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Solar collectors and adsorption materials aspects of cooling system

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ABSTRACT

The selection of solar collector and adsorbent-adsorbate materials are crucial to improve the solar cooling system. Different type of solar collectors are integrated with different sorption chillers. Traditional flat plate, evacuated tube and high efficient parabolic trough collector can provide temperature of 60–80 °C, 80–150 °C and 150–400 °C respectively. Solar collector selection and optimization is of paramount options in adsorption refrigeration system. Different adsorbents have different equilibrium reaction pressure, which is related to different refrigeration performance. Several studies were discussed about selection and optimization of adsorbent-adsorbate materials both theoretically and experimentally. Some of them focused on cost effective materials and improving efficiency of the systems. The current investigation summarize an overview of traditional and emerging collector technology, sorption materials as well as state-of-the-art developments.

1. Introduction

Solar energy is sustainable as it is sources that are inexhaustible. It conversion used for many applications such as thermal or electrical energy. Solar cooling is a promising alternative solution for preservation of agricultural, dairy products as well as in areas with no electricity supply, as for the case of undeveloped countries or remote rural areas. The solar collector and sorbent materials are the main components for solar refrigeration system. In recent years various kind of collector has been studied to increase the efficiency with minimum cost [1]. Still the collector cost comparatively high [2]. It is essential to choose suitable collector technology to meet temperature needs of refrigeration system. While, adsorption system behave higher COP relatively higher temperature. The temperature of Flat Plate Collector (FPC) 60–80 °C, Evacuated Tube Collector (ETC) 80–150 °C and Parabolic Trough Collector (PTC) can provide 150–400 °C.

Though a wide range of adsorbent-adsorbate materials are presented, most of the working pairs used water due to high latent heat of vaporization, non-toxic nature and easy handling. The drawback of water is limited (above 0 °C) cooling application. For refrigeration or ice making below 0 °C, ammonia or methanol is used as a refrigerant materials. The current investigation summarize an overview of traditional and emerging collector technology, sorption materials as well as state-of-the-art developments. The objectives of this manuscript are (1) to evaluate superior collector technology for solar cooling and (2) to review appropriate adsorbent-adsorbate materials for refrigeration.

2. Development of solar collector for refrigeration

Solar collectors of different kinds have been studied throughout the world [1]. Solar collector design is a vital role for cooling applications. Fig. 1 depicts the taxonomy of different kinds of collector and their temperatures have been used for refrigeration system. In solar powered adsorption system, collector and adsorber are the main parts. These combinations are one of the key factors to increase the performance (COP) of the system. Number of studies has discussed about the combination of collector adsorber technology based on: (1) integrated collector-adsorbent bed (2) adsorbent bed separated from collector and (3) heat transfer to the adsorbent-adsorbate media.

Lazzarin [3] compared three types of solar collector technology for adsorption refrigeration like FPC, ETC and PTC with different heat source temperature 70 °C, 90 °C and 160 °C. The highest efficiency of 55% was attained by ETC followed by PTC (40%) and FPC (15%). Appreciable performance was obtained by ETC and PTC system.

2.1. Flat plate collector

Several researchers have been using flat plate collector for refrigeration system. The performance of the refrigeration system was influenced by parameters like.

a) Fewer capture of solar radiation
b) Poor heat and mass transfer inside the adsorbent bed
c) Coating materials
d) Number of glass cover

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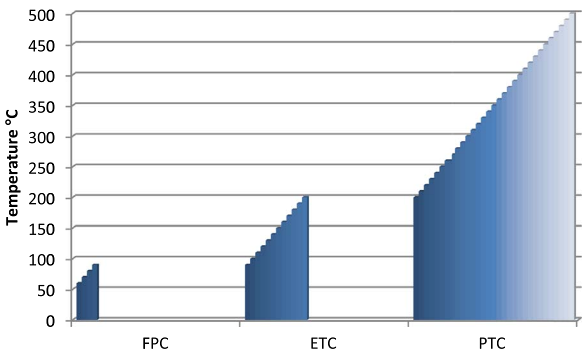

Fig. 1. Types of Solar collector Technology used in adsorption refrigeration system.

e) Ambient temperature
f) Wind speed etc.

Among these parameters, the most important parameters are poor heat and mass transfer inside the adsorbent bed, the number of glazing and selective coating materials. A study was achieved the COP of 0.11 and 0.113 respectively for single and double glass covers [4]. The study found that double glass cover with selective coating improved the performance of solar refrigeration system and prevented the heat loss from wind and atmospheric effect. Chi Yan et al. [5] presented flat plate collector with three different configuration of single glass, double glass and transparent insulated material cover. The study found that the double glazed cover shows best cooling performance. The heat transfer inside the adsorbent bed enhanced by black paint coating and number of fins. Due to that, the temperature reaches maximum of 110 °C and COP was found to be 0.12–0.14 [6]. Fig. 2 shows the cooling performance of some of the existing flat plate collector system.

