Application of Solar Air-condition System to Prevent Wall Condensation and Sick Building Syndrome in Humid Area

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Abstract: The wall condensation plays a significant role to increase probability of sick building syndrome in humid countries. The risk of condensation of air water vapor on the wall in buildings which are in the hot and humid region is high. One of best the methods to prevent wall condensation is controlling dew point temperature of room air. In this study to evaluation of dew point controlling by means of cooling system, application of two different cooling systems (namely, conventional HVAC system, and solar hybrid desiccant cooling system) for one test room in Malaysia was analyzed by TRNSYS simulation software. Temperature, and humidity ratio, and also dew point of room air for each system were detected. According to thermal condition of wall condensation (T_{wall} < T_{dew point}) and also, simulation results, It was achieved that the risk of wall condensation is very less when solar desiccant cooling system is used as cooling system because of chemical dehumidification with desiccant material. Application of conventional HVAC system has high risk for wall condensation in humid area.

Keywords: solar cooling system, dew point control, wall condensation, HVAC system

1. Introduction

Due to much attention to only energy saving of HVAC system, and also, lack of attention to Indoor Air Quality (IAQ) of the building, the Sick Building Syndrome (SBS) has become common issues in recent year in Malaysia [1]. The term SBS has been used to describe symptoms (including headaches, fatigue, and irritation in the upper respiratory tract, nose, throat, eyes, hands and/or facial skin) that can be influenced by the indoor environment [2]. The high humidity ratio of indoor air causes that the dew point of indoor air becomes higher than wall temperature. Then the water vapor of indoor air condenses on the wall. The condensed water on the wall is the best place for growing mould and fungus inside the room. As regards the existing mould and fugues inside the building increase the risk of SBS, therefore, the wall condensation is an important issue in the field of SBS. Perverting of wall condensation can be reduce the probability SBS. In recent years, many scientific and researchers [3-6] have studied to evaluate the solar desiccant cooling system as alternative solution to improve IAQ of the building. Angrisani et al.,[7] investigated dehumidification capacity of one solar hybrid desiccant cooling system experimentally, they demonstrated that the proposed system improved IAQ. Fong et al.,[8] evaluated the conventional HVAC system and solar desiccant cooling system in subtropical weather of Hong Kong. They found that over cooling problem and wall condensation in subtropical countries is due to using the conventional HVAC system. Subramanyam et al.,[9] investigated the application of the desiccant wheel to control humidity in air-conditioning system. Their results show that the proposed system can deliver supply air at much lower dew point temperature compared to the conventional system. A review study about the effect of different types of solar desiccant cooling system on humidity control separately with sensible cooling was carried out by La et al., [10]. They clouded that various types of the solar desiccant cooling system in comparison to the conventional HVAC system have great potential to control humidity.
This paper presents an investigation of wall condensation condition in one building in Malaysia by application of two different cooling systems (conventional HVAC and solar desiccant cooling).

2. Methodology

The methodology of this study is including three steps to investigate the behavior of wall condensation. In first step critical point of wall condensation is explained. In the second step the trend of temperature and humidity of the room under the conventional HVAC system is analyzed by TRNSYS software. In the third step, behavior of temperature and humidity of room under solar desiccant cooling system is detected by simulation. Then by comparison result of two systems, the feasibility of the best cooling system to prevent wall condensation was carried out. The three steps are explained in following sections.

2.1 Identification of critical condition for wall condensation in building

Due to hot and humid weather of Malaysia which have ambient temperature, and humidity in range of 29°C-34 °C and 70% -90%, and also using humid fresh air in HVAC system, the risk of wall condensation in a building is high. Figure 1 shows the sample of condensation of air water vapor on the wall in Malaysia.

Figure 1: Condensation on wall due to high humidity of room air

To prevent condensation of water vapor of the air on the wall, identify of condensation causes should be evaluated. In fact, as shown in figure 2, when the wall temperature is less than dew point temperature of room air, the condensation of water vapor of air will be happened on the wall surface. Therefore the dew points of room air and wall temperature were as critical points of condensation. Regarding to constant value of wall temperature, the control of dew point is the best method to avoid of condensation in buildings. For controlling dew point of room air, effect of room temperature, and humidity on the dew point was considered while the humidity ratio of room air had direct relation with dew point. So, to prevent wall condensation under constant temperature value of a wall, dew point should be reduced. To decrease the dew point, humidity ratio of room air should be reduced. To reduce the humidity ratio of room, the humidity ratio of supply air must be reduced.

Figure 2: schematic of wall condensation condition in building

Therefore, application of cooling system to provide supply air with low humidity ratio has an important role in control dew point method. In order to investigate the effect of the cooling system on the dew point control, also wall condensation, two different cooling systems were applied in one building with a constant value of wall temperature.

