Research on a Dehumidifier of Liquid Desiccant Type Solar Air-Conditioning System for Full Year-round Use

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Abstract. In full year round term, the air conditioning system should be available to use for winter and summer season. The solar desiccant system is a type of air conditioner that uses solar energy in operation, hence this type have been developed. A dehumidifier is one of the essential components in liquid desiccant air-conditioning system. This paper is an experimental study on a structured packed tower of liquid lithium chloride dehumidifier system with different air velocity and flow rate of liquid desiccant. Experimental apparatus in this experiment is divided into three components; those are load chamber, packed tower and chiller. Load chamber’s volume is 40m\textsuperscript{3}, and packed tower dimension is cubic with length 0.4m occupied with packed column. Desiccant temperature set into 10°C and desiccant concentration is 0.4. The result of this study shows that averagely, the moisture removal rate and the heat transfer rate are influenced both by the air velocity and desiccant flow rate. The result shows that high air velocity will obtain the fast air dehumidification but has low effectiveness and high liquid desiccant will obtain high.

Keywords: Dehumidifier, Effectiveness, Lithium chloride, Flow rate, Packing tower

Nomenclature

\begin{itemize}
  \item \(\omega\) : humidity ratio (kg'/kg air)
  \item \(\dot{m}\) : mass flow rate (kg/s)
  \item \(p\) : saturation pressure, Pa
  \item \(T\) : absolute temperature, K
  \item \(\varepsilon\) : dehumidifier effectiveness
\end{itemize}

Subscript

\begin{itemize}
  \item \(\text{in}\) : inlet
  \item \(\text{out}\) : outlet
  \item \(\text{des}\) : desiccant
  \item \(w\) : water vapour
  \item \(ws\) : water saturated
1. Introduction

Humid air can cause mold and mildew to grow inside homes, which has various health risks. To be comfortable, people require a certain amount of ambient humidity.

An air-vapor condensation method could be one of those in the cooling system. When the air is cooled by below dew point the humidity can be reduced. This system has merits of high effectiveness of heat transfer, compact size and convenience for operation. But it is inefficient since it needs additional energy to overcool and reheat the air to achieve both temperature and humidity set-point.

Air dehumidification process also can be achieved by absorption/adsorption of moisture by a solid or liquid desiccant. The unique beneficence they have is that the sensible and the latent heat can be processed separately. And it is found that desiccant systems are quite efficient in dealing with the latent load.

Liquid desiccant have several advantages over solid desiccant. The pressure drop through the liquid desiccant is lower than that through a solid desiccant system and can be stored for regeneration by some inexpensive energy such as solar energy and waste heat. Liquid desiccant system combined with vapor compression system can reduced area of evaporation and condensation by 34%, and power consumption by 25%, compared with vapor compression system alone [1]

Zurigatet al. [2] investigated the performance of an air dehumidifier using triethylene glycol (TEG). The performance of the dehumidifier was evaluated and expressed in terms of the moisture removal rate and the dehumidifier effectiveness.

Many researchers have developed analysis of the coupled heat and mass transfer dehumidifier processes in steady state.

This paper presents a experimental research on results of effectiveness in a regenerator with packed bed liquid desiccant dehumidifier in unsteady state condition. It is suitable for the high desiccant flow rate conditions that are used in practical dehumidification column.

2. Experiment set-up and methods

The experimental apparatus was designed for keeping the flow rate constant during the experiment. The flow rate of air and liquid desiccant are 110 m³/h and 5kg/m²s respectively. The main packed layer was constructed with an acrylic and the volume was 35cm(in height) x 35cm(in width) x 30cm(in length).

In the experiment, the porous plastic was used as a packing material because it allowed the flow of the desiccant to be wide and uniform along with downward. Many plastic packing materials were stuffed inside the packed layer at random and each one has a height of 3cm and a diameter of 3cm.

