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Mathematical Modelling of the Internal Heating Regenerator of a Liquid Desiccant system

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Abstract - *The vapor compression refrigeration system is used for air conditioning purpose and Liquid desiccant system has various advantage over vapor compression refrigeration system. In this paper Liquid desiccant system analyzed by mathematical modelling. Mathematical modelling consists of coupled ordinary differential equation. Lithium bromide is used as liquid desiccant, Mass and energy balance equation applied on regenerator of Liquid desiccant system and prepare coupled ordinary differential equation. Derived equation solve by using mat lab programming with simultaneous Runge-Kutta fourth order method. Equation derived from mathematical modelling solve by using mat lab programming and derived result compared with experimental case study with indicate resulted obtained from liquid desiccant system nearly equal to mathematical modelling of liquid desiccant system. And difference in values shows in percentage. Analyzing system by mathematical modelling is time and money saving and It is easy for the parametric analysis of system. The comparison between experimental data and result after mat lab programing is compared.*

Key Words: **Liquid Desiccant System, Regenerator, Mat lab Programming, Mathematical Modelling, Differential equation**

1. INTRODUCTION

The liquid desiccant system is the best option for traditional VCR system. It is a low-cost and low-pollution system. In a VCR system, dehumidification and regeneration need a lot of electricity, but in an LDS system, desiccant solution is used for dehumidification, which absorbs moisture from the air. The air dehumidification has been investigated for several years and many air dehumidification technologies have been developed, such as condensation dehumidification technology. Here liquid absorption system is used. In Liquid Desiccant Air Conditioning systems, the extra moisture is removed by liquid desiccant absorption and the sensible and latent heat can be handled separately. LDS has two main part 1. Dehumidifier, 2. Regenerator

1. Dehumidifier is used to absorb the moisture from the humid air to desiccant solution is driven by vapor pressure difference between liquid-desiccant solution and humid air this way air dehumidification is carried out. The latent heat released during the dehumidification process may increase the temperature of liquid desiccant solution and the equilibrium vapor pressure accordingly

2.Regenerator-Regenerator is the exact opposite to dehumidifier/absorber. It contains air absorb the moisture from the solution by using heated air passes through system. It improves the performance of desiccant system The mathematical equation is derived from applying mass and energy balance equation on regenerator and dehumidifier with putting required data from referred paper. Then coupled ordinary differential equation is formed then it solved by mat lab programming. [3] S. Jain et al. experimented The liquid desiccant system was tested in the lab with a solution as the absorbent and solar heated air as the regeneration medium. Developed mathematical modelling and used computer programming to calculate unknown parameters.

[5] X.Y. Chen prepared Based on the proposed finite difference model, an analytical solution for adiabatic heat and mass transport in a dehumidifier or regenerator was developed under some realistic assumptions. The classic numerical solution is quick to compute and can be utilized for seasonal performance simulations. With intuitionistic components, sensitive analyses such as moisture removal rate may be easily carried out. An ideal flow rate ratio for both dehumidifiers and regenerators may be calculated using this technique.

2. MODELLING PROCEDURE

Applying the mass and energy balance equation to the air, desiccant solution regenerator, and absorber, and then forming a coupled ordinary differential equation that can be solved using Mat lab programming.

2.1 Modelling procedure for regenerator

Inlet value for different parameter

m_a = 0.16 kg/s ,
m_s= 0.64 kg/s
Ta_i = 41.9°C= 41.9+273.15=315.05K
Ts_i= 54.9°C =328.05 K
Wa_i = 0.0094 kg w.v./kg d.a.
Cs_i= 43%, U_a=5.83 w/m^{2}K

