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Performance of Physico-chemically Activated Carbon in a Single Chamber Pressure Swing Refrigeration System

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Abstract

This paper emphasizes on the enactment of a physico-chemically activated carbon (PCAC) in pressure swing adsorption (PSA) system for generation of cooling effect towards replacement of halogenated refrigerants. CO_2 and carbon activated with steam followed by phosphoric acid was investigated as the working pair in the PSA system. Surface area and micro-pore volume of PCAC were 1014.2 m^2/g and 0.6563 cm^3/g respectively. The coefficient of performance (COP) and refrigerating effect were observed to be 4.315 and 134.08 J/s respectively using 600 grams of PCAC. Results revealed that the dual-stage activated carbon could be a potential adsorbent in PSA system towards significant cold production.

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Keywords: Activated carbon; Carbon dioxide; Pressure swing adsorption; Refrigeration.

1. Introduction

The technology of refrigeration is indispensable to meet the necessities of our lifestyle since the late twentieth century. Modifications of policy and the governing environment have intensely persuaded the choice of refrigerants. Stratospheric deterioration in ozone layer and global warming caused due to the emission of orthodox refrigerants from HVAC (Heat Ventilation and Air Conditioning) systems have proven to be a potential threat to life on earth. Halogenated refrigerants like Chlorofluorocarbons (CFCs), Hydrochlorofluorocarbons (HCFCs) and Hydrofluorocarbons (HFCs) owing to their unparalleled thermo-physical as well as thermodynamic properties have

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been reining the heat pump, refrigeration and air conditioning industries since 19th century. But in view of their Ozone depletion potential (ODP) and Global warming potential (GWP), multilateral international agreements (Montreal and Kyoto Protocols) was structured and imposed on industrially developed and developing nations to curb their production and lessening of emission of halogenated anthropogenic refrigerants, followed by phasing them out completely to the earliest possible period. Researchers all across the globe have not only limited their work to cold production by means of mechanical work but also are also exploiting the non-conventional means such as using heat, magnetism, electricity, acoustics etc. as the driving force.

Nomenclature

PCAC	Physico-chemically activated carbon
ss	Stainless steel
m_{ac}	Mass of activated carbon, g
m_{sst}	Weight of stainless steel tube, g
m_{cu}	Mass of copper tube embedded in the adsorption-desorption chamber, g
m_w	Mass of water, g
m_{ssc}	Mass of adsorption-desorption chamber, g
s_{ac}	Standard heat capacity of activated carbon, J/g/K
s_{ss}	Heat capacity of adsorption-desorption chamber (stainless steel), J/g/K
s_{cu}	Heat capacity of copper, J/g/K
s_w	Heat capacity of water, J/g/K
ΔT_{ac}	Temperature drop/ rise of physico chemically activated carbon, chamber and pipelines, K
ΔT_w	Drop in temperature of water, K
T_{total}	Total cycle time, s
T	Final Absolute Temperature, K
T_{adsorb}	Adsorption time, s
H_a	Heat generated during adsorption, Joules
h_a	Heat of adsorption of adsorbate at 5 kg/cm^2, J/g-activated carbon
H_{ac}	Cooling required for physico chemically activated carbon, chamber and pipelines, J
H_w	Refrigeration taken out by coolant (water), J
H^*	Refrigeration generated, J
H	Cooling, watt
ρ_b	Apparent density, g/cm^3
$P = P_2$	Final working pressure, kg/cm^2
P_1	Inlet pressure, kg/cm^2
R_g	Universal constant of gas, J/mole-K
V	Volume of the gas occupied, litre

Adsorption refrigeration in particular solid adsorption based refrigeration system is advantageous not only for its aptitudes for a wide range of energy consumption rate [1] but also for being nonthreatening to the environment, having low initial investment, less primary energy consumption and high performance with simple control mechanism. Several works have been reported for cold production [2] using different adsorbent-adsorbate pairs in Temperature Swing Adsorption [3]. Pressure Swing Adsorption system apart from finding industrial solicitation for the purpose of gas separation may also make place in refrigeration industries henceforth. Anupam et.al [4] has already reported the ability to cool water from 26°C to 4°C in a single bed chamber employing carbon which was physically activated and carbon dioxide as the adsorbent-adsorbate working pair in a Pressure Swing Adsorption system. Choice of adsorbent-adsorbate working pair for such systems is an imperative issue on the note of their affinity for each other apart for their individual properties. The adsorbent material is desired to possess high dormant heat of adsorption in comparison to its functional load, it should adsorb large amount of adsorbate and desorb most of it on depressurization to generate better performance of the system accompanied by no degradation with age and