow into air-cooled heat exchanger outside the vehicle for condensation process. ~~Thereafter~~ After that, it flows into liquid storage drier through the one-way valve. Then the refrigerant flows into the main expansion valve after going through the intermediate heat exchanger, and then low pressure and low-~~-~~temperature flow enter~~s~~ into an air-cooled heat exchanger inside the vehicle for evaporation through the one-way valve. Eventually, it is absorbed by the compressor after going through the four-way valve.

In heating mode, the four-way valve switches into the heating channel, the circulating refrigerant is discharged ~~through~~from the compressor at high pressure and high-~~-~~temperature state. Then the flow enters into an air-cooled heat exchanger inside the vehicle for condensation purpose, later on, it flows into the liquid storage drier through the one-way valve and directly flows into the main circulating pipeline of the intermediate heat exchanger. Different from the cooling mode, the circulating refrigerant is~~are~~ separated into two streams after flowing out of the intermediate heat exchanger in order to achieve both mass flow and temperature reduction by the air-supplying expansion valve. The auxiliary circulating pipeline is~~are~~ formed ~~in order~~ to exchange heat in the intermediate heat exchanger with circulating refrigerant in the main circulating pipeline. ~~This~~ It will help increase the degree of the pipeline. On the other hand, the circulating refrigerant in ~~main~~ primary circulating pipeline flows into the air-cooled heat exchanger outside the vehicle for evaporation purpose through the one-way valve after mass flow and temperature reduction in the air-supplying expansion valve and main expansion valve. Finally, the main flow is~~are~~ absorbed by the compressor through the four-way valve, and it is also blended with the circulating refrigerant from an auxiliary pipeline in the compression chamber in which the flow are from air-supplying opening through the one-way valve.

When the air-cooled heat exchanger outside the vehicle is in defrosting mode, the reverse cycle rapid defrost technology of enthalpy and temperature rise can be applied. The four-way valve switches into cooling mode, the circulating refrigerant are discharged by the compressor and then flow into the air-cooled heat exchanger outside the vehicle through the four-way valve for condensation and defrosting purposes. Afterwards, the refrigerants flow~~s~~ into the liquid storage drier through the one-way valve, and high-~~-~~pressure refrigerants flow into the main expansion valve through the intermediate heat exchanger. Eventually, the flow with low pressure and low-~~-~~temperature enters into an air-cooled heat exchanger inside the vehicle for evaporation process and the full cycle will be finished by the compressor through the same four-way valve.

The theoretical cycle of the electric vehicle-based low-temperature heat pump air-conditioning system, designed by this article, is shown in Fig.2, the working medium in air recirculation pipelines enters the compressor suction cavity of compressor through the intake port on the compressor ende~~r~~ cover, which is an insulating and throttling process[20]: After the working medium in the recirculation pipeline travels through the intake port, a middle pressure is reduced to be the suction pressure of compressor, there are a few circulating medium mixed with the suction of the compressor in the recirculation pipelines. During the course, the superheat of circulating medium was reduced in the compression cavity of the compressor, after compression, the discharge temperature was reduced, or there are still a few liquid of circulating medium, according to the insensitiveness of scroll compressor to wet compression, the circulating medium will continuously evaporate and absorb the heat generated due to vapour compression and friction of kinetic and stationary scroll plates of compressor during the compression, which greatly reduced the air discharge temperature of the compressor, as shown in Fig. 2, the process from 9' to 2'. The mixture of working medium in the recirculation pipelines and that of compressor suction cycle reduce the superheat of working medium in the compression cavity from the compressor or some carry a little liquid, which both increase the quality and flow of working medium for compression in the compressor. Thus it ~~increased~~ improved the quality and flow of the working medium in the condensing process and increased the heating capacity of the heat pump system [21]. The working medium in the recirculating pipelines will evaporate and absorb heat in ~~the middle~~intermediate heat exchanger~~.~~, which is a latent heat of~~in~~ vaporization, yet the liquid working medium in the condensing heat pump in another pipeline of ~~the middle~~intermediate heat exchanger released heat, which is a sensible heat. The liquid medium ~~work~~ of the heat pump before entering the main expansion valve has a great super-cooling effect, which increases the cooling capacity of the heat pump working medium in the evaporator. While~~,~~ the super-cooling is limited by the mixed air pressure, that is, the working medium of the lowest main loop heat pump is super-cooling which exceeds the saturated temperature corresponding to the air supply pressure. After working medium in the air recirculation pipelines is mixed with that of the air intake heat pump of the compressor, it will increase the quality and flow of working medium of the heat pump in the compression cavity of the compressor, so the compressor power is increased a little. Meanwhile, ~~the middle~~intermediate heat exchanger increases the super-cooling of heat pump working medium in the main expansion valve, the refrigerating capacity of the heat pump system is increased in the evaporator. The expansion valve of recirculation controls the air pressure and the quality and flow of working medium in the pipelines, if losing the air expansion valve, the air recirculation pressure and the quality and flow of working medium will rise; vice versa it will drop, which has higher influence to the performance of air circulation-based heat pump air conditioning system.