$h_m = 0.0057 kg/m^2/s$

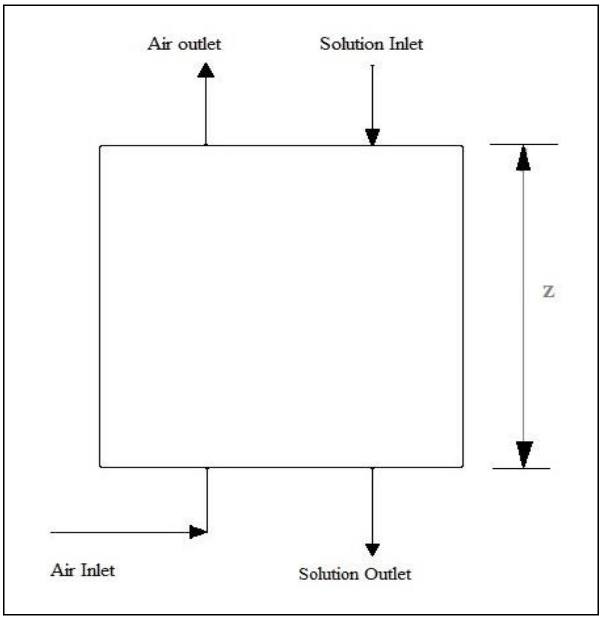

Fig.1 Regenerator

- For air

$$m_a \frac{dW_a}{dZ} = -h_m P_w (W_e - W_a)$$

$$\frac{dW_a}{dZ} = 0.0267 W_a - 0.0267 W_e$$

$$\frac{dW_a}{dZ} = 0.0267 W_a - 7.85 \times 10^{-5}$$

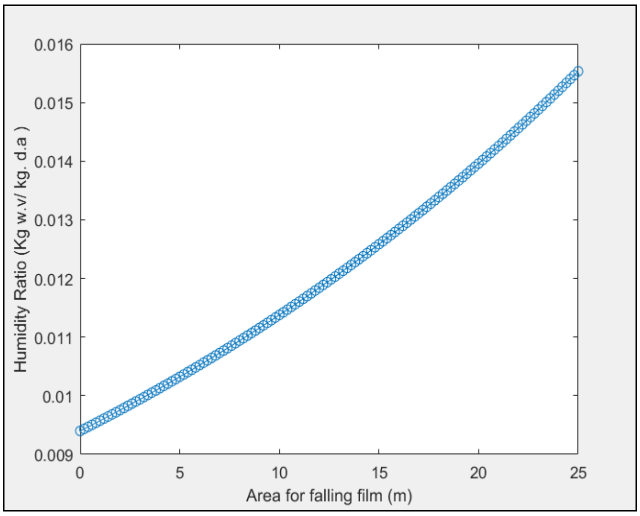

Fig.2 Variation in humidity of air

Calculated value by matlab programming
W_{a_o}=0.0155 kg w.v / kg d.a

- For Solution

$$\frac{dC_s}{dZ} = -(0.00667)(W_e - W_a)$$

$$\frac{dC_s}{dZ} = 0.00667 W_a - 0.00667 W_e$$

$$\frac{dC_s}{dZ} = -0.00667 C_s + 0.000665$$

$$C_{s_i} = 43\%$$

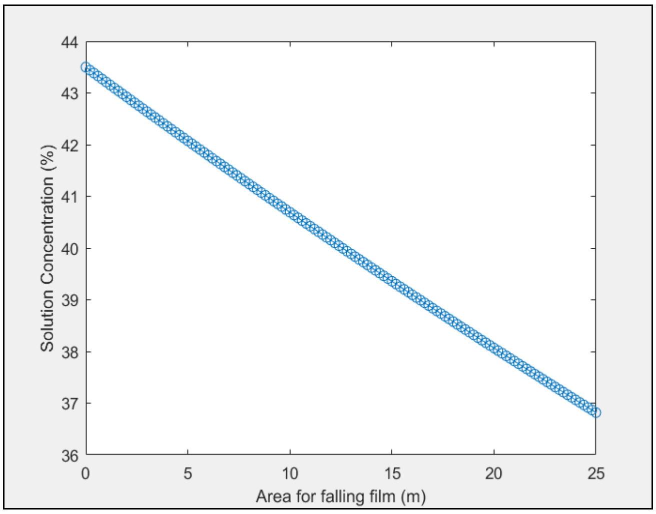

Fig. 3 Variation in solution concentration
Calculated value by mat lab programming $C_{s_o} = 37.2\%$

