

# CHAPTER 5

## CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE WORK

### 5.1 Conclusions

The performance of a solid desiccant dehumidification system depends on a complicated interplay of system operating and design parameters. Optimal system capacity and operating efficiency depend on balancing these operational components against the design limitations of individual equipment components. The current investigation is a strong step on the way of understanding and modeling of the performance of silica gel desiccant wheels as they are widely used in a lot of industrial and cooling/air conditioning applications.

The mechanism of dehumidification/regeneration process in a stationary disc of Silica-Gel desiccant is a highly coupled mass and heat transfer process which depends on different interconnected characteristics of the processed air, the desiccant types and properties the geometry and dimension of desiccant material etc. The proposed coefficient " $K_{mcoef}$ " to augment the mass transfer coefficient used in the early mathematical model depends on the processed air mass flow rate and its speed along the desiccant wheel channels. The polynomial form of the dehumidification rate which is introduced in thesis is nonlinearly related to the dew bulb temperature while it pseudo-linear related to the relative humidity of the processed air. In other words, the effect of the dry bulb temperature is dominant over the effect its humidity ratio on the dehumidification rate. To reach to the optimum dehumidification rate for a fixed value of the processed air relative humidity, a certain combination between the processed air and its mass flow rate need to be used. The air mass flow rate of optimum dehumidification rate is found to be between 69 and 70 kg/hr. Relating the coefficients of the proposed polynomial of the dehumidification rate to the velocity/mass flow rate of the processed air makes the model more comprehensive for more parameters affecting the dehumidification performance.

## 5.2 Recommendations for Future Work

As the performance of the desiccant wheels depend on their inside structure geometry, their composition and the type of desiccant material beside air-related parameters discussed in this thesis, more points of investigation are recommended for future investigation. These future studies include:

1. Study the effect of desiccant geometry/size on the performance.
2. As the desiccant wheel commercially available is a composite material of various composition of the desiccant, binder and substrate materials, more investigation points related to this need to be stimulated.
3. Deeper chemical/mechanical studies to increase the dehumidification capacity of the desiccant need to be inspired.
4. The effect of macro and micro-structure of the surface of the desiccant wheel/material need to be considered as the dehumidification is a coupled/mass and heat transfer process.
5. The effect of air passage shape inside the wheel need to be studied such that the desiccant subjected area to air stream will increase and the dehumidification rate will accordingly increase.
6. As the current model is based on the stationary of the desiccant wheel, the model needs to be adjusted to consider the effect of rotation speed on the desiccant performance and compare it with other mathematical model of rotary desiccant used in non-cyclic dehumidifier types.
7. More accurate parameters need to be created such that the model will be robust against any changes on which these parameters depend such as mass flow rate air properties initial desiccant water contents etc.

The largest cost associated with desiccant technology in cooling/air conditioning systems are its installation and its distribution, enhancing the characteristics of the desiccant material, trying to use solar energy in regeneration process, and reduce the size of dehumidifier. Based on this fact, some main research points of the desiccant applications in cooling and air conditioning systems are listed below.

- Propose and Improve desiccant component integration with the conventional/commercially available cooling and air condition systems.
- The state-of- art desiccant systems often has coefficients of performance below 1.0. To increase the benefits offered by this technology, its operating efficiency must be improved. This can be accomplished by research projects to develop materials components to cool air in the system more efficiently.
- Proposing better methods of controlling system operation and lowering the cost of the reactivation methods.

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## Appendix A

The experimental data of 5 dehumidification process in a non-cyclic desiccant dehumidifier of “stationary” desiccant wheel. These experiments are conducted on an experiment test rig described in details by A. Abdou [19]. The desiccant bed in the test rig is lagged by thin aluminum sheet forming a cylindrical test section of 100 mm diameter and 500 mm length. The air is blown through the section using a compressor of variable speed such that the air velocity can be controlled between 1 m/s and 5 m/s. The desiccant material is silica gel and the cross section of the disc has a corrugated structure of triangular desiccant channels as shown in Figure A.1. The diameter of desiccant wheel is 10 cm and two wheels are used in series as the thickness of each is 20 cm. The air mass flow rate, the velocity of air inside the channel, the regeneration temperature, and the humidity ratio of the air stream are listed above each table containing the experimental data of the dehumidification processes.