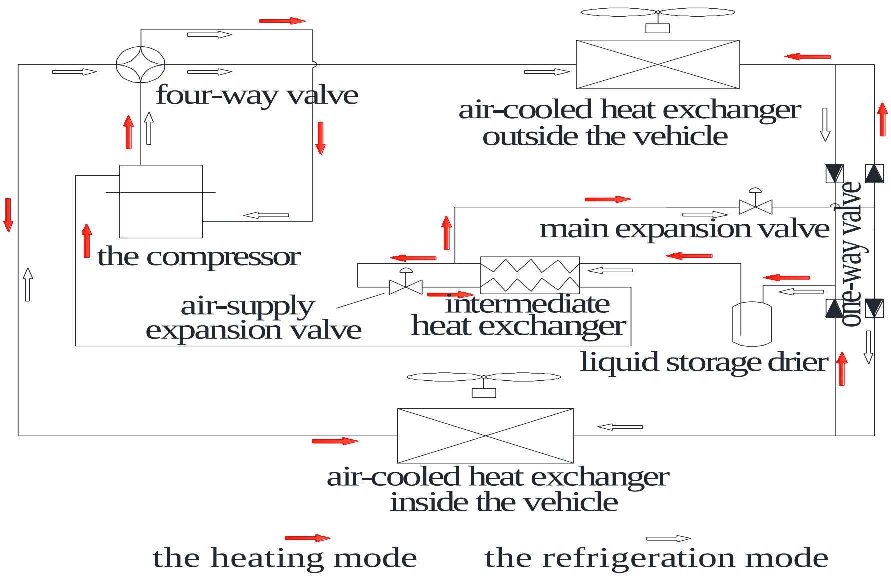


Fig.1. Diagram of the heat pump air conditioning system of the pure electric vehicle.

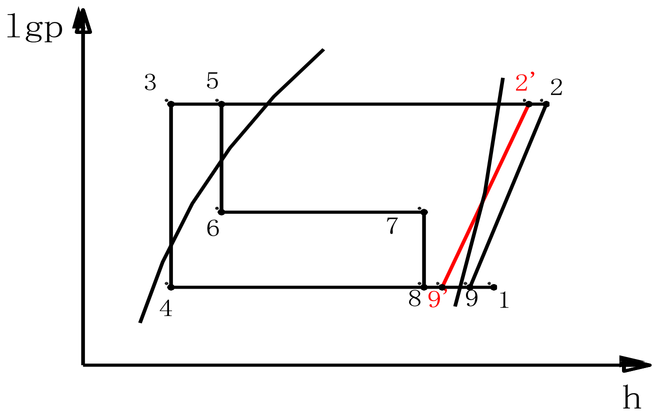


Fig.2. Log p-h diagram of the heat pump cycle with middle heat exchanger

3. The Modelling of Concentric Cylindrical Thermoelectric Generator

The experiment is to study the characteristics of the defrosting mode in heat pump air conditioning system of PEV.; therefore Therefore heating is supplied within the cabin, and the air conditioning system is working at low temperature and high humidity condition which leads to heat exchanger frosting outside the vehicle. The frosting conditions of this experiment are described in Table1.