2.2 Conventional HVAC

As shown in figure 3, in order to remove latent load of air, the temperature of cooling coil should be below dew point temperature of the air. Once the order hand, in the conventional HVAC system the dehumidification of air is based on condensation of water vapor of air in cooling coil.

Figure 3: schematic of conventional HVAC system

Therefore the air after mechanical dehumidification and reduce temperature goes to room as supply air. Almost 20% of return air goes into ambient air as
exhausted air, and 80% of return air cloud be mixed with 20% of fresh air. In the second step, in order to detect the effects of the application HVAC system on the dew point control, one model of a conventional HVAC system was simulated by TRNSYS software.

2.3 Simulation of solar cooling system

As shown in figure 4, solar desiccant hybrid cooling, consist of solar collector, desiccant wheel, heat recovery wheel, humidifier, air flow rate controller, chiller, and heat exchanger. In this system the dehumidification process is based on chemical dehumidification by using silica-gel as desiccant material. With crossing air through the desiccant material, the water vapor of the air is absorbed by means of desiccant material in process air section then it can be removed from the desiccant material by hot air in regeneration section.

In the third step, in order to evaluate the effect of the solar desiccant cooling system on the control dew point, one model of this system was simulated. Figure 5 shows the simulation model of solar hybrid desiccant cooling system which is applied to the one building in Malaysia.

Figure 4: schematic of solar hybrid desiccant cooling system

Table 5: simulation model of solar hybrid desiccant cooling system
3. Results and Discussion

In this section, the simulation results of conventional HVAC system and solar hybrid desiccant cooling system are explained. As mentioned in section 2.1, dew point of room air has direct relation to temperature and humidity ratio of the room. Therefore, for each system temperature and humidity of supply air, and room air is detected.

3.1 Conventional HVAC system

Figure 6 shows the trend of temperature (°C) of supply air, room air, and ambient air versus time (hour) when one HVAC system applied to one room as cooling system. The range of supply air temperature is between 16 °C - 20°C. The average supply air temperature for one year operation (8760 hour) was 18°C, while it was 27°C for room temperature. The ambient air temperature of Malaysia was in the range 21-37 Celsius.

Figure 6: temperature of supply air and room under conventional HVAC system

Figure 7 shows humidity ratio (kg/kg) of supply air, room air, and ambient air versus time (hour). The average humidity ratio of supply and room air are 0.0125, 0.015 kg/kg respectively. The average humidity ratio of ambient air during the one year is around 0.020 kg/kg.

Figure 7: humidity ratio of supply air and room under conventional HVAC system

3.2 solar desiccant cooling systems

Figure 8 shows the trend of temperature (°C) of supply air, room air, and ambient air versus time (hour) when one solar hybrid desiccant cooling system applied to one room as the cooling system. The average temperature of supply air and, room air during the 8760 hour operation of the solar desiccant cooling system are 16 °C, and 25 °C respectively. Fluctuations of supply and then the room air temperature are less, due to chemical dehumidification which is separated from sensible cooling.

Figure 8: temperature of supply air and room under solar desiccant cooling system

Figure 9 shows humidity ratio (kg/kg) of supply air, room air, and ambient air versus time (hour). The average humidity ratio of supply and room air are 0.005 (kg/kg), and 0.009 (kg/kg) respectively.

Figure 9: humidity ratio of supply air and room under solar desiccant cooling system

Figure 10 shows the different properties of room air by application of two different cooling systems (HVAC system and solar desiccant cooling system) on the psychrometric chart diagram.

According to air properties of room air under operation of two different cooling systems, the dew point temperatures of were detected as shown in Table 1. With a constant value of wall temperature, the dew point of room air under the operation of a conventional HVAC system was 19.9 °C, while it was 12.4 °C when the solar desiccant cooling system was used as cooling system. Therefore by comparison between wall temperature and dew point temperature for each system, the potential of condensation of water vapor of the air on the wall was identified.
For application of HVAC system, temperature of the wall was less than the dew point temperature of the room air, so condensation happened, while when the solar desiccant cooling system was used condensation was not happening because the wall temperature was higher than the dew point temperature.

4. Conclusion

This paper presents an evaluation of risk of wall condensation by application of two different cooling systems such as conventional HVAC system and solar hybrid desiccant cooling system for one test room in Malaysia. To find air room properties, two systems with test room were simulated by TRNSYS software. The results show that by using solar hybrid desiccant cooling system instead of a conventional HVAC system, due to separated dehumidification, and then easy control dew point temperature of the room, the risk of wall condensation is very less.

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References