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HEAT AND MASS TRANSFER IN CIRCULATING DESSICANT AIR DEHUMIDIFIER

انتقال الحرارة والكتلة فى مجفف هواء دوّار

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KEYWORDS:
packed bed, adsorption, desorption, fluidized bed, desiccant, silica gel

الملخص العربي:-فى هذا العمل تم عمل دراسة عملية وعددية لمجفف هواء دوار مبتكر. الاختبارات العملية والتحليلات العددية أُجريت لبحث عمليتى الإمتزاز(**Adsorption**) والإدمزاز (**Desorption**) فى عمودى المهد المعبأ والمهد المميع حيث يرتبطان بواسطة إنبوبتين مائلتين. عملية نزع الرطوبة تحدث فى المهد المعبأ وعملية اعادة التوليد تحدث فى المهد المميع. مادة السيليكا جل تم استخدامها كمادة ماصة فى هذا العمل، وتم التحكم فى معدل سريانها بواسطة صمامات يدوية. تم تصميم الجهاز التجريبى وإنشائه ووصفه بالتفصيل. تنتقل السيليكا جل باستمرار بالجاذبية الى المهد المميع، وبواسطة تمييع الجسيمات (**Particle fluidization**) الى المهد المعبأ. تم عمل محاكاة ببرنامج كمبيوتر للتنبؤ بأداء النظام وتحليل حساسية لمتغيرات التشغيل الأساسية. أظهرت النتائج أنه عند استخدام مبرد بينى بين العمودين وجود تحسين ملحوظ فى عملية الامتزاز. معدل اعادة توليد مرضيا بصورة مؤكدة عند درجة حرارة **90 ^{o}C**. وأن معدل الامتزاز والادمزاز يعتمد على رطوبة الهواء الابتدائية. كما وجد ان معدل إعادة التوليد مثالى عندما تكون فتحة الصمام السفلى **30%**. فى النظام المقترح، تم اختبار عملية الامتزاز والادمزاز ومعدل انتقال الرطوبة فى الحالة المستقرة خلال هذة العمليات وتم تحقيقة

***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 ^{o}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.**

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NOMENCLATURE

A	Cross section of area, m^2
a	Specific surface area of the bed, m^2/m^3
c	Specific heat, kJ/kg.k
dz	Element height, m
g	Gravitational constant, m/s^2
h	Heat transfer coefficient, W/m^2.k
H	Height, m
h_m	Mass transfer coefficient, Kg/m^2.s
L	Length, m
$\dot{m}$	Mass flow rate, kg/s
m	Weight, kg
q_A	Heat of sorption, kJ/Kg$_w$
P	Pressure, pa
T	Temperature, ^{o}C
t	Time, sec
u	Velocity, m/s
u_o	Minimum fluidization velocity, m/s

w Silica gel water content, Kg_w/kg_{ds}
z Axial position in the bed, m

GREEK LETTERS
μ Air Dynamic viscosity, $N.s/m^2$
ω Specific humidity of air, g_v/kg_a
ν Air Kinematic viscosity, m^2/s
ρ Air Density, kg/m^3
ε_b Porosity
ε_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

AIR 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℃.

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/m^3, and the average particle diameter is 3.5 mm. Locations of the hygrometer props and thermocouples are shown in Fig 1

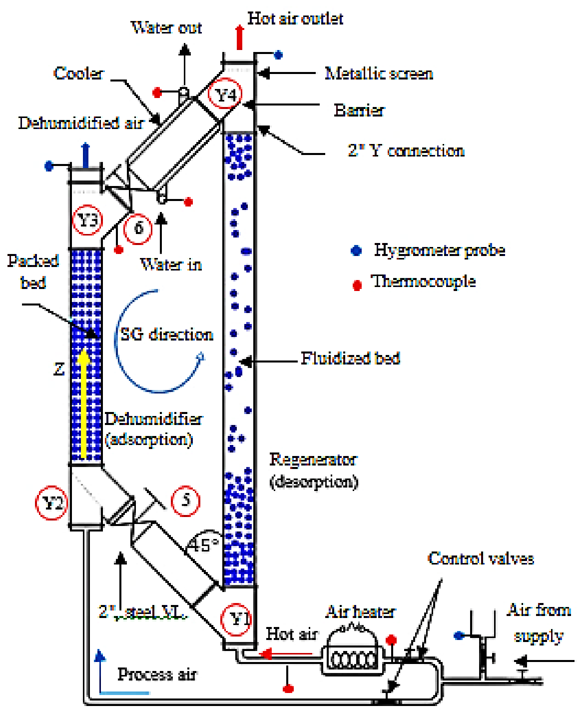

Fig. 1. Schematic diagram of the experimental setup

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.

