HEAT AND MASS TRANSFER IN CIRCULATING DESSICANT AIR DEHUMIDIFIER

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Abstract—In the present work, a novel circulating desiccant air dehumidifier is numerically and experimentally investigated. Experimental tests and numerical analysis are conducted to investigate the adsorption and desorption processes in fluidized and packed bed columns which are connected via two inclined tubes. The dehumidification process occurs in the packed bed and regeneration process is carried out in the fluidized bed. Silica gel is used as a working desiccant, and its flow rate is controlled using manual valves. The experimental setup is designed, constructed and described. Silica gel is transferred continuously by gravity to the fluidized bed and particles fluidization to the packed bed. A simulation computer code was developed to predict the performance of the system and analyze its sensitivity to the main operating parameters. Results show that when applying intercooling between the two columns a significant improvement in adsorption process is observed. A satisfactory regeneration rate is confirmed at a regeneration temperature of 90 °C. The adsorption and desorption rates are dependent on the initial humidity of air. It was found that circulation rate is optimal when the bottom valve opening is 30 %. In the proposed system, continuous processes of adsorption and desorption and steady state moisture transfer rate during these processes are achieved.

NOMENCLATURE

A Cross section of area, m²
a Specific surface area of the bed, m²/m³
c Specific heat, kJ/kg.k
dz Element height, m
g Gravitational constant, m/s²
h Heat transfer coefficient, W/m².k
H Height, m
hm Mass transfer coefficient, Kg/m².s
L Length, m
ṁ Mass flow rate, kg/s
m Weight, kg
q_oper Heat of sorption, kJ/Kg_w
P Pressure, pa
T Temperature, °C
t Time, sec
u Velocity, m/s
u_o Minimum fluidization velocity, m/s
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Greek letters

- \( \mu \): Air Dynamic viscosity, N.s/m²
- \( \omega \): Specific humidity of air, g/kg
- \( \nu \): Air Kinematic viscosity, m²/s
- \( \rho \): Air Density, kg/m³
- \( \varepsilon_b \): Porosity
- \( \varepsilon_o \): Porosity at minimum fluidization

Subscripts

- \( a \): Air
- \( f \): Fluidized
- \( i \): Initial
- \( o \): Outlet
- \( r \): Regenerator
- \( s \): Silica gel
- \( v \): Vapor
- \( P \): Packed bed

Abbreviations

- \( Ad \): Adsorption process
- \( da \): Dry air
- \( De \): Desorption process
- \( ds \): Dry silica gel
- \( Op \): Opening
- \( Re \): Reynolds number
- \( RH \): Relative humidity, %
- \( S \): Silica gel
- \( Sat \): Saturation
- \( Vl \): Valve
- \( Pr \): Particle

I. INTRODUCTION

IR dehumidification is one of the most important processes for many practical applications like air conditioning [1], air drying [2], solar cooling [3] and water production from atmospheric air [4-5]. Desiccant dehumidification systems are considered good alternative for the commonly used air-conditioning systems that can offer reduction in energy consumption. The drying process contributes approximately 12% of the total energy used in industrial sectors worldwide [6]. Desiccant materials can be liquid or solid. For liquid, a deliquescent material such as calcium and lithium chlorides perform absorption, while solid desiccants can be either polymer sorbent or a porous material such as silica gel, alumina silicate and zeolite. Many desiccant-dehumidifiers have been investigated including a solid-packed bed [7] rotating honeycomb [8] and a fluidized bed [9]. Air-solid fluidized beds, in which solid particles are fluidized by a air injected from the bottom, have been used extensively in chemical, petrochemical, metallurgical, food and pharmaceutical industries. One of the advantages of fluidized bed is the high rates of heat and mass transfer between the air and particles compared with other modes of contact [10]. A fluidized bed is also characterized by a uniform temperature throughout, unlike fixed bed.

This can be very useful in increasing desorption of the sorbent in a desiccant chamber. The efficiency of the process is improved when the desiccant has a high moisture capacity and a large surface area [11].

In a two-bed system the fluidized desiccant is circulated continuously between the two chambers by spiral tubes with geared motors [12], or by transferring from chamber to another by gravity. The sorbent can be circulated due to the difference in the air flow velocity between the two chambers.

