Conference Agenda

15th ROOMVENT Conference

Session

AD1: Air distribution & ventilation efficiency 1

Session Chair: **Manuel Ruiz de Adana**

Presentations

Effects of ventilation use in non-occupied conditions on indoor air quality

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Concerns about indoor climate have led to an additional mechanical ventilation use in non-occupied conditions that may increase an energy consumption in public buildings without evidences on its necessity. Furthermore, many hypotheses exist on how ventilation should be operated in non-occupied conditions to guarantee healthy indoor climate at the beginning of occupancy period. However, the indoor climate problems are very common and it motivates to study the reason for that. Consequently, field measurements have been carried out under Nordic climate conditions in Southern Finland. The objectives were to study the effect of different night purging strategies on indoor climate during normal occupancy hours. Therefore, the normal, continuous and intermittent ventilation use were compared in 2-week test periods. The measured quantities were the toluene-equivalent TVOC-concentration, the organic and inorganic gaseous pollutants, PM2.5 and PM10 particulate matters, the air temperature and the air humidity. The results show that a selection of purging strategy may have a smaller effect on indoor climate than that of a normal variation of those measured quantities in a room space. This was believed to have an association with the indoor pollutant generation, interior usage and weather conditions. The effects of purging strategy was negligible on the measured TVOC-concentrations.

Towards using sensitivity analysis to compare the resilience of mechanical ventilation systems

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In cold and temperate climates, buildings are more and more insulated and their airtightness increases a lot. However, whereas those aspects are extremely beneficial in terms of energy efficiency, they affect a lot the indoor air quality (IAQ). The importance of ventilation has thus strongly increased aside from the building energy performances. Most of the time, dwellings are equipped with a mechanical extraction of indoor polluted air into wet zones through one or multiple fans and a natural supply of fresh air into dry rooms through dedicated vents. In order to comply with both energy and IAQ targets, the use of airflow modulations (Demand controlled ventilation strategies) has strongly increased. These are mainly single sensor based (like humidity based modulation widely spread in France) but can also be double sensor based (humidity and carbon dioxide concentration for instance). In order to make a step forward guaranteed performances in IAQ, some systems even proposes extracted airflows in dry rooms in addition to the existing wet room's ones.

Once installed in dwellings, ventilation systems have to deal with climatic conditions variations, occupancy and domestic activities scenarios and its performances might be not the expected ones.

In this work, one proposes to investigate the resilience of some mechanical ventilation systems through variances based methods. More specifically, we focused on the understanding of the IAQ behaviour and the reversed flows in a dwelling considering the variability of about 30 parameters (from envelope leakage distribution up the domestic activities through the released pollutant source fluxes). To handle this study, one has coupled MATHIS (nodal energy and mass balance numerical software developed by CSTB for ventilation system analyses) with a mathematical method. A sensitivity analysis is realized through the RBD-FAST method. It deals with a variance-based technique consisting in evaluating the influence of several input parameters on well-defined output indicators. Different scales of studies can be considered from the overall building to the zone. Moreover, indicators can be defined in different manners as aggregated values such as occurrence of reversed flows or of high CO_2 concentration, and temporal metrics such as CO_2 concentration or relative humidity. Finally, the studied input parameters can also take several forms with scalar values such as the ventilation characteristics or the CO_2 occupant release, and temporal variables such as weather solicitations or occupancy schedules. The chosen sensitivity analysis technique RBD-FAST allows managing with each of those considerations in order to study and to test the resilience of the system for many different conditions.

First results led to determine parameters affecting the ventilation systems operations according to IAQ considerations and the occurring phenomenon of reversed flows. Building orientation appears as an influent parameter explaining the occurrence of reversed flows but also the IAQ aspects in very specific weather conditions, especially through the wind direction and its velocity. Finally, the sensitivity analysis results allow deducing solutions to explain and even more to increase the resilience of the ventilation system to ensure IAQ targets and the decrease of reversed flows.

