Brief introduction of an automobile radiant cooling air-conditioning system based on photovoltaic power generation

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Abstract. This paper firstly analyzes the pain points of traditional automobile air-conditioning systems, then describes the relevant research status of automobile air-conditioning systems at home and abroad, and then focuses on the principle and structure of a new system, and finally analyzes its innovation and application advantages.

1. Introduction

In recent years, China has vigorously developed and promoted new energy vehicles, but the traditional compression air-conditioning systems equipped with new energy vehicles currently suffer from pain points such as high energy consumption and low comfort, and new energy vehicles themselves have serious concerns about insufficient mileage. In this paper, we have innovatively designed a new type of automotive radiant cooling air-conditioning system combined with a compression refrigerator, capillary radiant pipe network and photovoltaic power generation panels according to the structure of new energy vehicles and human comfort requirements, which are shown in Figure 1. The new system utilizes the photovoltaic power generation to drive a compression chiller, in order to cool down the flowing water medium in the capillary network laid on the car seat, floor, etc. through the chiller, and then exchanges heat of the car environment, and cooperates with the fresh-air system to assist dehumidification. The interior environment of the car is always maintained in an extremely comfortable state, while effectively ensuring the comfort requirements of the car’s air-conditioning, it also reduces the power burden of new energy vehicles to increase the mileage.

Figure 1 The physical model of an automobile radiant air-conditioning system device based on photovoltaic power generation-driven compression refrigeration
2. The research background and significance of the work

2.1 Research background
With the development of the national economy, the number of new energy vehicles is also showing a sharp upward trend, but additional problems such as limited energy storage and insufficient mileage of new energy vehicles still restrict the development of new energy vehicles. According to the 2020 National Economic and Social Development Statistical Bulletin released by the National Bureau of Statistics, the number of civilian new energy vehicles for China at the end of 2020 was 4.92 million, accounting for 1.75% of the total number of vehicles, a year-on-year increase of 29.18%. The increase in the number of new energy vehicles will inevitably bring people's high requirements for the mileage and comfort of vehicles. As an important symbol of the energy savings and comfort of new energy vehicles, automobile air conditioners will also receive the main attention of people.

At present, traditional car air conditioners on the market adopt a single vapor compression refrigeration method, and then utilize the air outlet at the front of the car to generate cold and hot air with a controllable temperature to achieve the purpose of regulating the internal temperature of the car. The air conditioner in this mode operates it also brings many key issues that need to be resolved:
(1) The energy consumption of air-conditioning in new energy vehicles is relatively large, especially in the high temperature in summer. The energy consumption of air-conditioning will seriously affect the mileage.
(2) With the improvement of people’s quality of life, people’s pursuit of high-quality riding experience has become intense, but traditional car air conditioners have strong blowing sensation, loud noise, and strong heat in the occupants’ buttocks and backs when the temperature in the car is high. Sense and other issues affect people’s to ride experience.
(3) After high-temperature outdoor parking in summer, when people return to the car, they often feel that the heat is too high, and the death of a child in outdoor parking is also common to the news. This is because the utilization of car air-conditioning is affected by the car’s startup and shutdown.

2.2 Current research status at home and abroad

2.2.1 Solar photovoltaic power generation
Nowadays, with the continuous advancement of solar cell technology, China’s consistent policy on “energy conservation and emission reduction” and the “13th Five-Year Plan for Energy Conservation and Emission Reduction” promulgated by the State Council to promote the large-scale development and diversified utilization of solar energy It can be seen that the application prospect of solar photovoltaic power generation technology in automobile air-conditioning has great potential. Since 1973, photovoltaic power generation began to be applied to the ground, and then "solar sunroof technology" that utilizes built-in solar panels for energy to drive a blower to introduce cold air outside the cabin and drive out the hot air in the car has appeared[1]. In addition, Qiang Liu and others have created a smart car air conditioner based on solar power generation and semiconductor refrigeration in order to address the problem of high temperature inside the car after sunlight exposure[2].

2.2.2 Capillary radiant air-conditioning system
Since the 1980s, capillary radiant cooling air-conditioning systems have been widely used in factories, apartments, public facilities and other buildings in famous cities in Europe and other countries. However, both foreign and domestic, the application of capillary radiant cooling air-conditioning to automobiles is always in a state of innovation. Foreign scholar Shuzo[3] used CFD simulation to analyze the energy consumption of capillary radiant air-conditioning cooling systems and all-air air-conditioning systems, and pointed out that the energy consumption and peak powered cooling consumption of capillary radiant systems are 30% and 27% less than that of all-air cooling systems; in China, Jinghong Zhang et al.[4] invented a radiant air-conditioning device for vehicles, which replaced the traditional convection air-conditioning with a capillary radiant air-conditioning cooling system in the interior of the car, so as to
not only regulate the internal temperature of the car, but also enable the car when the air conditioner is running. The air inside is clean, there is no noise, and the effect is good. Xinghui Du [5] proposed a capillary radiant heating system in a car and applied for a patent for the purpose of energy saving, emission reduction, and improvement of the thermal comfort of the passenger cabin, focusing on the thermal comfort of the passenger cabin under the operation of the heating system.