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load chamber volume</td>
<td>40m³</td>
</tr>
<tr>
<td>Packed tower dimension</td>
<td>0.4m x 0.4m x 0.4m</td>
</tr>
<tr>
<td>Liquid lithium chloride Volume</td>
<td>70cm x 50cm x 15 cm</td>
</tr>
<tr>
<td>Air input and output cross section area</td>
<td>R=6 cm</td>
</tr>
</tbody>
</table>

On the other hand, a regenerator consists of a fan, a heat exchanger, and a pump. The liquid desiccant is normally heated by hot water which was generated by solar thermal energy. The temperature of air stream and humidity entering and leaving the packed layer were measured just before around entrance and exit respectively. Lithium chloride with about 28(w.t.)% of concentration was used as liquid desiccant. The loop of liquid desiccant regenerating process is shown in Figure 1.
3. Theoretical analysis

A packed layer is filled with lots of packing materials. Desiccant trickles down from the top wetting the surface of the packing materials, while air is induced from the bottom as shown in Figure 2.

The driving force for regenerations is the difference at between equilibrium vapor pressure of the desiccant and the partial pressure of vapor in the air. As long as the partial pressure of the desiccant is higher than that of the air, mass transfer can take place from the solution to the air.

The theoretical analysis of the heat and mass transfer in a packed column was derived from Treybal’s work[8] on adiabatic gas absorption.

\[
L - L_1 = G(Y - Y_i)
\]

This relationship is fairly complex and will be developed in manner of Olander. The mass transfer rate per tower cross sectional area and the mass transfer resistance in the liquid phase is negligible.

\[
N_vM_vadZ = -GdY
\]

Sensible heat at gas side, as energy rate per tower cross sectional area, is the following:

\[
quad q_GadZ = h_Ga(t_G - t_i)dZ
\]

Enthalpy balance based on the envelope I sketch in Figure 3.

\[
GH - \{G(H + dH) - GdY[C'_v(t_G - t_0) + \lambda_0]\} = quad q_GadZ
\]

\[
G'dY = k_Ga(Y_i - Y)dZ
\]
4. Experimental result and analysis

The psychometric diagram shows that higher air velocity and desiccant flow rate has the lowest final air humidity ratio.

![Psychrometric analysis chart](image)

Fig 3. Psychrometric chart of air velocity variations

Since the load chamber is adiabatic, higher desiccant flow rate and air velocity causes the amount of air that contacted with lithium chloride is higher.

![Humidity ratio input](image)

Fig 4. Humidity ratio input of desiccant flow rate variations

The highest air velocity has highest differences for humidity ratio from 1.5x10^-2kg'/kg became 0.6x10^-2kg'/kg. This condition is also similar with experiment result in different flow rate shown on Fig. 4.

![Heat Transfer Rate](image)

Fig 5. Heat transfer rate of air velocity variations
The heat transfer can be known by enthalpy difference system between inlet and outlet side of the packed tower. With referenced to the Fig 5 and Fig 6, this slope indicates that dehumidifying process is done faster on higher air velocity with rather caused by a high of the air flow rate then the effectiveness of the humidifier process.

5. Conclusion

The experiments research of a dehumidifier has been verified based on the actual experiment data from different flow rate. In this paper, it has indicated that a method is to calculate volumetric mass transfer rate and effectiveness for liquid-air contacting in the packed layer, for the air and liquid desiccant flow rates are 2m/s, 3m/s, 4m/s/h and 4l/min, 6l/min, 8l/min. respectively.

The theoretical model of a dehumidifier has been verified based on the actual experiment data from air side. This analysis was adopted as the same fashion to figure out the most suitable flow rate ratio for dehumidification in the packed layer and conclusions are as follows;

The load chamber in this experiment was conditioned on adiabatic. The result shows that higher air velocity will obtain the faster air dehumidification, but it has low effectiveness. In addition the higher desiccant flow rate will obtain larger effectiveness for the early time, but slowly come down after 10 minutes of experiment.

6. Acknowledgement

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7. References