Effects of warm supply air jets on air diffusion performance index under stratum ventilation

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Stratum ventilation provides different air temperatures and velocities along the warm supply air jet under heating mode due to both entrainment and thermal buoyancy. In order to explore the effects of the warm supply air jets on the thermal uniformity of the environment, this study investigated the air diffusion performance index (ADPI) in the thermal environment heated by stratum ventilation. The ADPI model in ANSI/ASHRAE Standard-113 was adopted. Twelve cases with different combinations of supply air temperatures and velocities were conducted in a simulated classroom with dimensions of 8.4 m (length) × 5.4 m (width) × 2.6 m (height). Air temperatures and velocities were measured at a total of twenty-seven points distributed in the occupied zone. Results showed that the ADPI was significantly related to the location of the deflection point where the warm supply air jet starts to flow upward due to thermal buoyancy. Although the room temperatures were within a comfortable range of 19.3°C to 23.3°C, the ADPI varied from 59% to

96% with different locations of the deflection point. To meet the requirement of ADPI greater than 80%, the deflection points were supposed to be far away from the inlets.

Impact of internal partition curtains on temperature and contaminant concentration distributions in a four-bed hospital ward with displacement ventilation

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In this research, the displacement ventilation (DV) system is proposed to create a better odor environment in a hospital ward. DV is known as an efficient ventilation system, especially when the contaminant is emitted from the heat source. In the previous study, it was proven that the occupant zone of the lying or sitting person could be filled with fresh air; however, a huge amount of supply airflow rate is required to form the contaminant interface layer higher than the height of the breathing zone of the standing person. Additionally, there are internal partition curtains in the general multiple-bed wards for privacy, and it is predicted that these curtains will greatly influence air distribution in the room.

In this paper, the impact of partition curtains in a displacement ventilated hospital ward was investigated by experimental study. The measurements were carried out in a full-scale environmental chamber, which was set up as a four-bed hospital ward with partition curtains. Four person simulators and black lamps were used as heat sources, and CO_2 was emitted from the tube on the person simulator in order to simulate the odor from the body. The temperature and contaminant concentration distributions were examined under different bottom heights of curtains and the positions of supply inlets. As a result, it was figured out that the contaminant air could be exhausted more efficiently owing to the presence of the internal partition curtains. Furthermore, the room air outside the partitioned area where the contaminant source was located could be kept clean.

A STUDY ON DYNAMIC RESPONSE PROPERTIES IN A LARGE SCIENTIFIC FACILITY UNDER THE INFLUENCE OF A SINGLE VARIABLE

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This paper employs the numerical simulation method to study the dynamic response characteristics under the influence of a single variable in a large scientific device. The research finds the location of the optimal control point and the control period of the supply air temperature and supply air volume, which provides the reliable foundation for the realization of high-precision temperature control in the future. The research results show that the delay time coefficient and system time constant of the control point located in the middle of the large scientific device and equal to the design temperature are less than the conventional central control point of the air outlet under the influence of a single variable (heat dissipation, supply air volume and supply air temperature). In addition, the control period of the supply air volume is greater than that of the supply air temperature. When the ambient temperature changes in the large scientific device, adjusting the supply air temperature can restore the environment to its original state more quickly than adjusting the supply air volume.

Effect of supply air condition on temperature/contaminant distribution in a room with impinging jet ventilation system

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The mixing ventilation system (hereinafter referred to as MV) is the most popular and widely used air conditioning system in Japanese office buildings for decades, even after the development of the displacement ventilation system (hereinafter referred to as DV). It is believed that DV has better ventilation performance and air quality compared to MV, under cooling condition. However, DV has problems with draught risk due to the large temperature gradient within occupied zone, since it supplies the cool air with low momentum. In addition, DV is not appropriate system for heating, since the hot air easily rise upward before it reaches the inner part of office.The impinging jet ventilation system (hereinafter referred to as IJV)has been proposed as a new air distributing strategy, which was expected to overcome the disadvantages of MV and DV system.

Some full-scale experiments and CFD analysis have been done in previous studies, however, no simplified calculation model for IJV system has yet been established to date. The final goal of this study is to develop a simplified calculation model of temperature/concentration distribution for IJV system. In order to prepare for the calculation model, and also to understand basic characteristics ina room with IJV, full-scale experiment and CFD analysis are performed.