- Energy balance
  For air

$$\frac{dT_a}{dZ} = -(0.0271)(T_s - T_a)$$

$$\frac{dT_a}{dZ} = 0.0271 T_a - 0.0271 T_s$$

Calculated value by matlab programming T_{a_O}=321.02 K

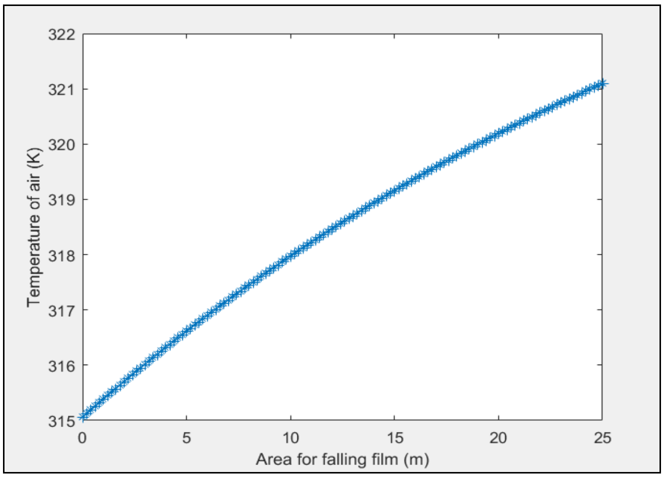

Fig. 4 Variation in Temperature

- For solution

$$\frac{dH_s}{dZ} = -(6.83)(T_s - T_a) + m_a \frac{dW_a}{dZ} H_{fg}$$

Using relation between Temperature and Enthalpy of solution

$$H_s - H_a = C_p (T_s - T_a)$$

Converting in form of Enthalpy of air

$$\frac{dH_a}{dZ} = 0.0067H_a + 0.512$$

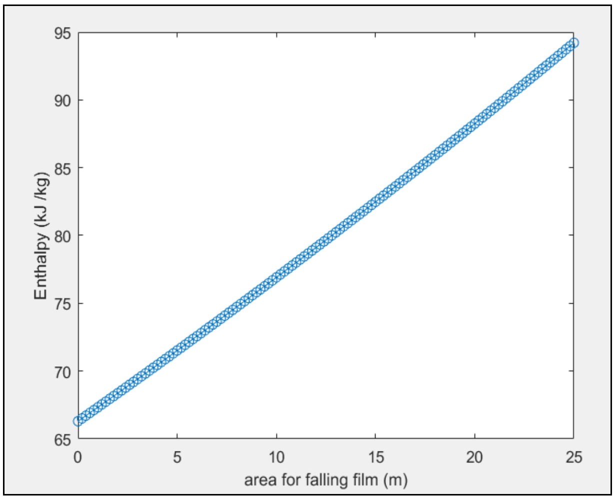

Fig. 4 Variation in Enthalpy

Calculated value H_{a_o}=94.212kJ/kg

2.2 Modelling procedure for dehumidifier

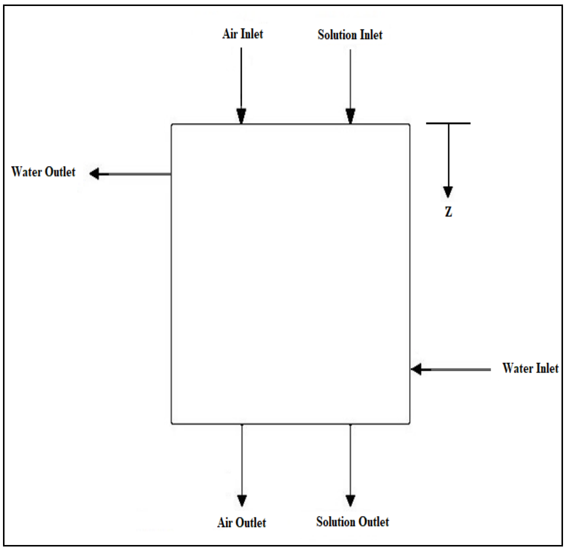

Fig.5 dehumidifier

Applying Energy and Mass balance equation for the dehumidifier

Input value for dehumidifier
m_a = 0.89 kg/s
m_s= 6.124 kg/s
Ta_i = 30.1°C= 30.1+273=303.1K
Ts_i=32°C =3050.15K
Wa_i = 0.018 kg w.v./kg d.a.

