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Testing Heat Operated Adsorption Refrigeration System for Space Cooling

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Abstract

Now a day due to development of economy and research in science the standard of living increases worldwide and hence energy consumption in the houses, building, corporate offices is increase worldwide. In case of air conditioning the HVAC system is developed and electrically driven vapor compression air conditioning unit specially in hot weather. Electrically driven VCR consumes very high grade energy and it is also hazardous to our environment. On other hand thermallydriven adsorption refrigeration and systems got considerable attention now a day not due to its manufacturing simplicity , but also having environment friendly adsorbent/refrigerant pairs. This paper work is aim for testing a prototype of vapour adsorption refrigeration system using aqua ammonia and 1KW capacity has been tested in the laboratory of vapour adsorption. In present work the heating time required to achieve the cooling effect is around 10 minutes.

Keywords: Adsorptionsystem,Ammonia-Activatedcarbon,Heatsource,Renewableenergy.

1. Introduction

In heat operated adsorption refrigeration system heat source is used to compress refrigerant rather than electric compressor. In adsorption refrigeration system important parts are vessel which contains adsorbant-refrigerant pair called generator and evaporator condenser along

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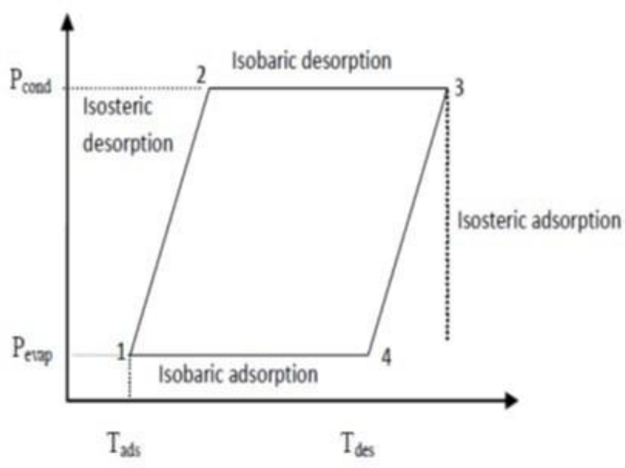
with expansion valve is used to complete adsorption refrigeration system.Adsorption refrigeration system is similar as absorption refrigeration system in which difference of a solid adsorbing material instead of liquid absorbing material. Adsorption refrigeration technology operates in low grade energy that is heat. In this refrigeration system the refrigerants used have zero ozone layer depletion potential and very low global warming potential. Adsorption system is driven by thermal energy, any kind of acceptable heat energy, which can be obtained from combustion of fuel which is a waste heat from engine exhaust. In adsorption refrigeration system the compressor of a conventional vapor compression refrigeration system is replaced by an adsorption compressor, which gives thermal compression powered by suitable heat source. In an adsorption system moving parts are very less like valves are required. As there is no mechanical compressor it requires no lubrication, it is simple in operation and very less maintenance is required. Adsorption refers to the binding of molecules(sorbate) to the surface of a material (sorbent) without any change.

1.1 ThermodynamicCycleofadsorptionrefrigeration



Schematic of Thermodynamic Cycle of adsorption refrigeration

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1. Process1-2(Isosteric desorption)

   The cool adsorber is heated and desorbs refrigerant vapouris osterically(i.e. at constant total mass in the adsorber), to state 2 slightly above Pcond.
2. Process2-3(Isobaricdesorption)

   Isobaric heating desorbs more refrigerant, forcing it into the condenser until state 3 attained, where the adsorberisn early devoid of refrigerant.

3 Process3-4(Isostericadsorption)

The hot adsorber is then cooled isosterically (at constant total mass), causing adsorption anddepressurization,untilthepressuredropsbelowPevap(state4),openinganot hercheckvalvetoallowvapourtoentertheadsorberfromtheevaporator.

3. Process4-1(Isobaricadsorption)

   Isobaric cooling to state1 the refrigerant saturates the adsorbent and thus completing the cycle.

1.2 Working pair

The working pair is the crucial part of adsorption refrigeration system.The basic propertieswhich are required for adsorption refrigeration are large adsorption capacity, large change inadsorption capacity with change in temperature and compatibility with refrigerant and low ad-sorption heat.The basic properties a refrigerant should possess are same as that required in a vapour compression system.

