Conference Agenda

15th ROOMVENT Conference

Session

TC2: Thermal comfort 2

Session Chair: **Donal Finn**

Presentations

CFD study of the indoor thermal comfort with an intermittently operated radiant floor heating system

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Accounting for the current requirements of thermal comfort and energy saving worldwide, the radiant floor cooling/heating system has become an increasingly important technology. An intermittently operated radiant floor heating system combined a ventilation system during the weekdays was proposed using a two-dimensional numerical model. The intermittent controls based on the minimum outdoor air temperature (T_{min}) were built. The study took an example of 14.2°C in the range of 15°C<T_{min}≤-10°C to evaluate the heating performance using operative temperature and local thermal comfort criteria including vertical air temperature ($\Delta T_{0.1–1.1}$), floor temperature (T_{fl}) and radiant asymmetry (ΔT_{pr}). Moreover, the percentage dissatisfied (*PD*) due to above discomfort factors were compared. The 2-hour shut off during day time and at least 4-hour shut off during night time for water supply controls were finally obtained so as to effectively reduce the energy consumption.

PROBLEMS AND QUESTIONS FOR PREDICTING COMFORT CONDITIONS IN A ZERO ENERGY RESIDENTIAL BUILDING

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Reducing buildings energy demand has been recently the main issue for researchers and companies, trying to develop strategies towards Zero Energy Buildings (ZEB) and Plus Energy Buildings (PEB). However, the higher envelope insulation applied to reduce the heating energy need led to rise HVAC systems efficiency to provide proper Indoor Air Quality (IAQ) in summer periods, whose management strategies may affect comfort if the operating conditions are not properly set. The most efficient system in cooling season should provide cool and dry air, which will be supplied by mechanical ventilation via a cold coil. However, in order to belong to the highest IAQ category according to the standard EN 16798, high air flow rates are needed, which may induce to undesired undercooling when the air is cooled and dehumidified. These issues have been widely investigated in literature, while less research focused on the clothing resistance change according to the time of the day over the year.

In the case study presented, the mechanical ventilation is coupled with radiant heating and cooling ceilings. Questions related to strategies to guarantee thermal comfort along the whole year are investigated. Different combinations of control strategies and clothing conditions are considered to set the most suitable dynamic simulation for a residential ZEB or PEB. The results obtained are relevant for experts to properly define dynamic calculations and systems' operating strategies.

Plan and Verification of a Midsize Office Aiming for ZEB : Thermal Comfort Evaluation of Variable Air Conditioning System using the Coanda Effect by Full Scale Experiment after Air Outlet Improvement

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In Japan, as the basic energy plan of 2014 has set the goal for new buildings on average to achieve ZEB by 2030, the demand for ZEB has increased in recent years, and uptake will spread quickly. While the development of energy-saving air conditioning equipment is required in order to realize ZEB, maintaining comfort in occupied space will present a challenge.
Therefore, we have verified the function of a variable air conditioning system using the Coanda effect (Figure 1 (a)) within a medium-sized office building scheduled to be completed in 2020. This is a ductless air conditioning system using the Coanda effect, and can blow the conditioned air from a wall surface near the ceiling to allow an air current to travel further. When the amount of blown air changes due to fluctuations in the thermal load, the position at which the conditioned air separates from the ceiling surface changes, which may cause problems such as airflow not reaching the occupied space and local drafts. In order to solve these problems, we developed an autonomous air outlet (Figure 1 (b)) that can maintain a constant air discharge speed even when the amount of airflow changes.
In this research, in order to adapt a wide range of airflows, we changed the number of air outlets from the current two to four in a full-scale laboratory that can reduce the number of air outlets when the air volume is decreased. The thermal comfort of this air conditioning system was evaluated using thermal environment measurements and an occupant survey.
As a result, the temperature difference in the occupied space was under 3K based on the measurement of the thermal environment, and the responses to the questionnaire revealed that the subjects were generally cool and comfortable. From this, even when the number of outlets was changed, a thermal environment equivalent to the conventional one could be established, and the heat accumulation and drafts of concern were reduced more than we assumed, and the comfort level was able to be maintained throughout the room.