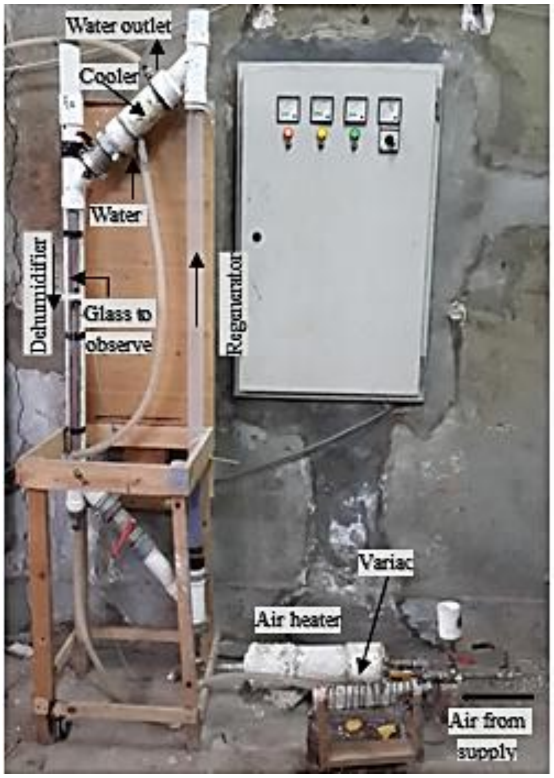

Fig. 2. Photograph of the experimental setup

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,

$$\frac{d\omega_{a,z}}{dz} = \frac{-h_m\,(aA)}{\dot{m}_a}\left(\omega_{a,z} - \omega^*_{s,z}\right) \quad (1)$$

Where, h_m is the mass transfer coefficient, a is the specific surface area, A is the cross section area of the column, $\omega_{a,z}$ is the specific humidity of the air, ω^*_s is the specific humidity of the adjacent air to silica gel particles and $\dot{m}_a$ is the air mass flow rate.

Applying the same equation to the silica gel particles,

$$\frac{dw_z}{dz} = \frac{h_m\,(aA)\,(\omega^*_{s,z} - \omega_{a,z})}{\dot{m}_s} \quad (2)$$

Where, w_z is the water content of silica gel and $\dot{m}_s$ *is* the silica gel mass flow rate.

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

$$\frac{dc_a T_{a,z}}{dz} = -\frac{h\,(aA)\,(T_{a,z} - T_{s,z})}{\dot{m}_a} \quad (3)$$

Where, $T_{a,z}$ and $T_{s,z}$ 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,

$$\frac{d(C_s T_{s,z})}{dz} = -\frac{q_A\,(h_m)\,(aA)}{\dot{m}_s}\left(\omega^*_{s,z} - \omega_{a,z}\right) + \frac{h\,(aA)}{\dot{m}_s}\left(T_{s,z} - T_{a,z}\right) \quad (4)$$

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,

$$\frac{T_{rai} - T_s}{T_{rai} - T_{so}} = exp\left(-\frac{\rho_a\,c_a}{\rho_s\,c_s}\frac{\dot{m}_a}{(1-\varepsilon_f)L_f}\,t\right) \quad (5)$$

Where, T_s 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 ε_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,

$$\frac{dw}{dt} = \frac{a\,h_m}{(1-\varepsilon)\rho_s}\left(\omega_{rai} - \omega_{rao}\right) \quad (6)$$

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],

$$RH = c_1 Tsw^2 + c_2 Tsw + c_3 w^4 + c_4 w^3 + c_5 w^2 + c_6 w \quad (7)$$

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

c_1 = - 0.04031298, c_2 = 0.02170245, c_3 = 125.470047, $c4$ = -72.651229, c_5 = 15.5223665 and c_6 = 0.0084266