Table 1 The working condition of frosting for the experiment.

Working condition	Parameters
Ambient temperature outside the vehicle /℃	-20
Ambient temperature inside the vehicle /℃	15、20、25
Relative air humidity outside the vehicle/%	80
Revolving speed of compressor/rpm	5000
Air output of fan inside the vehicle/(m^3/h)	540
Fan speed outside the vehicle/(m/s)	4.5
Air supplement rate /%	30

If the wind speed at air-cooled heat exchanger outside the vehicle is lower than 0.2 m/s, it is noted that the frosting of air-cooled heat exchanger outside the vehicle completes thoroughly. The frosting scenario is shown inas Fig. 3.

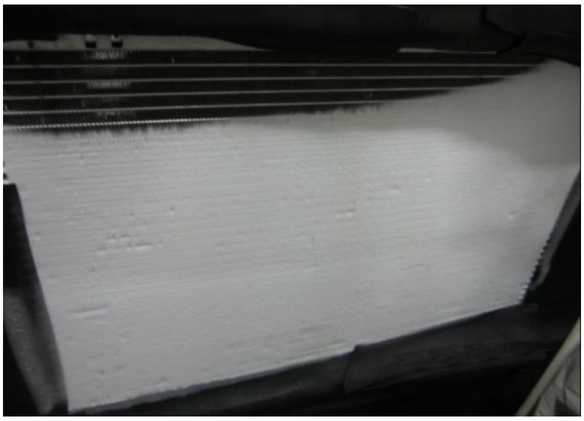
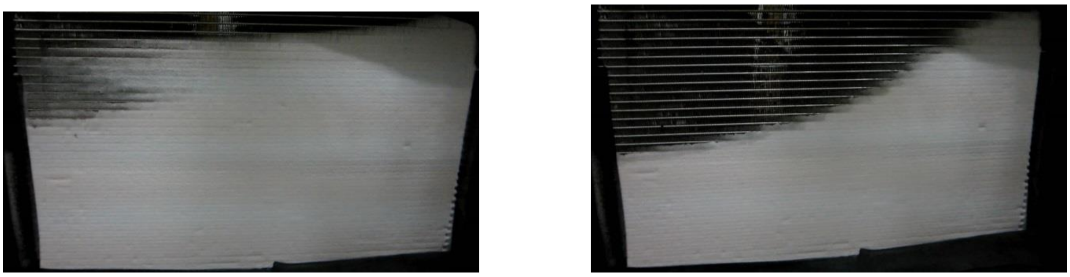


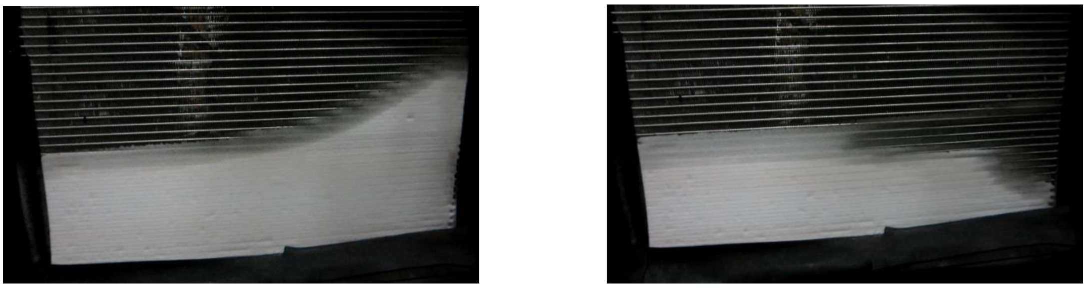
Fig. 3. Complete frosting of heat exchanger outside the vehicle.

