

The Research and Development Trend of the Adsorption Refrigeration Technology and A New Exhaust Heat Powered Rotary Wheel Solid Adsorption Refrigeration System

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Abstract: To improve the integrated using extent of energy sources, many kinds of exhaust heat can be used as heat source needed in desorption to realize refrigeration. The research status and the developing trend of the adsorption refrigeration are analyzed. The traditional design methods of adsorbent bed are concluded, indicating that the adsorbent mechanism should be designed according to the whole system. A new exhaust heat powered rotary wheel solid adsorption refrigeration mechanism is presented, the circular flow is labored. The structure of the rotary wheel solid adsorption refrigeration mechanism is designed.

Keywords: Adsorption Refrigeration, automobile air-conditioning, Design, Exhaust Heat, rotary wheel solid adsorption refrigeration.

1. INTRODUCTION

The solid adsorption refrigeration system can be driven directly by low grade energy, such as solar energy and industrial waste heat which is an efficient method to save energy and develop new energy. It can utilize a great deal of low grade energy to solve the problem of electric power scarcity, answering for the trend of harmonious development of energy sources. Though problems such as the low coefficient of performance, long cycle and bulky adsorbent bed have hindered the process of production, the competitive advantage of adsorption refrigeration is in the realm that the traditional refrigeration technology is inapplicable, such as the using of solar energy and waste heat etc. The key of study should focus on the using of waste heat, especially in the realm of cars, trains or shipping^[1].

In this paper, the research status and the developing trend of the adsorption refrigeration are analyzed. The traditional design methods of adsorbent bed are concluded, indicating that the adsorbent mechanism should be designed according to the whole system. A new exhaust heat powered rotary wheel solid adsorption refrigeration mechanism is presented, the circular flow is labored. The structure of the rotary wheel solid adsorption refrigeration mechanism is designed.

2. THE FEASIBILITY AND ADVANTAGE OF ADSORPTION REFRIGERATION BEING USED IN AUTOMOBILE

Above a quarter of the fuel energy is taken away by the engine exhaust. The temperature of engine

exhaust is above 400~500°C. So the using of exhaust heat is much considerable. The COP of the solid adsorption refrigeration system with single adsorbent bed is about 0.15, with two beds is about 0.2~0.3. So the power of solid adsorption refrigeration system with two adsorbent beds can reach 5%~7.5% of the fuel energy power^[2].

The advantages of automobile exhaust heat powered solid adsorption refrigeration system are not to increase the energy cost of car, not to reduce its power. It's more feasible to be applied into automobile air-conditioning than traditional refrigeration; at one time, because of its good aseismatic performance, no leak, no noise, adsorption refrigeration greatly alleviate the pollution of the environment, answering for the trend of green environmental protection of automobile air-conditioning.

3. TRADITIONAL DESIGN METHODS OF ADSORBENT BED

3.1 Heat transfer intensifying of adsorbent bed

The most distinct difference between adsorption refrigeration and traditional ones is that adsorbent bed replaces the compressor in the adsorption refrigeration cycle, so the adsorbent bed is the key part which affects the adsorption refrigeration system. The performance of the adsorbent bed is determined by the heat and mass transfer. It requests that the adsorbent bed transfers the energy from outside to the sorbent as soon as possible to realize the desorption during the heating desorption process; also desorbs the energy quickly during the cooling adsorption process to realize adsorption and then to achieve the refrigeration effect. Thus, to improve the performance of adsorption refrigeration system, the system should

be intensified, especially the heat and mass transfer of the adsorbent bed.

3.2 Traditional methods to intensify the heat transfer of adsorbent bed^[3-4]

Traditional methods to intensify the heat transfer of adsorbent bed can be classified into three types: first is to improve the sorbent to intensify the heat and mass transfer process; second is to use high efficient heat transfer structure to intensify the heat transfer; third is to use advanced refrigeration cycle.

3.2.1 sorbent improvement

The method of sorbent improvement is to mix some inorganic or organic materials with well heat conduction into the sorbent to adjust the distribution of the sorbent grain in the adsorbent bed; or to solidify, compress the sorbent etc.

3.2.2 structure improvement

The method of structure improvement is to increase the heat exchange area between the adsorbent bed and outside or to heighten the heat conduction coefficient by improving the existing adsorbent bed or redesign new structure of adsorbent bed.

3.2.3 refrigeration cycle improvement

Improving the refrigeration cycle is a relatively new and potential method to intensify the heat and mass transfer of the adsorbent bed. To get the continuous refrigeration, two or more than two adsorbent beds work alternately. Many kinds of advanced refrigeration cycles such as continuous adsorption refrigeration cycle with heat recovery, thermal wave cycle, convective thermal wave cycle, multi-effect cascade cycle are put forward^[5-6].