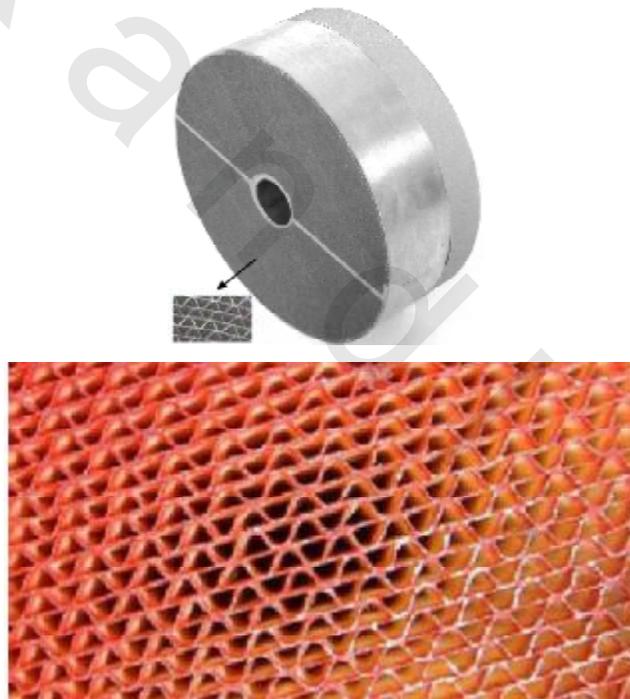


Figure A.1 Cross Section Zoomed-in View of the Desiccant Wheel

Table A.1 the Second Experiment, Air mass flow rate =34.3kg/hr; Intake humidity ratio=.0096 kg/kg, and Presetting bed temperature=90°C

Time (sec.)	Intake Temp. (°C)	Middle temp.(°C) at L=10cm	Outlet temp.(°C) L= 20 cm	Outlet Humid Ratio(g/kg)
0.000	42.80	73.50	80.00	9.500
8.000	36.50	69.20	78.00	8.400
16.000	33.70	69.10	76.50	6.700
24.000	30.30	62.10	75.00	3.900
32.000	29.80	75.50	73.80	2.700
40.000	29.30	54.80	67.20	2.200
48.000	28.90	52.70	62.50	2.100
56.000	28.50	51.00	59.80	2.100
64.000	28.40	49.60	57.90	2.100
72.000	28.20	48.30	56.70	2.200
80.000	28.00	47.20	55.70	2.200
88.000	27.90	46.10	54.90	2.300
96.000	27.80	45.10	54.00	2.400
104.000	27.70	44.20	53.10	2.500
112.000	27.50	43.30	52.30	2.600
120.000	27.40	42.70	51.90	2.700
128.000	27.30	42.10	51.10	2.800
136.000	27.20	41.30	50.60	2.900
144.000	27.20	40.70	49.90	3.100
152.000	27.10	40.00	49.20	3.200
160.000	27.00	39.30	48.70	3.300
168.000	27.00	38.90	48.10	3.400
176.000	27.00	38.30	47.40	3.500
184.000	27.00	38.00	46.90	3.600
192.000	27.00	37.50	46.30	3.700
200.000	26.90	37.00	46.00	3.800
208.000	26.80	36.50	45.20	4.000
216.000	26.80	36.10	44.90	4.100
232.000	26.60	35.30	43.90	4.300
248.000	26.60	34.90	43.00	4.500
264.000	26.60	34.20	42.20	4.700
280.000	26.50	33.80	41.40	4.900
296.000	26.40	33.20	40.70	5.100
312.000	26.40	32.80	40.00	5.300
328.000	26.40	32.30	39.20	5.500
360.000	26.30	31.60	38.00	5.700
392.000	26.30	31.00	36.90	6.000
424.000	26.30	30.50	36.00	6.300
456.000	26.20	30.00	35.00	6.500
488.000	26.20	29.80	34.30	6.700
520.000	26.20	29.20	33.80	6.800
552.000	26.20	29.10	33.20	7.000
584.000	26.20	28.80	32.80	7.200
616.000	26.20	28.40	32.10	7.300
648.000	26.20	28.20	31.80	7.500
680.000	26.20	28.10	31.30	7.700

Table A.2 The First Experiment, Air mass flow rate =36.4 kg/hr; Intake humidity ratio=.0088kg/kg, and Presetting bed temperatures=125°C