In the present study, the composite defrosting technology is adopted based on the defrosting of reversed cycle, integrally uses the technology of increasing enthalpy by air-supplying of compressor, technology of preheating and raising temperature and increasing enthalpy of heat exchanger inside the vehicle, technology of increasing condensing temperature of heat exchanger outside the vehicle, to make heat release of condensation and heat transfer temperature difference of condensation increase obviously, which realize defrosting rapidly and reduce draft of cold air supply inside the vehicle when defrosting. Fig. 4 shows the defrosting of heat exchanger outside the vehicle, which is taken after the defrosting begins with an interval of 20 seconds. Fig. 4(a) is taken when defrosting begins. Fig. 4(b) is after defrosting operates 20 seconds. At that time, the air exhaust of compressor passes upside of heat exchanger outside the vehicle to melt the frost here firstly. Fig. 4(c) is after defrosting operates 40 seconds. At that moment, the defrosting area of heat exchanger outside the vehicle is enlarged. After defrosting ~~operates~~ runs 60 seconds (Fig. 4(d)), the area of defrosting of heat exchanger outside the vehicle is further ~~enlarged~~extended; after the defrosting operates 80 seconds (Fig. 4(e)), the frost layer on the surface of heat exchanger outside the vehicle is ~~basically~~ melted completely. Only the frost layer on the surface of the flat tube that is close to the bottom doesn't melt; after the defrosting operates 100 seconds (Fig. 4(f)), the defrosting of heat exchanger outside the vehicle complete.

(a) (b)



(c) (d)



(e) (f)

Fig. 4. Defrosting of heat exchanger outside the vehicle: (a) defrosting begins. (b)defrosting operates for 20 seconds.(c) defrosting operates for 40 seconds.(d) defrosting operates for 60 seconds. (e)defrosting operates for 80 seconds.(f) defrosting operates for 100 seconds.

4. ~~Analysis on experiment~~ Experiment results

4.1 Influence of environment temperature inside the vehicle on defrosting characteristics

When the ambient temperature outside the vehicle is 0℃ and the temperatures inside the vehicle are 15℃, 20℃ and 25℃ respectively, under frosting conditions, defrost after the frosting completes on the surface of heat exchanger outside the vehicle. When defrosting begins, other parameters shall stay the same with those under frosting conditions. In the defrosting process, the situation that the average condensation temperature and defrosting time change with the temperature inside the vehicle ~~is~~ are shown in Fig. 4.

It is shown in Fig. 5 that the higher the environment temperature inside the vehicle, the higher the average condensation temperature in the defrosting process be and the shorter the defrosting time will be. ~~This~~ It is because when the system is in defrosting mode, the heat exchanger inside the vehicle changes from the condenser to evaporator. The environment inside the vehicle changes from the side of the cold source to the side of the heat source. The higher the environment temperature inside the vehicle, the higher the evaporating temperature will be. The performance of the system will be better. The speed of defrosting accelerates.

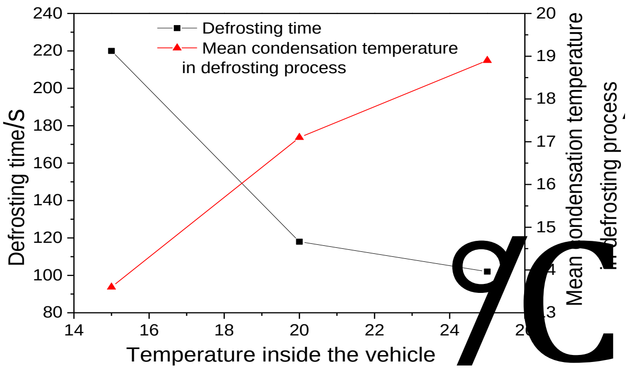


Fig. 5. Influence of temperature inside the vehicle on average condensation temperature and defrosting time during the defrosting process.

