

The Optimization of Hybrid Air Ventilation System Combined with Silica Gel and Thermoelectric Using Monitoring Control

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ABSTRACT

In this paper, the experimental is evaluated temperature, humidity and air pollution from CO₂ by monitoring control of hybrid air ventilation for producing fresh air. The experimental divided into 2 conditions: hybrid air ventilation on-off, recovery silica gel unit. That research consider of a voltage of thermoelectric devices relative with air cooling under thermal comfort zone Thailand climate conditions. In the experimental was designed by the DOAS system (dedicate outdoor air system) concept. Whereas, the hybrid air ventilation was improved by old air ventilation which the hybrid air ventilation combined with silica gel unit and thermoelectric device. Monitoring control is written by Arduino program that is open source for control performance of processes such as sensors, electric current and fan unit. That working is specified temperature and humidity Thailand thermal comfort range. In the part of CO₂ was released rate approximately 900 ppm corresponded with indoor air quality standard (IAQs). The results of experimental suggested that in case of hybrid air ventilation system explained thermal, humidity and CO₂ distribution due to the system was adapted significantly in the comfort zone temperature and humidity about 28°C and 58% respectively. However, the CO₂ released into the hybrid air ventilation although control during 900 – 1,000 ppm. High CO₂ concentration in comfort zone used the hybrid air ventilation that decreased CO₂ inlet under ASHRAE 62.2. Therefore, the experimental is an evaluation of monitoring control hybrid air ventilation for management comfort zone. Finally this research concept of the optimization of the hybrid air ventilation combination with thermoelectric devices and silica gel unit.

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1. INTRODUCTION

In the present, the new investigation and research topics have studied by the engineering, scientist, etc. that realize to the environment. Including of the world is affected by global warming and climate change. The high outdoor air temperature impact to the occupants inside. Due to a lot of a people spent their times more than 6-8 hours in the building such as working, relaxing, sleeping and other activity [1]. Therefore, the thermal comfort and indoor air quality (IAQs) are essential to designation for the building. However, the losing thermal comfort zone consists of heating, lighting, air pollution, bacteria, humidity and a lot of people per room [2]. Thus, the solution is using ventilation and air condition system inside the building. But the air condition system demands high energy consumption that influences to energy costs.

So, the research topic has an assumption for the improvement of older air ventilation system. Due to older air ventilation system has lower enegy demand. That the hybrid air ventilation system has developed by

older air ventilation conception. And using the monitoring control for carrying out the system in the case of addition fresh air. The hybrid air ventilation system has applied and considered in the part of fresh air temperature and humidity control that referred by DOAS (Dedicated outdoor air system) [3]-[5]. In the case of thermal comfort and indoor air quality are studied by DOAS concept. A most of topic considered attention energy management by using auto system combination with simulation models [6]. In case of some topics was studied the development of thermal comfort models for various climate zone of north-east India. For considratoin is shown 4 condition inddor-outdoor air temperature and relative humidity. The model developed using the measurement data of January and July months and validated with measured data of April and October months. This research proposed that it is not possible to obtain a generalized thermal comfort model for all climate zone due to adaption process, expectation and perception of people are region specific requirement [7].

Heating, Ventilating and air conditioning (HVAC) system in building are designed to provide thermal comfort to maintain indoor air quality (IAQ) Due to HVAC system are often a large percentage of the energy total energy consumption of building. And constitutes 40% of the primary energy consumed in the US. In this study were performed using the multi zone air flow model CONTAM. Annual energy simulations were also performed in Energy plus. By ventilating at lower rate for 24 h. a day saved energy compared with ventilation at the higher rate prescribed in ASHRAE 62.2 and that the simulated indoor containment concentration did not exceed common benchmark or health guideline [8].