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2. Literature review

Habib et al. [5] have analyzed the performance of combined ADRS (with 70°C energy source)in which a heat exchanger is used not only as an evaporator, but also as a condenser at the same time. By Using R134a and activated carbon adsorbent for high cycle and activated carbon adsorbent R507a refrigerant for low cycle, they reached the result of 85 kW cooling capacity with 10^0C chilled water outlet temperature, and0.069 coefficient of performance.

Tamainot- Teltoetal.[6]investigated Carbon ammonia pairs for adsorption refrigeration applications. The simulation results of 26 various activated carbon ammonia pairs for three cycles(single bed, two bed and infinite number of beds).The carbon adsorbents investigated were mainly coconut shell and coal based types in multiple forms: monolithic, granular, compacted granular ,fiber, compacted fiber, cloth ,compacted cloth and powder and the driving temperature varied from 800C to 2000C.

H.Tiwarietal.[8]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 kWhas been designed and developed and tested in laboratory. A cooling effect of 1 to 1.2 kW hasbeen obtained.The COP of the system is in the range of 0.4 to 0.45.The dimensions of thesystem are compact. It can be easily accommodated on a Transport Truck. The total weight ofthe system for a cooling capacity of 1 kW is 30 kg. The heating time required to achieve the cooling effect is around10 minute.

W.S. Chang et al. [9] designed and tested an adsorption cooling system with silica gel asthe adsorbent and water as the adsorbate. This was experimentally studied to reduce the manufacturing costs and simplify the construction of the adsorption cooling system. a vacuumtank was designed to contain the adsorption bed and evaporator/condenser. Flat-tube

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Type heat exchangers were used for adsorption beds in order to increase the heat transfer area and improve the heat transferability between the adsorbent and heat exchanger fins. Under the standard test conditions of 80^{0}Chot water,30^{0}C cooling water, and 14^{0}C chilled water in let temperatures, a cooling power of 4.3 kW and a coefficient of performance (COP) for cooling of 0.45 was beachieved.It provided a specific cooling power (SCP) of about 176 W/ (kg adsorbent).Withlowerhotwaterflowrates,ahigherCOPof0.53wasachieved.

Meng et al. [14] studied the energy saving mechanism of an adsorption and vapour compression hybrid refrigeration cycle with a working pair of R134a and DMF.Based on the irtwo newly proposed criteria, comparing with the compression refrigeration cycle, this hybrid refrigeration cycle could save 16.1 to 67.1% of electricity under generating temperatures of 60^{0}C to90^{0}C.

2.2 Literature gap

After studying literature review we come to know that two bed adsorption systems are less developed. In existing adsorption system there is a scope on study of initial pressure and heating time cycle. To achieve maximum COP, we can focus on these two parameter.

3.Case study

Any case study for adsorption refrigeration can solved by using following equations.
The designpressure for condenser and evaporator are decided as 15 bar and 5 bar for water cooled condenserandevaporator.

Thefollowingsetofequationsisusedforthesecalculations[9].

$$m_r = \frac{R.E.}{L} \Delta t. \quad (3.1)$$

$$m_{ad} = \frac{m_r}{(X_1 - X_2)} \quad (3.2)$$

(3.3)

Where,

X_1=Concentrationatbeginningofdesorption

X_2=Concentrationattheendofadsorption

$$Density = \frac{m}{V}$$

$$V = AXT \quad (3.4)$$

$$Q_{Sensible} = \frac{((m_{ad})(CP_{ad})(\Delta T_{ad}))+((m_{ad})(CP_{ad})(\Delta T_{ad}))}{\Delta t} \quad (3.5)$$

$$Q_{Latent} = \frac{(m_{ad}(X_1 - X_2)X(H_2 - H_1))}{\Delta t} \quad (3.6)$$

$$Q_{ad} = Q_{Sensible} + Q_{Latent} \quad (3.7)$$

Proposed work

In this we will perform multiple number of experiments. We will do study of Initial pressure of refrigerant and time cycle. We will then investigate result for maximum COP.

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