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A Study on the Performance of a Solar Desiccant Cooling System by TRNSYS in Warm and Humid Climatic Zone of IRAN

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Abstract

Increase in air humidity leads to discomfort and can cause health problems. Nowadays, traditional vapour compression air conditioning systems are widely used to decrease the moisture content of the air, but they result in high electricity bills. Recent studies show that use of absorbent material in the conventional systems can reduce electrical energy consumption. The desiccant systems are reasonably-priced, produce no CFCs, and capable of both drying and filtering the air. They provide an opportunity to control humidity and temperature independently, and have the capability of using low quality thermal energy. The aim of this study is to determine the performance of a Solar Desiccant Cooling System by TRNSYS in warm and humid climatic zone of IRAN. This paper computed the performance of a simple desiccant evaporative cooling cycle in four selected cities in Warm and Humid climatic zone of IRAN (i.e. Kish, Bandarabbas, Bushehr and Gheshm). The coefficient of performance (COP) has been computed for each location and compared. The results show that for Kish, this system shows high potential for comfort cooling in buildings compared to other locations in the same climatic zone.

Keywords: *Desiccant system, COP, warm and humid climate, TRNSYS*

1. Introduction

There are growing concerns about building thermal load and energy consumption and their effects on the global environment. Statistics indicate that buildings are dominant energy consumers in cities. In Iran, 40% of the total energy produced is consumed in buildings [1] Moreover, the large part of the energy demand by building is used to support indoor thermal comfort condition. Therefore, predicting the thermal behavior of a building, mainly cooling or heating load behavior, is necessary for optimization of its energy consumption. Due to high electrical consumption of conventional vapor compression systems, desiccant cooling system is one of the promising alternatives to cooling air where sensible and latent heats of air are being removed separately. A desiccant dehumidifier is a tool for controlling humidity (moisture) levels for conditioned air spaces. Desiccant systems work in conjunction with conventional air conditioning systems to dehumidify the air. Desiccant materials are those that attract moisture due to differences in vapor pressure. Desiccants can be in the form of a solid or liquid and have been identified to be appropriate as a component of commercial heating, ventilation and air conditioning (HVAC) systems. These desiccants have been

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selected based on their ability to hold large quantities of water, their ability to be reactivated, and their cost. In order to be effective, the desiccant must be capable of addressing the latent cooling load in a continuous process. In order to accomplish this, commercial desiccant systems consist of a process air path and a reactivation air path. The desiccant wheel is rotated through a “supply” or “process” air stream. The “active” section of the wheel removes moisture from the air and the drier air is routed to the building. In a standard installation, the dry process air leaving the desiccant then passes over a conventional cooling coil which addresses the sensible cooling work required to meet the air specification of the conditioned space [2]. Jain, *et al.,* [3] evaluated ventilation, and recirculation cycles based on India weather data, to find effect of the effectiveness of evaporative coolers on COP of cooling system. Dezfouli M. M. S, *et al.,* [4] evaluated simulation ventilation and recirculation modes of desiccant systems, they were found that, amount of ventilation and recirculation COP was 0.8, and 1.6 respectively. Therefore it was achieved that the recirculation solar desiccant cooling system in hot and humid area is higher efficient than the ventilation solar desiccant cooling system. Dezfouli M.M.S., *et al.*, [5] investigated solar hybrid desiccant cooling System in Hot and Humid Weather of Malaysia. They found that solar hybrid solid desiccant cooling system provided considerable energy savings in comparison with conventional vapor compression in hot and humid area. Subramanyam, *et al.*, [6] applied a desiccant wheel for low humidity air conditioning and also explained how the different parameters affects the performance like air flow rate, compressor pumping capacity, speed of wheel *etc.*, and found optimum wheel speed of about 17.5 rpm for high moisture removal and maximum COP. Kodama, *et al.*, [7] shows that there is an optimal speed by which high sorption rate exists in the rotation desiccant wheel. Fong, *et al.*, [8] have designed a simulation model (TRNSYS) of an integrated radiant cooling by absorption refrigeration and desiccant dehumidification. Dhar, *et al.,* [9] proposed various solid desiccant cycles for hot and humid climate and found that amongst ventilation, recirculation and Dunkle cycle, Dunkle cycle is better for a wide range of outdoor conditions. Haddad, K, *et al.*, [10] have studied about simulation of a desiccant-evaporative cooling system for residential buildings. They found that the use of solar energy for regeneration of the desiccant wheel can provide a significant portion of the auxiliary thermal energy needed.

This paper presents a simulation study on performance of a solid desiccant base evaporative cooling system in warm and humid climatic zone of IRAN.

