Conference Agenda

15th ROOMVENT Conference

Session

NVD: New ventilation & design techniques

Session Chair: **Zhenjun Ma**

Presentations

Applicability of a vacuum-based membrane dehumidifier in a dedicated outdoor air system

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The main objective of this study was to investigate the feasibility of a dedicated outdoor air system (DOAS) integrated with vacuum-based membrane dehumidifier (VMD). As DOAS is a decoupled ventilation system, it is mainly concerned to deal effectively with the latent load on its energy performance. The vacuum-based membrane dehumidifier is a dehumidifier that can only control the humidity of the conditioned air with the isothermal process, which is hard to achieve in conventional dehumidifiers. The vacuum-based membrane dehumidifier composed of a vacuum pump and a bundle of hollow-fiber membrane modules. When the vacuum pump makes secondary channel depressurize for generating partial pressure gradient between the membrane layer, the part of water vapor in humid air can permeate through the membrane layer. In the dehumidification process of the VMD, it does not require cooling and heating source for obtaining the dry air and reduces latent cooling load to meet target humidity ratio as the isothermal dehumidification process. The investigated system (VMD-DOAS) is composed of an enthalpy exchanger, a VMD, and a chiller. To investigate the feasibility of the VMD-DOAS, its energy-saving potential and thermal performance were conducted by comparing with two conventional dedicated outdoor air systems: a DOAS adopting for cooling coil with condensation dehumidification (Reference A) and for desiccant wheel by using desiccant materials (Reference B). The result shows that the average coefficient of performance of the studied DOASs is 1.98 in the VMD-DOAS, 2.70 in Reference A, and 0.80 in Reference B. However, in the VMD-DOAS, the isothermal dehumidification process reduces 50% (Reference A) and 70% (Reference B) of the dehumidification cooling load and it saves 28% in Reference A and 53% in Reference B of the auxiliary cooling and heating requirements. Consequently, the proposed system shows 18.5% and 58.3% lower annual operation energy consumption than References A and B, respectively.

Experimental Analysis of a Hydrophilic Hollow Fiber Membrane-based Dehumidification System

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Recently, membrane-based dehumidification technologies have been suggested as one of the promising dehumidification technologies for ventilation air systems decoupling dehumidification and sensible cooling functions. This paper experimentally investigated the dehumidification performance of a hydrophilic composite hollow fiber membrane-based dehumidification system. In the hollow fiber membrane module, dehumidification occurs when the process air flows through the membrane layer while the secondary air is exhausted to opposite direction. When the water vapor difference between the process air and the secondary exists, the water vapor from the process air is absorbed and diffused on the membrane layer, and then, desorbed to the secondary air. Therefore, the conditions and mass flow rate of the process air and the secondary air are considered as the main operating parameters. An experiment chamber was used to maintain the conditions of the process and secondary air at a certain target point, and the diaphragm vacuum pumps with 65 l/min flow rate were installed at the process air and exhaust air side to modulate the air flow rate at a target point. The dehumidification effectiveness and enthalpy effectiveness were adopted as performance indices of the proposed membrane dehumidification system. Empirical correlations predicting the dehumidification effectiveness and enthalpy effectiveness were derived to predict the dehumidification performance of the proposed membrane dehumidification system under various operating conditions. And then, the characteristics of the dehumidification performance in various operating conditions were analyzed based on the parametric analysis of each operating parameter by using the proposed empirical models.

Energy Performance for Humidification of Liquid Desiccant and Evaporative Cooling Assisted 100% Outdoor Air System

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The purpose of this study is to evaluate the energy performance for humidification of liquid desiccant and evaporative cooling assisted 100% outdoor air system (LD-IDECOAS). In the liquid desiccant unit for LD-IDECOAS, the process air travels the absorber and the heat and mass transfer occurs between the process air and desiccant solution because of the water vapor difference in the summer season. On the other hand, the liquid desiccant unit have not been operated in the winter season. In this study, the opposite operation of heat pump and liquid desiccant unit was proposed for humidification process in the LD-IDECOAS. The process air travels the regenerator because the absorber and regenerator were transposed by opposite operating of heat pump. The process air was humidified and heated because of the mass and heat transfer between the process air and desiccant solution in the regenerator. The operating energy consumptions of the LD-IDECOAS for humidification performance and conventional variable air volume (VAV) system consist of steam humidifier were compared via detailed energy simulation. The results indicated that the LD-IDECOAS could save 30% of primary energy consumption compared with the VAV system consist of steam humidifier because the steam humidifier consumed the more energy for making steam, and the regenerator needed more less energy for desiccant solution heating.