Reichhold and Hofbauer [13] investigated an internally circulating fluidized bed for continuous adsorption and desorption, using an inorganic sorbent. Akhiiko and Sukmawaty [12] have studied a two fluidization bed system with an organic sorbent. Hamed [14] developed a system in which an inclined-fluidized bed using silica gel as sorbent. Circulation of silica gel occurs in the same tube due to inclination and homogenous distribution of moisture concentration through the whole tube is approved. Ramzy et al [15], investigated an intercooled packed bed to increase the utilization of desiccant material in the trailing layers of the bed and attain homogenous distribution of moisture concentration through the whole bed.

In this study, a novel double column desiccant dehumidification system is demonstrated; blue indicating silica gel is used as an adsorbent. A mathematical model for heat and moisture transfer is presented and validated. The utilization of a simple cooling heat exchanger is investigated.

II. EXPERIMENTAL SETUP AND PROCEDURE

A schematic diagram of the experimental setup is shown in Fig. 1. The setup consists of four main parts; dehumidifier (packed bed) and regenerator (fluidized bed) tubes for air dehumidification and desiccant regeneration respectively, air supply unit (with and without heater), and desiccant cooler. The process air supply flows to the dehumidifier and the hot air stream enters the regenerator. The dehumidifier (PVC) and regenerator (Glass), tubes are connected with two inclined tubes; one of them is a desiccant cooler as shown in the figure.

The dehumidifier tube is a 2" diameter and 80 cm length PVC tube, packed with silica gel particles to dehumidify the process air. The PVC tube has a rectangular glass window to observe the motion of silica gel particles as shown in Fig. 2. The regenerator tube is a 2" inch diameter and 150 cm length glass tube. The tube is supported in a vertical position and contains fluidized silica gel to be regenerated.

The desiccant cooler consists of two concentric tubes, where 2" copper tube inside another 3" PVC tube. The tube has two openings in the lower and upper ends for the cooling water inlet and exit; respectively, as shown in Fig. 1. The lower inclined tube connection is a 60 cm length and 2"
diameter PVC tube, to transfer silica gel for regeneration purpose.

The dehumidifier and regenerator tubes are connected with two inclined tubes via four Y connections (Y1, Y2, Y3 and Y4), as shown in the figure. The Y1 receives the hot air entering through a metallic screen from lower end and is connected to the regenerator from the top. The Y2 receives the process air entering through a metallic screen from lower end and is connected to the dehumidifier from its upper end.

The Y3 is connected to the dehumidifier tube from its lower end. The Y4 is connected to the regenerator from its lower end. A metallic screen is supported to the upper end of Y4 to prevent desiccant particles from flying outside the regenerator tube. The upper and lower 2" steel ball valves (5, 6) are used to adjust the silica gel transfer rate from one column to the other.

Air is supplied from a tank (of a reciprocating compressor) to the system. The air is divided into two streams; process air which undergoes an adsorption process in the dehumidifier tube, while regeneration hot air stream is blown to the regenerator column. An electric heater is fitted to the regeneration air pipe. The heater is adjusted to control the regeneration temperature.

The electric heater is a heating element of Nickel-Chrome coil (10 kW) inside 3" diameter pottery and 40 cm length pipe. The heater is covered with glass wool thermal insulation of 0.5" thickness and 4" diameter PVC pipe for protection. The variac shown in Fig. 2 is used as a temperature controller. Air flow rate through the heating coil is controlled with a manual valve. The setup is suitably instrumented to measure the relative humidity and temperature of the air at the inlet and exit of the system. The relative humidity is measured by thermal-hygrometers (Testo-435/636) with a time constant < 10 sec and accuracy of ±2.0 %.

E-type thermocouples for temperature measurements were connected to digi-sense scanning thermometer 12 point recorder with accuracy of ±0.5°C.

The readings of the thermocouples and hygrometer are recorded with a sampling rate of 1 sec, using data acquisition system. Blue indicating silica gel is used as the desiccant material during the experimental tests. The particle density is 1200 kg/m³, and the average particle diameter is 3.5 mm. Locations of the hygrometer props and thermocouples are shown in Fig 1.