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

$$h = 0.732\,\rho_a\,c_a\,v\,Re^{-0.51} \quad (8)$$

$$h_m = 0.683\,\rho_a\,v\,Re^{-0.51} \quad (9)$$

The values of c_s and c_a are calculated as [19],

$$c_s = 4.186\,w + 0.92 \quad (10)$$

$$c_a = 1.884\,\omega_a + 1.004\,(1 - \omega_a) \quad (11)$$

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

$$q_A = \begin{cases} (3500 - 12400\,w) & w \le 0.05 \\ (2950 - 1400\,w) & w > 0.05 \end{cases} \quad (12)$$

The value of ω^*_s is calculated as follows,

$$\omega^*_s = \frac{0.622\,RH\,P_{sat}\,(T_s)}{P_a - RH\,(T_s)} \quad (13)$$

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

Element height dz, mm	Solution
> 50	Error and not steady
40	Error and not steady
20	not steady
10	No variation
1	No variation
< 1	No variation

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).

Test	Tai, °C	T_r, °C	ω_{ai}, g_v/kg_a	u_s, cm/min	u_{ai}, m/s	u_{rai}, m/s	Bottom valve op. (%)
1	35	80	12.2	8.9	0.9	1.9	30
2	25	80	6.3	38	0.9	1.9	40
3	24	80	6	8.9	0.9	1.9	30
4	19	80	6	--	0.9	1.9	100
5	23	80	6.1	--	0.9	1.9	47
6	22.5	65	6.4	8.9	0.9	1.9	30
7	21.5	100	6	8.9	0.9	1.9	30
8	23	50	6.3	8.9	0.9	1.9	30
9	25.5	120	6	8.9	0.9	1.9	30

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 (ω_{rao}-ω_i), was approximately the same as that adsorbed in the sorption column (ω_{ai}-ω_{ao}).

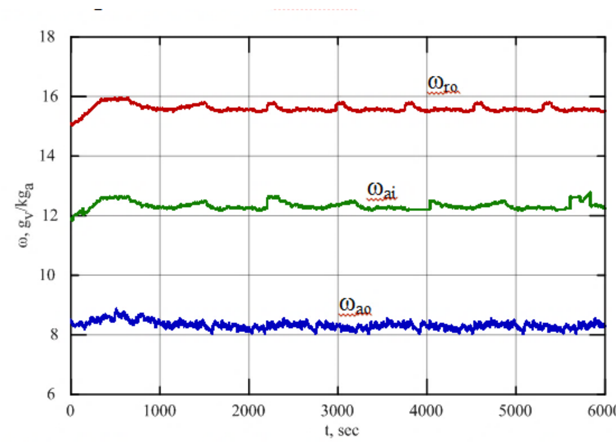

Fig. 3 The specific humidity versus time of (test 1)

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.

		ω_{ao} (g_v/kg_a)	T_{ao} (°C)	T_{si} (°C)
		Test. 1		
a	Experimental	8.44	44.2	44.5
	Numerical	8.54	44	44.3
		Test. 3		
b	Experimental	3.8	41	40.9
	Numerical	3.9	41.19	41.1

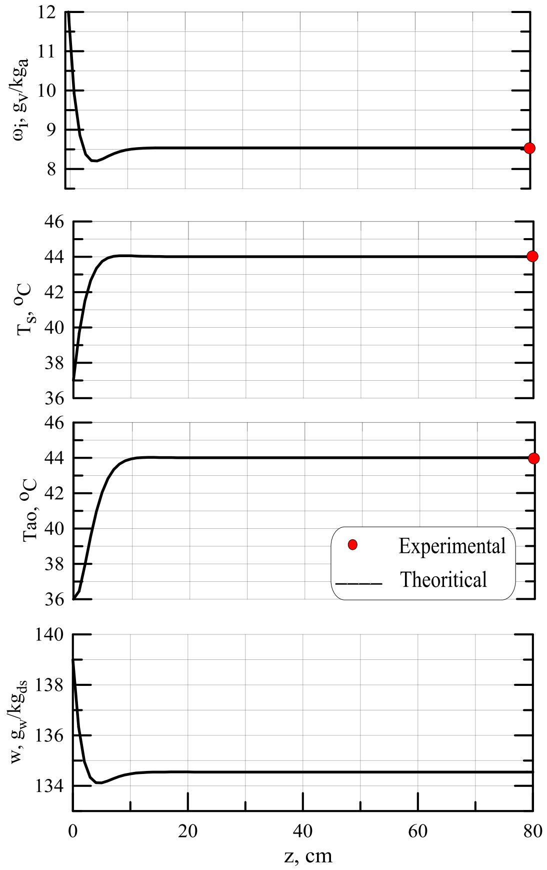

Fig. 4 a (Test 1).