4.2 Influence of revolving speed of compressor on defrosting characteristics

When the ambient temperature outside the vehicle is 0 ℃, and the temperature inside the vehicle is 25 ℃, under frosting conditions, defrost after the frosting completes on the surface of heat exchanger outside the vehicle. When defrosting begins, change the revolving speeds of the compressor into 5000 rpm, 6000 rpm and 7000 rpm respectively and keep other parameters stay the same with those under frosting conditions. The situation that average condensation temperature and defrosting time change with the revolving speed of compressor during the defrosting process ~~is~~ are shown in Fig. 6.

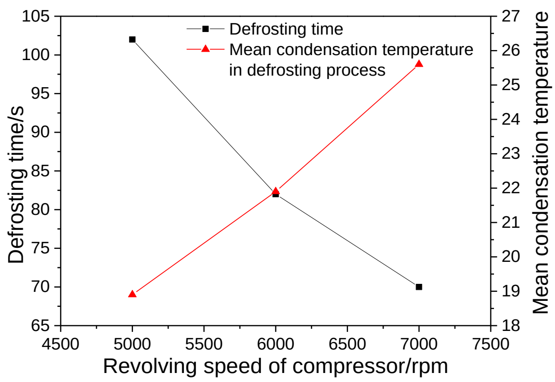


Fig. 6. Influence of revolving speed of compressor on average condensation temperature and defrosting time during defrosting process.

It can be seen from Fig. 6 that the higher the revolving speeds of the compressor, the higher the mean condensation temperature in defrosting process will be and the shorter the defrosting time will be. The revolving speed of compressor increases. The mass flow rate of refrigerating fluid that enters condenser increases. The heat release of condenser increases~~.~~, ~~T~~the ~~speed~~ rate of defrosting accelerates [22].

4.3 Influence of air output of fan inside the vehicle on defrosting characteristics

When the ambient temperature outside the vehicle is 0 ℃, and the temperature inside the vehicle is 20℃, under frosting conditions, defrost after the frosting completes on the surface of heat exchanger outside the vehicle. When defrosting begins, change air output of fan inside the vehicle into 450 m³/h, 500 m³/h and 540 m³/h respectively and let other parameters stay the same with those under frosting conditions. The situation that average condensation temperature and defrosting time change with air output of fan during the defrosting process ~~is~~ are shown in Fig. 7.

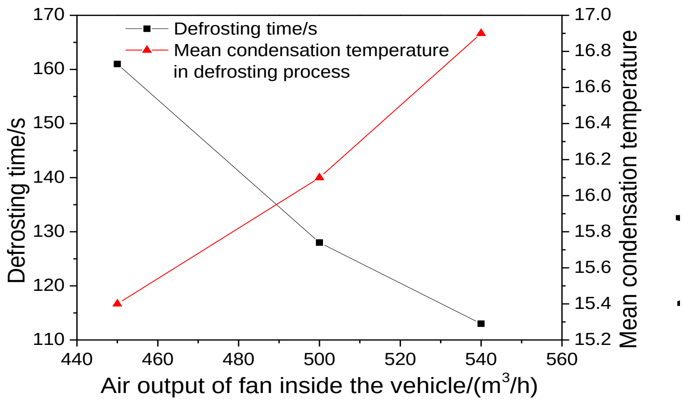


Fig.7. Influence of air output of fan inside the vehicle on average condensation temperature and defrosting time during the defrosting process.

Fig. 7 shows that the greater the air output of fan inside the vehicle, the higher the average condensation temperature in the defrosting process will be and the shorter the defrosting time will be. ~~This~~ It is because when the system is in defrosting mode, the heat exchanger inside the vehicle changes from the condenser to evaporator. With the increase of air output of fan inside the vehicle, the heat exchange amount of evaporator increases. The heat release of condenser also increases~~.~~, ~~T~~the ~~speed~~ rate of defrosting of heat exchanger outside the vehicle accelerates.