To reduce the cost of the system a single glazed collector-condenser technology was developed [43] by a flexible tube. A no valve solar ice maker was established by Li et al. [24] as illustrated in Fig. 3. Liu et al. also designed a no valve system [44] which reduced the cost and less moving parts.

Louajari et al. presented a system with and without fins in solar collector [45]. The maximum COP was attained 0.11 for with fins and 0.075 without fins. The cycled mass of refrigeration is comparatively high in the flat plate collector with fins. It results indicated that embedded fins increased the COP of the system.

An adsorber was fabricated with copper plate of 1.2 mm thickness [25] as depicted in Fig. 3d. It is a paralleled pipe with a side of 85 cm and a width of 6 cm. It contains 14.5 kg of activated carbon, which are spread between 13 fins. The fins are 85 cm long and 5 cm large rectangular in shape. This arrangement increased the performance ranges between 5 to 8% compared to normal system. The results showed that the unit can produce cold air even for rainy and cloudy days.

The uneven temperature distribution on the adsorbent bed was reduced by Ji et al. [47]. The aluminium-alloy finned-tube casings (shown in Fig. 4) had low specific heat capacity and showed an excellent heat transfer performance. The adsorbent bed efficiency was improved between 31.64% and 42.7%. The temperatures are similar on the east, west and sunshine side of the adsorbent bed, which are higher than that on the back side. The average temperature difference between back side and sunshine side was 7.84 °C. Generally, temperature on the sunshine-side of the adsorption tubes was close to that on the east and west sides. The area of the three sides occupied ¾ of total area of the adsorption tubes. The temperatures of the adsorption tubes on different parts of the adsorbent bed collector also differ little.

Chekirou et al. studied the effect of 1 m^2 surface area of flat plate collector integrated with nine copper tubes [48]. The study observed that both COP_{th} and COP_{solar} decrease with an increase in the solar collector surface area. This can be justified by the fact that increase in solar collector surface area induces an increase in the cooling production until 6 m^2, and after that the cooling production decreases. A 10 pipes bundle integrated adsorbent bed was fabricated with a collector area of 1.2 m^2. This lead to more compact and reduce the heat transfer between collector and adsorbent [33].

2.2. Concentrating collector

Usually solar cooling system constructed based on flat plate collector, whereas in recent years Manuel and Lu presented a concentrating collector [49] with a collector area of 0.55 m^2. The experimental results showed that, COP_{solar} range from 0.078 to 0.096. Fig. 5 shows a proposed adsorption ice maker with PTC made from triangle cavity [50]. The experimental results showed that one adsorption cycle produced 50 kg of ice per day with a parabolic collector area of 20 m^2. The outcome of the study indicates the feasibility for industrial as well as the residential application.

The combination of evacuated tube collector based adsorption bed equipped with parabolic collector reached a maximum temperature of 125 °C [51]. Headley et al. constructed a compound parabolic collector with 2.0 m^2 which exceeds the temperature of more than [52] 150 °C. Balghouthi et al. used Linear Parabolic [53] Trough Collectors (LPTC) to heat 39 m^2 adsorption bed. The study found net COP_{solar} of 0.159

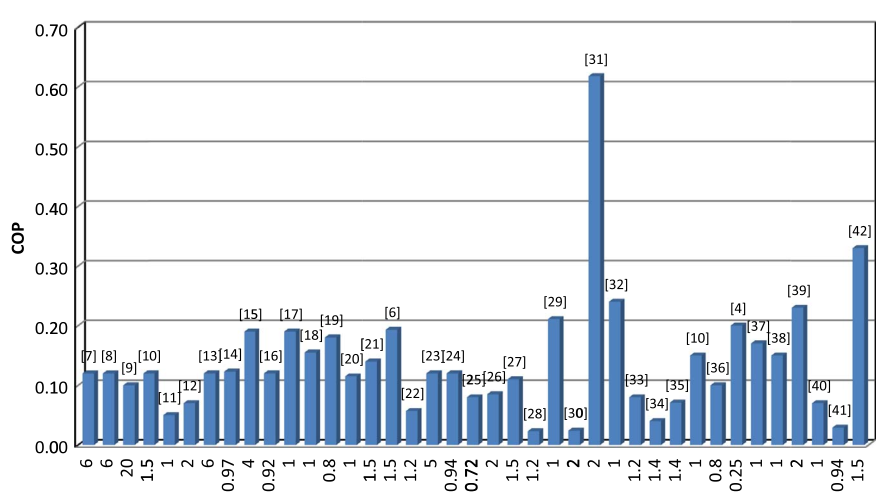

Fig. 2. Cooling performance of different size flat plate collector [8,11,13–16,18,19–32,35–42].