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Energy-efficient ventilation with air-cleaning mode and demand control in a multi-residential building

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ABSTRACT

Adequate ventilation is important because it protects both our health and home. However, the ventilation and energy requirements necessary to achieve good indoor air quality (IAQ) may interfere with one another. This paper presents the energy-saving potential of a ventilation system with an air-cleaning unit and demand control in a multi-residential building. This strategy is based on the demand to save energy in ventilation by reducing the supply of outdoor air using air cleaning while maintaining the desired air quality. Hence, the operation mode of the ventilation system in this study senses the indoor CO_2 and HCHO concentrations according to the IAQ code for homes in Korea. The ventilation and air-cleaning modes are then operated independently or simultaneously to optimize the energy usage for ventilation.

The simulation results indicate that, in maintaining the required IAQ level, the proposed ventilation system reduces the operation rate of the induction of outdoor air for slightly less than 50% of the operating time and decreases the energy use by approximately 20% with its air-cleaning and demand control mode compared to the conventional systems that employ a continuous ventilation mode.

1. Introduction

Recently, indoor air quality (IAQ) has become more important in addressing certain occupant health and safety concerns. In order to improve and maintain the IAQ in buildings, the use of a proper ventilation system and the control of pollutant sources by using non-toxic construction materials to decrease the amount of emissions from the materials and equipment have emerged as key issues. Rather than increasing ventilation, usually the most effective way to improve IAQ is to eliminate individual sources of pollution or to reduce their emissions because the former can increase energy costs [1]. As part of the research for energy savings in ventilation, Nielsen et al. [2] investigated energy-efficient demand-controlled ventilation (DCV) in single family houses in Denmark and showed that the ventilation could be reduced to the low rate 37% of the time without significant changes in the CO_2 concentration or the moisture level in the house through the DCV, where all the sensors and controls were located in the air handling unit. In theory, this procedure reduced 35% of the electric energy required by fans. DCV is a commonly used strategy in HVAC systems based on signals from the indoor sensors, e.g., a CO_2 sensor [3]. Kusiak et al. suggested an optimal control model in DCV for maintaining CO_2 concentration within an acceptable range while achieving energy savings. They developed a scheduling model to optimize the run time of the mechanical ventilation system. This model involves three parameters: the fan-on time period, average CO_2 concentration above a specified threshold, and the time period corresponding to when the CO_2 is above the specified threshold [4].

Additionally, energy savings for conditioning fresh air can be achieved by the application of a heat recovery ventilator. Zang et al. analyzed the yearly performance of a membrane-based energy recovery ventilator (MERV) in Hong Kong. Hour-by-hour calculations disclosed that in hot and humid regions like Hong Kong, approximately 58% of the energy required for conditioning fresh air could be saved annually with an MERV, which recovers both latent and sensible energy, while only about 10% of the energy could be saved with a traditional sensible-only energy recovery ventilator (SERV) [5].

The ventilation method is sensitive to the ventilation and energy performance. Lin et al. discussed the annual energy performances of different ventilation methods for cooling using