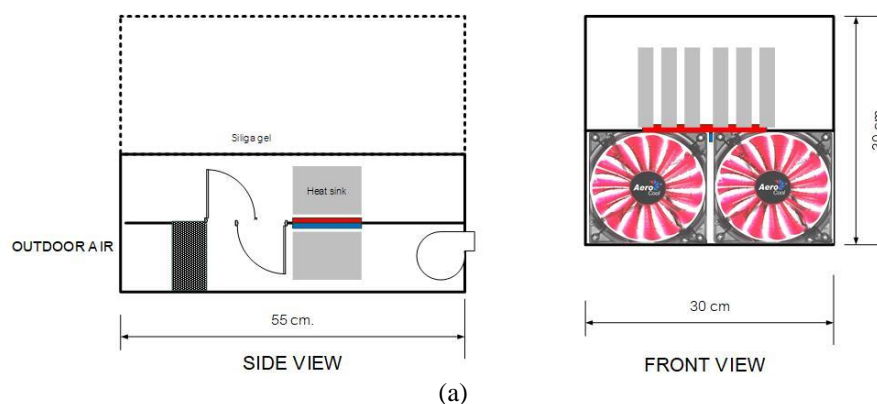
Moreover, the hybrid air ventilation system chooses thermoelectric devices to control temperature. The thermoelectric devices have a performance for thermal and power generation depending on working. For the heating/cooling producing has carried out by an electric current from the power source [9]-[11]. Including applied and combined with other systems [12]-[14]. Therefore, this paper considers the optimization of the hybrid air ventilation is composed of the thermoelectric devices and silica gels for increasing fresh air by using the monitoring control sensor.

2. DESCRIPTION SYSTEM

The experimental prepared for measurement of temperature, humidity and air pollution (CO_2) condition by using monitoring control system. However the experimental aim of improvement of older air ventilation that using an automatic system in combination with silica gel and thermoelectric

2.1. Experimental design

The hybrid air ventilation system had designed similarly with the dedicated outdoor air system. But the hybrid air ventilation system decided smaller than a requirement for replacement older generally air ventilation. This system decided the dimension width, height, and length 30 cm x 30 cm x 55 cm respectively. That shown Figure 1. The system consists of a silica gel unit approximately at 5 cm. That contained inside the system. Next, the thermoelectric cooling type (TEC-12708) used 6 modules. That thermoelectric connected in series electric circuit 3 modules, after that parallel electric circuit. The system carried on a base of optimization of reduction humidity, the temperature of outdoor air before transfer to indoor. Including of control CO_2 for addition fresh air into the room.



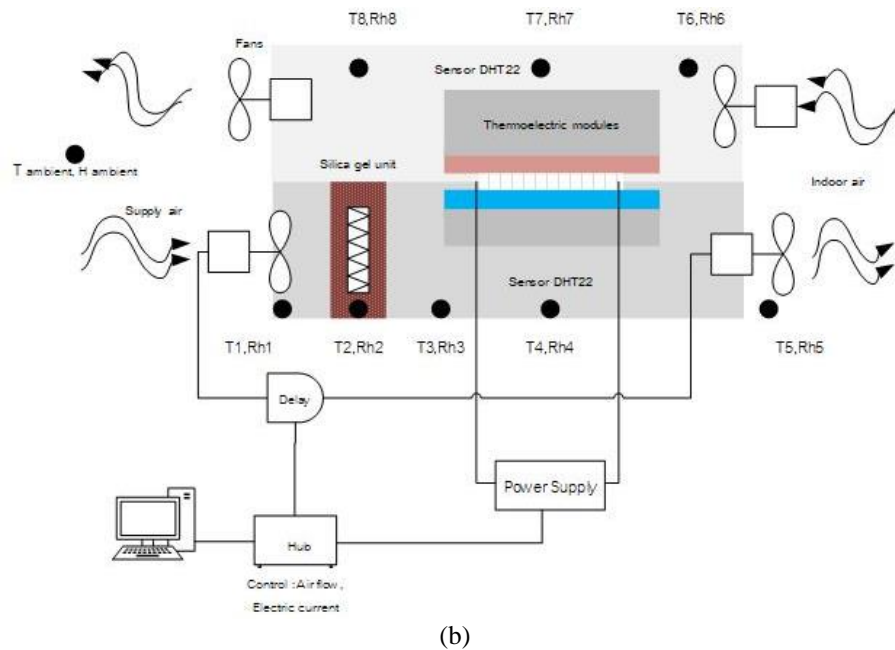


Figure 1. Design the experimental of hybrid air ventilation (a) Design of hybrid air ventilation system, (b) Sensor and monitoring of hybrid air ventilation system

2.2. Hybrid air ventilation system process

The hybrid air ventilation system divide of air chamber into 2 space. The indoor-outdoor air used to flow in the process condition. In the part of consideration divided into 2 pattern: hybrid air ventilation-on or control indoor air quality under ASHRAE 62.2 standard guideline and regeneration dehumidification unit. In this process is brought outdoor air by the fan unit. Next outdoor air is dehumidified by the silica gel unit that running with sensor control. The process decreases the humidity with the silica gel unit before passes to the thermoelectric section. That controls the temperature and humidity of the outdoor air shown as Figure 2 and Figure 3 Meanwhile, the indoor air transferred by the fan unit for increased temperature by the hot side of thermoelectric. Therefore silica gel unit is regenerated by high-temperature form indoor air.

