Experimental investigation of a solar desiccant cooling system

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Abstract: - Solar assisted desiccant cooling is a good alternative for air conditioning in hot and humid climates Malaysia. It permits to reduce of chlorofluorocarbons (CFC) and consumption of fossil fuel. In the present work, an experimental investigation on desiccant cooling handling unit powered vacuum tube solar collector. Performance parameters such as the coefficient of performance (COP) of the unit of system component are presented. A desiccant cooling model is developed and applied to the humidifier and direct evaporative cooling modes. The effects of the regeneration temperature of the desiccant wheel on the COP and output cycle are investigated. Experimental results indicated that average thermal COP cooling cycle is 0.6 in hot and humid climate condition. Calculating these values has significant effect on the energy use of these cycles.

Key-word: - Solar, Desiccant cooling, Performance, Experiment, Regeneration temperature

1 Introduction

Desiccant cooling system powered by vacuum-tube solar collectors to be interesting option for cooling application. In solar desiccant cooling cycle, solar energy is used to regenerate a desiccant that dehumidifies moist air, the resulting dry air is cooled in heat recovery wheel and then in an evaporative cooler. The technique uses water as refrigerant and solar energy; electricity is only used in the auxiliaries, so the technique is environmentally friendly.

In the context of Malaysia the ability of renewable energy sources issues is under estimated consequently we do not see widespread commercial solar applications in the society. For space cooling requirement, availability of solar energy coincides with the need for cooling. Similarly the summer peak demand of electricity due to extensive use of air conditioners matches with the peak solar irradiance, thus offering an opportunity to use solar energy in the space cooling system. Desiccant cooling system requires medium temperature heat for regeneration about 60°C to 80°C of desiccant wheel part of which can be supplied from solar collector or auxiliary heater.

Desiccant cooling systems show great energy saving potential by using low-grade heat source, such as solar energy. A lot of study solar assisted desiccant cooling; Dai et al. \cite{1} conducted a comparative study of a standalone VCS, the desiccant-associated VCS, and the desiccant and evaporative cooling associated VCS. The authors found an increase of cold production by 38.8–76% and that of COP by 20–30%. Henning et al. \cite{2} conducted a parametric study of a combined desiccant/chiller solar assisted cooling systems and showed not only their feasibility but also the primary energy savings of up to 50% with a low increased overall costs. Kodama et al. \cite{3} investigated the impact of the desiccant wheel speed, air velocity and regeneration temperature on the COP. The authors showed the existence of an optimal speed and established that the COP decreased when the airflow rate increased and, on the contrary, the temperature of regeneration and the cooling capacity had the same evolution tendency. Eicker et al.\cite{4} study component performance and seasonal operational. Seasonal
performance monitoring carried out in the German installation showed that average seasonal COP was close to 1.0.

In this study showed that two different types of rotary desiccant cooling system were studied both analytically and experimentally. Two modes desiccant based air conditioning system was designed and tested experimentally to improve the indoor air quality and reduce energy consumption.

2 Methodology

Energy analysis of the system considered will be carried out and suitability of the system will be investigated for the health care facilities in which hygiene is crucially important. Figure 1 shows the desiccant cooling system, which is considered in this study. Since the system is considered for the health care facilities, 100% fresh air will be used. Fresh air duct is used to supply fresh air for the air-conditioned room. The waste air sucked from the air-conditioned room is sent to outside via waste air duct. Regeneration air duct is used to remove moisture of desiccant unit. Various components (dehumidifier, heat exchangers, fans, heaters, temperature and relative humidity sensors) were located into these channels to control and adjust the conditions of the air streams. Psychometric diagram of the system considered for the design air conditioning is shown in Figure 1. Figure 1 show a desiccant cycle operates as follows: (1) is dehumidified in a desiccant wheel (2); it is then cooled in the heat recovery wheel (3) by the return cooled air before being further cooled in humidifier (mode 1), an evaporative process (mode 2) (4), finally, it is introduced into condition room. The operating sequence for the return air (5) is as follows: it is cooled to its saturation temperature by evaporative cooler (6) and then it cools the fresh air in the heat recovery wheel (7). It is then heated in the heat exchanger by solar collector or heater (8) and finally regenerates the desiccant wheel (9) by removing the humidity before exiting the system.

The experimental setup used to investigate the desiccant cooling technology. The desiccant cooling units consist of a desiccant wheel, a heat recovery wheel, two evaporative cooler, blower and a regeneration heat exchanger (water to air). The desiccant wheels are designed to operate with both a 50% area for reactivation and 50% for process (50/50 split). The diameter of the wheel is 250 mm and the width is 533 mm with the angular velocity of 8 rev h⁻¹ for a nominal air-flow rate of 6000 m³ h⁻¹. The heat recovery wheel is an aluminium honeycomb structure. It rotates at 12 rev min⁻¹. The diameter of the regenerator is 700 mm and its width is 700 mm. The installed evaporative cooler max air flow 6000 m³h⁻¹. The electrical consumption of the motor is about 150 W.

![Mode 1 in Psychometric chart](image1)

![Mode 2 in Psychometric chart](image2)

Fig 1. Different process modes plotted in a psychometric chart.
The system mainly includes 12 m² solar air collectors with temperature range of between 80 and 95°C, feeding a storage tank of 1000 L. In reality this storage capacity is over dimensioned since energy is needed to raise the tank’s temperature the desired level for regeneration. However this storage volume was chosen to protect the collectors from overheating since the installation is used for experimental purpose only and yet is not operational every day thus high capacity is needed.

**Result and discussion**

To compare various mode and effect of parameters on performance, effect of regeneration temperature on the COP of the cycles is shown in Fig. 2. In this case, the indoor sensible heat ratio (SHR) and temperature difference between state point 0.75 and 6°C, respectively. The result show that the COP of all cycles drops with the increase in regeneration temperature. Because of constant indoor SHR and temperature difference between 4 and 5, it can be assumed a constant cooling effect for all regeneration temperature. On the other hand, when increasing the regeneration temperature, the energy required in the heater rises. Therefore, the COP of the cycles drops. Also, in the same operational conditions, the ventilation cycle has the highest COP value compared to other cycles. If is due to the use of only return air in regeneration section which causes more energy saving.

**Fig. 2.** Effect of regeneration temperature on the COP cycles.

![Fig 2. Effect of regeneration temperature on the COP cycles.](image)

**Fig. 3.** Effect of regeneration temperature on outlet cycle temperature.

Fig. 3 shows the effect of regeneration temperature on the outlet air temperature ($T_{DB}$) of each cycle. The outlet cycle air temperature first drops then rises by the increase in regeneration temperature. Therefore, there is an optimum value for regeneration temperature in which the outlet cycle temperature has its minimum value. The lower the outlet cycle temperature, the more cooling effect can be obtained. Also, lower energy is used when the cycles operate in optimum regeneration temperature. The temperature at state point 4 closely depends on the wet bulb temperature at state point 3.

**Conclusion**

Two model desiccants cooling powered solar thermal collector were conceptually designed and monitored by National University of Malaysia. Both system works well with average coefficients of performance around 0.6., when all operation modes are included. In case the solar air collector field is underdimensioned for the regeneration air volume flow, auxiliary energy is often needed to reach the required regeneration temperature. Adjustable regeneration temperatures are necessary to reduce auxiliary energy consumption.
References