III. MATHEMATICAL MODEL

The energy and moisture conservation equations are applied to incremental volume with the tube diameter and height dz, of silica gel particles considering the following assumptions:

1. Humid air flow behaves as ideal gas mixture, and contains only water vapor as adsorbate.
2. Moisture diffusion and Heat conduction are neglected compared to convective heat transfer.
3. Air flow stream is uniform and in the axial direction only.
4. Lumped capacitance method is adopted for the energy and moisture balances for fluidized bed column.
5. Porosity along the packed bed is uniform.
6. The exiting air can be considered in equilibrium with the silica gel particles in the packed and fluidized beds.
7. The heat and mass transfer occurs only by forced convection.
Fig. 2. Photograph of the experimental setup

Equations from (1-4) describe the flow in the dehumidifier tube and from (5-6) refers to regenerator tube.

Applying the moisture balance equation on the air in the volume with column,

\[
\frac{d\omega_{a,x}}{dx} = -\frac{h_m(A)}{m_a} (\omega_{a,x} - \omega_{s,x}^*) \tag{1}
\]

Where, \( h_m \) is the mass transfer coefficient, \( A \) is the specific surface area, \( A \) is the cross section area of the column, \( \omega_{a,x} \) is the specific humidity of the air, \( \omega_{s,x}^* \) is the specific humidity of the adjacent air to silica gel particles and \( m_a \) is the air mass flow rate.

Applying the same equation to the silica gel particles,

\[
\frac{dw_z}{dt} = \frac{h_m(A)}{m_s} (\omega_{s,x}^* - \omega_{a,x}) \tag{2}
\]

Where, \( w_z \) is the water content of silica gel and \( m_s \) is the silica gel mass flow rate.

For air, if convective heat transfer coefficient is \( h \), the energy balance equation can be written as,

\[
\frac{dc_{a,x}}{dx} = -\frac{h(A)}{m_a} (T_{a,x} - T_{a,z}) \tag{3}
\]

Where, \( T_{a,z} \) and \( T_{a,x} \) are the temperatures of air and silica gel, \( c_a \) and \( c_s \) are the specific heats of air and silica gel respectively.

If \( q_A \) is the heat of sorption, the silica gel energy balance equation can be derived as,

\[
\frac{d(C_{s,x})}{dx} = \frac{q_A(m_s(A))}{m_s} (\omega_{s,x}^* - \omega_{a,x}) + \frac{h(A)}{m_s} (T_{s,x} - T_{a,x}) \tag{4}
\]

The initial and boundary conditions are, at \( z = 0 \): \( T = T_a \) and \( \omega = \omega_a \). From isotherm equation (7), suitable assumption for \( w \) at the bottom of the dehumidifier and \( T_s \) at \( z=0 \) can be obtained.

Due to the rapid movement of particles in the fluidized bed, the temperature of the bed particles can be considered independent of location. Assuming the regenerator is one unit, the heat balance equation is written by [16] as,

\[
\frac{T_{rai}-T_{so}}{T_{rai}-T_{so}} = \exp \left( -\frac{\rho_a c_a \, m_a}{\rho_s c_s (1-\varepsilon_f) L_f} t \right) \tag{5}
\]

Where, \( T_i \) is the silica gel temperature after time \( t \), and \( T_{so} \) is its initial temperature, \( T_{rai} \) is the regenerator hot air temperature, \( L_f \) and \( \varepsilon_f \) are the height of bubbling fluidized bed and void fraction in regenerator respectively.

For calculating the water content of silica gel at the fluidized bed, variable water content along the bed is considered [17]. Therefore the moisture balance equation is,

\[
\frac{dw}{dt} = \frac{a h_m}{(1-\varepsilon_f) p_s} (\omega_{rai} - \omega_{rdo}) \tag{6}
\]

At equilibrium, relative humidity of air, \( RH \) can be evaluated in terms of temperature, \( T \) and water content in silica gel \( w \), as given in Ref [18].

\[
RH = c_1 T w^2 + c_2 T w + c_3 w^4 + c_4 w^5 + c_5 w^2 + c_6 w \tag{7}
\]

Where \( c_1, c_2, c_3, c_4, c_5 \) and \( c_6 \) are given by:

\[
\begin{align*}
    c_1 &= 125.470047, & c_2 &= 0.04031298, & c_3 &= 0.02170245, \\
    c_4 &= 72.651229, & c_5 &= 15.5223665, & c_6 &= 0.0084266
\end{align*}
\]

The heat transfer coefficient, \( h \) and the mass transfer coefficient, \( h_m \) are given by [19] as,

\[
\begin{align*}
    h &= 0.732 \rho_a c_a v Re^{-0.51} \tag{8} \\
    h_m &= 0.683 \rho_a v Re^{-0.51} \tag{9}
\end{align*}
\]

