Comparison of Behaviour and Energy Performance of Desiccant Air Handling Unit under Various Control Method

To cite this article: Makiko Ukai and Masaya Okumiya 2019 IOP Conf. Ser. Earth Environ. Sci. 238 012027

View the article online for updates and enhancements.
Comparison of Behaviour and Energy Performance of Desiccant Air Handling Unit under Various Control Method

Makiko Ukai, Masaya Okumiya
Furo-cho, Chikusa-ku, Nagoya, Aichi, Japan

ukai@davinci.nuac.nagoya-u.ac.jp

Abstract. Desiccant air handling unit (DAHU) dehumidifies moisture in the air with adsorbent or sorbent. Hot water is necessary to regenerate them. In many buildings, for regeneration of the dehumidifier, hot water from combined heat and power (CHP) is used because it can supply hot water at stable temperature. When using fluctuating energy such as hot water from solar thermal collector, it is mixed with hot water from CHP in order to compensate the fluctuation, and supplied. In order to use renewable energy including solar thermal energy efficiently, we propose flexible control compared to ordinary fixed control. The ordinary fixed control controls outlet air temperature of pre-cooling coil at fixed temperature, for example 19°C, and the relative humidity is 100%. Therefore, dehumidification amount at dehumidification wheel as well as regeneration coil demand does not fluctuate very much. On the other hand, flexible control controls outlet condition of pre-cooling coil with absolute humidity of supply air and hot water temperature to regenerating coil. When hot water temperature is enough hot, absolute humidity of supply air fulfills set point, therefore pre-cooling coil demand decreases. When hot water temperature is not hot enough, supply absolute humidity does not fulfill the set point. In this case, outlet temperature of pre-cooling coil will get lower in accordance with hot water temperature. This study investigates the behavior and performance of DAHU under different control methods through energy simulation. Simulation results show that when installing flexible control, outlet air state of pre-cooling coil is determined depending on the hot water temperature to regenerating coil. It proves that it is possible to handle required latent heat load even when hot water temperature is low around 45°C. DAHU with flexible control can contribute the effective use of solar thermal heat.

1. Introduction

Desiccant air handling unit (DAHU) is one of the major dehumidification system for temperature and humidity independent control of air handling unit, and it’s increasing in installation of DAHU widely in office buildings. DAHU dehumidifies moisture in the air with adsorbent or sorbent. Hot water is necessary to regenerate them. In many buildings, for regeneration of the dehumidifier, hot water from combined heat and power (CHP) is used because it can supply hot water stably. When using fluctuating energy such as hot water from solar thermal collector, it is mixed with hot water from CHP in order to compensate the fluctuation, and supplied. In order to use renewable energy including solar thermal energy efficiently, we propose flexible control. The ordinary fixed control controls outlet air temperature of pre-cooling coil at fixed temperature, for example 19°C, and the relative humidity is 100%. Therefore, dehumidification amount at dehumidification wheel as well as regeneration coil demand does not fluctuate very much. On the other hand, flexible control controls outlet condition of pre-cooling coil
with absolute humidity of supply air and hot water temperature entering regenerating coil. When hot water temperature is enough, supply air fulfills set point, therefore pre-cooling coil demand decreases. When hot water temperature is not enough, supply dew point does not fulfill the set point. In this case, outlet temperature of pre-cooling coil will get lower in accordance with hot water temperature. This study investigates the behavior and energy performance of DAHU under different control methods through simulation in cooling period.

2. Target building

The target building is office building located in Tokyo, in Japan. It has five stories and air-conditioning area of typical floor is 983m2 as shown in Figure 1. It is designed with some energy saving methods including eaves, high insulated walls and roofs, and LED lighting. The room set temperature is 28°C and relative humidity is 40% in cooling period according to comfort zone by Kato1) and “COOL BIZ”2) campaign where appropriate room condition and clothes are proposed. The load calculation is conducted with Micro PEAK3) which has periodic stationary calculation for one week. Figure 2 shows outdoor condition and the hourly heat load of the typical floor.

