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Experimental study of correlation between aqueous lithium chloride-air temperature difference and mass transfer performance

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Abstract

Liquid desiccant material, such as lithium chloride (LiCl) or halide salts are usually used on air conditioning application for controlling the humidity of high Outdoor Air (OA). Solar energy is usually used to heat the liquid in regeneration process of those desiccant. The mass transfer it self is driven by the temperature different between the liquid desiccant and the input air. This experiment study is analyzing the characteristic of the aqueous LiCl-air temperature different in variance specific gravity. especially in range of temperature different using the solar energy as the heat generator.

The experiment has done by variating the concentration of the LiCl with specific gravity 1.210 and 1.150. For the comparison the pure water is also used. The result show that the mass transfer rate is increased in every variation as the increases of the temperature different. and the weeker aqueous solution of the LiCl the highest mass transfer coefficient

Keywords : Liquid desiccant, Lithium chloride, Performance, Aqueous, Mass transfer

Nomenclature

ϕ	: Concentration(mol/m^3)
ω	: Humidity(kg$_m$/kg$_{da}$)
p	: Partial pressure
m	: Mass (kg)
V	: Volume (m^3)
M_r	: Molar mass (kg/mol)
k_c	: mass transfer coefficient (m/s)
$\dot{n}$	: mass transfer rate (mol/s)

1. Introduction

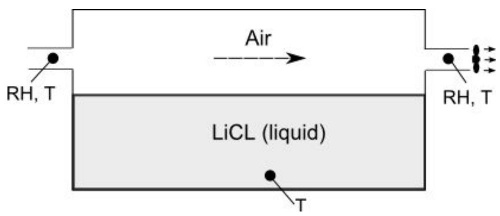
Liquid desiccant air conditioners are an approach to effectively manage humidity under challenging conditions such as buildings with high outdoor air (OA) requirements located in humid regions. They remove moisture and latent heat (and, possibly, sensible heat) from process air via a liquid desiccant material, such as lithium chloride (LiCl) or halide salts.[1,2]

Liquid desiccant AC has two essential components, an absorber and a regenerator. In a basic configuration, strong and cooled liquid desiccant flows into the absorber and down through a packed bed of granular particles (or other enhanced mass transfer surface or packing). In regeneration phase, the weak and heated desiccant meets the cool air to get the heat and mass transfer. The regeneration phase can be driven by solar energy that is renewable, clean and free. Therefore the characteristic of the desiccant especially related to it performances should be studied deeply.

Due to the importance of the characteristic of the mass transfer in desiccant, this study will analyze the mass transfer rate for the lithium chloride (LiCl) type desiccant. This study is focused in regeneration process driven by temperature different that usually generated by solar energy. The best performance of the process the saver energy will be obtained.

2. Experimental apparatus

Experiment apparatus in this study is simple, an isolated chamber is half filled with desiccant. then the air is flowed trough the surface of that liquid desiccant. The temperature before and after passing the surface are monitored. the detail of the apparatus can be seen in figure 1.



Picture 1 experimental apparatus

The blower is small centrifugal fan single inlet providing air flow 30 m^3/s. The chamber wall is fully isolated to avoid heat losses. Table 1 shows the detail configuration of the apparatus.

table 1. Apparatus configuration

parameter	value
Chamber material	Plastic
area	0.14 x 0.28 m^2
height	0.1 m
liquid height	0.05 m

3. Experimental method

The experiment was done by varying the air LiCl specific gravity in 2 and 3 and also compare it with pure water. The other parameters are controlled at constant value.

The experiment is started with heating the liquid in specific temperature (70°C). and then turn the blower on and start monitoring the all sensor data including the air properties of the inlet and outlet and also the liquid temperature. Table 3 shows the parameters used in this experiment.

table 3. experimental parameters

parameter	value
LiCl specific density variation	1.210 and 1.150
LiCl initial temperature	70℃
air input properties	27%RH, 21℃
air velocity	1.2 m/s

Properties of air are calculated using ASHRAE standard formula [4]. Data obtained from experiment are temperature and relative humidity of the air input and output of structured packed tower. The humidity ratio is defined using this formula

$$\phi = \frac{p_w}{p_{ws}} \qquad (1)$$

as long as the relative humidity and the saturated pressure are known, the partial pressure of water vapor is obtained. Saturation vapor pressure which is a function of temperature can be calculated using Eq 2.

