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A comparison study on energy savings and fungus growth control using heat recovery devices in a modern tropical operating theatre

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ABSTRACT

Fungus growth has always been a problem in hot and humid areas. This particular problem is crucial for operating theatre as it could affect the success rate of operations. Many postoperative fungus infection cases had occurred in the past, and it is generally agreed that air-conditioning system play a very important role in resolving the fungus growth problem. Besides air quality, the energy consumption level of air-conditioning system is also very important. In this study, the operating theatre 3 in Putrajaya Hospital, Malaysia was chosen as the research subject. The air-conditioning system for OT3 was redesigned with the energy recovery wheel, desiccant dehumidifier and heat pipe heat exchanger to achieve the objectives of this study. A computer program called Transient system simulation program (TRNSYS) was utilized for analysis in this research. From the outcome of simulations, it was found that the heat pipe heat exchanger could reduce the most energy consumed by the air-conditioning system. It managed to reduce the energy consumption by 57.85%. Moreover, the payback period of the device is only 0.95 years, which is the shortest among all the systems studied. Therefore, applying heat pipe heat exchanger is a good choice to save energy and resolve fungus growth problem in hot and humid areas.

1. Introduction

In offices, factories, commercial building and many other buildings, air-conditioning systems are essential in maintaining a comfortable indoor environment and to provide clean air to the occupants. However, the supplied air is often contaminated by microbes invisible to naked eyes, especially fungus. There were many postoperative fungal infection cases reported in hospitals due to the "*discharge of fungal spores from contaminated air conditioning units*" [1]. Colonies of fungus are often found at the air-conditioning components such as filter and fiberglass insulation materials [2,3]. Generally, fungus requires organic substances and moisture for growth. By eliminating either the organic substances or moisture, the growth of fungus could be halted. The moisture content of air is controlled by the cooling coil of the air-conditioner. By using a properly designed air-conditioning system, the fungus growth problem can be solved.

The main concern of an air-conditioning system lies not only on the cleanliness of the air but also on its energy consumption. Due to the prohibition of re-circulated air in operating theatres per American Society of Heating, Refrigerating and Air-conditioning engineers (ASHRAE) requirements [4], immense amount of conditioned air is wasted, which indicates the waste of energy. Therefore, it is obvious that energy consumption can be reduced by recovering the coolness potential from the exhaust air. This can be done by using some heat recovery devices such as the heat recovery wheel, heat pipe, fixed-plate and run-around coil loop. The use of these heat recovery devices not only recovers the coolness potential from the exhaust air, they can also be used to enhance the dehumidification. The applications of such devices are particularly useful when over-cooling of air is required. By installing these heat recovery devices across the cooling coil, the capacity of the cooling coil and electric heater can be reduced. On the other hand, the energy recovery wheel and desiccant wheel are capable of recovering the sensible cooling energy and dehumidifying fresh air independently by using the cool and dry exhaust air.

The aspect of energy savings in the building is not a new concern. Among available literatures, many aspects of energy savings in the residential and commercial buildings have been studies by using ancient technologies or modern innovations. Hatamipour and Abedi [5] studied on ancient architecture for passive cooling systems in buildings by using natural cooling in a hot and humid region. In their article, they presented useful ancient energy technologies used many years for natural cooling of buildings during summer in a hot and humid province in the South of Iran. By using these technologies, people were able to live in comfort without any electrical air-conditioning systems by using colour glazed windows, wooden windows frames, light coloured walls and roofs, insulated walls, wooden roofs covered with leaves and mud and

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Nomenclatures

ACH	air change per hour
AHU	air handling unit
DBT	dry bulb temperature
HPHX	heat pipe heat exchanger
HR	humidity ratio
HVAC	heating, ventilating and air conditioning
M&E	mechanical and electrical
OT3	operating theatre no. 3
RH	relative humidity
SHR	sensible heat ratio
TRNSYS	transient system simulation program

shading the buildings with the nearby buildings. Note that all of these techniques are now the modern experienced technologies.

Ameen and Bari [6] have studied on the feasibility of drying clothes using waste heat of a condenser of a typical split type domestic air-conditioner used in high rise urban apartments. They tested a drying chamber housing in which the waste heat rejected by the condenser was used for drying clothes via a heat pump. The drying rate for the test configuration was 0.424 kg/h in comparison to 0.319 kg/h for a commercial clothes dryer and 0.139 kg/h for indoor natural drying. The energy consumption was zero against 1.909 kW h/kg of moisture removal by the commercial dryer. They indicated that the time required for heat pump drying was 30.8% of natural drying and 77.9% of the commercial dryer.