3. Configuration of the system

Figure 3 shows the configuration of the desiccant air handling unit and hot water system for regenerating coil. Flesh outdoor air is supplied to desiccant system directly. DAHU handles flesh air load (flesh sensible heat load and flesh latent heat load) and indoor latent heat. The system in this study is composed of pre-cooling coil, desiccant wheel, sensible heat exchanger, after-cooling coil and regenerating coil in Figure 3. Flesh air (1, the number in brackets is correlated to the number in Figure 3) is provided to pre-cooling coil to be precooled and dehumidified (2), and then passes desiccant wheel (3), sensible heat exchanger with return air (4) and after-cooling coil (5). Return air (RA) (6) passes sensible heat exchanger (7), and then it is heated up at regenerating coil (8). High temperature air desorbs moisture from polymeric adsorbents and finally is exhausted (9).

Table 1 shows the specifications of solar thermal system. Evacuated tube type of solar collectors are installed on the roof and total area of the solar collectors is 196m2, which accounts for 20% of the roof area. Collected heat is firstly supplied to the solar thermal tank, and then supplied to the regenerating coil when the water temperature in the tank is enough hot. When solar thermal is not enough hot, the hot water with constant temperature at 85°C from CHP is supplied to the regenerating coil instead. The temperature of chilled water supplied to the pre-cooling coil and after-cooling coil is constant at 7°C.
Figure 3 Outline of the system

Table 1 Specifications of solar thermal system

| Specifications                                      | Number |
|-----------------------------------------------------|--------|
| Evacuated tube type solar thermal collector         | 64     |
| Effective area: 3.0m²                                |        |
| Gloss area: 3.4m²                                   |        |
| Efficiency: η=50.6-0.191*dT/Qsol tilt angle: 35°    |        |
| Completely mixed solar thermal tank                 | 1      |
| 4 m³                                                |        |
| dT: the temperature difference between average temperature between inlet and outlet temperature and ambient temperature [°C] |
| Qsol: solar radiation [kW/m²]                       |        |

4. Control method

In this study, two control methods are investigated. One is fixed control and the other is flexible control. Figure 4 shows the diagram of the controls. The ordinary fixed control controls (Figure 4(a)) outlet air temperature of pre-cooling coil at fixed temperature, for example 19°C, and the relative humidity is 95%. Therefore, dehumidification amount at dehumidification wheel as well as regeneration coil demand does not fluctuate very much. On the other hand, flexible control controls (Figure 4(b)) outlet condition of pre-cooling coil with dew point of supply air and hot water temperature entering to regenerating coil. When hot water temperature is not enough hot, outlet temperature of pre-cooling coil gets lower and dehumidification amount at pre-cooling coil increases.
5. Outline of simulation

Simulation is conducted for five continuous days with LCEM tool 4)5) which has been developed under the Ministry of Infrastructure, Land, Transport and Tourism. This simulation tool is based on Excel of Microsoft. By connecting modules which represent device and communicating each other, 1-hour static calculation is achieved.

The outdoor condition including temperature, relative humidity and solar radiation are the same condition as load calculation. Outdoor condition of the days is shown in Figure 2.

The operation time of DAHU is from 9:00 to 17:00. The set point of supply air (SA) is at 28°C and 6.56g/kg' of absolute humidity from 10:00 to 17:00. At 9:00, the set point of SA is 28°C and 7.13 g/kg' because indoor latent heat load is small. Supply air volume is determined by the number of the occupants (30m3/h/each occupant) and return air volume is assumed to be 90% of the supply air volume, therefore supply air volume and return air volume is 22120 m3/h (4424 m3/h/ floor) and 19905 m3/h (3981 m3/h/ floor) respectively.

Table 2 shows simulation case considered in this study. In fixed control, in order to fulfill the set absolute humidity, the required minimum temperature for regeneration is 54°C, therefore, the control of the solar thermal utilization to regenerating coil is set at 55°C.