4. STRUCTURE DESIGN OF A NEW ROTARY WHEEL SOLID ADSORPTION REFRIGERATION MECHANISM

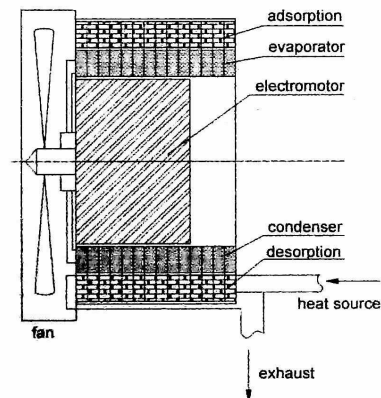


Figure 1: cutaway view of rotary wheel solid adsorption refrigeration mechanism

A new exhaust heat powered rotary wheel solid adsorption refrigeration mechanism (Fig.1,2) is presented in this paper. It is a rotating cylinder with an electromotor on principal axis which drives the whole mechanism rotating around the principal axis; a certain number of adsorption cooling tubes are radially distributed in the room between the electromotor and the inner wall of the mechanism. Both the evaporator, the condenser and the adsorbent bed are focused as a closed unit in the mechanism. Airflows of different temperature are inducted into this mechanism and contacted with different parts of adsorbent bed by the rotating of the mechanism. Thus the refrigeration cycle is realized by the process of adsorption and desorption.

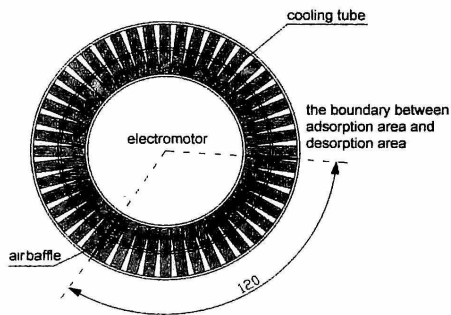


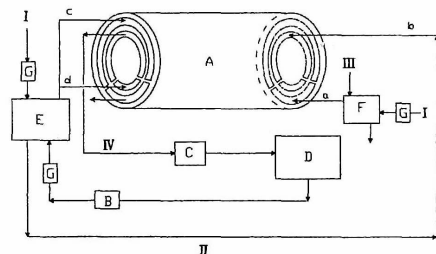
Figure 2: side view of rotary wheel solid adsorption refrigeration mechanism

This structure is compact and its performance of heat and mass transfer is much better than that of the common one. It can carry out commercial value after optimization. The advantages of this project are described as followed:

1. Using the vehicles' exhausted gas as desorption heat source, the exchange of the cold and heat airflow is achieved through the rotation of the adsorbent bed itself. Due to the non-valve control during the desorption and adsorption process, the disadvantages such as the instability of the high temperature electromagnetic valve and the difficulty in the system structure arrangement, can all be overcome;
2. With the crafty settings of adsorption cooling tubes and the baffles for the cool and hot airflow, the sections of adsorption, desorption, condenser, evaporator are assembled together. This can make the bed small and light with compact structure;
3. Where the baffles are laid shows the proportion of adsorption area and desorption area. And this is decided by the proportion of adsorption time and desorption time. So we can adjust the position of the baffles to meet the different needs of different working substance pairs.

5. REFRIGERATION FLOW

The refrigeration flow is shown in Fig.3. Airflows of different temperature are inducted into this mechanism and contacted with different parts of adsorbent bed by the rotation of the mechanism, so four channels in axes direction are formed, represented by a, b, c, d in figure 3[7]. Different part of the adsorbent bed contacts with each channel and simultaneously, the adsorption and desorption process are carried out.



A—rotary wheel solid adsorption refrigeration mechanism, B—humidifier, C—dust catcher, D—carriage, E—heat-exchanger 1, F—heat-exchanger 2, G—fan,

I. outside air, II. pre-cooled air,
III. engine exhaust, IV. blast air

Figure 3: refrigeration flow chart

Channel a: After increasing its temperature by absorbing heat from waste gas via heat - exchanger 2, the outside air flows into channel a to provide heat for desorption of the sorbent.

Channel b: After being pre-cooled by the desiccant cooling system, the air via heat-exchanger 1 flows into the channel b, and then flows into the chamber after pre- cooling and filtration.

Channel c, d: The cooling airflow from the chamber flows into heat-exchanger 1 after being humidified in humidifier B and then is divided into two sections. One flows into channel C as cooling source for the adsorption of the sorbent, the other flows into channel b as cooling source for the condenser.

When the car comes into the area polluted by radioactivity, the air from channel c and d can be inducted again into heat-exchanger 1 and thus a closed cycle is formed. Of course, the air humidity and oxygen content should be taken into account at the same time.

This mechanism has compact structure, but there is some difficulty in manufacturing. The structure is being researched and the experiment projects are being optimized.

6. CONCLUSION

Both domestic and foreign investigators have done a lot on the heat-transfer intensifying or the design of new adsorbent bed, but obvious breakthrough has not been published. Though the traditional methods can heighten the heat transfer efficiency of the adsorbent bed, the adsorbent mechanism should be designed according to the whole system. The characteristic of adsorption refrigeration should be taken into account if we want to radically improve the heat transfer performance of adsorbent bed. The author hopes that this new rotary wheel solid adsorption refrigeration mechanism can call out a new way for the study of heat and mass transfer of adsorption refrigeration system.

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