In this experiment carried out between control outdoor air and indoor air quality and regeneration desiccant unit. Although indoor air value unexceed handbook of IAQ standard that was part of improving air quality going to stop. In the same way, the regeneration process will start for recovery desiccant unit that is solid silica gel unit.



Figure 2. System configuration of hybrid air ventilation system

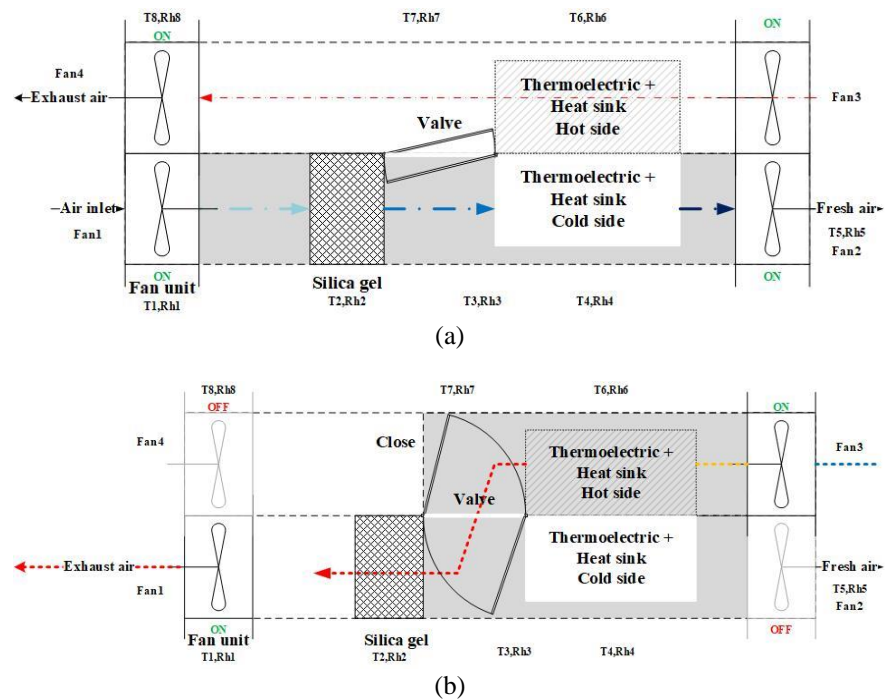


Figure 3. Performance operated of hybrid air ventilation system: (a) Hybrid air ventilation system-on; (b) Hybrid air ventilation system-on

Table 1. Specification of thermoelectric in hybrid air ventilation

Material Types	Q_{max} (W)	ΔT_{max} (°C)	V_{max}	R Ω	Number of TEC (n)
TEC –Module 12708	79	75	15.4	1.5	6

2.3. Thermoelectric and silica gel unit

The thermoelectric devices used approximately 6 modules in the experimental. That thermoelectric used TEC-12708 cooling types. Table 1 in this research chose 6 modules for producing the temperature difference between the cold side and hot side. Because power supply and specification of thermoelectric had electric potential approximately 12 - 15 V could produce $\Delta T = 45^\circ\text{C}$ if used more than effect to lifetime of thermoelectric. In the same way, the thermoelectric working coupled with silica gel unit. Thus research supposed dehumidification and temperature control shown as Figure 4.