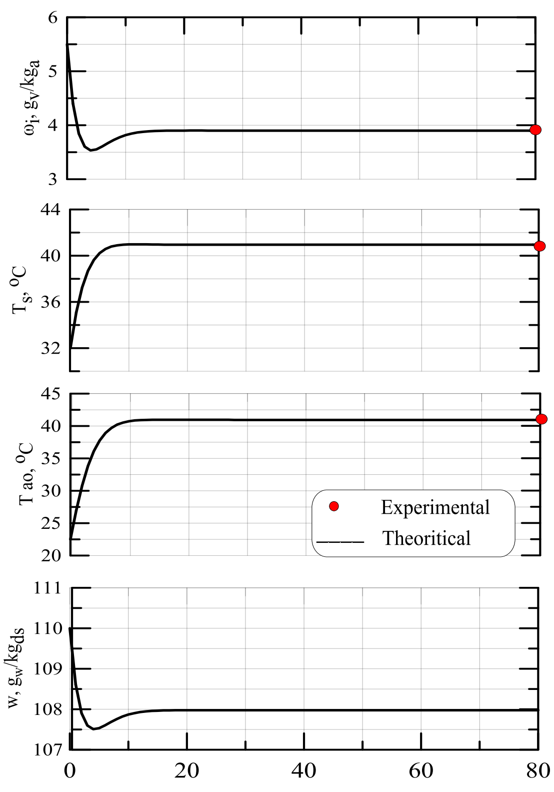

Fig. 4 b (Test 3)

Two preliminary tests are carried out without desiccant cooling, under the following conditions: H_{sr} = 40 cm, valve opening 30%, T_{ai} = 17 ^oC, ω_{ai} = 6.3 g_v/kg_a, u_{ai}= 0.9 m/s, u_{rai} = 1.9 m/s and T_{ra} = 50 and 100 ^oC. In this case, the silica gel particles surface has a high vapor pressure. Therefore, the value of ω_{po} is approximately the same as ω_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

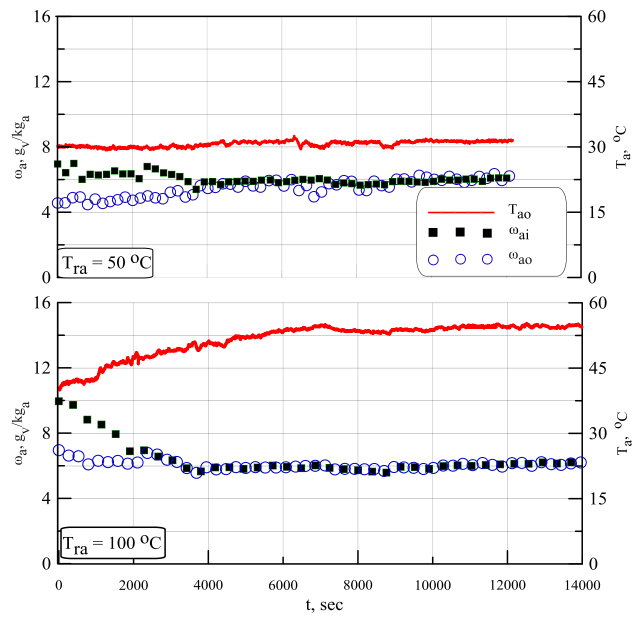

Fig. 5 Exit humidity and temperature with time for tests without cooler

4.1 Adsorption tests

The test results, for exit air humidity, ω_{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.