Time (sec.)	Intake Temp. (°C)	Middle temp.(°C) at L=10cm	Outlet temp.(°C) L= 20 cm	Outlet Humid Ratio(g/kg)
8.00	43.00	101.20	128.6	10.40
16.00	39.80	85.80	124.0	10.40
24.00	36.00	73.40	112.0	8.700
32.00	34.40	66.60	94.00	7.900
40.00	33.40	62.10	78.00	7.500
48.00	32.80	59.40	69.00	7.000
56.00	32.20	57.00	64.30	6.500
64.00	31.80	55.00	61.9	5.700
72.00	31.60	53.80	60.20	5.000
80.00	31.00	52.20	59.20	4.400
88.00	30.70	51.20	58.40	3.700
96.00	30.50	51.10	57.90	3.400
104.0	30.20	48.70	57.30	3.100
112.0	30.00	47.80	56.70	2.800
120.0	29.80	46.50	55.80	2.500
128.0	29.60	45.70	54.90	2.400
136.0	29.50	44.40	54.00	2.300
144.0	29.30	43.90	53.40	2.200
152.0	29.00	43.00	52.52	2.200
160.0	28.80	42.20	52.00	2.200
168.0	28.50	41.70	51.20	2.300
176.0	28.50	41.00	50.50	2.300
184.0	28.30	40.20	49.90	2.300
192.00	28.20	39.90	49.40	2.400
200.0	28.00	39.60	48.80	2.500
208.0	28.00	38.80	48.30	2.600
216.0	27.80	38.20	47.70	2.800
232.0	27.70	37.60	46.40	2.900
248.0	27.60	36.60	45.10	3.200
264.0	27.60	35.80	44.30	3.300
280.0	27.50	34.80	43.50	3.600
296.0	27.40	34.10	42.50	3.700
312.0	27.30	33.70	41.60	4.000
328.0	27.30	33.00	41.00	4.100
360.0	27.20	32.20	39.30	4.500
392.0	27.00	31.70	38.00	4.800
424.0	27.00	31.00	36.70	5.100
456.0	26.90	30.30	35.90	5.400
488.0	26.80	30.10	34.90	5.700
520.0	26.80	29.80	34.10	5.900
552.0	26.70	29.60	33.60	6.100
584.0	26.70	29.40	32.92	6.300

Table A.3 the Second Experiment, Air mass flow rate=49.4 kg/hr; Intake humidity ratio=.00991kg/kg, and Presetting bed temperature=121°C

Time (sec.)	Intake Temp. (°C)	Middle temp.(°C) at L=10cm	Outlet temp.(°C) L= 20 cm	Outlet Humid Ratio(g/kg)
0.000	37.00	93.00	102.0	8.000
8.000	35.00	79.00	97.00	4.000
16.00	33.00	65.80	92.00	2.700
24.00	31.00	59.50	76.00	2.400
32.00	31.00	55.60	66.00	2.400
40.00	30.00	53.20	61.00	2.500
48.00	30.00	50.50	58.60	2.400
56.00	30.00	49.10	57.00	2.500
64.00	30.00	47.90	55.80	2.500
72.00	30.00	46.84	54.40	2.400
80.00	29.80	45.90	53.90	2.200
88.00	29.00	44.80	53.00	2.800
96.00	28.80	43.20	52.90	3.000
104.0	28.60	42.50	50.60	3.100
112.0	28.40	41.60	49.60	3.300
120.0	28.20	40.60	49.00	3.400
128.0	28.10	44.00	48.00	3.500
136.0	28.10	39.20	47.00	3.600
144.0	28.00	38.50	46.00	3.800
152.0	28.00	37.90	45.50	3.900
160.0	28.00	37.30	44.70	4.100
168.0	28.00	36.90	44.00	4.200
176.0	27.90	36.20	43.40	4.300
184.0	27.90	35.90	42.80	4.400
192.0	27.90	35.60	42.10	4.600
200.0	27.90	35.10	41.80	4.800
208.0	27.60	34.50	41.00	4.900
216.0	27.40	34.20	40.51	5.100
232.0	27.00	33.90	39.71	5.400
248.0	27.00	33.70	38.90	5.500
264.0	27.00	33.20	38.00	5.700
280.0	27.00	32.90	37.20	5.900
296.0	27.00	32.50	36.80	6.100
312.0	27.00	32.10	36.00	6.200
328.0	27.00	32.00	35.60	6.600
360.0	27.00	31.30	34.60	6.800
392.0	27.00	31.00	33.60	7.000
424.0	27.00	30.20	33.00	7.200
456.0	27.00	29.80	32.20	7.400
488.0	27.00	29.50	31.80	7.600
520.0	27.00	29.40	31.20	7.700
552.0	27.00	29.00	31.00	7.900
584.0	27.00	28.60	30.60	7.900
616.0	27.00	28.40	30.40	8.000

Table A.4 the Second Experiment, Air mass flow rate =74.3kg/hr; Intake humidity ratio=0.0094 kg/kg, and Presetting bed temperature=94.5°C