In general, the capillary radiant air conditioner has a rich foundation in theoretical research at home and abroad, and has achieved remarkable results in the application of the interior of the building, and the application of the interior of the new energy vehicle is still in the innovative stage, so the previous theory of this project Based on technology, we strive to improve and carry out secondary innovation.

2.3 Meaning

The new system has high energy saving, strong comfort and health quality. As a new mode of vehicle air conditioner, its low energy consumption characteristics, combined with photovoltaic power generation modules, significantly increase the cruising range of new energy vehicles; relying on the original automobile compression cooling air-conditioning system, it enhances the stability of the system’s operation; The characteristics of noiseless wind, no pollution, rapid and extensive coverage effectively eliminate the disadvantages of old-fashioned automobile air conditioners, make up for the shortcomings of new energy vehicles, and further broaden the market for new energy vehicles. Nowadays, in the direction of promoting energy structure optimization, China has proposed strategies such as "promoting the diversified utilization of photovoltaic power generation industry" and "promoting the large-scale development of new energy vehicles", and the advanced performance of the capillary network radiation end has satisfied people's increasing demand for energy saving and comfort, so this system closely follows the theme of sustainable development, conforms to the design concept of "energy saving and environmental protection", "comfort and health", and has a very broad application prospect.

3. Innovation and advantages

This work combines the capillary network radiation terminal technology with the on-board photovoltaic power generation technology, combined with the traditional compression refrigeration automobile air conditioner. The innovations and advantages are as follows:

1. Under high temperature conditions in summer, traditional automobile air-conditioning systems mostly utilize direct evaporators for cooling, and their refrigerant temperature is mostly 5-7°C, while the radiation end of the capillary network utilizes a circulating water system for radiant cooling, and the refrigerating source supplies back water. The temperature is only between 17 and 19 degrees Celsius. Therefore, under the premise of achieving the same cooling effect, the latter combined with photovoltaic power generation modules can radically reduce the energy consumption of air-conditioning and decrease the power burden of vehicles.

2. Introduce the capillary network radiation terminal system, adopt static radiant cooling mode, simulate the comfortable environment brought by natural heat transfer, ensure constant temperature and humidity, uniform heat distribution, and quickly adjust the room temperature, avoiding the local strong blowing of traditional car air conditioners Sense leads to discomfort of the human body and improves the riding experience.

3. The operation of this system is not subject to the startup and shutdown of the car, and is continuously powered by the car battery. It can also run when the car stops, with greater freedom.

4. This system relies on the original compression refrigeration system, organically combines new systems such as photovoltaic power generation, capillary network radiation end, etc., which not only makes up for the shortcomings and deficiencies of the original system, but also effectively solves the poor supply security of the new system, Pain points such as low control stability, which reflects good system complementarity.
4. Design plan

4.1 Work design ideas

The design idea of this work is shown in Figure 2.

This system is mainly composed of three modules: photovoltaic power generation module, compression refrigeration module, and capillary network radiation terminal module.

4.2 Principles of work design

The design principle diagram of this work is shown in Figure 3.

This new system utilizes the car battery to store the electric energy generated by photovoltaic power generation, and the controller controls the battery to supply power or store electricity, so as to support the refrigeration system to work at any time. At the same time, the refrigeration system continuously cools down the flowing water medium in the capillary nets laid on the car seat, floor, etc., and then exchanges heat with the car's environment, so that the car's environment has always been in an extremely comfortable state.

4.2.1 Photovoltaic power generation module

Photovoltaic power generation modules, as shown in Figure 4-7, are composed of photovoltaic power generation panels, controllers, batteries, inverters, etc., and are mainly responsible for the production, storage, and transmission of electrical energy.
Figure 4 Photovoltaic panels

Figure 5 Battery

Figure 6 Controller

Figure 7 Inverter
Photovoltaic power generation is a technology that utilizes the photovoltaic effect of the semiconductor interface to directly convert light energy into electrical energy. Its system is primarily composed of photovoltaic cells, controllers and batteries. Under sunlight, the crystalline silicon wafers in the photovoltaic battery pack absorb light energy and generate a large number of positive and negative charges at the junctions of the silicon wafer and the surface diffusion layer. The separated charges from an external current field to generate photocurrent. Under the adjustment of the controller, on the one hand, it provides electric energy for the refrigerator, and the refrigerator can realize the cooling function; on the other hand, it collects the surplus electric energy and supplies it to the car battery for energy storage, so that it can be utilized when photovoltaic power generation is not possible.

4.2.2 Compression refrigeration module
The compression refrigeration module, as showed in Figure 8-10, is composed of radiating fins, throttling devices, water pumps, compressors, condensers, evaporators, etc., and is mainly responsible for providing cold sources for the radiation end of the capillary network.

