Renewable and Sustainable Energy Reviews 62 (2016) 109–120

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

A review on low grade heat powered adsorption cooling systems for ice production

Ramesh P. Sah [a,*], Biplab Choudhury [b], Ranadip K. Das [c]

[a] Department of Mechanical Engineering, Asansol Engineering College, Asansol, India
[b] Thermal Engineering Division, CSIR–Central Mechanical Engineering Research Institute, Durgapur, India
[c] Department of Mechanical Engineering, Indian School of Mines, Dhanbad, India

ARTICLE INFO

Article history:
Received 30 March 2015
Received in revised form
22 January 2016
Accepted 16 April 2016

Keywords:
Adsorption refrigeration
Solar/waste heat
Cooling performance
Activated carbon, methanol

ABSTRACT

Due to the ecological problems and energy crisis in the world, the development of sustainable energy utilization systems has attracted more attention. An adsorption ice maker may be used for storing perishable foodstuffs, fruits, medicines, etc. These adsorption ice makers are powered by low grade heat sources like solar heat, automobile/industrial waste heat etc. This study presents previous mathematical and experimental models of adsorption ice makers powered by solar heat/waste heat of automobile engines, etc. Though the environmental benefits of these ice makers are impressive, these refrigeration systems have been found to suffer from low performances. Researchers need to focus on development of new adsorbents, advancement in energy collection system and its utilization technology, design of efficient heat exchangers, optimal use of advanced cycles (mass recovery, heat recovery, mass and heat recovery, thermal wave, multi–bed, multi–stage cycles, etc), use of topping up cycles with different adsorbent/adsorbate combinations to maximize the performances of these ice makers to a promising level.

© 2016 Elsevier Ltd. All rights reserved.

Contents

1. Introduction

In remote areas, there is huge demand of cooling to preserve food, drugs and vaccines. Cooling is also needed to conserve fish on fishing boats where there is sizeable amount of waste heat of the diesel engines. In urban areas, cooling demand for preservation of food and vaccines is supplied by conventional vapour compression refrigeration machines. These machines use dwindling fossil fuels and work with non natural working fluids or refrigerants such as chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs) or hydrofluorocarbons (HFCs) that have serious effects on environment due to their undesirable ozone depletion potential (ODP) and global warming potential (GWP)

* Corresponding author.
E-mail address: sramesh2031@gmail.com (R.P. Sah).

http://dx.doi.org/10.1016/j.rser.2016.04.036
1364-0321/© 2016 Elsevier Ltd. All rights reserved.

Nomenclature

AC	activated carbon
ACF	activated carbon fibre
c_p	specific heat capacity (kJ/kg)
CFCs	chlorofluorocarbons
HFCs	hydrofluorocarbons
HCFCs	hydrochlorofluorocarbons
COP	coefficient of performance
D	constant in D-A equation
h_{sg}	isosteric heat of sorption (kJ/kg)
K	thermal conductivity ($W\,m^{-1}\,K^{-1}$)
m	mass (kg)
P	pressure
$\dot{Q}$	heat flow rate ($kJ\,s^{-1}$)
SCP	specific cooling power (W/kg)
Tt	temperature
X	concentration ($kg\,kg^{-1}$)

Greek symbols

ρ	density (kg/m^3)

Subscripts

ad	adsorbent
r	refrigerant

levels. Recent studies on the environment show that CFC/HCFCs emissions are responsible for about one third of the global greenhouse effect [1]. Based on the new environmental regulations, it has been agreed to phase-out CFCs and HCFCs. The Montreal Protocol restricts the production of the individual chemicals of concern, leading to their ultimate phase-out for most uses [2]. The Kyoto Protocol imposes national limits on emissions of important green house gases (GHGs) [3]. To meet the cooling demand in rural regions, fishing ships and to mitigate the menace of ozone depletion, global warming and dwindling fossil fuels caused by the use of conventional vapour compression machines, low grade thermal heat driven refrigeration systems have been gaining attentions. These systems are environmentally benign as they use natural refrigerants or alternative refrigerants of CFCs, HCFCs or HFCs that have zero ODP as well as zero GWP levels [4,5]. Moreover, they have also advantages of being powered by low temperature driving sources like solar heat, industrial/automobile waste heat and geothermal heat, which can reduce the dependence on fossil fuel resources.

These systems have simpler control, less vibration and lower operation cost, compared to conventional vapour compression systems. Moreover, these systems have some attractive advantages over absorption cooling systems [6,7]. Adsorption cooling systems can work with wide range of low grade heat source temperatures (50–500 °C) without any corrosion problem, whereas corrosion occurs in absorption cooling systems above 200 °C. In adsorption refrigeration systems, the use of adsorbent-adsorbate pair depends on application goal. Silica gel–water [8,9], activated carbon–methanol/ethanol/ammonia [10–12] and zeolite–water [13] are commonly used working pairs. Among these working pairs, activated carbon–methanol and activated carbon–ammonia pairs are suitable for ice production.

Numerous research works have been reported on environmentally benign and sustainable adsorption refrigeration systems in the past. Hence, there are many review papers published about these systems.

Wang et al. [14] have studied advanced adsorption cycles and concluded that poor mass and heat transfers in the adsorbent bed is the major responsible factor for low performance. Wang and his co-workers have discussed different techniques to enhance the heat and mass transfer in the adsorbent bed. In this study, the problem of the adsorption deterioration in the adsorption refrigeration system has also been analysed. Choudhury et al. [15] have presented solar powered ice makers and air conditioners and have also discussed the challenges to commercialization of these systems. The authors have also studied different techniques to enhance the adsorption systems performance.

Fan et al. [16] have classified and presented solar powered sorption cooling systems for air conditioning purposes (8 –15 °C), refrigeration (0–8 °C) for food and vaccine storage, and freezing (< 0 °C) for ice making purposes. The authors have also discussed the development history and recent progress in solar sorption refrigeration technologies. Hassan and Mohamad [17] have presented previous researches and developments of the solar driven closed physisorption refrigeration systems. Various adsorption refrigeration technologies and advancements were also discussed and suggested to enhance the performances of such systems. Sah et al. [18] have presented a review on adsorption cooling systems based on silica gel and activated carbon as adsorbents. In this study, system description, system design, numerical and experimental analyses have been discussed. Moreover, advanced cycles and new techniques have been also suggested to improve the performances of these systems. Although some literature review are present on adsorption ice makers, comprehensive study of adsorption ice makers powered by both solar heat and waste heat of engines has not been yet reported.

The main objective of this study is to present a review on existing low grade thermal energy powered adsorption refrigeration systems for ice production and research activities in this field. These systems are discussed to highlight the advantages of adsorption cooling systems over conventional vapour compression systems in order that more research works might be carried out to enhance the system performances such that they can be commercialized in future. This study involves system description, system performance, and numerical and experimental analyses of these systems. These adsorption ice makers are classified on the basis of type of driving heat sources as solar–powered adsorption ice makers and waste heat driven adsorption ice makers. These ice makers with different working pairs are presented in the later sections.

2. Adsorption ice makers

Researchers have studied a number of adsorption refrigeration systems with various working pairs. Among these working pairs, activated carbon–methanol and activated carbon–ammonia pairs are generally used for ice production. This study will present system description, system design, numerical and experimental analysis of different adsorption ice makers. On the basis of driving heat source used, adsorption ice makers may be classified as:

a) Solar-powered adsorption ice makers
b) Waste heat driven adsorption ice makers

Download English Version:

https://daneshyari.com/en/article/8113372

Download Persian Version:

https://daneshyari.com/article/8113372

Daneshyari.com