The experiment was conducted in a climate chamber with heating elements distributed inside, in order to simulate the heat load in an office room.The distributions of air temperature and CO_2concentration were measured in the climate chamber whose floor area is 27.0 m^2. Heat load was simulated by black lamps (incandescent bulb covered with dark purple glass) distributed uniformly. As for contaminant, $CO_2$was generated from four locations. As the experimental parameters, number of IJV supply terminals and also the combination of supply air temperature and supply flow rate were changed to investigate the effect of supply air momentum.

The experimental results were evaluated based on the specific Archimedes number defined in this paper, and were compared between the distribution of temperature and CO_2concentration. It was shown that the vertical distribution of temperature and CO_2 concentration were clearly stratified when the supply airflow momentum was small. Moreover, it was shown that there is a correlation between Archimedes number and vertical temperature difference.

To propose a simplified calculation model, further parametric study is required, and CFD analysis was chosen as the method, since it is easy to change the parameters. In order to validate the CFD calculation method for IJV system, the results of CFD analysis and full-scale experiment were compared in this paper.

Three turbulence models: standard k-ε model, RNG k-ε model and SST k-ω model were compared, and it seemed that SST k-ω model is the most appropriate method.

Development of HVAC System with Short Cycle Variable Airflow Feel and its Verification

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In recent years, as people become more aware of the effects of the indoor environment on intellectual productivity, wellness, and other matters, people are also asking the air conditioning industry to address a variety of needs related to the comfort level of indoor thermal environments. To improve the thermal environment of an entire air conditioned area, an HVAC system that can allow occupants to feel air currents flowing at different speeds (an HVAC system with variable airflow feel) was developed as a solution to problems of current air conditioning systems.

The purpose of this study is to validate an HVAC system with variable airflow feel (HVAC system giving a feeling of the air moving at different speeds) developed to improve the thermal environment throughout the target area.

This study reports basic airflow characteristics in an office building equipped with an HVAC system with variable airflow feel. This study also reports the results of a subject experiment in a laboratory made in light of the observations in the office building.

We checked the control and basic airflow characteristics through observation in an office equipped with the HVAC system with variable airflow feel. We confirmed that the HVAC system with variable airflow feel periodically changes the supply air volume. The subject experiment suggests that the HVAC system with variable airflow feel improves the level of comfort.

Simplified Prediction Model for Vertical Profile of Temperature and Contaminant Concentration in a Room with Impinging Jet Ventilation System

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The impinging jet ventilation (IJV) system is a relatively new air distribution strategy that supplies air vertically toward the floor. As well as displacement ventilation (DV) system, IJV system can provide higher ventilation effectiveness compared to the conventional mixing ventilation. Due to the medium momentum of supplied air, the IJV system could overcome the difficulties that could exist in DV system with low momentum supply, e.g., ununiform horizontal temperature distribution, large temperature gradient within occupied zone. To date, however, no simplified prediction model to predict indoor environment of an impinging jet ventilated room has been established. Therefore, this study aims to propose a calculation model of the vertical profile of both temperature and contaminant concentration for IJV system.

This paper first presents a parametric study using computational fluid dynamics (CFD) as a numerical experiment. The basic floor plan of the studied room is 9,000mm long × 5,000mm wide, which was the same as the laboratory experiment conducted in the preceding work. A heating element of relatively large heat generation rate, 2.0 kW, was located at the centre of the room, assuming an industrial building where IJV system seemed to be available. CO2 gas was emitted as a tracer. Here, two cases of ceiling height, 2,700 and 5,400mm were studied. Total supply flow rate was also changed as a parameter, and four conditions of 400, 600, 900, and 1,200 m3/h were studied. The number of air supply terminals was changed as well. This parameter was set to understand the impact of supply airflow momentum among the cases of the same total supply flow rate, and four cases were studied, i.e., 1, 2, 4, 6 terminals. In total, therefore, 32 cases were analysed by CFD.