The values of \( c_1, c_2, c_3 \) and \( c_4 \) are calculated as [19],

\[
\begin{align*}
    c_1 &= 4.186 w + 0.92 \tag{10} \\
    c_2 &= 1.884 w_a + 1.004 (1 - \omega_a) \tag{11}
\end{align*}
\]

The heat of adsorption, \( q_A \) is calculated as [19],

\[
q_A = \begin{cases} (3500 - 12400 w) & w \leq 0.05 \\ (2950 - 14000 w) & w > 0.05 \end{cases} \tag{12}
\]

The value of \( \omega_{s,x}^* \) is calculated as follows,

\[
\omega_{s,x}^* = \frac{0.622 RH P_{sat}(T_s)}{P_{sat} - RH (T_s)} \tag{13}
\]

Where, \( P_{sat} \) is the saturation vapor pressure.

Equations from 1 to 13 are solved numerically using finite difference method forward scheme using Matlab (R2014b). Validation of the mathematical model is carried out by comparing the numerical results with the experimental data. Since the numerical results are not depending on the element height < 10 mm as shown in Table (1), a mesh of 3.5 mm is used.
TABLE 1. EFFECT OF ELEMENT HEIGHT ON THE SOLUTION

<table>
<thead>
<tr>
<th>Element height dz, mm</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 50</td>
<td>Error and not steady</td>
</tr>
<tr>
<td>40</td>
<td>Error and not steady</td>
</tr>
<tr>
<td>20</td>
<td>not steady</td>
</tr>
<tr>
<td>10</td>
<td>No variation</td>
</tr>
<tr>
<td>1</td>
<td>No variation</td>
</tr>
<tr>
<td>&lt; 1</td>
<td>No variation</td>
</tr>
</tbody>
</table>

IV. RESULTS AND DISCUSSION

The performance of the desiccant air dehumidifier during adsorption and desorption modes is evaluated by conducting a series of experimental tests at different inlet conditions. The following parameters are also evaluated and recorded with time:

- Water content in the bed.
- Vapor pressure in air stream at exit.
- Rate of adsorption.
- Rate of desorption.
- Specific humidity of air.

The water content of the sorbent is obtained by using the linear fitting of equilibrium data for silica gel [18]. The air flow condition and bottom valve opening in each test is listed in Table (2).

During each test, air inlet and exit parameters are recorded with time. Due to the rapid change of air outlet parameters during the starting period, measurements are recorded at small time intervals of 1 sec. Temperature and humidity of air at the dehumidifier exit are used to evaluate the properties of air and bed respectively.

TABLE 2. AIR FLOW CONDITIONS AND BOTTOM VALVE OPENING FOR TESTS (1-9).

<table>
<thead>
<tr>
<th>Test</th>
<th>Tai, °C</th>
<th>Tr, °C</th>
<th>ωao, g/kg.a</th>
<th>uao, cm/min</th>
<th>uai, m/s</th>
<th>uao, m/s</th>
<th>Bottom valve op. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>35</td>
<td>80</td>
<td>12.2</td>
<td>8.9</td>
<td>0.9</td>
<td>1.9</td>
<td>30</td>
</tr>
<tr>
<td>2</td>
<td>25</td>
<td>80</td>
<td>6.3</td>
<td>38</td>
<td>0.9</td>
<td>1.9</td>
<td>40</td>
</tr>
<tr>
<td>3</td>
<td>24</td>
<td>80</td>
<td>6</td>
<td>8.9</td>
<td>0.9</td>
<td>1.9</td>
<td>30</td>
</tr>
<tr>
<td>4</td>
<td>19</td>
<td>80</td>
<td>6</td>
<td>--</td>
<td>0.9</td>
<td>1.9</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>23</td>
<td>80</td>
<td>6.1</td>
<td>--</td>
<td>0.9</td>
<td>1.9</td>
<td>47</td>
</tr>
<tr>
<td>6</td>
<td>22.5</td>
<td>65</td>
<td>6.4</td>
<td>8.9</td>
<td>0.9</td>
<td>1.9</td>
<td>30</td>
</tr>
<tr>
<td>7</td>
<td>21.5</td>
<td>100</td>
<td>6</td>
<td>8.9</td>
<td>0.9</td>
<td>1.9</td>
<td>30</td>
</tr>
<tr>
<td>8</td>
<td>23</td>
<td>50</td>
<td>6.3</td>
<td>8.9</td>
<td>0.9</td>
<td>1.9</td>
<td>30</td>
</tr>
<tr>
<td>9</td>
<td>25.5</td>
<td>120</td>
<td>6</td>
<td>8.9</td>
<td>0.9</td>
<td>1.9</td>
<td>30</td>
</tr>
</tbody>
</table>