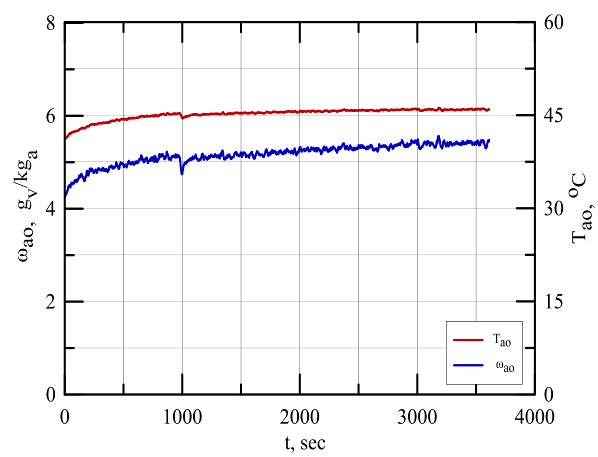

Fig. 6 Exit humidity and temperature with time for adsorption (test 2):

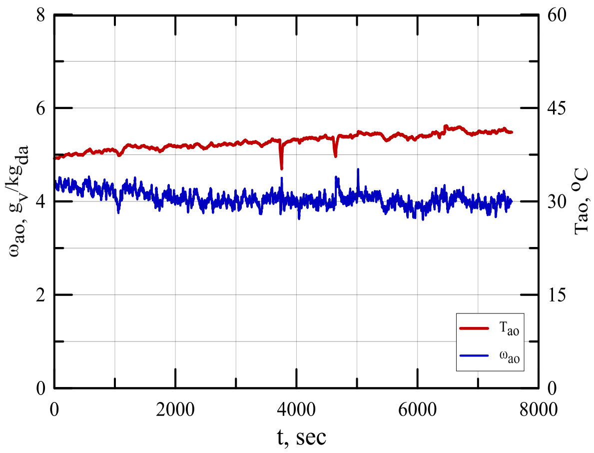

Fig. 7 Exit humidity and temperature with time for Adsorption (test 3):

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.

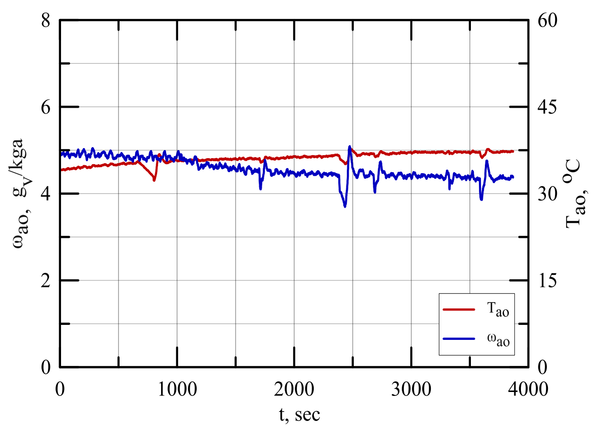

Fig. 8 Exit humidity and temperature with time for Adsorption (test 4):

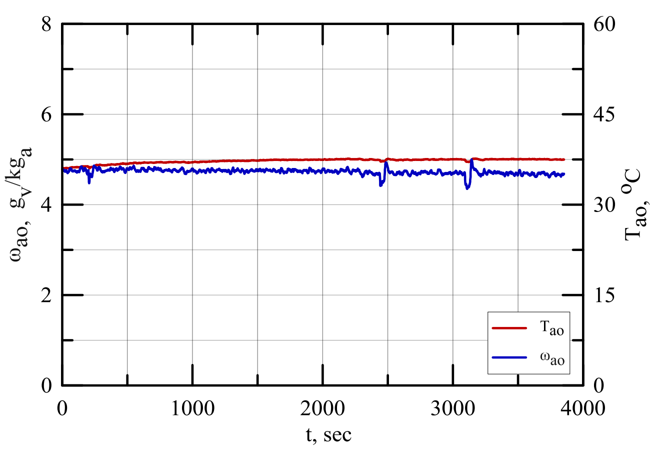

Fig. 9 Exit humidity and temperature with time for Adsorption (test 5)

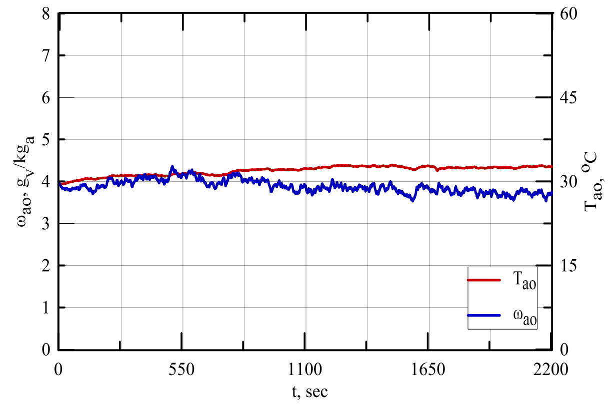

Fig. 10 Exit humidity and temperature with time for Adsorption (test 6).