Energy savings in livestock houses through the use of variable speed fans

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Agricultural buildings are interesting from the point of view of ventilation. In livestock houses (especially pig, broiler and laying hen houses), IAQ control is fundamental due to the presence of microbiological active contaminants the presence of dust particles, odorous vapors and noxious gases that can affect the animal health. Furthermore, no mechanical cooling is present inside livestock houses and high ventilation flow rates (up to 50 ach) are provided to decrease the indoor air temperature during the warmest periods. In warm and dry climates evaporative pads can be used to decrease the supply air temperature.

On the one hand ventilation guarantees good environmental conditions to animals and workers, on the other hand, it represents a considerable energy consumption (up to 60% of the primary energy for climate control) and a financial cost for the farmers.

To decrease this energy consumption, manufacturers are constantly working in improving the performance of fans for agricultural applications. In this sense, one of the most promising solution are variable angular speed fans equipped with an Electronically Commutated (EC) motor. If compared with traditional Alternating Current (AC) motor fans that are still commonly used in agricultural applications, the new equipment improves the energy performance for two main reasons. The first one relies on the higher efficiency of an EC motor that decreases the electrical energy consumption for its working. The second reason relies on the possibility to provide precisely the airflow rate through the modulation of the angular speed of the blades. In this way the excess of airflow (typical of fixed angular speed fans) can be avoided, decreasing the electrical energy consumption and minimizing the ventilation heat losses.

In this work, the effectiveness of this new technology is numerically assessed against the commonly used fixed (angular) speed fans. The numerical assessment is performed through a dynamic energy simulation model that was *ad-hoc* developed and validated for broiler houses. The model is adopted to perform energy simulation on the same case study with the same boundary conditions, with the only exception of the ventilation system. The main outputs of the model are the thermal and electrical energy consumption for climate control and the average indoor environmental conditions. The selected case study is a typical broiler house of 1,500 m^2 and a stocking density of 42 $kg \cdot m^{-2}$.

The results demonstrate that the new technology reduces both the electrical and the thermal energy consumption of the broiler house. In particular, the adoption of the variable speed fans entails a reduction in the energy use by about 20% if compared to a traditional ventilation system, maintaining the same indoor environmental conditions.

Thermal environment in simulated office rooms generated by ceiling diffusers with variable air volume system

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Ventilation airflow rates are typically controlled based on occupancy and heat load levels in office rooms with variable air volume system. The target of the system operation is to maintain good thermal environment for occupants and stable ventilation air distribution in varying conditions. Challenging situations for variable ai volume system operation with ceiling diffusers can be situation with small ventilation airflow rate when cool air jets may detach from ceiling and may cause draught. Other situation can happen with big airflow rate when strong ventilation air jets and interaction with heat loads may cause discomfort for occupants.

The target for this research was to study the thermal environment in simulated office room with different room layout and occupancy / heat load levels when variable airflow system with different type of ceiling diffusers were used. Office and meeting room layouts were simulated in full-scale test room (floor area 27 m^2). Heat loads levels in different cases varied from 11 - 46 W/m^2_{floor} and cool ventilation airflow rate (1.0 - 4.3 $l/s,m^2_{floor}$) at 16 °C was maintaining room temperature at 25 °C. Two ceiling diffusers were used for air distribution, first typical, static radial ceiling diffusers, and then active radial ceiling diffusers. Thermal environment was measured with calibrated air velocity, turbulence and temperature sensors in steady state conditions.

The air distribution and generated thermal environment was visualized in different cases based on measurement results and smoke visualizations. The thermal environment was more uniform when active radial ceiling diffusers were used than with static ceiling diffusers. With small air flow rates supply air jet was detached from ceiling with static ceiling diffusers. In the situations with big airflow rates, non-uniformity increased in thermal environment. Still good thermal environment (with draught rates less than 20%) was maintained with both static and active ceiling diffusers.

Demand Controlled Ventilation Strategies in Residential Buildings

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This work is about evaluation of energy saving potential of different Demand Controlled Ventilation Strategies for residential buildings using whole building energy simulation in EnergyPlus. Ventilation involves bringing outside air to the conditioned zone to maintain indoor air quality and provide comfort to occupants. Thus ventilation has an effect on air conditioning processes and systems and the associated energy consumption. Ventilation requirements are specified by national building codes and standards and are based on area or volume of the conditioned zone and occupancy in the conditioned zone. However, the zone occupancy is bound to change with time and hence this requires changes in the ventilation rate which can directly affect the energy consumption.