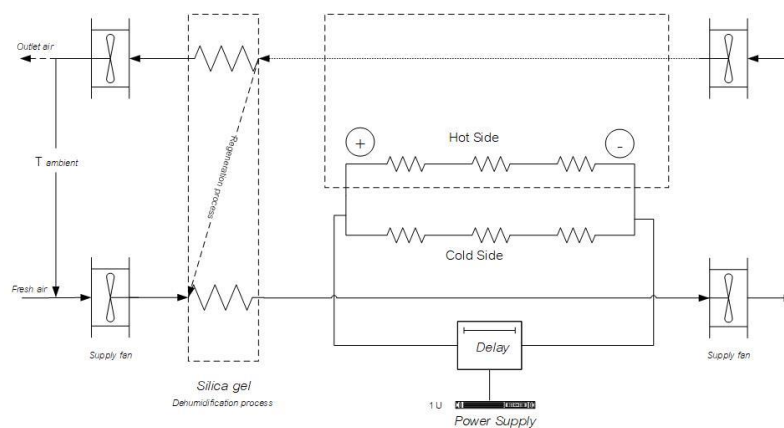


Figure 4. Processing of the hybrid air ventilation system

3. MONITORING HYBRID AIR VENTILATION CONTROL

The hybrid air ventilation working switched depending on a specification of outdoor air flow condition. The processing of the system divided into 2 types. Opening the hybrid air ventilation is controlled by IAQ parameters under ASHRAE 62.2. And the system recovered dehumidification of the silica gel unit. In this process is brought outdoor air by the fan unit. After, the outdoor air is dehumidified by the silica gel unit that running with sensor control. In this process is written by Arduino program for measurement management. The sensor used receiving values for carried out responding with the fan unit and air valves shown as Figure 5. Meanwhile, the indoor air transferred by the fan unit for increased temperature by the hot side of thermoelectric. Therefore silica gel unit is regenerated by high-temperature form indoor air.