Field investigation of thermal comfort level of patients and surgical staff in operating rooms at St. Olavs hospital

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In healthcare facilities and hospital environments, it is essential to be able to predict thermal comfort as a parameter of indoor air quality, and this has a critical impact on the working conditions of medical staff, and on the wellbeing, safety and health of patients. Ventilation systems play important role in operating rooms enabling clean and comfort indoor environment. Unstable thermal conditions are much more critical in the operating room (OR) environment, and may reduce the work efficiency and increase the possibility of surgical errors. Although there is an increasing number of studies covering the area of thermal comfort, there have been few literature reports written on the comfort of healthcare staff and patients in hospitals and in the OR environment. The objective of this study is to clarify the thermal comfort level of patients and surgical staff in various operating rooms with different ventilation solutions in operating rooms at St. Olavs hospital. In this study, field measurements of the indoor thermal environment, including temperature, relative humidity, airflow velocity etc, in operating rooms with different ventilation systems. The results of measurements show that the thermal comfort level of different users in ORs will depend on their activity levels and the location of various heat sources. The results of this study may be used to develop new indoor environment solutions ensuring both indoor air quality and thermal comfort levels of surgical staff and patients.

Intermittent Draught Rate

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Fanger developed a draught rate (*DR*) formula that was included in the standard EN ISO 7730 and is valid for steady conditions. In addition to the air temperature and the air velocity, it uses the turbulence intensity to quantify the influence of unsteady air fluctuations.

In intermittent ventilation with a rectangular on/off pulse form, the calculated turbulence intensity does not vary with the period length of the pulses. Therefore, the *DR* formula will yield a draught rate that does not change with the period length of the on/off phases. It is arguable that the draught rate is independent of the period length and especially the exposition time to cold air for longer period lengths. In the present investigation of a cooling scenario in intermittent ventilation, this assumption was found to be inappropriate. It is proposed that the draught rate formula should be revised.

To evaluate the thermal comfort in intermittent supply air conditions, measurements and subject tests were carried out at the Hermann-Rietschel-Institut. Seated test persons were exposed to a rectangular on/off pulse airflow at 19 °C. The air was coming from behind, mainly affecting the neck region while the room air temperature was held at 22 °C. The maximum air velocities were v = 0.2 ms^{-1}, 0.4 ms^{-1} and 0.6 ms^{-1}. On pulse durations were T =10 s, 20 s and 30 s.

In the first step, the unsteady temperature and velocity field in front of conventional displacement diffusers was investigated. At small pulse durations, the unsteady temperature and velocity profile does not follow a rectangular pulse form due to the inertia of the airflow and mixing of the supply air with the ambient room air. At the beginning of the off-phase, there is a remaining movement of the air. At the beginning of the on-phase, the steady state is only approached gradually. The air temperature will not approach the limits 19 °C and 22 °C in dynamic conditions due to these effects.

Subject tests with 37 subjects were carried out to assess the thermal comfort. The draught rate depended on the pulse (or period) length. For a maximum velocity of 0.2 ms^{-1} and 0.4 ms^{-1} it increased with increasing period length and for a maximum velocity of 0.6 ms^{-1} it decreased with increasing period length. The turbulence intensity was in all cases roughly the same. Therefore, in the context of draught rate, velocity fluctuations cannot be represented with turbulence intensities only.

Performance Analysis of Hybrid Solid Desiccant Cooling System with Different Locations of Evaporator in Different Climates

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The solid desiccant cooling system has become a research hotspot due to its ability to improve indoor comfort via temperature and humidity independent control, and its potential energy saving and eco-friendly nature. This study analyzes the heat-pump assisted hybrid solid desiccant cooling (HPDC) system with different locations of the evaporator. Energyplus was used to simulate the indoor thermal comfort and dehumidification performance of the HPDC systems. As a result, for a HPDC system with the evaporator located upstream of the desiccant wheel (Type A), the indoor temperature and humidity can be controlled within comfort range in 84.6% of the system operation time under Seoul climate. In Shanghai, this value is only 31.6%, while in Singapore the thermal comfort requirements cannot be met at all. Therefore, Type A is only suitable for high latitude regions with relatively low temperature and high humidity. In contrast, a HPDC system with the evaporator located downstream of the desiccant wheel (Type B) can satisfy indoor thermal comfort in all regions.The dehumidification performance of Type A is 64.9%, 50% and 57.5% higher than Type B in the three cities and the higher the humidity, the better the dehumidification performance of Type A. In addition, the dehumidification performance of HPDC system decreases with increasing outdoor humidity.

