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An Ecofriendly Cooling for Car Cabin

P.Vaisakh[1], A Ramaraju[2]
[1]*Mechanical Engineering Department, T K M College of Engineering, Kollam, Kerala.India-691005*
[2]*Mechanical Engineering Department, National Institute of Technology, Calicut, Kerala.India-673601*

Abstract: *An innovative exhaust-heat-powered solid adsorption air conditioning system with activated carbon-ammonia as working pair is designed for providing air-conditioning for a diesel passenger car. Two adsorber bed or regenerator is used in the system with two condensers to obtain continuous cooling. Experiments on the laboratory prototype have been carried out and a mean cooling of 167 KJ is obtained when the evaporator temperature shows a drop of about 4ºC. The influences of some operating conditions on the system performance are analyzed by experiments.*
Keywords: *ammonia, adsorption, cycle time, cooling, activated carbon.*

I. Introduction

Passenger car air conditioning is no longer a luxury.Presently car cabin air conditioners use conventional vapour compression refrigeration system, which is driven by high grade energy like electrical and mechanical. More over since it uses fluorinated and chlorinated hydrocarbons as refrigerants, which if gets leaked contribute to ozone layer depletion and the greenhouse effect. However, air-conditioning technology is required to evolve due to the environmental regulations, notably Montreal Protocol in 1987, Kyoto Protocol in 1997.These regulations are concerning about the depletion of the ozone layer and also global warming, which decided to phase out CFCs and followed by HCFCs and HFC-134a. As a result, this has led to a strong demand for a new air-conditioning technology [1].Among the emerging air- cooling technologies, adsorption air-cooling system has good energy-saving potential.This system has advantages of using waste heat for power, long lasting, low maintenance cost, uses non-polluting refrigerants which are eco-friendly. Unfortunately, no working prototypehas been practically run in present automobiles due to various restrictions, like sizing and cooling capacity limitations. Adsorption refrigeration cycle powered by solar energy or waste heat from engine exhaust has registered success for ice making and cold production. For example, solar adsorption ice maker, silica gel–water adsorption refrigeration cycle driven by waste heat of near-ambient temperature [2], zeolite–water solar cold storage system [3] and a combined solar thermoelectric adsorption cooling system using activated carbon–methanol working pair [4]. Adsorption systems can be activated by a heat source with a temperature as low as 50°C (122°F), while the heat source temperature for an absorption system should be at least 90°C (194°F).

Zhang and Wang [5] showed a numerical study of the dynamic performance of an adsorption cooling system for automobile waste heat recovery .It was the first work which concluded that SCP is more sensitive to parameter changes than COP with regard to adsorption cooling methods against the conventional cooling methods .Wang and Wang [6] done an experimental investigation of adsorption refrigeration with a single generator (adsorbent bed) in a basic cycle, which verifies the previous theoretical conclusions that the cycle time and the maximum desorption temperature are key factors which influences SCP and COP on a prototype machine. L.Z. Zhang [7] in his work describes an experimental adsorption cooling system driven by the waste heat of a diesel engine. Zeolite 13X-water is used as the working pair and a finned double-tube heat exchanger is used as the adsorber. To evaluate the performance of the system, some control and instrumentation facilities are also designed.

II. Experimental Setup

It consists of two parts:-Adsorber assembly and Alternate air supply system. Double adsorber bed with two condensers, an evaporator coil with two control valves forms the adsorber assembly as in fig.1-a**.** Adsorber bed consists of three concentric cylindrical stainless steel (SS) tubes with dimensions as in fig.1-b.SS tubes are to be used since ammonia corrodes most materials especially those having copper content. Adsorbent activated carbon-(AC, 200 gm) is filled in the concentric area between inner and central tube and sealed at both ends using bushes welded to it .Two tapping are taken from central tube, one for fixing ammonia pressure gauge and the other for connecting bed into the cooling circuit One of adsorber has a charging unit attached as in fig.2, for initial supply of ammonia which will be used inside the circuit. Both inner most and outer most tubes are