Time (sec.)	Intake Temp. (°C)	Middle temp.(°C) at L=10cm	Outlet temp.(°C) L= 20 cm	Outlet Humid Ratio(g/kg)
0.000	75.00	90.00	91.00	8.000
8.000	57.00	87.00	81.00	2.000
16.000	35.50	69.00	73.00	2.600
24.000	32.60	57.50	70.00	3.400
32.000	31.50	52.10	60.50	3.700
40.000	30.80	49.00	55.30	4.000
48.000	30.00	46.70	52.42	4.300
56.000	29.40	44.80	50.30	4.500
64.000	29.00	43.00	48.60	4.000
72.000	28.60	41.60	47.10	4.100
80.000	28.40	40.50	46.10	4.100
88.000	28.00	39.70	45.00	4.400
96.000	27.90	38.60	44.00	4.600
104.000	27.70	37.80	43.00	4.800
112.000	27.40	36.90	42.20	4.900
120.000	27.20	36.10	41.40	5.100
128.000	27.00	35.50	40.60	5.200
136.000	27.00	34.90	39.80	5.400
144.000	27.00	34.40	39.20	5.500
152.000	26.90	33.90	38.60	5.600
160.000	26.80	33.30	38.00	5.700
168.000	26.70	32.90	37.50	5.900
176.000	26.60	32.50	36.90	6.000
184.000	26.50	32.20	36.50	6.200
192.000	26.40	31.90	36.00	6.300
200.000	26.30	31.60	35.50	6.400
208.000	26.30	31.20	35.10	6.500
216.000	26.30	31.00	34.80	6.600
232.000	26.20	30.40	34.00	6.800
248.000	26.20	30.00	33.40	6.900
264.000	26.10	29.80	32.90	7.100
280.000	26.10	29.30	32.30	7.300
296.000	26.10	29.10	32.00	7.500
312.000	26.10	28.80	31.50	7.600
328.000	26.10	28.60	31.10	7.700
360.000	26.00	28.10	30.50	7.900
392.000	26.00	27.80	30.00	8.100
424.000	26.00	27.60	29.50	8.300
456.000	26.00	27.30	29.00	8.400
488.000	26.00	27.10	28.70	8.600
520.000	26.00	27.00	28.50	8.700
552.000	26.00	27.00	28.20	8.800
584.000	26.00	26.80	28.00	8.900
616.000	26.00	26.70	27.80	8.900
648.000	26.00	26.50	27.60	9.000
680.000	26.00	26.40	27.50	9.100

Table A.5 the Second Experiment, Air mass flow rate = 100.3kg/hr; Intake humidity ratio= 0.0098 kg/kg, and Presetting bed temperature=83°C

Time (sec.)	Intake Temp. (°C)	Middle temp.(°C) at L=10cm	Outlet temp.(°C) L= 20 cm	Outlet Humid Ratio(g/kg)
0.000	40.00	75.50	77.00	8.600
8.000	37.50	65.00	65.00	6.600
16.000	33.00	53.50	63.00	4.200
24.000	32.30	48.80	55.00	4.200
32.000	31.40	46.00	51.00	4.300
40.000	31.00	43.00	48.30	4.900
48.000	30.40	42.10	46.50	5.300
56.000	30.10	40.80	45.00	5.600
64.000	29.80	39.60	43.70	5.900
72.000	29.50	38.60	42.60	6.100
80.000	29.20	37.80	41.60	6.300
88.000	29.10	36.90	40.70	6.500
96.000	28.90	36.10	39.90	6.700
104.000	28.90	35.10	39.20	6.800
112.000	28.70	34.90	38.50	7.000
120.000	28.60	34.40	37.90	7.100
128.000	28.40	33.20	37.20	7.300
136.000	28.40	33.50	36.60	7.400
144.000	28.30	33.10	36.20	7.500
152.000	28.20	32.80	35.80	7.700
160.000	28.10	32.50	35.40	7.800
168.000	28.10	32.20	34.90	7.800
176.000	28.00	31.90	34.60	7.900
184.000	28.00	31.60	34.30	8.000
192.000	28.00	31.20	33.90	8.100
200.000	28.00	31.10	33.70	8.200
208.000	28.00	31.00	33.40	8.300
216.000	28.00	30.80	33.10	8.400
232.000	28.00	30.60	32.70	8.500
248.000	28.00	30.30	32.40	8.600
264.000	28.00	30.00	32.00	8.700
280.000	28.00	29.80	31.50	8.800
296.000	27.90	29.50	31.30	8.900
312.000	27.90	29.40	31.00	8.900
328.000	27.90	29.30	30.80	9.000
360.000	27.90	29.00	30.30	9.100
392.000	27.90	28.90	30.10	9.200
424.000	27.90	28.70	29.80	9.300
456.000	27.90	28.50	29.50	9.400
488.000	27.90	28.40	29.30	9.500
520.000	27.90	28.40	29.20	9.500
552.000	27.90	28.30	29.00	9.600
584.000	27.90	28.20	28.80	9.600
616.000	27.90	28.10	28.70	9.600
648.000	27.90	28.10	28.60	9.600
680.000	27.90	28.00	28.50	9.700