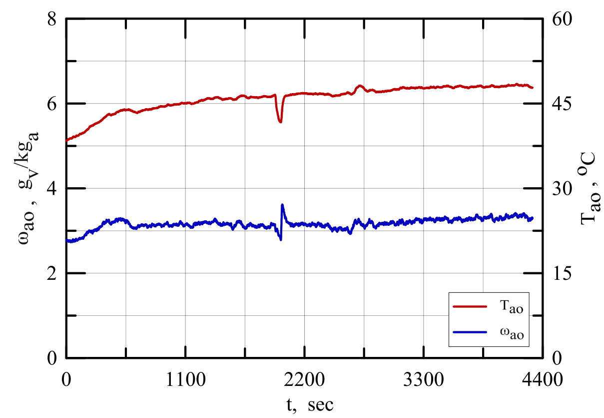

Fig. 11 Exit humidity and temperature with time for Adsorption (test 7):

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]

$$\dot{m}_{ad} = (\omega_i - \omega_o)\,\dot{m}_a \quad (14)$$
$$\dot{m}_{de} = (\omega_o - \omega_i)\,\dot{m}_a \quad (15)$$

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

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

$$\dot{m}_a = (\rho_0)\,A\,u \quad (16)$$

Where, ρ_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 ω_i. For example, when ω_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 ω_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.

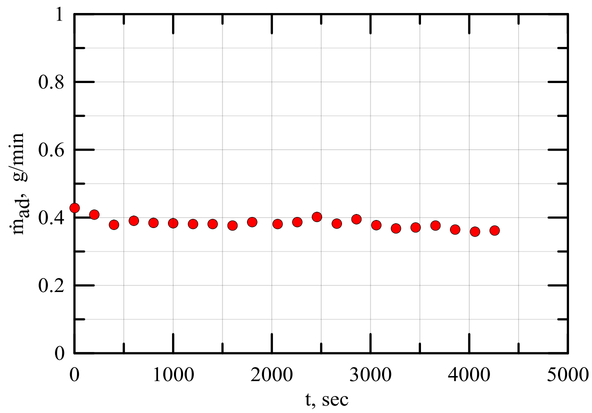

Fig. 12 Water adsorption rate with time (test1)

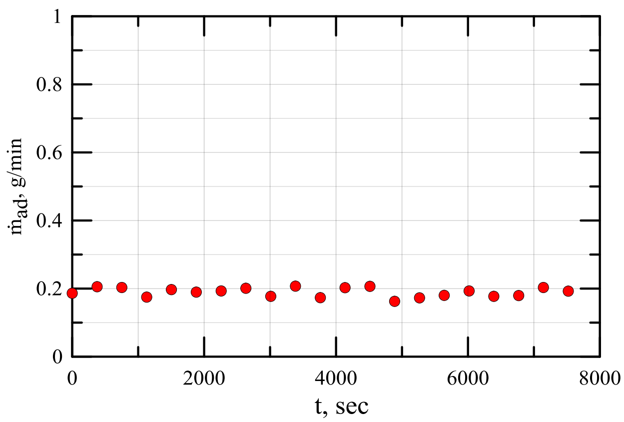

Fig. 13 Water adsorption rate with time (test3).

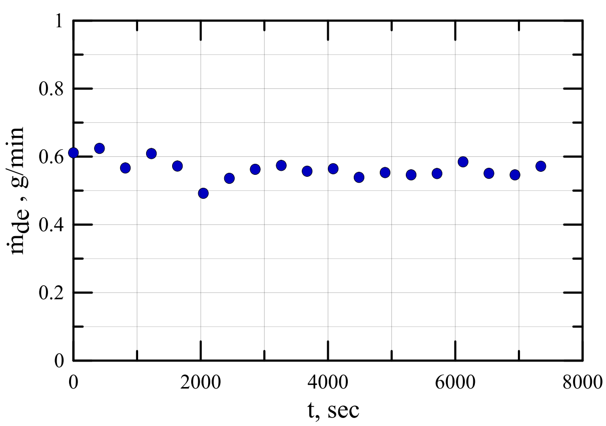

Fig. 14 Water desorption rate with time (test3).

