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REVIEW ON VAPOUR ADSORPTION COOLING SYSTEM POWERED BY EXHAUST HEAT OF AUTOMOBILE

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ABSTRACT

Vapour adsorption cooling system does not require the electric power or any other mechanical power for working. It uses waste heat from exhaust of automobile engine to power the adsorption cooling cycle to produce cooling effect. Parameters affecting the working of cooling cycle are discussed and working of experimental system with composite adsorbent and refrigerant pair is also discussed and studied in this review paper.

KEYWORDS: Adsorberbed, adsorption cooling system (ACS), desorption

INTRODUCTION

The increasing concerns related to the environment and ecology of recent years has brought about escalating interests in using heat sorption systems for cooling applications. This is due to its capability of directly utilizing thermal energy sources, including low grade waste heat from various sources, including solar hot water, industrial waste heat as well as geothermal sources. The adsorption (AD) is advantageous when 550C low temperature heat sources, are available. Much work has been carried out to find novel solutions to integrate the AD Chillers technology into the existing refrigeration industries. The current state of the art of cooling cycle applications is mostly water based with silica gel or zeolite as the adsorbent, most of which has successfully been implemented in Japan and parts of Europe.

The development of refrigeration technology produces the thermally driven cold production systems. These systems are considered good substitute for the electricity powered vapour compression machines in terms of electricity consumption as well as environmental issues such as green house gases emission and ozone layer depletion Recently, the booming progress in the field of green cooling technology offers cooling systems which can be powered by exhaust heat and renewable, green technology offers cooling systems which can be powered by exhaust heat from engines or turbines and renewable, green energy sources like solar energy.

The use of waste heat for refrigeration and air conditioning purposes have been accepted by people and various systems have been developed and proven attractive but its implementation in real applications is still limited. Electric driven air conditioning systems have reached a COP of over 4,

while absorption systems are usually in the range of low COP 1.1 1.25. The adsorption system is advantageous in small scale systems if compared with absorption systems. Solid adsorption system is possibly the best system for refrigeration purposes if we used exhaust heat for powering the system. A large part of the energy from the fuel that is burnt gets wasted through the exhaust gases. If a system that uses all the energy from the exhaust of an engine to run its cooling system can be designed, it could be very well accepted in the society.

Adsorption refrigeration cycles rely on the adsorption of a refrigerant gas into an adsorbent at low pressure and subsequent desorption by heating the adsorbent. The adsorbent acts as a “chemical compressor” driven by heat. When the adsorber is cooled, the adsorbate gets adsorbed onto the adsorbent bed. While the adsorber is heated in the next cycle, this adsorbate gets desorbed at high temperature to the condenser. Pressure vessel and a check valves are used to increase its pressure value . The rest of the refrigeration system remains the same as that of a vapour compression system which contains evaporator, condenser and expansion device. Exhaust heat recycling is gaining popularity these days because of the increased stress on fuel consumption and increased in the fuel prices and also because it helps to reduce pollution levels to an extent there by making it ecofriendly

PRINCIPAL OF COOLING CYCLE

In a thermally driven solid sorption system, there are three essential components that must be present. They are (i) the adsorber bed where adsorption or desorption occurs (ii) the evaporator and (iii) the condenser. As shown in Figure, the basic processes that the bed undergoes are as follows [1]

•First, the bed is disconnected from both the evaporator and the condenser and then it is cooled by an external coolant. This is known as the pre-cooling switching stage

. **Figure**:

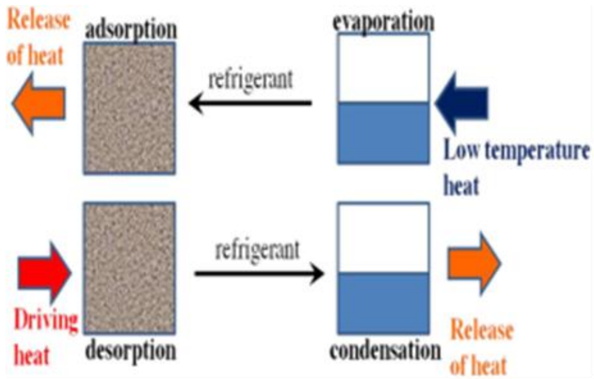

Fig 1 Process diagram of thermally driven adsorption chiller

- Then, valve between bed and evaporator is opened and adsorption process starts. The adsorbent adsorbs the refrigerant vapour from the evaporator due to this heat is released which continues to be cooled by the external coolant.
- The valve to the evaporator is closed and disconnected from both the condenser and the evaporator. The external coolant supply is stopped while external heat source is applied to the sorption bed due to this there is pressure build up in the bed. This is known as the pre-heating switching stage.
- Finally, the valve to the condenser is opened and the external heat source continues to be applied to the sorption bed therefore refrigerant from the bed is released to the condenser

THERMODYNAMIC CYCLE

Adsorption cooling system (ACS) based on two main steps: heating–desorption-condensation and cooling–adsorption–evaporation. By using this steps ACS produces cooling effect. Thermodynamic cycle consist of following four processes [2]

- Isosteric heating (ih), process 1-2, adsorbent temperature increases which induces a pressure increase from the evaporation pressure to condensation pressure. This phase is equivalent to "compression" phase in compression cycle

. **Figure**:

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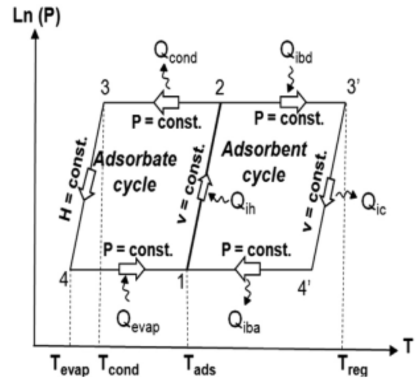

Fig 2. Thermodynamic cycle of two adsorber bed ACS

- Isobaric desorption (ibd), process 2-3, during this period, the absorber continuously receiving heat while being connected to the condenser, which now superimposes its pressure. The adsorbent temperature continues increasing, which induces desorption of vapour. This desorbed vapour is liquefied in the condenser. This period is equivalent to the "condensation" in compression cycles.
- Isosteric cooling (ic),process 3-4, During this period, the absorber releases heat while being closed. The adsorbent temperature decreases, which induces the pressure decrease from the condensation pressure down to the evaporation pressure. This period is equivalent to the "expansion" in compression cycles.
- Isobaric adsorption (iba), process 4-1, during this period, the adsorber continues releasing heat while being connected to the evaporator, which now superimposes its pressure. The adsorbent temperature continues decreasing, which induces adsorption of vapor. This adsorbed vapour is evaporated in the evaporator. The evaporation heat is supplied by the heat source at low temperature. This period is equivalent to the "evaporation" in compression cycl

LITERATURE REVIEW

This fragment should obviously state the foremost conclusions of the exploration and give a coherent explanation of their significance and consequence. This section should be typed in character size 10pt Times New Roman, Justified
(1) Azhar Bin Ismail et.al performed analysis of single-stage two bed adsorption refrigeration cycles working at pressurized conditions. Four specimens of activated carbon adsorbent and refrigerant pairs, which are Maxsorb III with Propane, n-butane and concluded that The specific cooling effect increases with the required evaporating temperature and regenerating temperatures. It however decreases with increasing ambient temperatures due to the higher cold reservoir available to the system and At higher required chilling temperatures and lower ambient temperatures, R-32 is preferred with higher specific cooling capacities.[1]

(2) Amir Sharafian et.al in 2014, worked on the design of adsorber bed for waste heat driven adsorption cooling system of vehicle and found that in different types of adsorber bed ,finned tube adsorber bed was observed to have better performance. [2]