4.4 Influence of air supplement rate (air recirculation percentage in the air discharge of compressor) on defrosting characteristics

When the ambient temperature outside the vehicle is 0 ℃, and the temperature inside the vehicle is 20 ℃, under frosting conditions, defrost after the frosting completes on the surface of heat exchanger outside the vehicle. When defrosting begins, it is necessary to control the air supplement rate at 10%, 20% and 30% and keep other parameters stay the same with those under frosting conditions. The situation that the average condensation temperature and defrosting time during defrosting process change with air supplement rate is shown in Fig. 8.

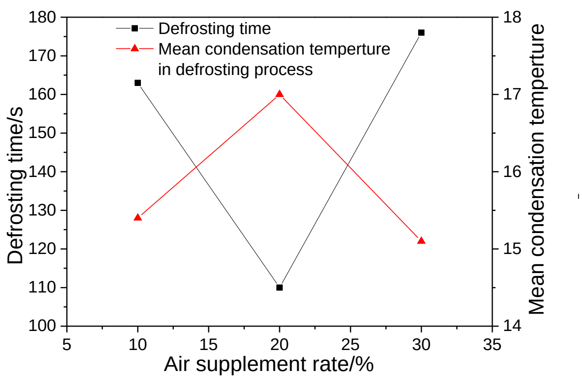


Fig. 8. Influence of air supplement rate on average condensation temperature and defrosting time during defrosting process

Fig. 8 shows that when the air supplement rate is 20%, the average condensation temperature in the defrosting process is the highest and the defrosting time is the shortest. Compared with the situation that the air supplement rate is 20%, when the air supplement rate is 10%, the mass flow rate of refrigerating fluid in circulation line of air supplement reduces. The heat exchange amount in intermediate heat exchanger between it and working medium of the main line is small It causes that the condensate depression before the main expansion valve is small and leads to the fact that the proportion of working medium of gas state in evaporator increases. The resistance increases. Evaporating temperature and evaporating pressure reduce. It goes against the absorption of the evaporator, thus reduces the heat release of the condenser and prolongs the defrosting time. When the air supplement rate is 30%, although the condensate depression before the ~~main~~ primary expansion valve increases and the resistance of working medium in evaporator reduces, the mass flow rate of working medium that enters evaporator is small. The ~~influence~~ impact ~~of it~~ on the reduction of heat absorption capacity of the evaporator is bigger than the influence of reduction of working medium resistance in evaporator on increase of heat absorption capacity of the evaporator. It causes the reduction of total heat absorption capacity of evaporator and heat release of the condenser. Compared with the moment when the air supplement rate is 20%, defrosting time increases.

4.5 Influence of fan delivery outside the vehicle on defrosting characteristics

The change of fan delivery outside the vehicle is realized through changing the frequency of fan outside the vehicle. When the ambient temperature outside the vehicle is 0℃ and the temperature inside the vehicle is 20℃, under frosting conditions, defrost when the frosting completes on the surface of heat exchanger outside the vehicle. When defrosting begins, change the frequencies of fan outside the vehicle into 0Hz, 5Hz and 10Hz, keep the revolving speed of compressor at 6,000 rpm and keep other parameters stay the same with those under frosting conditions. Figs 9, 10 and 11 show the situations when refrigerating capacity of the system, exhaust gas temperature, outlet air temperature, temperatures at inlet and outlet of heat exchanger outside the vehicle change with time of defrosting operation of the system. With the operation of defrosting, the refrigerating capacity of the system reduces gradually. The exhaust gas temperature reduces firstly and then increases. The outlet air temperature reduces gradually. The temperatures at inlet and outlet of heat exchanger outside the vehicle increase~~s~~ gradually. When the frequency outside the vehicle change with the time of defrosting operation of the system of a fan outside the vehicle is 0Hz, the refrigerating capacity of the system reduces 26.6 %. The outlet air temperature reduces 3.2℃. When the frequency is 5Hz, the refrigerating capacity reduces 36.2 %. The outlet air temperature reduces 4.9℃. Although the outlet air temperature reduces, the lowest temperature is above 24℃. So it will not let people inside the vehicle have the feeling of cold air.

