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Novel packing materials for open liquid desiccant system

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Abstract

The objective of this study is to design and test a liquid dehumidification system that can operate with a maximum performance under atmospheric conditions without any mass transfer problems. For this purpose, polycarbonate panels were used as packing materials in the absorber and desorber innovatively. Polycarbonate has high surface tension among other polymeric based packing materials. This feature can improve the wetting property of liquid desiccant (LiBr-water, LiCl-water and $CaCl_2$-water etc.) and the mass transfer within the system as well. Temperatures of air and liquid sides, relative humidity of inlet and outlet air, velocities of air and liquid sides, variation of concentration of desiccant solution will be measured and investigated to analyze the performance of the system.

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Keywords: Open liquid desiccant system, polycarbonate, packing materials;

1. Introduction

Nowadays, energy demand of human being is increasing in parallel to the developing life standards. 75% of the energy is supported from fossil fuel (primary fuel) in Turkey. According to the data for 2005, 6.1% of the energy is consumed for space heating/cooling. The energy used for space heating is directed to space cooling in the summertime due to the relatively high number of sunny days in Turkey. The solar energy potential atlas of Turkey

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published by the General Directorate of Renewable Energy showed that Mediterranean Region of Turkey (where this study will be performed) has an annual mean insolation of 1650 kWh/m^2. Moreover, due to the 65% annual relative humidity average in this region, both dehumidification and cooling systems are being intensively used especially in summertime. Therefore, most of the consumed energy is utilized for the dehumidification process.

The open-system liquid desiccant system will be operated with the support of solar-energy systems. Thus, it will be possible to reduce consumption of the fossil fuel and to benefit from the solar energy at maximum level. Application of open liquid desiccant system with air conditioning system in crowded places (cinemas, mall, conference hall, hospital etc.) would reduce 25-35% of the consumed electricity since latent heat load can be removed by the proposed system and sensible heat load can be provided by air conditioning system.

Working principle of the open liquid desiccant (OLD) system is similar to the absorption heat pumps. The main parts of the open liquid desiccant system are absorber, regenerator (or desorber) and heat exchangers. The differences between OLD system and absorption heat pumps are; OLD can operate under atmospheric conditions and be used for dehumidification of air. Liquid desiccant system was started to be investigated at the beginning of 90s [1].

The main advantages of liquid desiccant system are:

- No leakage problems due to operation under atmospheric conditions
- Construction with polymeric base materials. Hence, this causes low construction cost and lightness
- No corrosion problem due to polymeric materials
- Remove organic (fungus, virus, bacteria etc) and inorganic dirt from air [2]
- Operate with low temperature heat sources.

The disadvantages of liquid desiccant system are [3,4]:

- Low coefficient of performance,
- Low performance at low relative humidity
- Salt can transport to the environment at high air velocities.

The surface area of packing materials directly influences mass transfer in the column as well as the performance of the system. Differentiation of surface tension of desiccant solution and packing materials prevents to wet whole surface area of packing materials. For that reason, proclaimed surface area of the commercial packing materials (especially polymeric materials) and wetted surface area of packing materials in the column are different from each other. In this study, polycarbonate packing materials which surface tension is close enough to surface tension of liquid desiccant was manufactured with 30^o angle. This phenomenon can be provided increase wetted surface area of packing materials in the column as well as increase contact area between air and liquid desiccant. Preliminary results were revealed by this study.

2. Materials and methods

2.1 Materials

The liquid desiccant was prepared with 43% wt of anhydrous LiBr (Acros organics, 99%). Packing materials were prepared by cutting polycarbonate (PC) panels with 30^o angle. Fig.1 shows PC packing material and placing packing material in the column. Surface area and porosity of PC packing materials were 637±9 m^2/m^3 and 87.6±1.3 %, respectively. Packing materials were placed in the column in zig-zag position in order to increase contact time of air-liquid flows.