2. Description of Desiccant Cooling System

A desiccant evaporative cooling system is composed of four principle components such as: a desiccant wheel as dehumidifier, Heat recovery wheel, evaporative cooling as humidifier, and solar evacuated tube collector as heat source. Figure 1 shows a schematic of the desiccant evaporative cooling unit. Two counter current air streams, the process and the regeneration air streams drive the operation of the desiccant cooling system. This system is not open cycle. Process air side is close loop while regeneration air side is one open cycle.

In process air side, room air that including sensible load and latent load goes to desiccant wheel to removing latent load. Heat recovery wheel acts as per cooling in process air side. The main purpose of the heat wheel is for sensible heat recovery only. In the next step, air become cold by evaporative cooler and then air goes to room as supply air. In the regeneration side, ambient air becomes cold by evaporative cooler. In the next step, Heat recovery wheel acts as per heater in regeneration air side. Then heat from heat exchanger and heater transfers to air. So, in the last step of regeneration side, hot air takes humidity of desiccant wheel and releases to ambient as exhaust air.

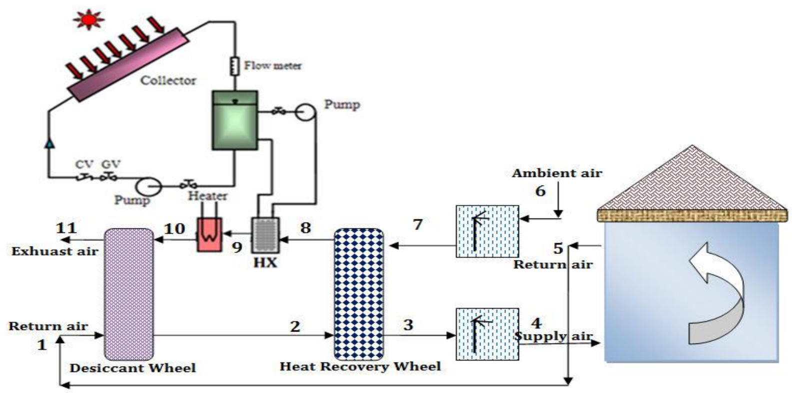

Figure 1. Desiccant Evaporative Cooling System Schematic

3. Methodology

The Coefficient of Performance (COP) of the solar desiccant cooling system can be calculated by rate of heat extracted share on rate of heat regeneration. Rate of heat extracted is cooling capacity of this system that supplied cooling air to room. Rate of heat regeneration is consisting regeneration heat input by heater and solar thermal. Therefore, the COP of the system is obtained by following relation:

$$\text{Cop} = \frac{Q_{Cool}}{Q_{Regeneration}} \quad (1)$$

For analyzing the desiccant cooling cycle, following assumptions have been made.

1) The reactivation temperature of desiccant wheel is 90^0C.
2) Effectiveness of direct evaporative cooler is assumed to be 1.
4) The effectiveness of heat recovery wheel and was 1.
5) Efficiency of others components such as pump, fan, heat exchanger was 1.

$T_1 = T_{Ret}$ (2)
$T_3 = T_2 - \varepsilon_{cw} (T_2 - T_7)$ (3)
$T_4 = T_3 - \varepsilon_D (T_3 - T_{3W})$ (4)
T_6= Ambient air
$T_7 = T_6 - \varepsilon_D (T_6 - T_{6W})$ (5)
$T_8 = (T_2 - T_3)/ (M_R/ M_P) + T_7$ (6)
$T_{10} = 90^0$C for reactivation of desiccant wheel

Heat input to generator to regenerate the desiccant wheel

$Q_R = (T_{10} - T_8)\, M_P.\, C_P$ (7)
$T_{11} = T_{10} - (T_2 - T_1)/ (M_R/ M_P)$ (8)
The COP can be written as:

$$\text{Cop} = \frac{M_p\ (h_5 - h_4)}{M_R\ (h_{10} - h_8)}$$

4. Simulation

The simulation models are used with the TRNSYS software. Figure 2 shows simulation modeling of desiccant cooling system that was designed by TRNSYS software. In this simulation, type 683 is desiccant wheel, type 506c is evaporative cooler, and type 760b is heat recovery wheel. The type 91 is heat exchanger, type 71 is evacuated tube solar collector, type 3b is pump, type 112a is fan and type 690 is zone load (room).