The residential buildings considered in this study include single family houses located across different climate zones in the USA. The building's HVAC demands are met by roof top units that include direct expansion cooling and heating coils and furnace. The ventilation strategies evaluated in this study include air side economizers, ventilation rate procedure, proportional control and indoor air quality procedure. These strategies were combined with different direct expansion system types namely single speed, two speed and variable speed systems. Further, the ventilation strategies were also compared with temperature setpoint setback strategy. The energy consumption, both electric energy and gas, were obtained through annual simulation and the strategies are compared based on the total cost evaluated using net present value method.

Experimental learning of aerodynamics for students in architecture

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The design of a building and its interaction with the wind, have important consequences on the functioning of natural ventilation, on the structure dimensioning to wind actions and on outdoor comfort. We focus here on natural ventilation, that is activated through the openings of a building, by the interaction between the wind and envelope shape. Consequently only with a correct understanding of this interaction a designer can choose a good design of a naturally ventilated building that requires interdisciplinary knowledge of architecture, building physics and aerodynamics and a culturally

based approach from a generalist perspective which encompasses systems knowledge and interactions among many disciplines that are needed in sustainable design education.
Obviously, there are many numerical tools to perform fluid dynamics simulation, but these are not within the reach of architecture students and architects, since their level of complexity.

This study presents three workshops able to overcome the abstract knowledge of physical phenomena and useful for teaching fluid dynamics to to 20 undergraduated students in Architecture. The workshops are three intensive teaching weeks focused on single and special activities as laboratories and projects. The first is a week focused on an aerodynamic experimental campaign on a large scale prototype, the second week is focused on an aerodynamic experimentation with a portable wind tunnel (designed especially for this purpose) and the last is a session where we experiment numerical simulations coupled to the previous campaigns. The educational teaching applied in the three workshops is an experiential learning method composed by a concrete experience, a reflective observation, an abstract conceptualization and an active experimentation.
Moreover the succession of the workshops, all oriented to the understanding of the fluid-dynamics to facilitate the conception of naturally ventilated buildings, passes from the measurement of physical quantities in a large scale construction, to the experimentation and repetition of physical phenomena by a wind tunnel, to finish in the study of detail through Computational Fluid Dynamics simulations. The overlapping of the numerical results and photos of air flow smoke views facilitates the comprehension in aerodynamics for a neophyte in aerodynamics. Even the measurements on a large scale prototype are used to give a scale to the sensations. In the last session the students are not able to independently perform CFD simulations, but are able, with the help and comparison with experimentation, to interpret correctly the results and to use them for the building design.
The students realize some graphics' productions showing the effect of the flow over the models, representing the interaction between the shape and the wind. The results of the students' works prove the power of this tool and method in teaching.
In the paper all methods and tools used, built and designed for the purpose during the tree workshops are fully described.

Comparison of steady-state and dynamic methods to calculate airflow rate with displacement ventilation

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A temperature-based method is usually applied in displacement ventilation (DV) design, when overheating is the main indoor climate concern. Different steady-state models have been developed and implemented to calculate airflow rate in rooms with DV. However, in practical applications, performance of DV depends on potentially dynamic parameters, such as strength, type and location of heat gains and changing heat gain schedules. In addition, thermal mass affects dynamically changing room air temperatures. The study presents case studies of dynamic DV design for typical applications in different premises, such as lecture halls, lobbies, theatres and arenas. The desined airflow rate with combinations of different outside and inside heat gain sourses, heat gain schedules and building structures was calculated with different models in both dynamic and steady-state conditions. Among the presented models, dynamic DV model demonstrated a capability to take into account the combination of dynamic parameters in typical applications of displacement ventilation.

Experimental Verification of a Dynamic Insulation System Applied to Windows of a Detached House

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Because heat loss from windows constitutes most of the heat loss from a building, improving thermal insulation performance of windows is necessary to save energy. This study describes experimental verification of dynamic insulation technology applied to windows of a detached house. A dynamic insulation window comprises two panes of glass divided by an insulation blind. In winter, air from outside is brought inside by mechanical exhaust ventilation through an air inlet on the window frame, and the heat loss from inside is recovered using the air inside the double window.

To demonstrate the performance of dynamic insulation windows, the technology was applied to the windows of a detached house in Shibukawa City, Gunma Prefecture, a warm region in Japan. A field survey was conducted throughout the year, but this paper mostly describes results from winter. The indoor temperature and humidity, surface temperature of window glazing, heat flow and pressure difference inside and outside the house were measured. The U_{dyn} value of the dynamic insulation windows calculated from the measurement results differed because the blind was opened and closed. The U_{dyn} value when the blind was closed was smaller than that when the blind was open. During the winter, reverse flow, in which air is discharged from the air inlet on the dynamic insulated windows of the second floor, was caused by the external wind and the factors that influenced this behaviour were analysed.