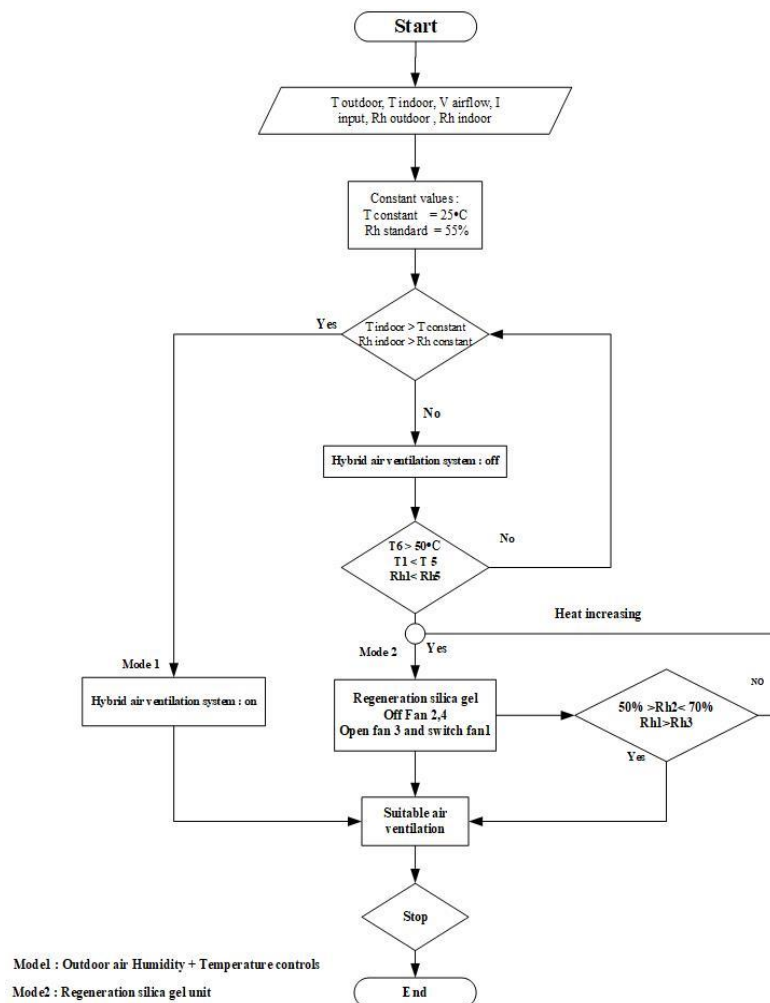


Figure 5. Flowchart of hybrid air ventilation control

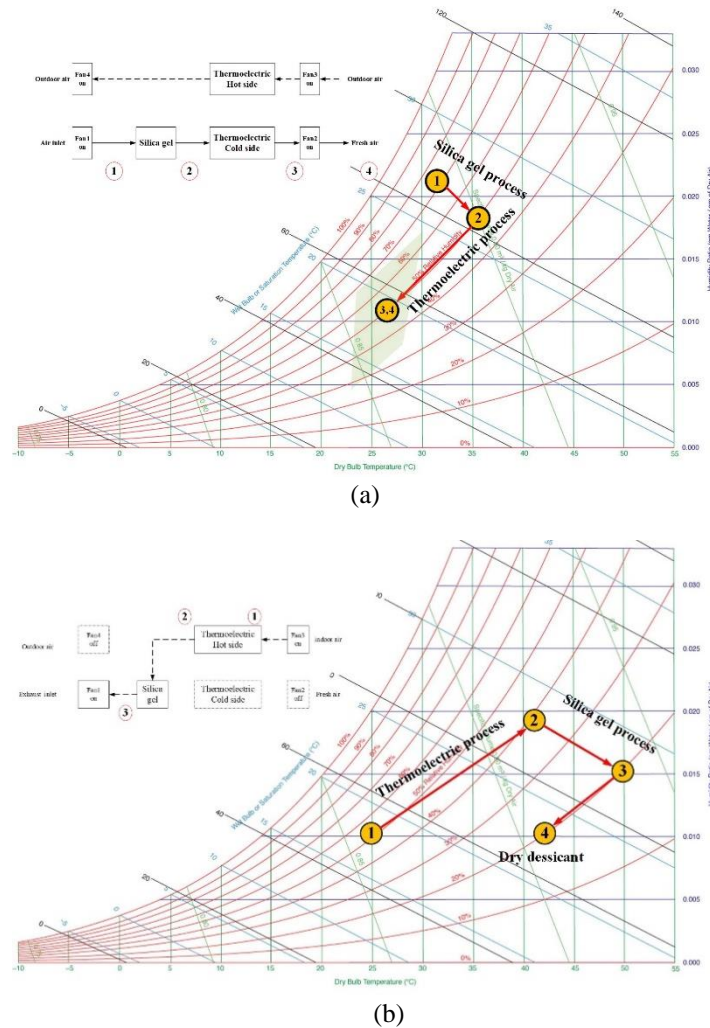


Figure 6. Psychrometric chart of hybrid air ventilation system process: (a) Mode1: Cooling and ventilation – on process; (b) Mode2: Regeneration of silica gel

4. RESULTS AND ANALYSIS

The indoor temperature and humidity controlled by the hybrid air ventilation including of monitoring sensors for management cases study divided to 4 cases: The electric current of thermoelectric relative indoor air, Thermal comfort and indoor air quality condition, Regeneration of silica gel, *COP* of the system.

4.1. Control temperature and humidity monitoring under electric control

Figure 7 Show experimental of the hybrid air ventilation at 2 days between 6:00 AM.-12:00 PM in August. This august is a rainy season of Thailand due to during higher humidity. Indoor temperature is proposed thermal comfort zone depended on ASHRAE standard 62.2. The boundary of outdoor temperature during 33–38°C. Thus in the experimental controlled constant supply air for this operation. The result suggested to an effect of silica gel unit and the thermoelectric module for control temperature and humidity under hot and wet condition. The electrical voltage at 12 V could be improvement air inlet nearly with thermal comfort standard. Due to the thermoelectric has high temperature that differences effectively to lower of the cold side of thermoelectric, so that air inlet connection with the cooling side had been transferred thermal under thermodynamic principle temperature different of air inlet with fresh air is about 5°C. In the same way, relative humidity of air inlet is reduced by silica gel unit if compared with outdoor air at average 58.9% and 62.5%. The dehumidification process proposed by using silica gel unit for absorption humidity of air inlet. But, the silica gel isn't working continuously. Due to silica gel has a saturation point. Therefore, the silica gel unit should be obtained regeneration in during close the hybrid air ventilation system.