2.2 Methods

Fig.2 illustrates the designed and constructed open liquid desiccant system. OLD system was composed of adsorber, desorber, air fans, two heat exchangers (for cooling and heating desiccant) and liquid pumps. Relative humidity and temperatures of air at inlet and outlet of the towers, conductivity of desiccant solution, air and liquid velocities and temperatures of fluids at inlet and outlet of the heat exchangers were measured for evaluating performance of the OLD system by using various sensors. All data gained from sensors was acquired and monitored by using SCADA control and automation programme. Air fans, valves and liquid pumps were controlled by SCADA. Thus, air and liquid velocities can be adjusted.

a b

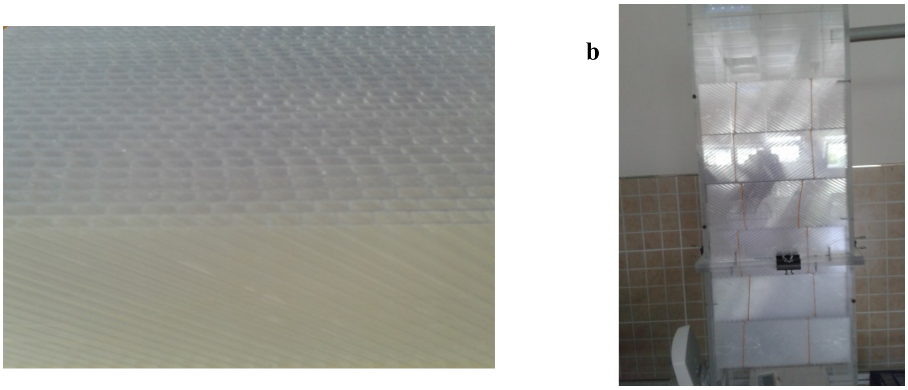

Fig.1. (a) Polycarbonate packing material (b) packing material placing zig-zag position in column

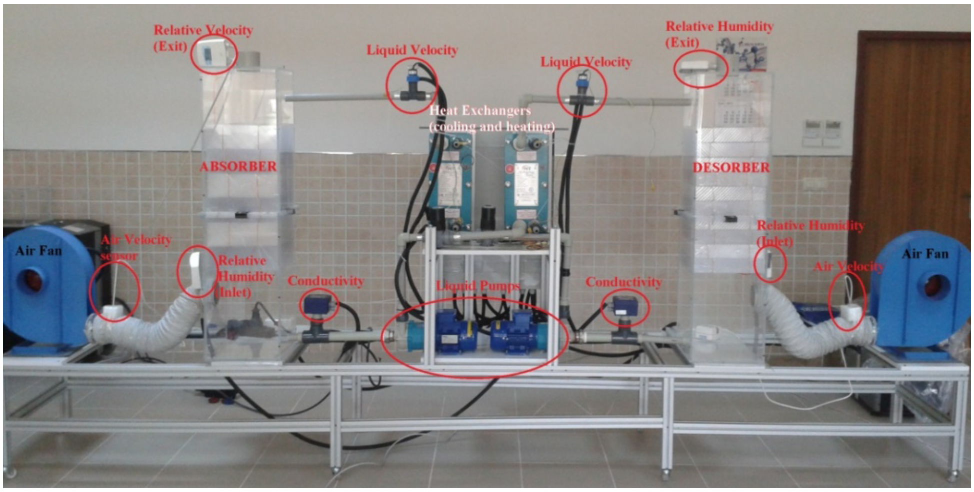

Fig. 2. Photograph of constructed open liquid desiccant system

The experimental procedure of OLD system can be explained by following steps.

- The absorber and desorber columns were filled with 35L LiBr-water solution.
- Packing materials were placed into the columns.
- Top of columns (absorber and desorber) were placed and connections were tighten.
- Switch on for control panel.
- SCADA control programme was started from computer.
- First air fans were started.
- Selenoid valves were opened.
- Liquid pumps were operated.
- Rpm of fans and pumps were adjusted according to experimental plan.
- Data was saved after the OLD system operates in equilibrium for a while.

3. Theory

First stage of air conditioning process is dehumidification of ambient moist air with active desiccant in the absorber (Fig. 2). The water vapor is removed from the air by absorption of water into the desiccant. During the water vapor absorption into desiccant, the heat is evolved and the temperature of dehumidified air and weak desiccant are increased. This process is adiabatic with the latent heat of air being changed into sensible heat at approximately constant enthalpy as shown in Fig. 3. Hot dry air is cooled by heat exchanger as represented by line 2-3 on the psychrometrics chart in Fig. 3.