Thermal Comfort in Residential Buildings: a Case Study

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Delivering thermal comfort to the inhabitants is one of the main functions of buildings, but understanding the best way to evaluate the quality of the indoor climate is not an easy task. This is especially true for residential buildings, where inhabitants have a great possibility of adaptation and personal preferences and habits play a crucial role. In this paper, three models taken from standards and literature are tested on a residential single-family house from the DHOMO project. The different outputs are discussed and speculation are made about emerging approaches to indoor thermal quality design.

Effects of vegetation on outdoor thermal comfort in a Mediterranean city and a northern European city

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This study aims to investigate the effect of urban vegetation on outdoor thermal comfort in neighbourhoods of a Mediterranean city (Lecce, Italy) and a northern European city (Lahti, Finland) by field measurements and modelling simulations with a Computational Fluid Dynamics (CFD) model.

The growing phenomenon of urbanization with the increase of concrete and asphalt surfaces, at the expense of green areas, vehicle emissions and heating and cooling systems of buildings has exacerbated the phenomenon of Urban Heat Island (UHI) making cities warmer than rural areas (about 0.5 and 3 °C more) and increasing the thermal discomfort. Outdoor human comfort depends on urban planning and design and it has a heavy impact on the liveability of cities and the health of citizens, thus strategies for its improvement are needed. Vegetation in urban environment could mitigate the effects of climate change and UHI. However, a careful planning of vegetation planting is necessary because its effects are strictly dependent on the interaction of local factors, such as site geometry and meteorological conditions.

In this perspective, this study assesses the effects of arrangements and types of vegetation of the chosen cities under typical winter and summer days and evaluate the optimum scenarios for the improvement of thermal comfort. Specifically, field measurements are performed to characterize the vegetation in terms of species, height, crown width and leaf area index (LAI), as well as the building geometry (height and width of buidlings, street aspect ratio) and the meteorological conditions (air temperature, wind speed and direction, relative humidity).

Numerical simulations are performed with ENVI-met, a prognostic non-hydrostatic model for the simulation of surface-plant-air interactions composed by a 3D main model and in addition a onedimensional atmospheric boundary layer model which extends from the ground surface up to 2,500m. As for vegetation, it permits to consider both the shadow effect and the plant physiological process of evapotranspiration. The thermal comfort is evaluated in terms of indices such as the Predicted Mean Vote (PMV) which depends on air temperature, relative humidity, wind velocity and mean radiant temperature and also on the personal factors heat resistance of clothing and human activity.

Model accuracy is first validated with field measurements and then employed to evaluate different scenarios by removing and adding vegetation in critical areas. In this way, it is possible (i) to evaluate the optimum scenarios tailored to the improvement of thermal comfort and (ii) provide adaptation and mitigation solutions to improve citizens' quality of life and urban planners' decisions.

Investigation of microclimate and thermal comfort around an art – driven and air penetrable architectural structure

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This paper explores the microclimate and thermal comfort around an art-driven and air penetrable architectural structure placed in an open space. In particular, an environmental investigation is conducted with computational simulation for selected climatic/boundary conditions around an architectural design solution which is produced through an art motivated process. The architectural configuration provides the potential of air flowing through the specific form, while shaping a novel outdoor spatial construction. An analytic 3d microclimate simulation software (ENVI - met) with respective input for geometry, material properties and climate data is used for examining the impact of geometric and material characteristics on the microclimate and the thermal comfort. Specifically, the simulation results for microclimate characteristics, such as air temperature, humidity, airflow and radiant temperatures, and for thermal comfort indices are analyzed to examine the interaction between the structure and its surroundings in terms of the thermal and radiant environment, wind field and outdoor comfort. Thus, the evaluation focuses on finding the options that enhance the environmental conditions of the space and produce an improved open area of every day life.