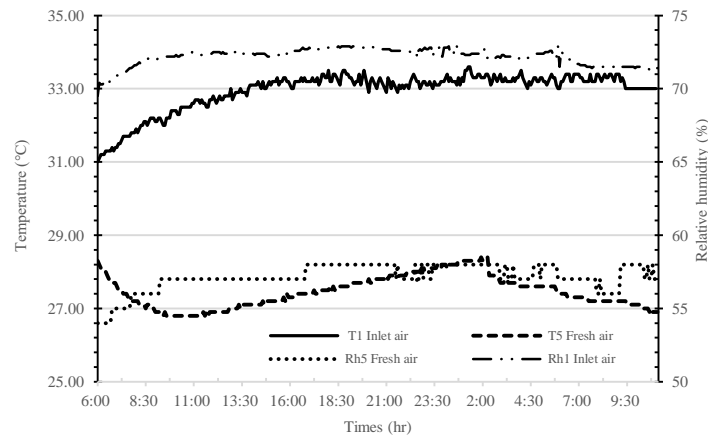


Figure 7. Hybrid air ventilation controlled temperature and humidity at 9 V

4.2. Control temperature and humidity monitoring under electric control

The performance methodology called coefficient of performance (*COP*) that explained in quantify of process. So, the evaluation of *COP* important to consider. Therefore, this paper evaluates of energy consumption of thermoelectric relative to increasing fresh air. The experimental is explained by the equation, which application defined [15],[16].

$$Q_c = c_p m_{air} (\Delta t) \quad (1)$$

If Q_c is the air cooling produced by thermoelectric devices under electric current. c_p is the specific heat, m_{air} is the mass flow rate and Δt is the different temperature between cold side of thermoelectric with air temperature across.

$$COP_{tec} = \frac{Q_c}{Q_{in} + W_{tec}} \quad (2)$$

Q_{in} is heat transfer form outdoor into hybrid air ventilation in the part of thermoelectric modules. And W_{tec} is power supply using for produce temperature different. However coefficient of performance is referenced by energy conservative that using in calculation the indoor air quality handbook [17],[18].

$$COP_{hybrid} = \frac{Q_{out}}{Q_{in} + W_{tec} + W_{fan}} \quad (3)$$

In the part of COP_{hybrid} is the coefficient of performance of the hybrid air ventilation system. The calculation method considered by principle of original *COP*. Table 2 shows the determined *COP* of thermoelectric of hybrid air ventilation system. Thus the experimental proposed electric current 12 V most *COP* when compared with the other. But in the part of energy consumption and lifetime of thermoelectric modules is not suitable for a long time. Due to thermoelectric modules is electronic devices when obtained overheating impacted to efficiency system inside. Therefore electric current at 9 V has appropriate for saving energy input including of producing temperature comfort zone.

4.3. Regenerate process

According to the experimental result as shown in Figure 10. The hybrid air ventilation system combined with thermoelectric and silica gel unit is effected evaluation by regeneration silica gel desiccant. In the case study using thermoelectric hot side for increasing hot air temperature in the exhaust chamber. So, this process affected heat transfer between silica gel with hot air for recovery desiccant handbook approximately 55 – 70°C [19]-[21]. Therefore, the experiment proposed of regeneration process regeneration relation times. The results removal humidity of silica gel about 12.66%.

$$\eta = \frac{Rh_{bf} - Rh_{af}}{Rh_{bf}} \times 100 \quad (4)$$

where, η is the efficiency of removal relative humidity of silica gel unit Rh_{bf} and Rh_{af} express for a relative humidity of before and after processing that is equation explained to efficiency calculation method.

Table 2. Experimental condition and consider

Description	Hybrid air ventilation system	
	Mode 1 On	Mode 2 Regeneration
Electrical current to Thermoelectric	3 ,6 ,9, 12 V	
Fan	\dot{m}/s	
Silica gel unit	30 cm x 30 cm x 5 cm	
Thermoelectric modules	TEC-12708 / 6 modules	
Weather location	Phitsanulok, Thailand	
Experimental period	July - October	

Table 3. Result temperature relative with input voltage of hybrid air ventilation system

Input voltage	Temperature (°C)		
	T1 Inlet air	T5 Fresh air	T8 outdoor air
3	33.01	31.00	32.71
6	32.92	29.53	32.23
9	31.48	28.40	31.57
12	31.13	28.01	31.52

Table 4. Result relative humidity with input voltage of hybrid air ventilation system

Input voltage	Relative humidity (%)		
	Rh1 Inlet air	Rh5 Fresh air	Rh8 outdoor air
3	70.99	62.26	65.35
6	70.70	61.24	65.18
9	70.71	57.62	59.15
12	70.25	56.47	59.91

