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Investigating the Performance of a Hybrid Desiccant Cooling System and Trombe Wall and Optimizing Wall Area in a Stable Condition

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ABSTRACT: This study focuses mainly on employing Trombe wall systems to provide the heat required for restoring the desiccant wheel and investigating the optimal surface area of the wall for attaining air conditioning comfort. In this study, a solar desiccant wheel which receives the thermal energy required for regeneration from a Trombe wall was modeled. In this system, first, the components of the desiccant wheel, the Trombe wall, and the insolation were separately modeled in MATLAB and then assembled. The integrated system may be examined in all humid weather conditions around the globe. The results of the model are compared with the experimental results and have an acceptable agreement with each other. The model had been developed for cooling the building in July in Rasht city by using the ground heat exchanger. A ground coil was incorporated in this system to pre-cool the process air. The optimal surface area of the Trombe wall was extracted as a function of the parameters of the desiccant wheel. For a wall output temperature of 66 °C, the comfort temperature was found to be 24 °C, the humidity ratio to be 12 g_w/kg_a, and the optimal wall surface area to be around 52 m^2.

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1. INTRODUCTION

Nowadays, comfort in buildings is associated with energy and the environment. For providing a comfortable condition, first of all, the air conditioning devices should be designed with the lowest possible energy consumption. Secondly, the consumed energy in these devices should be environment-friendly. Kabeel et al. [1] investigated the solar energy assisted the desiccant air conditioning system with Phase Change Material (PCM) as a thermal storage medium. Abbassi et al. [2] studied the comparative performance analysis of different solar desiccant dehumidification systems. The main thesis of the present study is to use the naturally heated air of the solar wall to regenerate the desiccant wheel.

2. DESCRIPTION OF THE SOLAR-COOLING DESICCANT SYSTEM

According to Fig. 1, two air flows, namely the process and regeneration air flows, pass through the desiccant wheel from two different paths. Humidity and heat are transferred from the hot process air to the secondary air flow through a humidity absorption network. The matrix used for heat and humidity transfer is composed of aluminum sheets coated with a dehumidifier desiccant (silica gel) which is supplied by passive solar energy (solar wall) along with an emergency heater.

3. MATHEMATICAL MODEL OF THE SYSTEM

For the sake of simplicity, the wheel was considered in a way that half of it is exposed to a humid airflow and the other half is exposed to a dry and hot airflow. Dry air stream flow rate and humid air stream flow rate are assumed identical. Half of the wheel, which is exposed to a wet airflow, is the absorbent section and the other half, which is exposed to a dry and hot airflow, is called the recovery section.

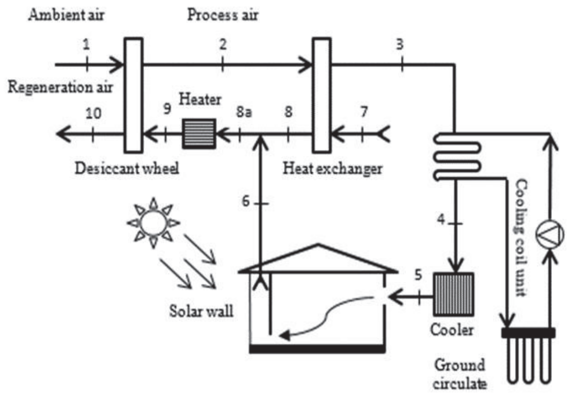

Fig. 1: A schematic view of the desiccant-based absorption cooling cycle combined with a solar wall.

4. SOLAR WALL MODEL

The structure of a solar wall is shown in Fig. 2. This solar wall is composed of a light and solar radiation absorption surface, an appropriate insulation implemented inside the wall, and a glass cover along the southward direction of the building.

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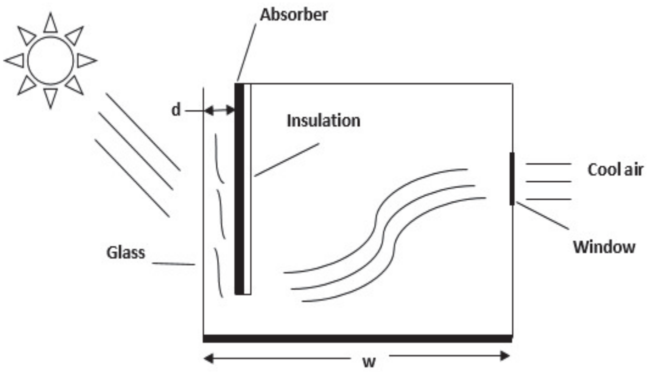

Fig. 2: Schematic view of the structure of the solar wall.

5. MODELING AND VALIDATION METHODS

MATLAB computer programming was used to solve the governing equations of the system. Desiccant wheel modelling becomes possible with the wheel conditions and characteristics, the environmental conditions of Point (1), and the heated exhaust air temperature of the solar wall at Point (9). Modelling is performed through computing and solving the conditions governing the system respectively at Points 2, 3, 4, and 5 on the process airflow direction. In Table 1, the experimental data of Kodama et al [3] were used to validate the mathematical model and to compare it with the experimental results.

To determine the solar wall outlet temperature, the energy equations governing the solar wall are solved using iterative method and glass temperature, wall temperature, and the air temperature flowing in the channel are obtained. The hot temperature of channel exhaust is obtained after solving the solar wall model and the temperature is used in the cooling model of the desiccant wheel at 9 points as the input parameter of the desiccant wheel.

6. RESULTS AND DISCUSSION

According to the system modelling, desiccant wheel parameters affect wheel exhaust air and the parameters are related to the area required for a solar wall. With respect to the comprehensive model outputs, the changes of the desiccant wheel parameters on the required area of the solar wall are studied and presented according to the Figs. 3 to 5.