(3)Y.Z..Lu and R.Z.wang et.al performed work on Experimental studies on the practical performance of an adsorption air conditioning system powered by exhausted heat from a diesel locomotive ware presented with zeolite and water as as working pair and found that this design is appropriate to cool the driver cabin successfully. [4]

(4) L.X. Gong and R.Z.Wang et.al performed work on design and performance prediction of new generation adsorption chillers using composite adsorbent which was lithium chloride in silica gel as adsorbent and wter as adsorbate and found that COP and cooling capacity increased by using this working pair. [7]

(5) Kai Wang et.al in ASHRAE (2011) journal performed work on performance of adsorption refrigeration system

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and composite adsorbent material and found that silica gel –water and activated carbon-methanol are appropriate working pair for solar energy and low temperature heat source due to their low desorption temperature. Zeolit – water, activated carbon –ammonia and composite adsorbent-ammonia are used for high temperature waste heat applications. [3]

(6) Harish Tiwari (2012) presented design development and experimentation of an adsorption refrigeration system powered by exhaust heat with only two control valves. The cooling capacity for a truck cabin is estimated as 1 TR a scale of 3.5:1 is decided and a prototype of 1 kW has been designed and developed and tested in laboratory. A cooling effect of 1 to 1.2 kW has been obtained. The COP of the system is in the range of 0 4 to 0.45. The total weight of the system for a cooling capacity of 1 kW is 30 kg. The heating time required to achieve the cooling effect is around 10 minutes. [6]

(7) Wang et al (2006) has presented a design of an adsorption air conditioner for locomotive driver cabin, powered by 350ºC – 450ºC exhaust gases. The cooling power and COP is 5 KW and 0.25 respectively". The cycle time of 1060 s with exhaust temperature of 450ºC cooling air temp of 40ºC and chilled water temp. of 10 ºC is achieved. The specific cooling power of 164 W/kg to 200 W/kg has been obtained. [9]

(8) Saha et al (2003) in the presented work have demonstrated dual mode silica gel water adsorption chillers design along with various temperature ranges and obtained optimum results for temperature range of 50ºC and 55ºC. Comparison of COP has been presented for three stage mode and single stage multiple modes. Simulation has been presented and the COP is in the range of 0.2 and 0.45 respectively."[8]

(9) Wu Jyangi et.al had studied operating parameters include heat source temperature, cooling water temperature, cycle time and stroke of flow control valve, etc. Though analyzing the experimental data, influences of the operating parameters on Clapeyron diagram, SCP and COP have been asserted and concluded that in real system, cycle time, heat source temperature, stroke of flow control valve and cooling water temperature have great influence on exerting of adsorber's operating capacity and system operating process. Corresponding to a certain cycle time, both COP and SCP have a certain optimum valve. Increase of heat source temperature improves operating capacity of adsorber, but causes decrease of COP.
Attempts have been made by researchers to improve the performance of the exhaust heat powered adsorption subsystems. It is seen that, for successful operation of such subsystems, a careful selection of the adsorbent-adsorbate pair is essential apart from system design and arrangement of subsystems. [5]

CONCLUSION

From the above literature review it can be concluded that the vapour adsorption cooling system powered by exhaust heat of automobile can be suitable to produce cooling effect .COP of the such system is less as compare to the traditional VCRS system but COP can be increase by doing some improvement in the cycle and increasing the source temperature of desorption process in thermodynamic cycle. Adsorbent material and refrigerant pairs are also deciding factor for the design of the ACS system as depending upon the adsorption and desorption process temperature. Silica gel-water, zeolite- water and activated carbon –ammonia these pairs has given the good results in ACS.
Two adsorber bed were required to obtain continuous cooling effect .I will perform the experimental evaluation of ACS by using composite adsorbent and refrigerant pair and use two adsorber bed, two condenser, evaporator and two control valves in my further experimental work.

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