$$\ln p_{ws} = \frac{C_1}{T} + C_2 + C_3 T + C_4 T^2 + C_5 T^3 + C_6 T^4$$

where

$C_1 = -5.8002206 \times 10^3$
$C_2 = 1.3914993$
$C_3 = -4.8640239 \times 10^{-2}$
$C_4 = 4.1764768 \times 10^{-5}$
$C_5 = -1.4452093 \times 10^{-8}$
$C_6 = 6.4549673$

(2)

using the air temperature and relative humidity data got from the sensors put in input and output of the chamber, the vapor pressure is obtained. And then the humidity ratio of the air can be calculated by Eq.3

$$\omega = 0.62198 \frac{p_w}{p - p_w} \quad (3)$$

Formulas to get the moisture concentration are described in Eq 4 - Eq 12.

$$humidity(\omega) = \frac{m_m}{m_{da}} \quad (4)$$

$$specific\ volume(v) = \frac{V_{(m+da)}}{m_{da}} \quad (5)$$

$$density(\rho) = \frac{m_{(m+da)}}{V_{(m+da)}} \quad (6)$$

$$concentration(\phi) = \frac{n_m}{V_{(m+da)}} \quad (7)$$

$$\phi = \frac{m_m}{M_r V_{(m+da)}} \quad (8)$$

based on Eq 4, the mass of the moisture is obtained as Eq.9

$$m_m = \omega\, m_{da} \quad (9)$$

$$\phi = \frac{\omega\, m_{da}}{M_r V_{(m+da)}} \quad (10)$$

4. Results and discussions

Fig. 1 shows the comparison between humidity different and temperature different. the higher humidity different shows the water transferred from liquid into the air stream is higher. The pure water shows the higher humidity different between inlet and outlet following by weak LiCl concentration (ɣ 1.150) and strong LiCl (ɣ 1.210). Both of them show the increment of the humidity different as the temperature increases.

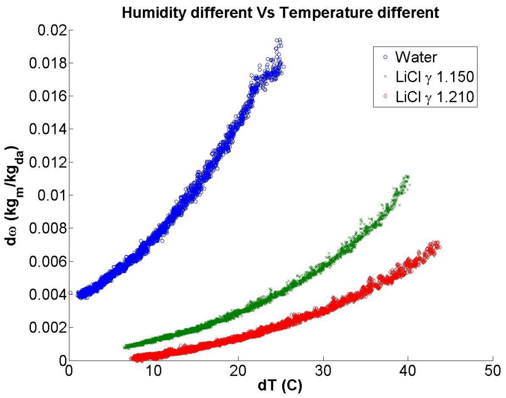


Figure 1 Humidity different

Mass transfer rate is obtained from above equation. In this figure. the mass transfer rate of the pure water shows the highest performances.

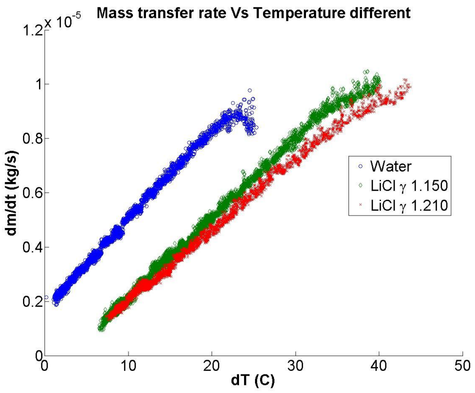


Figure 2 Mass transfer rate

The mass transfer coefficient is obtained from upper equation and can be seen from figure 2 bellow

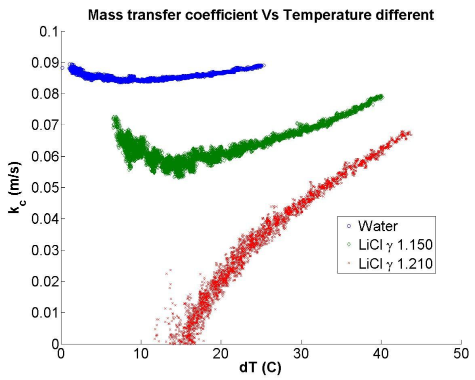


Figure 3 mass transfer coefficient

the mass transfer coefficient is related to the mass transfer rate, but as shown an Fig 3 that the curve is parabolic, its mean there is a minimum temperature different on performance profiles. Hence the study about this should be developed more to get more detail about this phenomena.

Conclusions

Experimental results of correlation between the aqueous lithium chloride-air temperature different has already done with results the weaker solution of LiCl will perform higher mass transfer rate indicated with the higher mass transfer coefficient.

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