Vapour Adsorption Refrigeration System in Vehicles

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ABSTRACT

The purpose of this paper is to propose a model of vapour adsorption refrigeration system to be used in vehicles. This paper describes the components that can be used for effective and regular working of the vapour adsorption system. A modification in the current models decreases the intermittent working of the model and increases regularity.

Keywords: Vapour Adsorption, Refrigeration, Heat Exchanger, Evaporator, Condenser.

I. INTRODUCTION

The ever increasing global warming and decrease in the fossil fuels necessitates the development of technologies which utilize renewable sources or at least reduce the current consumption of fuel. The increase in the greenhouse gases poses a threat to the climate and needs to be curbed by any means. Contribution, even a little, from every field in reducing the consumption of fuel will contribute as a solution for these problems.

The increase in the global temperature increases the demand of air conditioning as well as refrigeration, especially in tropical countries. The currently prevalent vapour compression systems are being installed with a compressor which acts as the heart of that system. The reliance of current air conditioning systems on electricity increases the demand of electricity, which is obtained mostly by burning fuels at thermal power plants. Moreover, the increasing cost of electricity and decreasing supply of fuels propels the need to develop a refrigeration system which could be run by a renewable power source or could utilize the energy which gets wasted.

One such refrigeration system is vapour adsorption system. This system abandons the conventional mechanical compressor and uses an adsorbent bed-refrigerant pair instead. Research is being done on this field and systems using solar energy or the waste heat have been developed. These systems could be used at industries where huge amount of heat gets wasted along with the exhaust. They can also be installed in vehicles which generate high temperature exhaust gases. When vapour compression systems are used in automobiles, they reduce the efficiency of the engine; as some part of the power developed is utilized to run the compressor. On the other hand, Vapour adsorption system utilizes the waste heat of the exhaust to run the refrigeration system. This technology is beneficial because it reduces the load on the engine and saves power. Pons and Grenier demonstrated [1],[2] that activated carbon and methanol can serve as most suitable pair for solar powered solid adsorption ice maker than other pairs. Activated carbon used as adsorbent bed and methanol is used as refrigerant because it gives best coefficient of performance [3],[4].
II. LITERATURE REVIEW

There has been increasing interest in the research related to the vapour adsorption system since the past two decades. Verde et al. (2010) [5] constructed and tested an adsorption system for truck cabin by using zeolite-water pair which can achieve cooling power of 2 to 3kW and coefficient of performance (COP) of 0.6. Lambert and Jones (2006a, b) described an adsorption chiller driven by exhaust gas and concluded that adsorption cooling system can reduce the fuel consumption while increasing the whole mass. Vasta et al. (2012) developed and tested a mobile adsorption air conditioner for truck which has overall size of 170dm$^3$ and weight of 60kg, giving cooling power of 2kW to maintain truck cabin temperature at 24°C. Wang et al. (2006) [6] has presented a design of an adsorption air conditioner for locomotive driver cabin, powered by 350°C – 450°C exhaust gases. The cooling power and COP is 5 KW and 0.25 respectively.

III. APPARATUS

The vapour adsorption system consists of two adsorbent beds, condenser, evaporator, two shell and tube type heat exchanger, expansion valve, reservoir and pump. The proposed model is similar to the model prepared by Harish Tiwari and G. V.Parishwad [7] but with a modification in evaporator as well as in use of electromagnetic valves for controlling the timing of direction of flow of exhaust gases and coolant.

IV. HEAT EXCHANGER

A two shell and tube type of heat exchanger is used to exchange heat between the exhaust gases and the absorbent bed. The inner and outer side of the tube enclosing the adsorbent bed contains fins, as depicted in the figure below, which increases the heat transfer between the exhaust gas - absorbent bed and coolant- absorbent bed. Exhaust gases are passed through the outer shell during the heating cycle, whereas, coolant is passed through inner shell during the cooling cycle of the absorbent. Electromagnetic valves could be used at the entrance of inner shell and outer shell to regulate the timing of entrance of exhaust gas as well as the coolant.

Figure 1. Cross Sectional View of Two Shell and Tube Type Heat Exchanger

V. EVAPORATOR

It is a heat exchanger which consists of tubes which cools the air of the cabin directly. The evaporator is proposed to be fitted with eutectic plates. These plates consist of eutectic fluid, which maintains a constant temperature for a long time [8]. These plates can be used for maintaining the cooling when the system is not working. During traffic hours enough heat cannot be obtained through exhaust gases, and then these eutectic plates provide refrigeration for sometimes. It removes the intermittent working of the system.
VI. CONDENSER

It is used for removing heat from the refrigerant through air convection. The condenser uses the air striking the vehicle to remove the heat. The outlet from the adsorbent bed is entered into the condenser. Two condensers are used in the system. The condensed refrigerant then passes through an expansion valve to reach the evaporator.

VII. ADSORBENT BED

Two adsorbent beds are proposed to be used, which are made of activated charcoal because of its high porosity. The adsorbent bed is fitted in the middle of the two shell and tube type heat exchanger. At any time one adsorbent bed is at heating cycle and the other is at cooling cycle.

VIII. RESERVOIR

Two reservoirs, one reserving the coolant and other reserving the refrigerant is proposed to be used. Coolant is supplied to the adsorbent bed with the aid of a pump.

IX. PROPOSED WORKING

The activated charcoal and methanol pair is used as the adsorbent bed and refrigerant respectively. The exhaust gas is passed through the inner tube of the heat exchanger 1 via an electromagnetic valve. Heat is exchanged between the gas and the adsorbent bed. The increase in the temperature of the adsorbent bed increases desorption of the adsorbed refrigerant vapours. Refrigerant is exuded with an increase in pressure. It is then passed through condenser 1, as depicted in the figure below, where it releases its heat and gets condensed. The liquid refrigerant is then passed through the expansion valve which decreases its pressure. The low pressure refrigerant then enters the evaporator where it provides the cooling effect and gets evaporated.

The refrigerant vapour then reaches the heat exchanger 2 which is in cooling mode. The refrigerant vapour gets adsorbed at the surface of adsorbent bed. Now the cycle is reversed; the adsorbent bed 1 will be in cooling mode and adsorbent bed 2 will be in heating mode. The EMV will regulate the direction of the flow of exhaust gas and the coolant; the exhaust gas will now flow through the heat exchanger 2 and the coolant through heat exchanger 1. The cycle will repeat for heat exchanger 2 and the refrigerant will now condense in condenser 2. This cycle repeat with a certain time interval and the EMVs regulating the flow of exhaust gases and the coolant works according to the time period of the cycle.
X. CONCLUSION

The use of vapour adsorption system eliminates the extra power usage due to the use of mechanical compressor and saves fuel. The eutectic plates proposed to be used in the evaporator will eradicate the intermittent working of the system and the fins on the inner and outer surface of the middle shell of the heat exchanger will increase the heat transfer rate and consequently will increase the Coefficient of performance of the system.

REFERENCES


