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Experimental thermodynamic cycles and performance analysis of a solar-powered adsorptive icemaker in hot humid climate

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Abstract

This paper analyzes and presents the thermodynamic cycles and the experimental performance parameters of a solar adsorptive icemaker that uses activated-carbon methanol pair. The solar energy technology employed is far less sophisticated than that of collectors using selective surface or evacuated tubes. The collector-adsorber is multi-tubular with an opaque black radiation-absorbing surface, and thermal insulated by means of transparent covers, the so-called transparent insulation material (TIM). The solar radiation hits on both faces of the tubes by means of semi-cylindrical reflectors. It is shown the results of tests carried out in a region of Brazil close to the Equator, on days characterized by the predominant cloud cover degree. Three cycles have been analyzed: one with clear sky, another with partially cloudy sky, and a third under entirely cloudy sky. The maximum regenerating temperatures were 100.1, 87.3 and 92.7 °C, with an ice production of 6.05, 2.10 and 0 kg by square meter of projected area, for cycles of clear sky, partially cloudy and overcast nights, respectively.

Keywords: Adsorption refrigeration; Activated carbon–methanol; Solar energy

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1. Introduction

Among the various applications of solar energy, refrigeration and air conditioning are the most interesting, because these demands are particularly strong in sunny regions. As a rule, the systems requiring thermal energy as their main power input for the production of cold effect are most dependent on absorption processes, either liquid or solid (chemical adsorption), or on processes of physical adsorption, commonly known as *adsorption*. Such systems are known as *thermal refrigerators*, in which the mechanical energy consumption is kept to a minimum or null, i.e. they utilize mainly thermal energy that comes from various sources, as such, process heat, thermal waste or solar energy. This represents a great advantage over the conventional vapor compression systems, especially in countries like Brazil whose energy consumption depends heavily on hydroelectric power.

The adsorption technology applicable to refrigerating systems differs significantly from that of absorption on account of its unsophisticated functioning. In adsorption, there occurs the interaction between a solid and a fluid, the transportation of the latter being thermal gradient dependable, i.e. it does not require the use of pumps, as in the case of the absorption one. However, adsorption refrigeration has shown performance coefficients lower than those obtained by liquid absorption. A comparative study between the three-sorption refrigeration systems (liquid, chemical reaction and adsorption) was published by Meunier [1].

Solar energy is abundant over large areas of northeast Brazil (annual average being over 6 kW/m^{2}day), securing, therefore, a great potential supply for use on helio-thermal conversion systems applicable for either heating or cooling purposes. In this region, many farm and fishing products are lost because of insufficient refrigeration, or otherwise, these products have their final values decreased for lack of an economical cold preservation.

Adsorption refrigeration systems, especially those used for ice production, adapt easily to solar energy since the required regeneration temperatures are compatible with those provided by flat plate collectors. The main disadvantages in relation to the vapor compressor cycles lies on the intermittent way in which adsorption systems operate; the cold effect takes a long time to occur, consequently, the coefficients of performance are very low. In the field of solar refrigeration by adsorption, there have been considered various kinds of fluid–solid pairs; zeolite–water [2,3] and silica gel–water [4,5] are used for cold storage, whereas activated carbon–methanol [6,7] and activated carbon–ammonia [8,9] are used for the production of ice. It may be justifiable to produce ice by using solar energy and by employing adsorption processes if both the thermal solar conversion and the adsorber heat dissipation, each one occurring separately, are enough.

The technological development of the adsorptive refrigeration systems is greatly impaired by the cost of the adsorber-collector, as well as the solar intermittent incidence, rendering such systems less competitive when compared to the conventional vapor compression refrigerators. Nevertheless, in remote rural areas without electricity, such as the northeast Brazil extensive rural areas, thermal-based adsorptive refrigeration systems may be just what one hopes to obtain from solar energy application. Different solar technologies duly adapted to adsorptive refrigeration have been tested with the sole purpose of enhancing ice production per m^2 of solar collection area, reducing, as a result, the adsorber-collector costs [10].

The present work describes the test results of an adsorptive solar machine that is equipped with a multi-tubular adsorber-collector and a methanol-activated carbon pair for the production of ice, for food and vaccine preservation in areas without electricity.