Table 1: Comparison of the present study with the experimental results at state points of desiccant cycle.

State points		Temperature (° C)		Humidity			
		Model/Exp.		Model/Exp.			
1	31	31	10.2	35%	10.2	35%
2	54	55.5	4.4	5%	4.5	4.4%
3	35	32	4.6	13%	4.7	16%
4	26	25	5	23%	6.1	30%
5	22	23	10.2	52%	10	54%
7	31	31	10.2	36%	10.1	34%
8	51.3	52	10	12%	10	11.5%
9	80	80	9.3	4%	9.5	3.5%
10	57	56	18.1	16%	18.16	17%

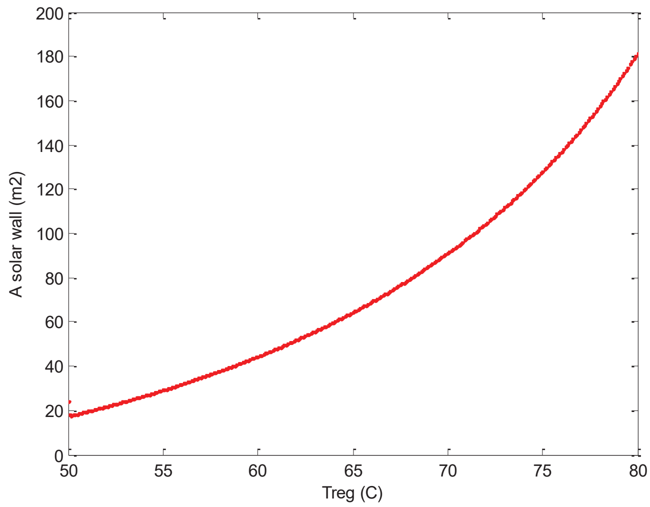

Fig. 3: Variations of solar wall area as a function of various regeneration temperature

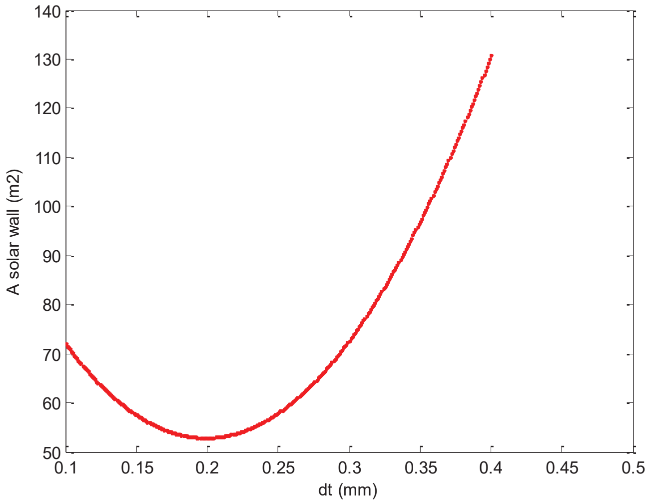

Fig. 4: Variations of solar wall area as a function of the various adsorbent thickness of the desiccant wheel

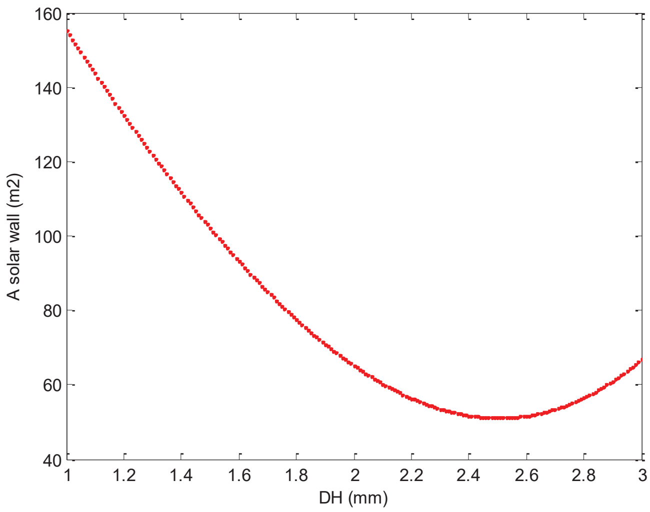

Fig. 5: Variations of solar wall area as a function of the hydraulic diameter of transmitting channels

Table 2: Operating conditions of the desiccant wheel

	value
Inlet air temperature to the desiccant wheel (° C)	35
Intake humidity (g / kg)	25
Hydraulic Diameter of Matrix (mm)	1.33
Absorbent thickness (mm)	0.2
Rotational speed of wheel RPM	15
Intake air velocity to the wheel (m / s)	2
Regeneration air temperature (Trombe wall model results)- (° C)	66
Solar absorbed radiation (w / m^2) - (from solar radiation model results)	730

7. CONCLUSION

The area of solar wall has been extracted and depicted as a function of various parameters of the desiccant wheel to represent a mathematical approach for optimization of the area. Some of the results can be summarized as follows:

1. Comfort conditions are determined by the humidity ratio to be 12 g_w/kg_a at 24 °C using the hybrid cycle of desiccant cooling and solar wall.

2. The wall area is considered 49 m^2 at the desiccant wheel rotational speed of 27 RPM.

3. With respect to the absorbent thickness of desiccant wheel (0.2 mm), the area required for the wall is considered 52 m^2.

4. Simulation results showed that when the hydraulic diameter of the channels, which transfer humid air of the desiccant wheel, becomes 2.5 mm, the required area for the wall is 52m^2.

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