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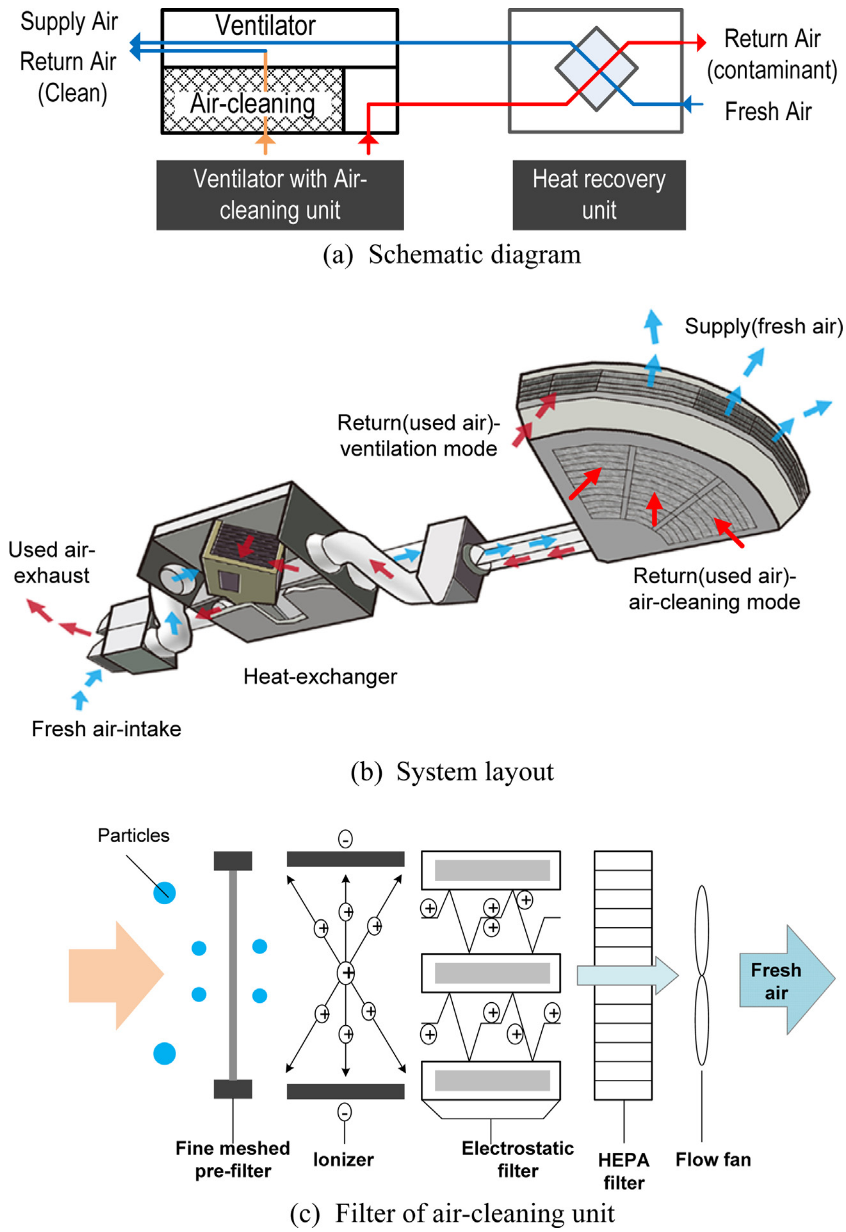

Fig. 1. Schematic diagram and system layout of the ventilation system with air-cleaning unit.

Table 1
Measurement conditions.

Period	12/01/2008–12/14/2008
Ventilation system	Ventilator: air flow rate was set at 70 CMH. Air-cleaning unit: air flow rate was set at 180 CMH. The ventilation system was operated for 5 h for each operation mode, according to the IAQ test method of Korea [11].
Indoor and outdoor conditions	Outdoor conditions: dry bulb temperature was 10–15 °C, relative humidity was 22–36%. Indoor conditions: dry bulb temperature was set at 25 °C, relative humidity was set at 30%. Infiltration rate was measured as 0.2 ACH. Average outdoor concentration of HCHO was 0.036 mg/m^3; CO_2 was 350 ppm. Indoor emission rate of HCHO was 0.0812 mg/(h m^3). Indoor HCHO and CO_2 levels should be controlled to under 0.12 mg/m^3 and 1,000 ppm, respectively, by the IAQ standard of Korea [11].

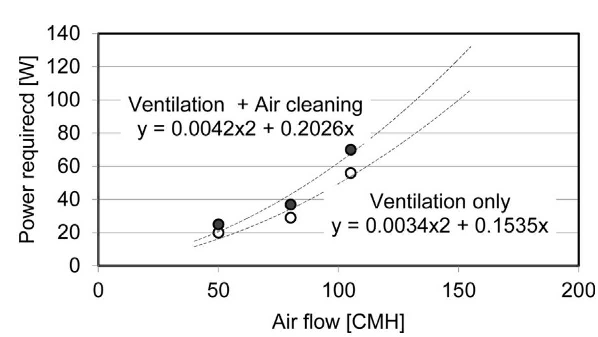

Fig. 2. Energy usage of ventilation system with operation modes.

a TRNSYS simulation. The annual energy usages of three systems—stratum ventilation, displacement ventilation, and mixing ventilation—were compared for typical configurations of an office, a classroom, and a retail shop in Hong Kong. The energy saving potential of the stratum ventilation was derived mainly from