Cs_i= 34.6%

- Mass balance equation for air become

$$m_a \frac{dW_a}{dZ} = -h_m P_w (W_a - W_e)$$

$$\frac{dW_a}{dZ} = 0.00002 - 0.0085W_a$$

W_{a_i} = 0.018kg /kg

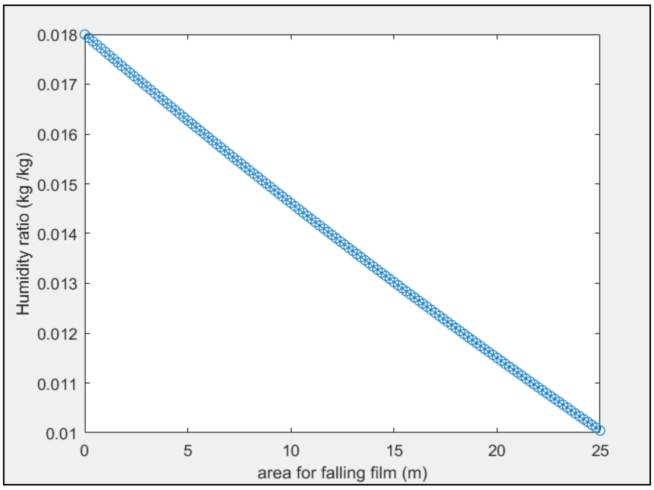

Fig. 6 Variation in Humidity of air

Calculated value by mat lab programming

W_{a_o}=0.0106 kg /kg

- For Solution

$$m_s \frac{dC_s}{dZ} = -h_m P_w (W_a - W_e)$$

$$\frac{dC_s}{dZ} = -(0.00124)(W_a - W_e)$$

$$\frac{dC_s}{dZ} = -0.00124W_a - 3.27 \times 10^{-6}$$

Inlet value for Concentration C_{S_i}= 34.6%

Calculated value by mat lab programming

C_{S_o}= 35.8%

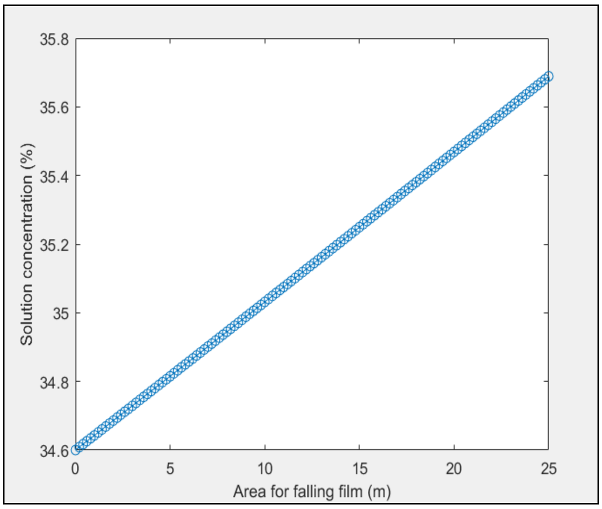

Fig. 7 Variation in solution of concentration

- Energy balance equation for air is become

$$m_a C_{pm} \frac{dT_a}{dZ} = U_a P_a (T_s - T_a)$$
$$\frac{dT_a}{dZ} = 0.0084(T_s - T_a)$$
$$\frac{dT_a}{dZ} = 2.54 - 0.0084T_a$$