In the regeneration cycle of open-cycle desiccant systems, concentration of desiccant in the solution is increased by removing water. Through the line 5-6, temperature of ambient air is increased by using heat exchanger. Thus, the relative humidity of air is reduced. In another word, the water uptake capacity of air is increased. Hot air is passed through the desorber (Fig. 2) for removing the water from weak desiccant solution indicating by line 6-7 in Fig. 3. The water is evaporated from desiccant to the air thus the temperatures of desiccant and air are reduced. Strong desiccant solution is ready to be used in the air conditioning cycle.

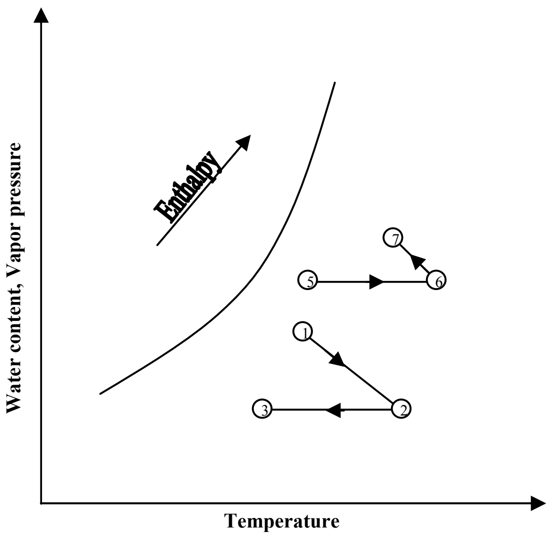

Fig. 3. Psychrometrics of open-cycle desiccant air conditioning [5]

Saturation pressures of the water vapor in the air at inlets and the outlets of the columns were calculated by Antoine equation.

$$lnP_{sat} = A - \frac{B}{T+C} \quad (1)$$

Where A=8.10765, B=1750.286 and C=235 are the Antoine parameters for water vapor. Specific humidity can be found by following equation [6].

$$\omega = 0.622\frac{\emptyset\, P_{sat}}{P-\emptyset\, P_{sat}} \quad (2)$$

Humidity ratio of LiBr-water solution is another important parameter since the mass transfer from the air to the liquid desiccant occurs only the humidity ratio of air higher than the humidity ratio of liquid desiccant. Otherwise, dehumidification of air cannot be achieved. Humidity ratio of liquid desiccant (ω^{sat}) was evaluated by using EES programme. The absorber efficiency was calculated by following equation [7,8]:

$$\eta_{Ab}(\%) = 100\frac{(\omega_{in}-\omega_{out})}{(\omega_{in}-\omega^{sat})} \quad (3)$$

The performance of the desiccant systems was evaluated by two different ways that the first COP definition includes only thermal energy supplied from electrical heater which can be replaced with solar collectors during application. Second COP definition regards parasitic losses (from fans and liquid pumps). Defined COP values can be determined by using following equations:

$$COP_1 = \frac{Q_{ev}}{Q_{HEx,heating}} \quad (4)$$

$$Q_{ev} = m_\alpha(\omega_{in} - \omega_{out})\Delta H_{ev} \quad (5)$$

$$Q_{HEx,heating} = m_{hw}xCp_{hw}(T_{out} - T_{in}) \quad (6)$$

$$COP_2 = \frac{Q_{ev}}{W_{elec}} \quad (7)$$

4. Results and discussions

Table 1 illustrates the measured data during experiments. Fig.4 presents variation of absorber efficiency with respect to time for two different air flow rates. Generally, absorber efficiency fluctuates according to relative humidity of inlet air. In spite of fluctuations, for low air flow rate system operates more orderly. Increasing air flow rate increase the disorderedness of absorber efficiency. Fig. 4 can be interpreted as the system can respond to the changes immediately. At low air flow rate, average absorber efficiency was above 20%.

Table 1. Measured data during monitoring the experiments

Name	Value
Heating water temperature	65^{o}C
Heating water flow rate, m_{hw}	0.4 kg/s
Cooling water temperature	20-25^{o}C
Cooling water flow rate, m_{cw}	0.274 kg/s
Air flow rate through the absorber, $m_{ab,\alpha}$ (0.0046xFreq. Hz)	0.092 – 0.138 m^3/s
Average air density through the absorber	1.15 kg/m^3
LiBr-water solution concentration	43%
Absorber and desorber fan power 60Hz	750W
Liquid pumps power 60Hz	550W
Total parasitic power, W_{elec}	860W – 990W