4.4. Thermal comfort evaluation

The indoor air has necessary for the human that spent times in the building, while the ventilation system increases thermal comfort zone. The experiment designed by the parameters such as the temperature, humidity and air pollution (CO_2). The experiment measured spending times of 3-12 hour. That working times under free air flow ventilation rate. So, the hybrid air ventilation system is controlled average temperature and humidity respectively. The experimental is using the electric voltage of 12 V. Therefore could supply fresh air at 28°C temperature 58% relative humidity. However, the outdoor air pollution reduced by hybrid air ventilation system lower than 1,000 ppm. That has approximately 600 – 700 ppm for filter outlet air into indoor. Consider of percentage. Similarly, indoor air pollution reduced 15% compared with 900 ppm standard to 680 ppm that is condition of 9 V. for carry out of thermoelectric combination with silica gel.

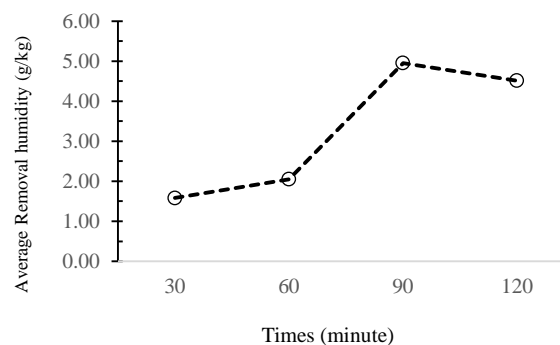


Figure 8. Regeneration relative with time of hybrid air ventilation in the experimental condition

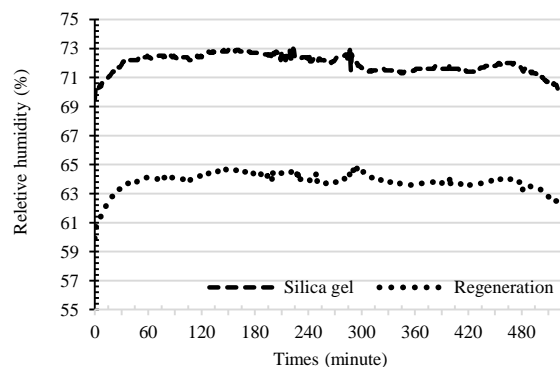


Figure 9. Regeneration relative with time of hybrid air ventilation in the experimental condition

5. CONCLUSION

In this research, the optimization of the hybrid air ventilation system combined with silica gel and thermoelectric studied by experimental method. Thus, the main experimental is the optimization of temperature and humidity control including of increasing fresh air as well introducing improve removal air pollution system such as CO₂ and use monitoring control for convenience.

The 12 v. of thermoelectric could be control temperature and humidity including air pollution CO₂ not exceed indoor air quality standard. The power of thermoelectric obtained by power supply. So, should be alternative power source for saving energy consumption. Increasing the system potential of supply fan with bigger than size for addition a many air inlet for produced fresh air including of setting in the various room. Hybrid air ventilation system is feasible in this study location. So *COP* of system depends on humidity and temperature of different condition.

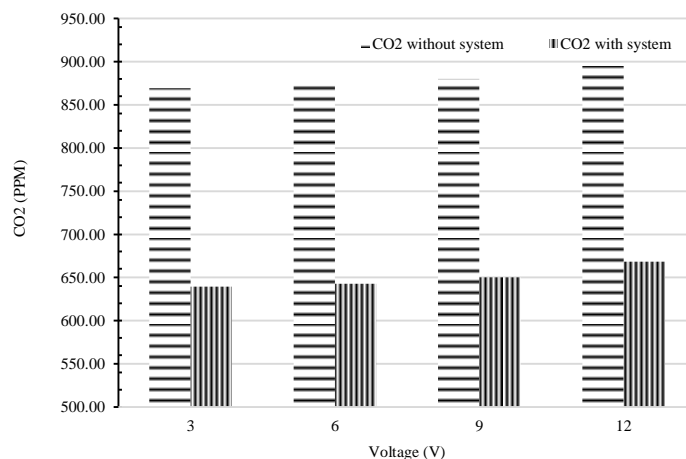


Figure 10. Comparison of performance hybrid air ventilation system reduced carbon dioxide

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