---

5. Outline of simulation

Simulation is conducted for five continuous days with LCEM tool 4)5) which has been developed under the Ministry of Infrastructure, Land, Transport and Tourism. This simulation tool is based on Excel of Microsoft. By connecting modules which represent device and communicating each other, 1-hour static calculation is achieved.

The outdoor condition including temperature, relative humidity and solar radiation are the same condition as load calculation. Outdoor condition of the days is shown in Figure 2.

The operation time of DAHU is from 9:00 to 17:00. The set point of supply air (SA) is at 28°C and 6.56g/kg' of absolute humidity from 10:00 to 17:00. At 9:00, the set point of SA is 28°C and 7.13 g/kg' because indoor latent heat load is small. Supply air volume is determined by the number of the occupants (30m3/h/each occupant) and return air volume is assumed to be 90% of the supply air volume, therefore supply air volume and return air volume is 22120 m3/h (4424 m3/h/ floor) and 19905 m3/h (3981 m3/h/ floor) respectively.

Table 2 shows simulation case considered in this study. In fixed control, in order to fulfill the set absolute humidity, the required minimum temperature for regeneration is 54°C, therefore, the control of the solar thermal utilization to regenerating coil is set at 55°C.

---

Table 2 shows simulation case considered in this study. In fixed control, in order to fulfill the set absolute humidity, the required minimum temperature for regeneration is 54°C, therefore, the control of the solar thermal utilization to regenerating coil is set at 55°C.

---

The operation time of DAHU is from 9:00 to 17:00. The set point of supply air (SA) is at 28°C and 6.56g/kg' of absolute humidity from 10:00 to 17:00. At 9:00, the set point of SA is 28°C and 7.13 g/kg' because indoor latent heat load is small. Supply air volume is determined by the number of the occupants (30m3/h/each occupant) and return air volume is assumed to be 90% of the supply air volume, therefore supply air volume and return air volume is 22120 m3/h (4424 m3/h/ floor) and 19905 m3/h (3981 m3/h/ floor) respectively.

Table 2 shows simulation case considered in this study. In fixed control, in order to fulfill the set absolute humidity, the required minimum temperature for regeneration is 54°C, therefore, the control of the solar thermal utilization to regenerating coil is set at 55°C.

---

The operation time of DAHU is from 9:00 to 17:00. The set point of supply air (SA) is at 28°C and 6.56g/kg' of absolute humidity from 10:00 to 17:00. At 9:00, the set point of SA is 28°C and 7.13 g/kg' because indoor latent heat load is small. Supply air volume is determined by the number of the occupants (30m3/h/each occupant) and return air volume is assumed to be 90% of the supply air volume, therefore supply air volume and return air volume is 22120 m3/h (4424 m3/h/ floor) and 19905 m3/h (3981 m3/h/ floor) respectively.

Table 2 shows simulation case considered in this study. In fixed control, in order to fulfill the set absolute humidity, the required minimum temperature for regeneration is 54°C, therefore, the control of the solar thermal utilization to regenerating coil is set at 55°C.

---

The operation time of DAHU is from 9:00 to 17:00. The set point of supply air (SA) is at 28°C and 6.56g/kg' of absolute humidity from 10:00 to 17:00. At 9:00, the set point of SA is 28°C and 7.13 g/kg' because indoor latent heat load is small. Supply air volume is determined by the number of the occupants (30m3/h/each occupant) and return air volume is assumed to be 90% of the supply air volume, therefore supply air volume and return air volume is 22120 m3/h (4424 m3/h/ floor) and 19905 m3/h (3981 m3/h/ floor) respectively.

Table 2 shows simulation case considered in this study. In fixed control, in order to fulfill the set absolute humidity, the required minimum temperature for regeneration is 54°C, therefore, the control of the solar thermal utilization to regenerating coil is set at 55°C.
6. Results and discussion

6.1. Behaviour of DAHU on the representative day (the fifth day)

Figure 5 shows the air state of DAHU on psychrometric chart at 12:00 on the fifth day. In fixed control, 63°C of hot water from solar thermal system is supplied to regenerating coil, and outlet of pre-cooling coil is 19°C. In flexible control with 45°C, 47°C of hot water from solar thermal system is supplied to regenerating coil and outlet of pre-cooling coil is 18°C. The number in brackets in Figure 5 is the same in Figure 3.