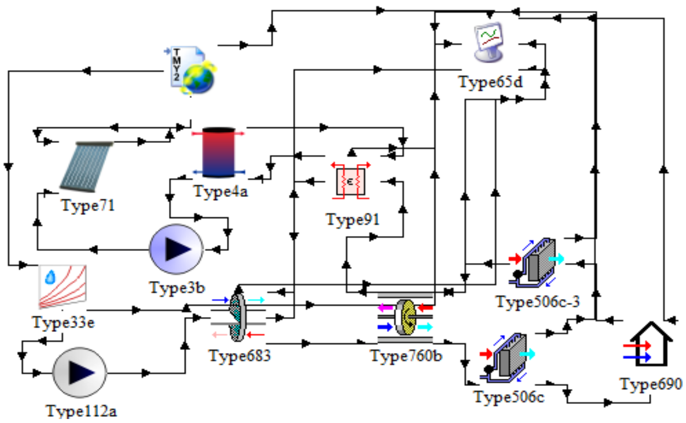

Figure 2. Studio TRNSYS Simulation for Desiccant Cooling System

For the analysis, four cities of IRAN were selected from the hot and humid climatic zone (*i.e.*, Kish, Bandarabbas, Bushehr and Gheshm) that is presented in Table 1.

Table 1. Weather Data

S.NO.	Name of Cities	Outdoor air		
		DBT(^{O}C)	WBT(^{O}C)	Specific humidity (g/kg)
1	kish	29	21.1	12.48
2	Bandarabbas	31	22.7	13.9
3	Bushehr	26	22	14.95
4	Gheshm	30	23.8	16.1

The performance of desiccant cooling system was evaluated for different places and it was observed that COP of the system is highest in Kish *i.e.*, 3.2 and lowest in Gheshm *i.e.*, 2.4 The COP of system is highly influenced by the outdoor absolute humidity, it decreases with increase in outdoor specific humidity. The COP of Kish is higher due to lower outdoor specific humidity and Gheshm have lower COP due to higher outdoor specific humidity.

Figure 3 shows variation of COP with specific humidity of outdoor air at different places. The desiccant cooling system shows highest COP (3.2) at Kish being place of lowest specific humidity of ambient air. On the other hand, the system shows lowest COP (2.4) at Gheshm having highest ambient specific humidity.

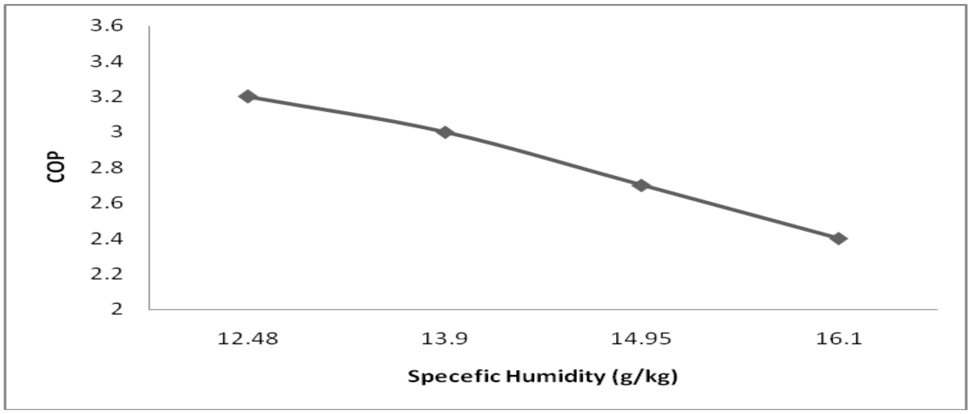

Figure 3. Variation of Coefficient of Performance with Outdoor Specific Humidity

5. Conclusions

This paper presents a study on the performance of a Solar Desiccant Cooling System by TRNSYS in warm and humid climatic zone of IRAN. It may be concluded that, the performance of desiccant cooling system is highly influenced by ambient air humidity ratio. Higher is the ambient air humidity ratio, lower is the COP. Four Iranian locations (Kish, Bandarabbas, Bushehr and Gheshm) pertain to same climatic zone (hot and humid) but potential of desiccant cooling is found to be different at different places. For Kish, this system shows high potential for comfort cooling in buildings compared to other locations in the same climatic zone.

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Nomenclature

Cop	*The coefficient of performance*
$\dot{Q}$	*Refrigeration produced (k w)*
$\dot{w}$	*Power input (k w)*
T	*Temperature (^0c)*
M	*Air flow rate (Kg/s)*
C_P	*Specific heat of air*
Q_R	*Regeneration heat (KW)*
WBT	*Wet Bulb Temperature (^0c)*
DBT	*Dry Bulb temperature (^0c)*
h	*specific enthalpy (kJ/kg)*

Greek symbols

ε_D	*Effectiveness direct evaporative cooler, dimensionless*
ε_{cw}	*Effectiveness energy conservation wheel, dimensionless*

Subscripts

Ret	*Return air from conditioned space*
P	*process*
R	*Regeneration*

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