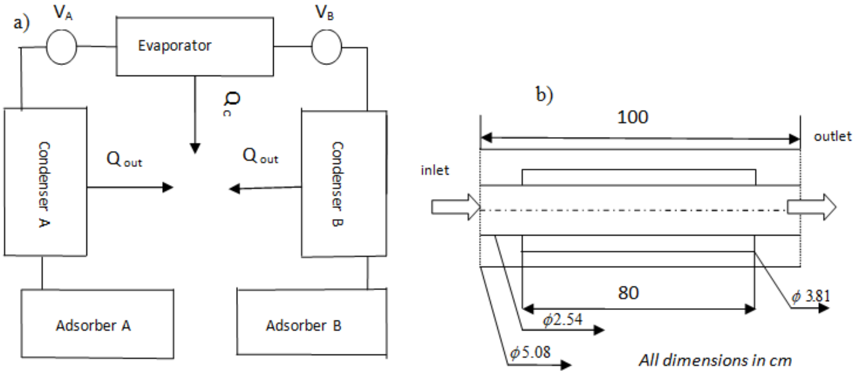

Fig .1 a) Setup outline and b) Adsorber model

Fig. 2 Adsorber (Bed A) with charging unit

open at both ends to allow alternate passage of hot exhaust air and blower air. Beds are fixed at an inclined position to augment the down flow of liquid ammonia and up flow of ammonia vapour. Ammonia pressure gauges are fixed at central tapping of both beds to find the bed pressure.All connections between equipments are done with cast iron tube of 6mm hole since copper tubes can't be employed since ammonia corrodes it. From bed A, connection tube taken to condenser A .It's outlet is connected to evaporator coil through control valve A. Evaporator outlet is connected to condenser B through control valve B. Its other end is connected to bed B. This completes the cooling circuit .Condensers used are common car A/C condensers .Evaporator is a coiled SS tube of 10 mm diameter and 2 m stretched length immersed in a tub of 10 litres (M_w) of water ,where the cooling effect is obtained and measured by dip of temperature obtained. Control valves are used for controlling the pressure in the bed at each stage. A combination of PVC tubes and GI tubes with four ball valves used to provide passage of blower air and exhaust air respectively .This alternate air supply system is attached to one end of the adsorber set up and the experiment is conducted.

III. Experimental Procedure

Fig. 3 Assembled view of setup

Entire setup is as in Fig.3.Experiment starts with charging of ammonia to bed A through valve arrangement and valve is closed. Adsorption takes place on bed at ambient temperature .Since this is exothermic ,for adsorption to complete blower air is supplied to cool it for 10 min .Then exhaust air is supplied at temperature in the range of 190 – 220 ˚C .Bed temperature and pressure rises, at a pressure of 4.8-5.5 bar vapour escapes to condenser A .The condensed ammonia passes to evaporator coil through control valve A. Cycle time (CT) is the time for which bed is heated until attaining required pressure .From evaporator the vapour pass through control valve B to condenser B. Condensed ammonia henceforth pass to bed B .This completes one cycle of operation. Then the cooling and heating of bed is reversed and again the cooling effect is obtained at evaporator section and thus cycle is repeated .Double bed ensure continuous cooling.

IV. Results And Discussion

Heat supplied and cooling effect obtained are calculated using following equations and graphs were plotted. Temperature drop of 3- 4º C is obtained at evaporator section. Maximum cooling effect of 167 kJ is acquired.

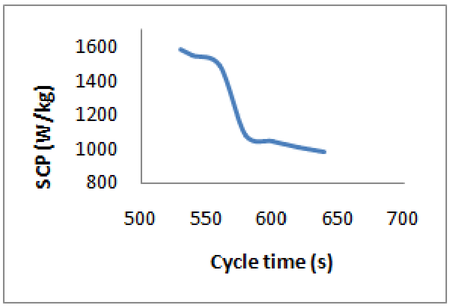

Fig. 4 Influence of CT on SCP

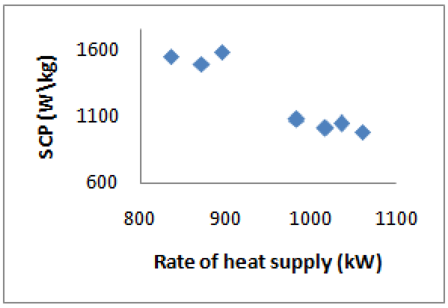

Fig. 5 Influence of Q_h on SCP

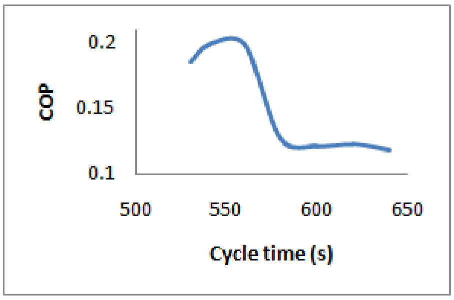

Fig. 6 Influence of CT on COP

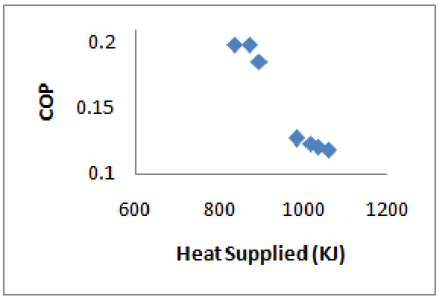

Fig. 7 Influence of Q_h on COP

$Q_h = M_e\, C_{pe}\, (T_{in} – T_{out}) / CT$ (1)
$Q_c = M_w\, C_{pw}\, \Delta T_w$ (2)
$COP= Q_c / (Q_h \times CT)$ (3)
$SCP = Q_c / (M_{ad} \times CT)$ (4)

SCP the major parameter in adsorption systems is cooling effect per mass of adsorbent in individual bed. From results it can be found that CT of 550 - 600 s is optimum for both maximum SCP and COP. Moreover optimum heat to be handled is 850 - 900 kJ for maximum SCP, which is the major performance parameter.

V. Conclusion

The developed experimental set up has given an SCP of about 1500 W/kg .Optimum values of performance parameters are sought out .The system is advantageous since it avoids use of fluorinated refrigerants, reduce engine power consumption and is a means for heat recovery of exhaust waste heat.

Nomenclature

SCP-specific cooling power W/kg, Q_h –rate of heat supplied k

Q_c - cooling effect kJ, C_p – specific heat kJ/kgK, M- mass kg

T – temperature ° C, ΔT_w - temperature drop of water

Subscripts

In- inlet, out -outlet

ad- adsorbent

w-water, e-exhaust

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