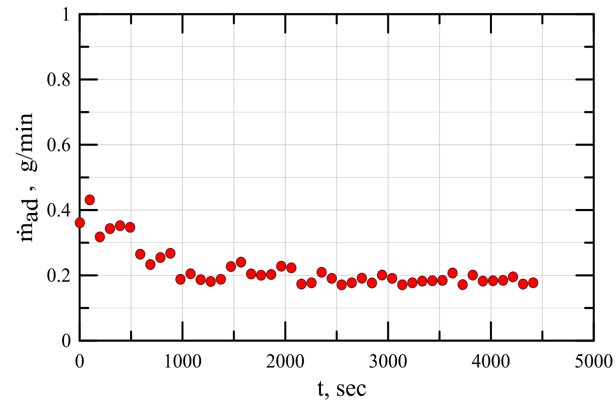

Fig. 15 Water adsorption rate with time (test 6)

4.3 Desorption tests

Figures (16-18) show the variation of ω_i 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

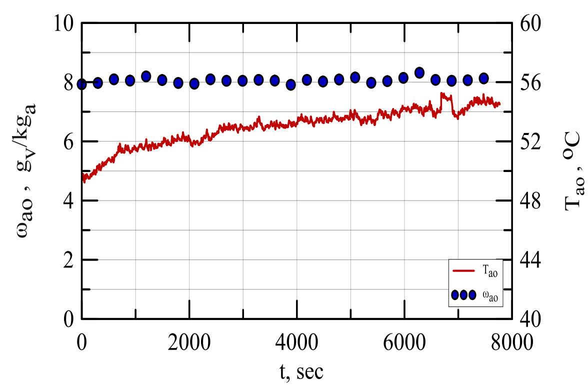

Fig. 16 Exit humidity and temperature with time for desorption (test 3).

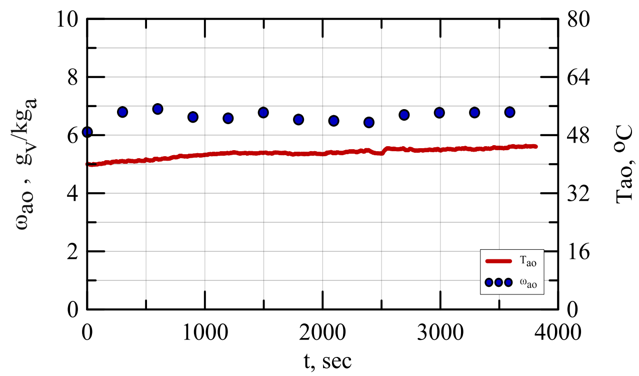

Fig. 17 Exit humidity and temperature with time for desorption (test 6).

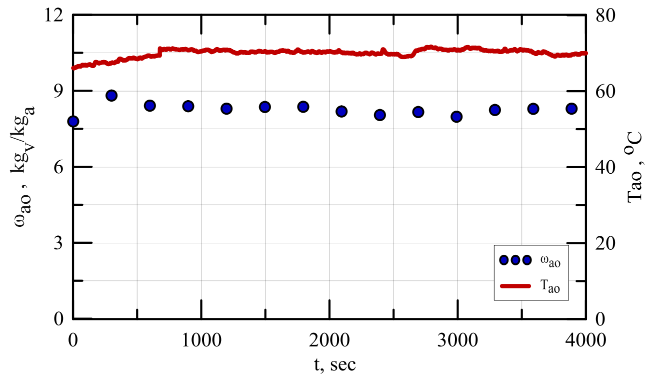

Fig. 18 Exit humidity and temperature with time for desorption (test 7).

The theoretical minimum fluidization velocity, u_o is obtained from Ergun equation [21] as,

$$\left(1.75\frac{\rho_a}{D_{Pr}\varepsilon_O{}^3}\right)u_o{}^2+\left(\frac{150(1-\varepsilon_O)\,\mu_a\,u_o}{D_{Pr}{}^2\varepsilon_O{}^3}\right)+(-g(\rho_s-\rho_a)=0 \quad (17)$$

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.