Carried out at height of the silica gel particles, \( H_{sr} = 40 \) cm. Results indicate that the sorption–desorption rates are in balance (the amount of water vapor released from desorption column (\( \omega_{ai} - \omega_{ao} \)) was approximately the same as that adsorbed in the sorption column (\( \omega_{ao} - \omega_{ai} \)).

Figure 4. a and b shows the results of tests 1 and 3 while Table (3) shows the comparison between experimental and numerical data at dehumidifier exit for the same tests. It can be concluded that the current model predicts the performance of adsorption and desorption process in the dehumidifier and regenerator with an acceptable agreement. The absolute error between experimental measurement of temperature and air humidity and numerical solution for them is nearly 0.19 and 0.1 respectively.

TABLE 3. COMPARISON BETWEEN EXPERIMENTAL AND NUMERICAL DATA AT DEHUMIDIFIER EXIT.

<table>
<thead>
<tr>
<th></th>
<th>( \omega_{ao} (\text{g/kg.a}) )</th>
<th>( T_{ao} (^{\circ} \text{C}) )</th>
<th>( T_a (^{\circ} \text{C}) )</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Test 1</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Experimental</td>
<td>8.44</td>
<td>44.2</td>
<td>44.5</td>
</tr>
<tr>
<td>Numerical</td>
<td>8.54</td>
<td>44</td>
<td>44.3</td>
</tr>
<tr>
<td><strong>Test 3</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. Experimental</td>
<td>3.8</td>
<td>41</td>
<td>40.9</td>
</tr>
<tr>
<td>Numerical</td>
<td>3.9</td>
<td>41.19</td>
<td>41.1</td>
</tr>
</tbody>
</table>
Two preliminary tests are carried out without desiccant cooling, under the following conditions: \( H_s = 40 \text{ cm} \), valve opening 30\%, \( T_{ai} = 17 \, ^\circ\text{C} \), \( \omega_{ai} = 6.3 \, \text{g} / \text{kg} \), \( u_{ai} = 0.9 \, \text{m} / \text{s} \), \( u_{rai} = 1.9 \, \text{m} / \text{s} \), and \( T_{ra} = 50 \) and 100 °C. In this case, the silica gel particles surface has a high vapor pressure. Therefore, the value of \( \omega_{po} \) is approximately the same as \( \omega_i \) at the steady state and different values of \( T_{ra} \) as shown in Fig. (5).

When the desiccant cooler is used, the vapor pressure on the silica gel particles surface is decreased, and hence the process air humidity.

4.1 Adsorption tests

The test results, for exit air humidity, \( \omega_{ao} \) as well as the exit temperature, \( T_{ao} \) versus time for adsorption runs at different inlet parameters are presented in Figs. (6-11). All tests are conducted with cooler.
The value of $w_{ao}$ for different tests has nearly the same trend irrespective of inlet parameters. Also, $T_{ao}$ rises from initial value, which is nearly equal to the inlet temperature to a constant value at steady state.

**4.2 Adsorption and desorption rates**

The rates of moisture adsorption, $\dot{m}_{ad}$ and desorption, $\dot{m}_{de}$ can be evaluated as follows, \[20\]

\[\dot{m}_{ad} = (\omega_i - \omega_o) \dot{m}_a\] \hspace{2cm} (14)
\[\dot{m}_{de} = (\omega_o - \omega_i) \dot{m}_a\] \hspace{2cm} (15)

Where, $\dot{m}_a$ is the mass flow rate of air through the bed, $\omega_i$ and $\omega_o$ are the inlet and exit air specific humidity.

The value of $\dot{m}_a$ is calculated from,

\[\dot{m}_a = (\rho_o) A u\] \hspace{2cm} (16)

Where, $\rho_o$ is the exit air density, $A$ is the column cross section area and $u$ is the exit air velocity.