Atthajariyakul and Lertsatittana [7] have used the technique of using small fans combined with an air conditioned space to increase the room air temperature set point in Thailand. The technique is based on the idea that Thai people have a tolerance to higher air temperature, and also, they are accustomed to high air movement from electric fans in non-air conditioned space. According to their proposed method, this can save energy for office buildings in the commercial sector as high as 1959.51 GWh/year.

A literature search has been carried out on the application of heat pipe heat exchanger (HPHX), energy recovery wheel and desiccant wheel research for energy savings in heating, ventilating and air conditioning (HVAC) systems. It revealed that complete energy saving research based on a Typical Meteorological Year (TMY) data for heat recovery devices just mentioned applied in tropical climates for yearly operation of 8760 h is virtually none.

The use of heat pipe heat exchanger to enhance dehumidification in HVAC system was studied by Yau [8]. In the study, the heat pipe heat exchanger was recommended to be integrated into tropical HVAC systems for dehumidification enhancement and to reduce energy consumption.

Christopher [9] has studied the amount of energy could be saved by installing an energy recovery wheel in the HVAC system for a two-level department store with area of 612 m^2 in Baton Rouge. The result from this study indicated that integrating energy recovery wheel could save approximately 7% in annual energy consumption.

Harriman et al. [10] carried out a year-round simulation for a hospital to compare the moisture removal capability and energy cost between active and passive desiccant wheels. The result showed that the energy cost for the active desiccant system was only 1.5% greater than the passive desiccant system but the moisture removal capability of the active desiccant wheel outperformed the passive one. It was obvious that active system was preferable for operating theatres.

Unfortunately, almost all these research works just described above were conducted in seasonal regions with distinctive diagonal swing of outdoor air conditions (i.e. winter, spring, fall and summer seasons) annually in comparison to tropical regions with almost constant outdoor air conditions (i.e. hot and humid summer season only year-round).

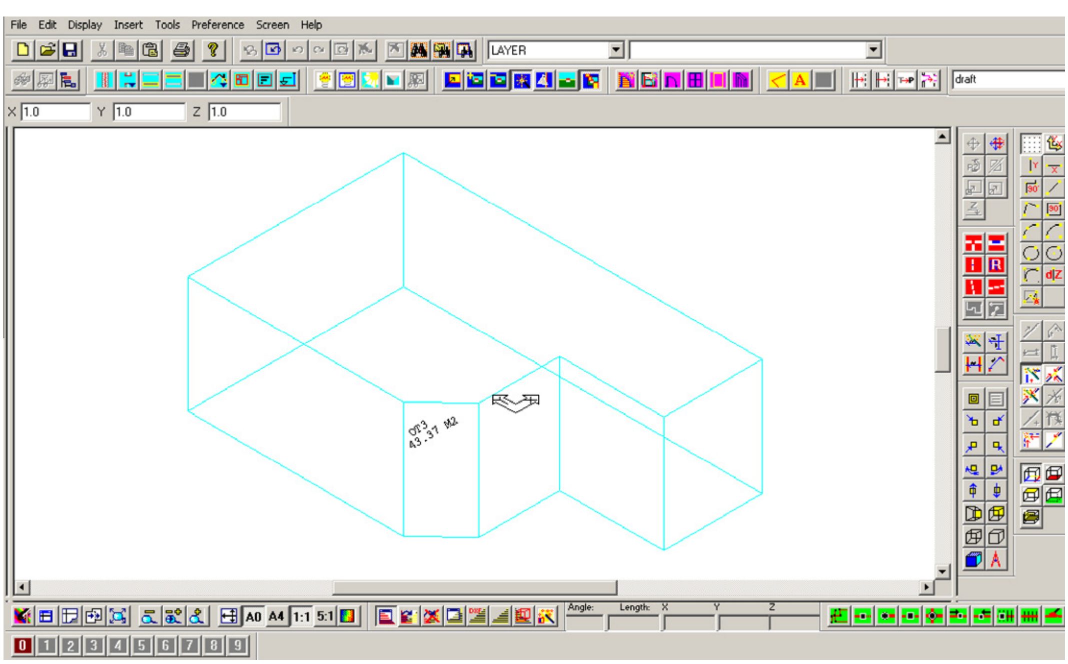

Fig. 1. Architectural modelling of OT3 in SimCad.