كلية الهندسة  
جامعة الاسكندرية

## نموذج رياضي مدعم لا

رسالة علمية

مقدمة الى الدراسات العليا بكلية الهندسة - جامعه الاسكندرية

استيفاء للدراسات المقررة للحصول على درجة

ماجستير الهندسية

هندسة الميكانيكية

مروة طلعت محمد عبد الغني عويضة

الاسكندرية

ديسمبر 2014



كلية الهندسة  
جامعة الاسكندرية

## نموذج رياضي مدعم لاسطوانات المجففات لمحاكاة أشمل لمعاملات الأداء

عويضة

ماجستير العلوم الهندسية الهندسة الميكانيكية

.. محمد عبد الحليم  
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وكيل الكلية للدراسات العليا والبحوث  
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/  
قسم الهندسة الميكانيكية- كلية الهندسة- جامعة الاسكندرية

. خميس منصور  
قسم الهندسة الميكانيكية- كلية الهندسة- جامعة الاسكندرية

يوفر البحث مزيد من الفهم لكيفية عمل  
كما يوفر وسيلة  
وايضا يعد مرشدا لتحسين التصاميم المستقبلية المتعلقة بهذه النظم .  
نموذج رياضي بحيث يتم فهم أداء اسطوانات المجففات المستخدمة على نطاق واسع  
قترحة من قبل بعض الباحثين في  
الفعلي لهذه  
لأنها استندت المحسوسة في استنتاجها .

بين أليتي انتقال  
المشكلتان لألية التجفيف. تم بناء استنتاج النموذج الرياضي لاسطوانة  
ثباتها حيث ان تأثير  
هو مناقش في هذه الاطروحة. مزيد من التفاصيل  
عليها المقترح حاليا النمذجة الرياضية  
طريقة بحيث يتم الحد بشكل واسع من كلا من خطأ  
الملازمين . لاجراء عملية التكامل تم اقتد  
الحدية والابتدائية للمعادلات من النتائج المعملية المسرودة في الملحق " ". تم اقتراح معامل جديد يتم ضربه في  
معامل انتقال الكتلة المستخدم في النمذجة الرياضية. هذا العامل المتغير المضاف يعكس تأثير كلا من سرعة  
ومعدل التدفق الكتلي للهواء على آلية المبادلة الكتلية بين الهواء المعالج والمجفف.  
دراسة تأثير التغير في الهواء عند قيم مختلفة النسبية  
للحواء . كثيرة حدود لا خطية من الهواء  
درجة حرارة الهواء المقاسة ببصيلة الترمومتر الجافة النسبية لهذا الهواء. حيث ان كثيرة الحدود  
السابق ذكرها تم استنتاجها عند قيم مختلفة لكلا من سرعة ومعدل التدفق الكتلي للهواء المعالج فكان لا بد من ربطهما  
بمعاملات كثيرة ال . كلا من سرعة ومعدل التدفق الكتلي للهواء المعالج  
المتغيرات المستقلة المستخدمة في تحديد قيم معاملات كثيرة الحدود المذكورة سابقا. واخيرا نستطيع القول ان  
التعديلات المقدمة في هذه الاطروحة على النمذجة الحسابية لألية التجفيف بجانب عدم اهمال الحرارة الكامنة جعلت  
التباين في المتغيرات

. حيث ان كلا من الخلفية التاريخية المسح التوثيقي  
يتحدث من الهواء عملية  
مزيلا وتطبيقاتها  
تأهيل المجفف لاعادة استخدامه  
التبريد/تكييف الهواء.  
داء وكيفية النمذجة الرياضية لأليتي  
خلال عملية التجفيف. في الفصل الرابع تم عرض وتفسير النتائج التي حصلنا عليها.  
الفصل الاخير تم عرض ملخص لما تم انجازه في الرسالة مع التوصية ببعض النقا البحثية لانجازها في المستقبل.