(a) fixed control

(b) flexible control

Figure 5 the air condition of DAHU on psychrometric chart at 12:00 on the fifth day

Figure 6 shows outlet of pre-cooling coil and hot water temperature to regenerating coil. The outlet air condition of the pre-cooling coil is determined in accordance with temperature entering to the regenerating coil.

Figure 6 outlet of pre-cooling coil and hot water temperature to regenerating coil under flexible controls with 55°C, 50°C, and 45°C

Figure 7 shows the amount and temperature of solar thermal heat supplied to regenerating coil. In fixed control, the amount of the solar thermal supplied to regenerating coil is 86 kWh, however in flexible
control the amount of the solar thermal supplied to regenerating coil fluctuates depending on the
temperature from solar thermal system.

![Figure 7 amount and temperature of solar thermal supplied to regenerating coil](image)

**6.2. Performance of the DAHU**

Figure 8 shows the processed air load and heat demand to each coil for five days. The processed air is
the same value in the all cases, therefore it proves that the set point of the desiccant air handling unit is
fulfilled even if the relatively lower temperature from solar thermal collector is provided to regenerating
coil.

When installing flexible control, compared to the installing fixed control, regenerating coil
demand decreases and cooling demand increases. Among flexible controls, the regenerating coil demand
of flexible control with 45°C solar thermal utilization control is lower than that with 55°C solar thermal
utilization control. This results from lower supplied temperature to regenerating coil.

For evaluation of the DAHU itself, desiccant COP \( COP_{des} \) is defined with equation (1).

\[
COP_{des} = \frac{Q_{pro}}{Q_{pre} + Q_{after} + Q_{re}} \quad (1)
\]

\( Q_{pro} \) is processed air load [kWh], \( Q_{pre} \) is pre-cooling coil demand [kWh], \( Q_{after} \) is after-cooling
coil demand [kWh], and \( Q_{re} \) is regenerating coil demand [kWh].

\( COP_{des} \) with fixed control is higher than that with flexible control because of lower outlet
condition of the pre-cooling coil. However, as shown in Figure 9, the collected solar thermal heat and
solar thermal heat supplied to the regenerating coil is larger with flexible control than fixed control.
Therefore, installing flexible control for DAHU can contribute more effective and efficient solar thermal
use in summer.
Figure 8 the processed air load and heat demand to each coil for five days

Figure 9 collected solar thermal heat and solar thermal heat supplied to the regenerating coil

7. Conclusion

This study investigates the performance and behaviour of two control methods for desiccant air handling unit (DAHU): one is fixed control and the other is flexible control. DAHU is assumed to be installed in five–stories office building and simulation for five continuous days is conducted. Simulation results show as follows.

1. When installing flexible control, outlet air state of pre-cooling coil is determined depending on the hot water temperature to regenerating coil. It proves that it is possible to handle required latent heat load even when hot water temperature is low around 45°C.
2. DAHU with flexible control can contribute the effective use of solar thermal heat.

For further investigation, it is required to consider energy performance of whole system including CHP, chillers and related devices. In addition, it is important to figure out the optimum solar thermal system with flexible control for DAHU.

References

[1] Kato M, Umemura S and et al. 1992 Architectural Institute of Japan annual meeting 857 (in Japanese)
[2] Ministry of the environment (in Japan) “COOL BIZ” Campaign, https://www.env.go.jp/en/earth/cc/framework/5th/04_chpt3.pdf, last accessed on 10th October 2018
[3] MICRO-PEAK 2010, http://www.jabmee.or.jp/soft/index.php, last accessed on 27th July 2018
[4] LCEM tool, http://www.mlit.go.jp/gobuild/SESAKU_LCEM_lcem.html, last accessed on 27th July 2018
[5] Ito M, et al. 2007 Proceedings of Building Simulation 1610