EXPERIMENTAL INVESTIGATION ON EFFECTS OF CLOTHING VENTILATION ON THERMAL COMFORT

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(Introduction)
Humans create their preferred thermal environments by wearing suitable clothing. Air trapped between clothing and body functions as a kind of insulator, however the air flow inside clothing microclimate contribute to dissipate heat from human body. This ventilation can improve thermal sensation under heat. In general, the energy balance of human has roughly a straight-line relationship with thermal sensation. In order to evaluate the thermal states of humans, the energy balance called "human thermal load" is calculated from multiple thermal factors such as environmental factors and human factors including clothing insulation. Normally internal clothing ventilation are not considered for calculating human thermal load, thus, we tried to develop a novel method for understanding effects of ventilation on human thermal load namely humans. In the present study, we prepared prototypes of sportswear for outdoor activity in summer aiming enhancing ventilation and verified the effects of ventilation on humans.
(Experimental results)
We conducted subjective experiments with three different types of garment; ventilation enhancing product, conventional product, and naked. They are used for this experiment to compare relationship between clothing characteristics and thermal comfort. Environmental factors and human factors are measured in order to evaluate the human thermal load. We also investigate the states of convective heat transfer in the clothing microclimate based on the Nusselt number correlations. To determine the Nusselt number, heat flux from clothing, human body, and characteristics of trapped air internal clothing are used. Each heat flux is obtained from measurings.
We confirmed ventilation rates differed due to the characteristics of each garment. In addition, differences in human thermal load were also confirmed by wearing different types of garment. Therefore, the characteristics of clothing affect internal clothing ventilation and thermal comfort. Totally, internal clothing ventilation would be a possible solution for comfort under heat and thus internal clothing ventilation can make better human living environment.

Considering Winter Health: An Evaluation Method for Retrofitting Residential Thermal Insulation

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The purpose of this study is to evaluate methods for optimizing housing thermal insulation, considering residents' winter health. About 38% of houses in Japan are non-insulated, while only about 6% fulfill the current energy conservation standards. In Japan, it is common for houses to only have heating in living rooms. However, the coldness of non-residential rooms correlates with incidences of health problems for residents; many residents die by heat shock, caused by bathroom coldness. Therefore, it is necessary to create healthy living environments by improving insulation and installing floor heating systems.
Using BEST-H, a building / equipment energy consumption calculation tool for Evaluating smart wellness housing, we predicted the energy consumption and thermal environment of each room in a house. We assumed that a typical Japanese detached house would be retrofitted with thermal insulation and have a floor heating system installed. The house model before retrofitting thermal insulation was given a UA value of 2.94 W/m2・K. UA values represent the overall thermal transmittance of the building envelope, therefore lower UA values have better insulation. From the thermal environment predicted by BEST-H, we calculated a warmth score using the CASBEE Housing Health Checklist. In addition, we estimated the cost of retrofitting thermal insulation and installing floor heating and used this, as well as health and energy saving, to evaluate the methods.
In a house where thermal insulation was upgraded to meet a UA value of 0.46 W/m2・K , the warmth score did not increase greatly in the residential room or when a heating system was installed in non-residential rooms. Conversely, the bathroom warmth score did increase greatly. This shows that, under these conditions, high comfort and a good health environment can be formed without installing a heating system in non-residential rooms. In houses with little thermal insulation, the temperature of non-residential rooms tends to decrease rapidly after the heating system is turned off. Therefore, retrofitting thermal insulation in the entire house does greatly improve residents' health. When a floor heating system was installed in the residential rooms, the warmth score increased, especially in bedrooms. This suggests that the introduction of a floor heating system in bedrooms (which can be cold) will greatly improve thermal comfort and residents' health in houses with little thermal insulation. Finally, the cost of these methods was considered. Retrofitting thermal insulation in the entire house cost less, saved energy, and produced higher warmth scores than installing a floor heating system after retrofitting thermal insulation only in the residential room. In conclusion, these results show how warmth score should be used to design a home for low cost, low energy consumption, and improved residents' health.