Figure 8 Schematic diagram of the refrigerator structure

Figure 9 The appearance of the refrigerator

Figure 10 The internal diagram of the refrigerator
The refrigerant in the refrigerator is pressurized by a water pump, and compressed into the compressor from a low-temperature and low-pressure state to a high-temperature and high-pressure state. After being rushed to the condenser, the refrigerant is cooled with the high pressure, and is condensed into a normal-temperature liquid refrigerant. The high-pressure and normal-temperature refrigerant is then reduced by the throttle element to obtain a low-temperature and low-pressure refrigerant, and then sent to the evaporator to absorb the heat of the water after heat exchange with the car seat and the car floor in the capillary net. The temperature of the refrigerant inside increases and then repeats the cycle.

4.2.3 Capillary net radiation ends module
The capillary net radiation end module, as showed in Figure 11-12, is composed of capillary nets, reducing connecting pipes and other parts.

The water medium in the capillary tube flows through the refrigerator to be cooled and transported to the back seat and floor of the car, exchanges heat with the high-temperature air in the car, takes away the heat of the car, and achieves the cooling effect. The normal-temperature water medium flows through the refrigerator and repeats the cycle.

5. Application assumptions and prospects

5.1 Assumption of installation plan
In the new type of automobile air conditioning system designed by this work, the installation of various components will make few changes to the original structure in the car, and will not affect the movement of the car seat and the opening of the airbag. Firstly, put solar panels on the roof of the car to make maximum utilization of light energy. Secondly, for new energy vehicles, there is no need to install additional batteries, but the car's own batteries can be utilized to reduce the volume of the car. Then,
install the capillary radiant panel on the car floor and seat back, and apply dressing to it. Package, the total thickness of the device is about 15mm, and it is small in size and easy to install; finally, connect the connecting water pipe of the capillary network to the original automobile refrigerator; in addition, connect the system such as thermostat, fresh air inlet and exhaust holes, etc. Components, keep installed in the original position to ensure its normal operation and utilization. The appearance model of this system device is illustrated in Figure 13.

![Figure 13 Appearance model diagram of the device](image)

5.2 Energy-saving benefits assumption
In the new automotive air conditioning system designed by this work, the estimated annual power generation is about 130 kWh, and the cumulative power generation in 20 years is about 2750 kWh, which is equivalent to using 0.91 tons of standard coal less, and the total emission reduction of harmful substances in the system is about about 0.91 tons, the total emission reduction benefit is 3,846.28 yuan. The benefits of system energy saving and emission reduction are shown in Table 1.

| parameter | CO₂ | SO₂ | NOₓ | Soot | Total (yuan) |
|-----------|-----|-----|-----|------|-------------|
| Emission reduction/t² | 0.639 | 0.019 | 0.009 | 0.015 | 0.682 |
| Emission reductionbenefits | 193.48 | 1208.80 | 1860.00 | 584.00 | 3846.28 |

5.3 Comparative advantages of similar products
This work innovatively utilizes photovoltaic power generation technology from the source, combining separate compression refrigeration automobile air-conditioning technology with separate capillary radiation air-conditioning technology, so that the disadvantages of traditional automobile air-conditioning can be eliminated to a considerable extent, compared with any of the above. The application of a single new technology in automobile air-conditioning, and the advantages of the combined development of the two are also needed in the current era. The comparative advantages of similar systems and the comprehensive advantages of this system are shown in Table 2 and Table 3 respectively.
Table 2 Comparative advantages of similar systems

| Product Name | Advantage | Disadvantage |
|--------------|-----------|--------------|
| Automobile air conditioner with separate traditional compression refrigeration | Compact structure, wide application range | ①Large operating energy consumption and indirect pollution ②Strong blowing feeling, poor occupant comfort |
| Car air conditioner with single capillary radiant refrigeration | Very comfortable, safe and environmentally friendly | ①There are doubts about the endurance of photovoltaic power generation ②The new system is more complicated and difficult to adjust and control |

Table 3 Comprehensive advantages of this system

| Product Name | Comprehensive Advantage |
|--------------|-------------------------|
| Automobile radiant air conditioner based on photovoltaic power generation to drive compression refrigeration | ①Photovoltaic power generation is more energy-efficient, and clean energy is utilized to reduce pollution ②Adopt radiation heat exchange method, no wind, no noise, comfortable and quiet ③Use original car battery to reduce installation volume and cost ④Retain the original vehicle control system to ensure the smooth operation of the new system |

6. Conclusion

Traditional car air conditioners for new energy vehicles often utilize electric energy as a power source and air as a heat transfer medium, which has disadvantages such as high energy consumption, strong blowing sensation, and low comfort. The automobile radiant cooling air-conditioning system is based on photovoltaic power generation driving compression refrigeration, integrated photovoltaic power generation driving refrigeration technology and radiant cooling air-conditioning technology, so that the disadvantages of traditional automobile air conditioning have been eliminated to a considerable extent. From the perspective of power source, it has the advantages of saving primary energy and reducing the power burden of the car; at the same time, the radiation end is installed on the surface of the seat and the inner surface of the passenger compartment, and the radiation end is directly exchanged with the human body, without blowing sensation, which can improve Thermal comfort of the human body. It is foreseeable that with the mature development of new energy technologies and the trend of energy saving and environmental protection, the future of green car air-conditioning technology will usher in a broad spring in the automotive field.

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