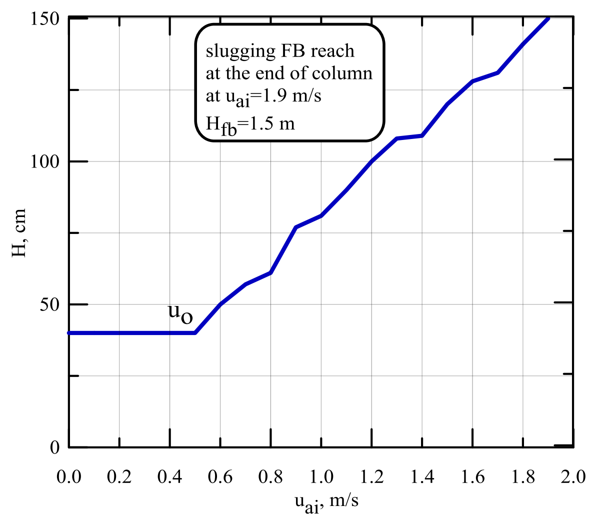

Fig. 19 Air velocity versus silica gel height in regenerator column

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],

$$t_d = \frac{m_0}{F_0} \quad (18)$$

Where, m_o (kg) is the silica gel mass in the column and F_O (kg/s) is the silica gel circulation flow rate.

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_O 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 ω_{ao}. Increasing the valve opening, increases ω_{ao} until it reached a maximum value of 5.4 gv/kga at 40 %, then it decreases again.

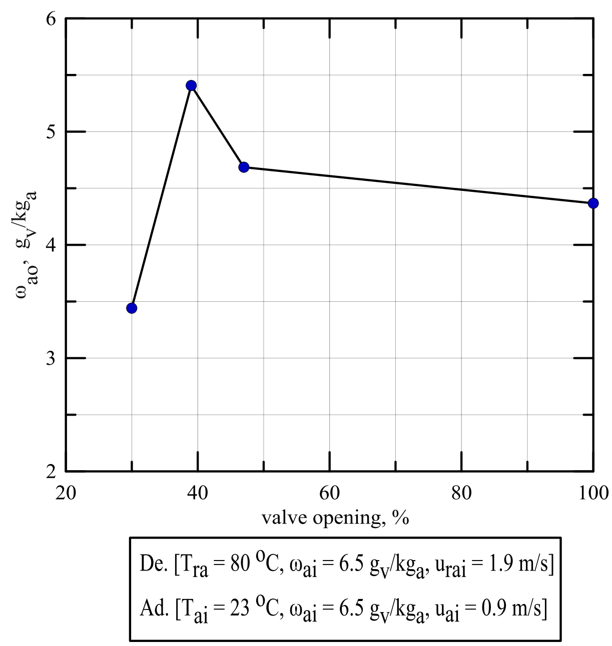

Fig. 20 Exit air specific humidity from sorption column versus bottom valve opening

4.5 Effect of regeneration temperature

The effect of T_r on ω_{ao} is shown in Fig (21). Remarkable decrease in ω_{ao} could be noticed with the increase in T_r. The value of ω_{ao} decreases from 4.3 g_v/kg_a to 2.7 g_v/kg_a when T_r increases from 50 °C to 120 °C; respectively

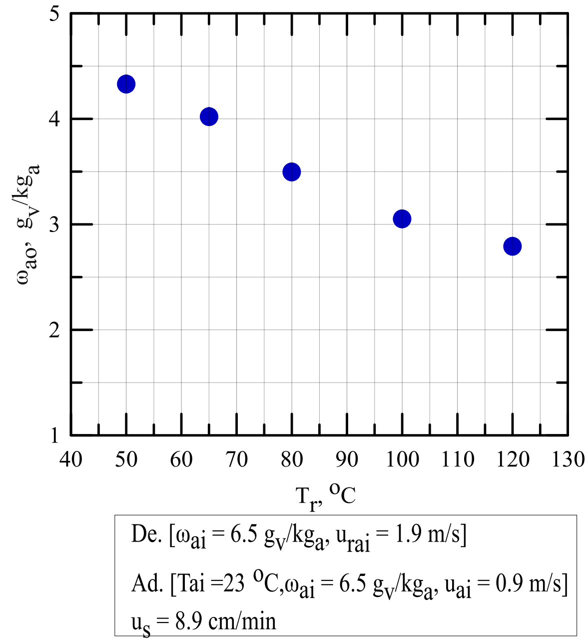

Fig. 21 Exit specific humidity versus regeneration temperature

V. Conclusion

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 ^oC, 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.

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