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Innovative compact solar air conditioner based on fixed and cooled adsorption beds and wet heat exchangers

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Abstract

In this work, a new all-in-one compact solar air conditioner concept is presented. The system is mainly based on a new DEC process which utilises fixed and cooled adsorption beds operating in a batch process and two wet heat exchangers. The proposed innovative adsorption bed is a fin and tube heat exchanger commonly used in the air conditioning sector, wherein the spaces between the fins are filled with silica gel grains. The main feature of this component is to allow simultaneous dehumidification and cooling of air. Furthermore, since the component hosts a considerable amount of adsorption material, solar energy can be efficiently stored in the desiccant media in terms of accumulated adsorption capacity. This potential can be used when regeneration heat is not available, strongly reducing the need for thermal storage in the solar loop. The indirect evaporative cooling process, operated downstream to the dehumidification, is realized by two wet plate heat exchangers connected in series. The process can be operated at relatively low temperature, allowing supply air temperature to the room of about 20°C.
A prototype of the compact solar air conditioner specifically developed for residential application is presented. The main features of the system as well as the thermodynamic cycle are first described. Monitoring results are presented by means of most commonly used performance indicators showing several advantages which can be obtained using the proposed solution.

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Keywords: All-in-one compact solar air conditioner, DEC, Adsorption fixed and cooled bed;

1. Introduction

Nowadays DEC systems are present on the market only for medium scale air conditioning applications. This is due to the fact that the concept on which large DEC units are based is not suitable for small applications in terms of costs, space and typical restrictions related to the installation of a centralized air system.

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In common DEC systems, desiccant rotors are normally used. However, the adsorption process realized by means of desiccant rotors presents the disadvantage of causing a temperature increase of the desiccant material. This phenomena is caused by the release to the process air of adsorption heat due to water condensation in the desiccant material and by the carry-over of heat stored in the desiccant material from the regeneration section to the process section. Moreover, desiccant rotor technology doesn't present the opportunity to store adsorption capacity into the desiccant material since adsorption rotors are generally built to host a relatively low mass of adsorbent. Therefore, the only option for energy storage can be related to the driving fluid, i.e. water heated by a solar plant. In addition, the use of hot air as regeneration fluid is suitable only with systems without storage.

The solution presented in this work was properly designed for residential application with the aim to overcome the mentioned limits typical of common DEC units.

Nomenclature

ADS	Adsorption	MR	Mass ratio [-]
EER	Energy Efficiency Ratio [-]	Rad	Solar radiation [W/m^2]
h	Specific Enthalpy [kJ/kg°C]	T	Temperature [°C]
HX	Heat Exchanger	x	Humidity ratio [g/kg]

2. Description of the system

An innovative patented compact solar air conditioner designed for ventilation, dehumidification and cooling (heating in winter is also possible) is presented. The system is mostly designed for air conditioning of under - roof spaces and can be configured to be installed both on flat and sloped roofs. The system is basically composed by a casing which comprises a solar air collector, two adsorption beds, an integrated cooling tower, two plate wet heat exchangers, fans and all other auxiliaries needed to realize the air handling process.

The system is mainly based on the use of two fixed packed desiccant beds of silica gel, operating in a batch process, and two wet evaporative heat exchangers connected in series. The adsorption bed is a fin and tube heat exchanger, commonly used in several air conditioning applications wherein the spaces between the fins are filled with silica gel grains. Therefore, the adsorption material can be cooled by means of the water loop of heat exchanger which is in connection with an heat sink. In addition, the component can be seen as a latent energy storage since an high adsorption capacity can be accumulated into the desiccant material when solar radiation is available and used it later when cooling energy is needed.

A system of air dumpers provides the commutation between the two adsorption beds in order to guarantee a continuous dehumidification process. For a detailed description of the component and its performances, refer to [1].

A cooling tower which is integrated in the system is used to reject the adsorption heat generated in the desiccant bed operating in dehumidification mode. Regeneration is carried out using a solar air collector. The air flow rate passing the adsorption bed is about 40% of the one delivered to the conditioned space. Electricity is only due to the operation of three fans and two pumps. Cooling power can be controlled through variable speed fans. Fig. 1 shows the concept and the scheme of the system. The thermodynamic cycle and the concept of the process air is described in Fig. 2. A flow rate of outside air (1) is drown through one of the adsorption beds for its dehumidification and partial cooling. Thanks to the simultaneous moisture and heat exchange, dehumidification process can indeed be carried out at almost constant temperature (2). Afterwards, dehumidified air is mixed with the return air from the building which is at conditions (6), reaching the conditions of point (3). The mixed air, which has a flow rate equal to 140% of the air flow rate supplied to the building, enters the wet heat exchangers reaching the supply conditions at point (4).