Secondly, the paper presents a simplified prediction model for the vertical profile of temperature and contaminant concentration for IJV system. The model is basically based on “block model”, which solves heat and mass transfer by advection and diffusion. Here, the turbulent diffusivity is the most important parameter. In the proposed prediction method, the room blocks are classified into two types, i.e., lower and upper part of a room. The blocks within the same part of the room, for simplicity, adopted the same value for turbulent thermal diffusivity, and the appropriate diffusivity was determined based on CFD for each case. Since it is important to predict turbulent diffusivity only from the design conditions such as flow rate, supply velocity, this paper arranges a correlation between turbulent thermal diffusivity and specific Archimedes number for upper and lower part respectively. By comparing the temperature profile obtained by using the correlation in the block model with CFD result, the accuracy of the simplified model is verified. As for the concentration, it was assumed that the turbulent mass diffusivity took the same value as that of thermal diffusion. The vertical concentration profile obtained from the proposed model was also compared with the CFD result and its accuracy was also verified.

THE INFLUENCE OF MANIKIN MOVEMENT ON TEMPERATURE STRATIFICATION STABILITY IN A CHAMBER WITH THE DISPLACEMENT VENTILATION SYSTEM

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Temperature stratification generally exists in the indoor environment with floor-level air-supply systems, such as displacement ventilation (DV). Such systems with vertical temperature difference have many potential advantages over mixing ventilation. Some dynamic factors can disrupt the temperature stratification, such as the human body movement. However, the influence mechanism of the factors remains unclear. In this study, a series of experiments were conducted to investigate the stability of the temperature stratification of the DV system in an environmental chamber by adopting a moving manikin. The concepts of temperature stratification stability (*TSS*) was proposed to quantify the influence of dynamic factors on temperature stratification. Orthogonal experiment was designed to identify the primary and secondary influencing factors for the *TSS* among four important indexes, i.e. manikin moving velocity (*v*), manikin moving duration (*t*), manikin heat generation intensity (*P*) and air change rate of the chamber (*ACR*). Results show that the importance of factors for the destruction of the mean *TSS*, ranked from highest to lowest, are *v*, *ACR*, *P* and *t*. Manikin moving velocity has a primary effect on temperature stratification. The affected area of the manikin movement was observed mainly around the manikin, not the whole chamber. The temperature stratification still existed after the manikin movement stopped, but the temperature stratification was weakened a lot considerably.

CO2 Based Ventilation Control – Importance of Sensor Positioning

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Indoor carbon dioxide (CO2) concentration is measured in buildings for the assessment and control of the air quality. The indoor CO2 concentration, measured at only one location in the room - either in the exhaust room air or at one of the walls, is considered the same as the concentration in the

inhaled air and is used for ventilation control. The main objective of the current study was to identify whether the CO2 concentration in the exhaust air or at the wall is the same as the CO2 concentration in the air inhaled of the occupants. CO2 measurements were performed in a simulated meeting room. Seven subjects and one breathing thermal manikin were present in the room. CO2 gas was dosed in the exhaled air of the manikin to simulate the metabolic CO2 generation by an average person. The room was ventilated either by mixing or displacement air distribution. The rate of the supplied clean air was determined based on mass balance of the average CO2 concentration in the air exhaled by the subjects and the manikin, so that the CO2 concentration at the exhaust to be 1000 ppm. Chilled ceiling was used in addition to the mechanical ventilation to maintain room temperature at 26 °C. The CO2 exposure was assessed by measuring the CO2 concentration in the air inhaled by the manikin. The CO2 concentration was also measured close to the breathing zone, on the walls, and in the supply and exhaust air. The results show a substantial difference in the CO2 concentration measured in the air inhaled by the manikin compared to the CO2 concentration measured at the exhaust air and on the walls. The air distribution method was of a high importance. In the case of mixing air distribution the CO2 concentration in the air inhaled by the manikin was 35% higher than at the exhaust and in the case of displacement air distribution it was 43% lower. Non-uniformity of the CO2 concentration was found in the room during the two studied air distribution methods. The CO2 concentration measured at 30 cm behind the occupants at 1.1 m height was the closest to the CO2 level in the inhaled air in the case of displacement air distribution. For the studied set-up with mixing air distribution, the CO2 concentration measured 1 m above the table around which the occupants were sitting was the closest to the concentration in the inhaled air.