Fig.12 shows the curve that average condensation temperature and defrosting time change with frequency of fan outside the vehicle in defrosting process. The greater the frequency of fan outside the vehicle, the greater the air output of fan outside the vehicle will be. The average condensation temperature in the defrosting process will be lower. The defrosting time will be longer. ~~This~~ It is because the system is in defrosting mode. The heat exchanger outside the vehicle serves as the condenser. The air output of fan outside the vehicle increases.

The condensing temperature of heat exchanger outside the vehicle reduces. The speed of defrosting of heat exchanger outside the vehicle slows down.

(a) Fan outside the vehicle 0Hz (b) Fan outside the vehicle 5Hz

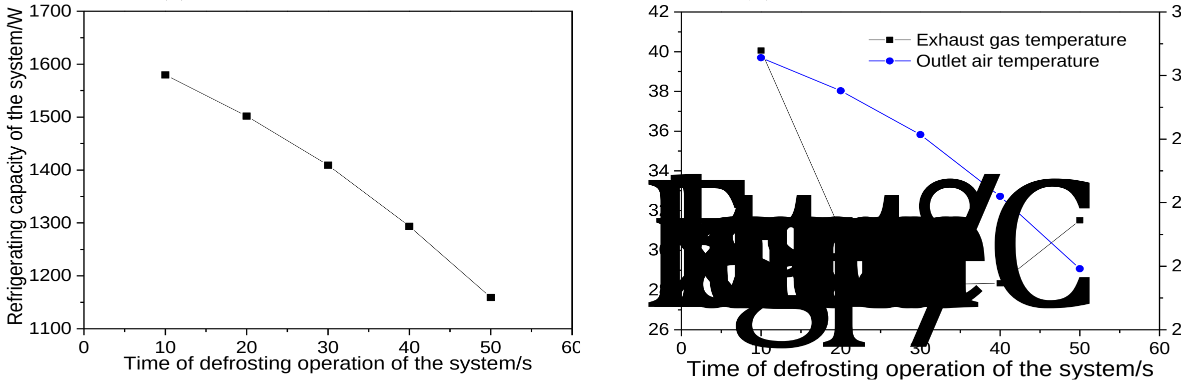


Fig. 9. Curve that refrigerating capacity changes with time of defrosting operation of the system.

(a))Fan outside the vehicle 0Hz. (b) Fan outside the vehicle 5Hz.

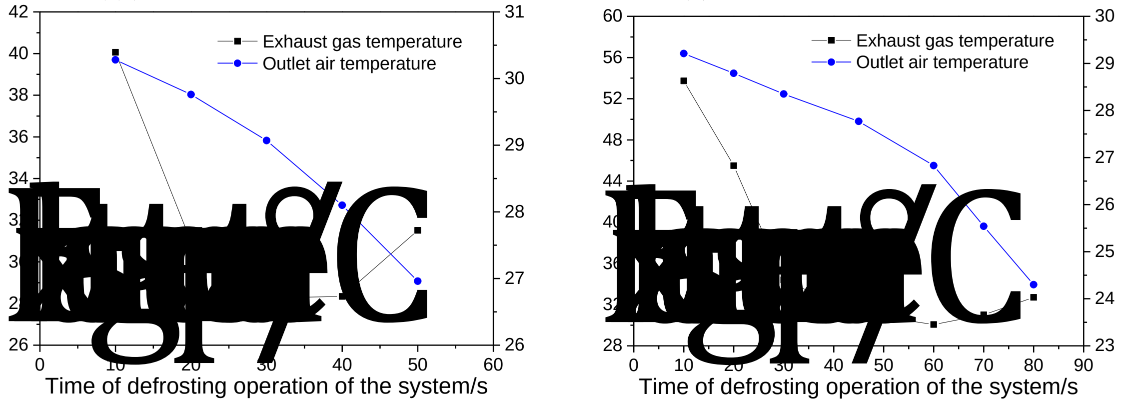


Fig.10. Curve that exhaust gas temperature and outlet air temperature change with time of defrosting operation of the system.