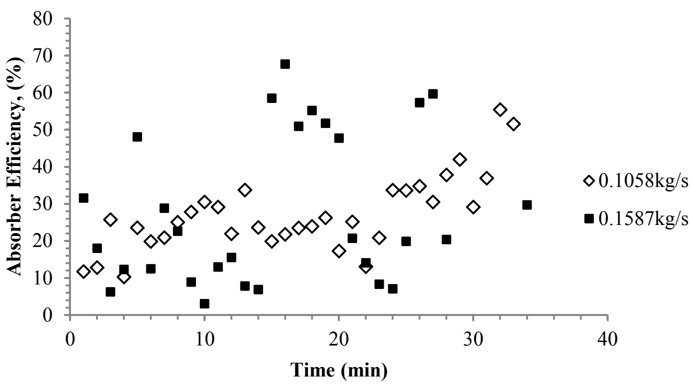

Fig.4. Instantaneous absorber efficiency for two different air flow rate

Fig.5 presents coefficient performance of dehumidification of system for different definitions. Thermal COP of the system was considerably low. However, thermal energy may be supplied from renewable energy resources during application of the system. For that reason, small achievement during operation of the system is invaluable besides the consumed thermal energy. Second definition of COP including parasitic losses was higher than COP_1. In some cases the COP_2 reached 0.30-0.35. Although the high COP_2 values gives good promises, the system needs some modifications.

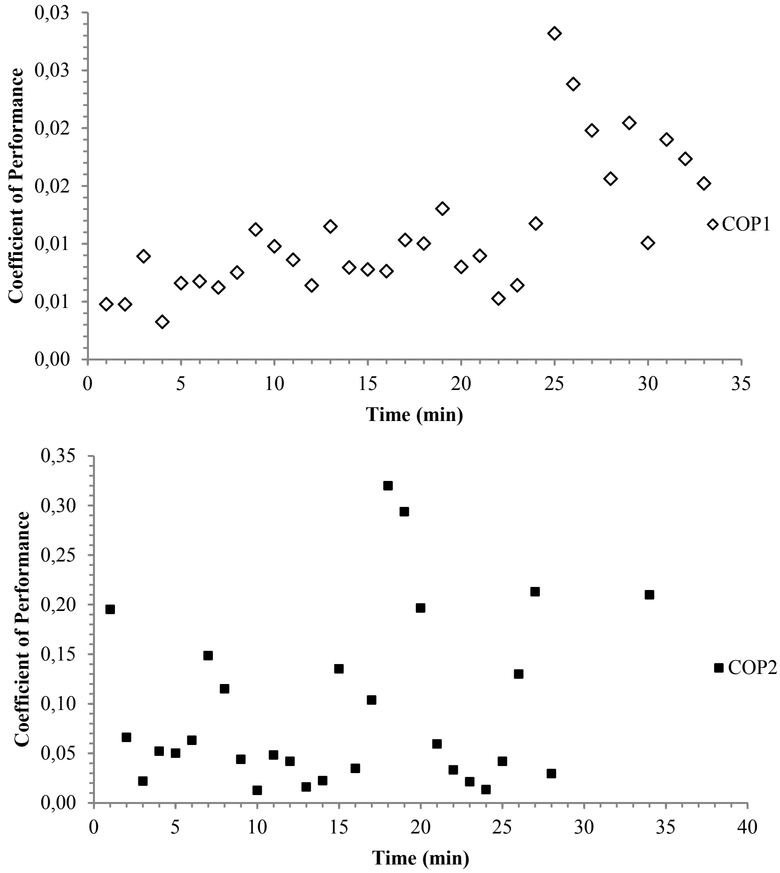

Fig.5. Instantaneous coefficient of performance of system according to two different definitions

5. Conclusions

The open liquid desiccant system was designed and constructed. The system was monitored using SCADA control and automation programme. The originality of this study was using polycarbonate packing materials having high surface tension which is close enough to surface tension of liquid desiccant. The packing materials were manufactured with 30^o angle and 43% LiBr – water solution was used as desiccant. Established study includes preliminary results of the experiments. The constructed system dehumidified air due to low coefficient of performances. Results indicate that the constructed system needs some modification such as increasing the contact area between liquid desiccant and air and decreasing temperature of liquid desiccant during inlet of absorber. In future study, these problems will be tried to eliminate and improve the COP of the system for both definitions.

Acknowledgements

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