Maintaining thermal comfort in buildings using energy efficient air handling units equipped with moisture recovery systems

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In non-residential buildings, more and more air-handling units (AHUs) are used to keep comfortable indoor air conditions inside the building, as natural infiltration decreases with the increased insulation standards. AHUs account for up to 60 % of the non-residential buildings' energy consumption in Germany. Next to the operation, the design of the AHU's components has a high influence on the energy consumption of an AHU. To calculate energy consumption and the resulting life cycle costs of air handling units, we developed a planning tool.

To reduce the energy consumption of AHUs, heat recovery systems are installed to transfer the heat of the extract air to the supply air. Moisture recovery systems, on the other hand, are used very rarely, since the consequences of too dry room air are usually underestimated. Moreover, no suitable design procedures for these systems exist. To predict the energy saving potential of moisture recovery systems in yearly operation and to provide a tool for dimensioning these systems for yearly operation, an analytical model of membrane-based enthalpy exchangers and rotary enthalpy exchangers was implemented into the planning tool.

The energy analysis shows that moisture recovery systems are able to save up to 6 times of the primary energy compared to a combination of heat recovery systems with steam humidifiers. The saving potential is strongly depending on the outdoor air conditions. Especially in dry and cold climates, as well as in hot and humid climates, moisture recovery systems are superior to heat recovery systems. The simulation with hourly resolved weather

data for a test reference year for the three different climate locations Aachen, Bangkok, and Chicago has shown, that moisture recovery systems are able to substitute humidifiers without violating the thermal comfort limits in the room, especially regarding the indoor air humidity.

As the modelling approach takes into account the enthalpy exchanger's geometry, it is possible to analyse different geometries for the yearly operation performance and derive design recommendations.

Numerical study of a pulsated round free jet in application of HVAC-systems

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Ventilation in buildings is becoming more popular and necessary while at the same time facing two opposed target criteria. On the one hand, aspects of thermal comfort essentially have to be ensured while operating the ventilation system. On the other hand, energy efficiency will become important for ecological and economic reasons.

In terms of increasing energy efficiency of ventilation systems, one possibility is to decrease volume flow rates for just satisfying the current demand. Hence, this partial-load operation can lead to a change in room airflow pattern due to a lower supply momentum, e.g. to a separation of ceiling jets in cooling mode. As a result, this varied velocity and temperature field in the room can possibly have negative effects on the occupants' thermal comfort.

Another means to reduce the volume flow rates is supplying the volume flow not in a constant, but in a pulsating way. This can be realized by having a sequence of the nominal high volume flow rate followed by a certain time, where the volume flow is turned off. Since pulsated jets are not yet sufficiently analysed in the field of HVAC systems, their effects on the near field of a ventilation outlet is subject of the investigation in this paper.

Based on a literature review, we investigate a round pulsated free jet with CFD calculations applying different scale-resolved turbulence models like Large-Eddy-Simulation. Since these models are very sensitive to the underlying numerical discretisation, a detailed mesh study is preceded. For validation, we use literature data from the constant round free jet.

For the parametric CFD study, the volume flow is superimposed by a simple square wave signal. The frequency of the signal is in a wide range from 0.1 to 10 Hz. The nozzle diameter changes between 10 mm and 30 mm, while the maximum nozzle velocity is limited to 10 m/s.

We found that the mean downstream velocity decay in a pulsated round free jet is similar to that in a constant jet, having the same corresponding volume flow rates. Due to smaller velocity downstream, also the distance between the pulses become smaller. This causes the pulse signals are increasingly blurred to their time averaged value. Depending on characteristic parameters like frequency of the pulsed jet, the results are evaluated in terms of self-similarity and dimensionless numbers like Strouhal and Reynolds number.

Additionally, some authors observed a wider spreading of the pulsated jet compared to the constant one. Reproducing this with simulations is still under investigation and will be presented in the full paper.

Regarding the numerical discretisation, the mesh study showed that hexahedral cells aligned to main flow direction performed much better than tetrahedra.

A new approach to a local residential ventilation unit regarding to supply air temperature

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The paper will present a technical solution of an advanced local ventilation unit that uses a heat exchanger with thermoelectric modules to adjust the temperature of fresh air. Together with regular heat recovery heat exchanger the unit provides capacity for air cooling and heating without any support of building heating and cooling systems.

The benefits of the solution will be supported by the results of laboratory measurements. At this point the range of heating output (both heat exchangers) has been measured between 300 to 700 W at supply air flow rate 50 m^3/h and COP 2,5 to 15. While the range of cooling output lays between 100 to 200 W at the same air flow rate and EER 1 to 5.

Despite the low efficiency of thermoelectric modules will be presented feasibility of the novel solution. Also will be described a specific behaviour of an exchanger with thermoelectric modules and requirements for control will be pointed out.