(a))Fan outside the vehicle 0Hz. (b) Fan outside the vehicle 5Hz.

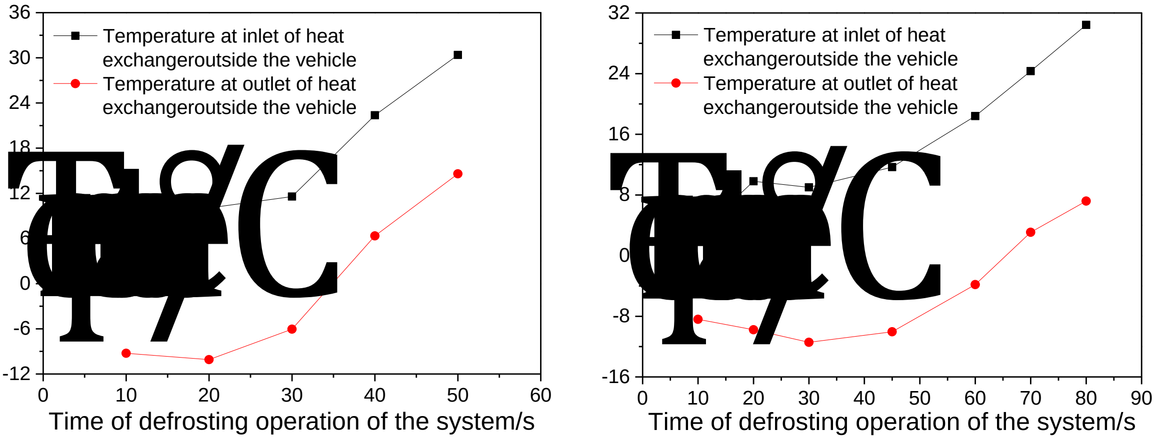


Fig.11. The ~~C~~curve that the temperatures of inlet and outlet of the heat exchanger.

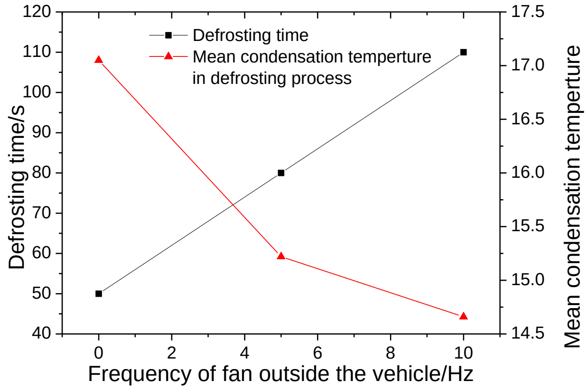


Fig.12. Influence of fan delivery outside the vehicle on average condensation temperature during the defrosting process and defrosting time

5. Conclusion

Aiming at the problem that the heat exchanger outside the vehicle is easy to frost when the heat pump type air conditioning system for PEVs operates under the environment of low temperature and high humidity, the article proposes a technical method of fast defrosting relying on increasing temperature and enhancing gas injection in reverse circulation. Following the basic principle of defrosting via reverse circulation, the method well integrates the air speed control outside, air and effect increase of compressor, air intake preheating inside and so on, so that during the defrosting operation of heat exchanger outside, the condensing temperature and heat release in condensing are both increased obviously so as to achieve rapid defrosting. Experimental research shows that it can obviously shorten the defrosting time through raising the in-car temperature, the revolving speed of compressor, air output of draught fan inside the car and reducing fan delivery outside the vehicle and controlling proper air supplement rate, and then adequatelyproperly improve the performance of air conditioning system to ensure the stable operation of air conditioning system of PEVs.

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