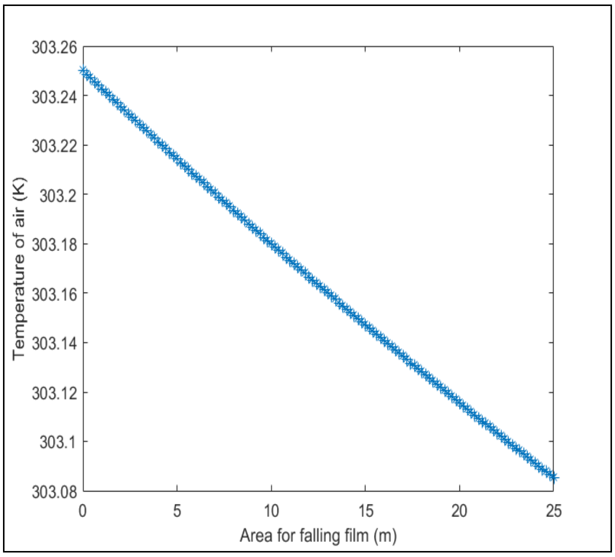

Fig. 8 Variation in Temperature

Calculated value by matlab programming

$$T_{a_o} = 301.01K$$

- For Solution

$$m_s \frac{dH_s}{dZ} = -m_s C_{pm} \frac{dT_a}{dZ} - m_w C_{PW} \frac{dT_w}{dZ} - m_a \frac{dW_a}{dZ} H_{fg}$$

$$\frac{dH_S}{dZ} = -1012 \frac{dT_a}{dZ} - 546.3 \frac{dT_w}{dZ} - 327.8 \frac{dW_a}{dZ}$$

Converting above equation for Enthalpy of by using relation

$$H_s - H_a = C_p (T_s - T_a)$$
$$\frac{dH_a}{dZ} = 0.0043 - 0.0083H_a$$

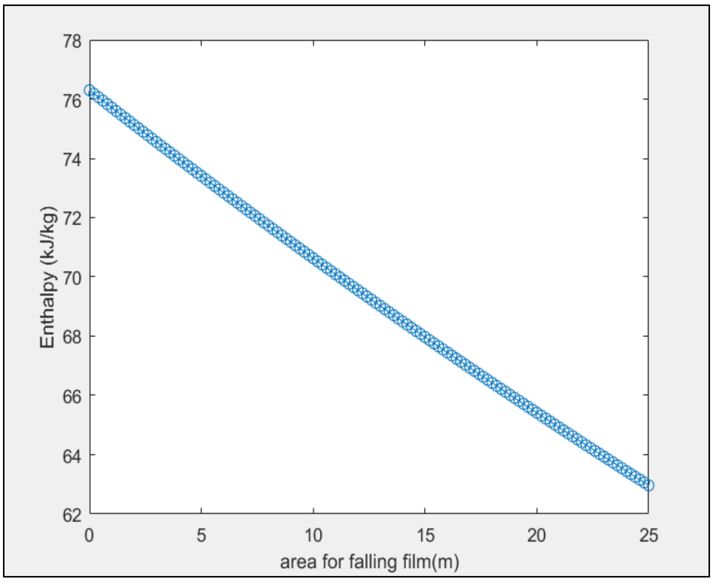

Fig. 9 Variation in enthalpy

Calculated value at outlet

$$H_{a_o} = 62.5 \text{ kg/kg}$$

3. RESULT AND VALIDATION

Collect the experimental data from referred paper and I prepared mathematical modelling and solve by matlab programming and compared it to experimental data.

3.1 Regenerator

Table -1 Comparison of result of regenerator

Parameter (Outlet value)	**Experiment Value[5]**	**Present study**	**Difference %**
Enthalpy of air (kJ / kg)	98.7 kJ/kg	94.212kJ/kg	4.7%
Humidity Ratio(kg d.a /kg w. v)	0.0179 kg/kg	0.0153 kg/kg	14.25%

Air outlet temperature
After solving the equation, the temperature of the air outlet steadily climbed, but the humidity of the air decreased.
Concentration of solution
The concentration of the solution changes at the outflow, going from a strong to a dilute solution.

3.2 Dehumidifier

Table -1 Comparison of result of dehumidifier

Parameter (Outlet value)	Experiment Value(Out let value) [5]	Present study	Difference %
Enthalpy of air (kJ / kg)	58.1 kJ / kg	62.2 kJ / kg	7.06%
Humidity Ratio (kg d.a /kg w. v)	0.0104(kg d.a /kg w. v)	0.0106(kg d.a /kg w. v)	1.9%

Temperature of solution
Temperature of air is decreased and then gradual increment in temperature of solution

4. CONCLUSION

From the result I can conclude that experimental value and mat lab programming result is nearly equal with difference is mention in percentage. For the mathematical modelling analysis is a reduce money as well as time then we can predict the performance system easily. From the graphical presentation we can observe the variation in a parameter over the total length.

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