The rates of moisture adsorption and desorption for different tests are depicted in Figs. (12-15). These processes reach quickly steady state, but in some experiments, the rate is gradually decreased until steady state as shown in Fig. 15. This is because silica gel at the beginning of the run has low water content. Therefore, the rate of adsorption is high in the first few minutes until reaching the steady state.

The largest value of adsorption rate is dependent on $\omega_i$. For example, when $\omega_i = 12.2$ g/kg, the rate of adsorption is about 0.37 g/min at steady state as shown in Fig. 12. While this rate decreases to about 0.2 g/min for $\omega_i = 5.9$ g/kg as shown in Fig.
13. However, the adsorption rate is also affected by the initial mass of the bed and air flow rate.

![Fig. 12 Water adsorption rate with time (test1)](image1)

![Fig. 13 Water adsorption rate with time (test3)](image2)

![Fig. 14 Water desorption rate with time (test3)](image3)

4.3 Desorption tests

Figures (16-18) show the variation of $\omega_3$ and $T_{ao}$ with time during desorption processes. The humidity for different tests has nearly the same trend irrespective of the inlet regeneration temperature. The temperature of exit air stream rises from a lower value to a constant value at steady state.

![Fig. 15 Water adsorption rate with time (test 6)](image4)

![Fig. 16 Exit humidity and temperature with time for desorption (test 3)](image5)

![Fig. 17 Exit humidity and temperature with time for desorption (test 6)](image6)
The theoretical minimum fluidization velocity, $u_o$ is obtained from Ergun equation [21] as,

$$
(1.75 \frac{\rho_a}{D_{Pr} \varepsilon_0^3}) u_o^2 + \left( \frac{150(1-\varepsilon_0)}{D_{Pr}^2 \varepsilon_0} \right) u_o + (-\rho_s \rho_a) = 0
$$

(17)

The theoretical value obtained from this equation is approximately equal to the measured one, which is 0.53 m/s. A preliminary experiment shows that increasing the regenerator air velocity, increases the height of silica gel in the column as shown in Fig. 19.

It is an important tool in the study of continuous flow systems to characterize the flow and mixing in the column. For the present system, the value of $F_\phi$ depends on the bottom valve opening (%) and air velocity in regenerator column. The amount of silica gel used in the preliminary experiments is 1.8 and 0.9 kg in the dehumidifier and regenerator respectively. The initial bed heights are $H_{sd} = 80$ cm and $H_{sr} = 40$ cm. Figure (20) shows the effect of bottom valve opening (%) on $\omega_{ao}$. Increasing the valve opening, increases $\omega_{ao}$ until it reached a maximum value of $5.4 \text{ g}_v/\text{kg}_a$ at 40 %, then it decreases again.

4.5 Effect of regeneration temperature

The effect of $T_r$ on $\omega_{ao}$ is shown in Fig (21). Remarkable decrease in $\omega_{ao}$ could be noticed with the increase in $T_r$. The value of $\omega_{ao}$ decreases from $4.3 \text{ g}_v/\text{kg}_a$ to $2.7 \text{ g}_v/\text{kg}_a$ when $T_r$ increases from $50 \degree C$ to $120 \degree C$; respectively

4.4 Silica gel circulation flow rate

The average time taken for a silica gel particle in a particular system is known as residence time, $t_d$ and is obtained from [12],

$$
t_d = \frac{m_0}{r_0}
$$

(18)

Where, $m_0$ (kg) is the silica gel mass in the column and $F_\phi$ (kg/s) is the silica gel circulation flow rate.
A novel design for circulating desiccant air dehumidifier that combines packed and fluidized beds has been investigated. A theoretical model was developed to predict the performance of the system and analyze its sensitivity to the main operating parameters. The exit specific humidity, air temperature and water content in the bed obtained from the theoretical model are compared with those from experimental tests for different operating conditions. Results show that when applying intercooling between the two columns a significant improvement in adsorption process is observed. A satisfactory regeneration rate is confirmed at a regeneration temperature of 90 °C, at which exit humidity is 3.2 g_v/kg_a. The adsorption and desorption rates are found to be dependent on the initial humidity of air. The circulation rate is optimal when the bottom valve opening is 30 % at the same regeneration temperature and air velocity. Additionally, the sorption and desorption processes are nearly in balance at steady state.

### References


