Conference Agenda

15th ROOMVENT Conference

Session

PV: Personal ventilation and comfort systems

Session Chair: **Mats Sandberg**

Presentations

LEVERAGING OCCUPANTS THERMAL EXPERIENCE WITH A NOVEL ADAPTIVE VENT SYSTEM

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This study presents the findings of the research activities on thermal comfort assessment of a novel adaptive vent system (AVS). The system involves an octagon-shaped ceiling air diffuser with eight individually operable-flaps which reinforces air movement inside the room toward desired directions. In other words, it enables asymmetric air-inlet to the rooms to manage indoor temperature distribution and aims to match varieties in temperature with the differences in occupant demands. By doing so, the system is intended to decrease the conditioned air volume that results in HVAC energy savings without sacrificing occupant comfort. Thus, the AVS is designed to create localized and personalized thermal comfort zones for better indoor thermal environments in an energy efficient way. The current study focusses on the CFD analysis of the indoor airflow regime in order to assess the system performance in terms of thermal comfort and potential energy savings.

The discussion is based on a validated CFD model of a multi-occupant office where the demonstration version of the AVS is already deployed. Following the CFD model development and its validation, four types of analyses were consecutively conducted for the numerical investigation of the performance of the AVS system: (i) air-jet characterization, (ii) indoor air-flow regime identification, (iii) thermal comfort analysis, and (iv) energy performance analysis. The analysis of air-jet characteristics aims to show the effect of air inlet temperature, speed and flap angle on the formation of air-jet properties (spatial distribution of velocity and temperature fields) in a room size empty box. Then, it was possible to conduct further analysis related to resulting air-flow regime inside the test room induced by air-jets, involving temperature and velocity fields. Once the flow related analysis was completed, the next step was investigating the thermal comfort performance of the AVS-system. The CFD based indoor airflow simulations were coupled with 1-D thermoregulation model for thermal comfort assessment of different body parts (head, torso, arms, legs, hands and feet). The last step was the analysis of the energy performance of the system under variety of environment and comfort conditions. Whole model development and analysis procedure was conducted with the propriety CFD software Simcenter STAR-CCM+ (version 12.04) and its Thermal Comfort Wizard.

Beside potential energy savings, the dynamic control of indoor temperature distribution with AVS can also prevent thermal monotony and thus get user engagement which is a crucial concept for energy efficiency technologies. Moreover, the control of the airflow by occupants can also augment the ‘perceived control’ for the HVAC systems which is an important factor for the system acceptability and human-building interaction. Hence, the proposed system is for leveraging thermal experience with an innovative perspective.

Evaluation of Personal Comfort System Using P-R Chart

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Conventional air-conditioning systems are designed to provide comfortable and thermally uniform environments by preventing temporal and spatial variations. However, in a previous survey regarding the thermal environment acceptability in offices, a proportion of the votes indicated an unacceptable environment even when the thermal environment was consistently maintained at comfortable levels according to the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) standards. In offices, the employees’ degree of comfort is based on their attire, physical condition, and activity level. Therefore, even if the indoor thermal environment is categorized as comfortable, workers sensitive to cold or heat will presumably complain of discomfort. Recently, personal comfort systems (PCSs) have attracted much attention as a solution to this problem for improving the thermal comfort of workers. However, the mainstream evaluation of thermal comfort improvement by PCSs is subjective and based on experiments, and a method for objectively evaluating the performance of PCS has not yet been established. A new thermal comfort index called the P–R chart was developed herein using the concepts of “provided temperature” and “required temperature” for evaluating uniform, high-quality indoor thermal environments and non-uniform, unsteady thermal environments. In this study, the thermal comfort improvement of PCS was evaluated by applying the P–R chart.
The effect of the thermal comfort improvement using a PCS, developed herein and called the HCC17, was calculated using a P–R chart. According to these results, the thermal comfort zone of the indoor set temperature for the workers improved significantly when the HCC17 was used. The P–R chart can be also applied to thermal comfort evaluation of various PCSs.

Impact of sensor types and positioning in office rooms on the energy demand of heating, cooling and ventilation systems with particular focus on unsteady situations

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The main objective of the studies on which this contribution is based was the determination of the quantitative impact of the sensor type and position on energy demand of heating, cooling and ventilation systems by preservation of the thermal comfort and in dependence of practically relevant parameters. Within the project a coupled simulation of building, system and indoor air flow was combined with a typical-day-procedure to predict the energy demand for heating and cooling periods. Furthermore the situation in open plan offices, the application of sensor fields and the influence of unsteady situations like user generated thermal load changes or solar gains, were investigated.

The investigations on the influence of temporally varying thermal loads on the energy demand and the sensor type showed that with otherwise identical boundary conditions, deviations in the daily energy demand between the individual control variations of more than 20 % can occur. The deviations determined can be attributed both to the type and position of the sensors used for control as well as to the inertia of the different heating and cooling systems. For example, the position and control specific differences in energy demand of a 24h-period caused by transient influences vary from 5% for mixed ventilation in the case of air cooling to 15% for displacement ventilation, up to 10% for cooling ceilings, up to 20% for underfloor heating and even more for concrete core activation. In the case of radiator heating, variations in the daily energy demand of up to approx. 20% occur. From the point of view of maintaining thermal comfort, air-based cooling systems, radiators and cooling ceilings succeed best in compensating for the additional transient influences. Underfloor heating systems and heating / cooling systems based on concrete core activation, on the other hand, do not succeed well. In the case of the fast-acting systems, it was shown that the sensors used for control are best suited to avoid additional injuries to thermal comfort if they are in the direct sphere of influence of the transient effect investigated. In the case of inert systems, the influence of control variation on thermal comfort is more difficult to determine. Here, the control variation has a greater effect on the data of the energy demand itself.

In addition, recommended actions and guidelines for optimum sensor positions were compiled and prepared for practical application.

LOW NOISE/HIGH EFFICIENCY SMART WINDOW VENTILATION SYSTEM WITH AN OUTDOOR AIR FILTER

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Ventilation is the most effective means to improve indoor air quality. Most ventilation systems work by diluting and displacing indoor pollutants. While many people are reluctant to open windows when ultra-fine dust levels are high, ventilation is recommended in such circumstances as well. This study introduced a smart ventilation system that can provide the benefits of ventilation effects even when outdoor fine-dust levels are high. The performance of this system was evaluated according to Korean standards for ventilation systems and windows. Furthermore, the system was tested in an experimental house to analyze its effectiveness for indoor ventilation and fine dust filtration. When the outdoor dust concentration (PM10) was the range of 31 to 80 μg/m³, the indoor concentration remained 3 μg/m³ when the system was operated. The system has the filtering effect, but when outdoor fine dust concentration was rising to 240 μg/m³, the indoor concentration continued to rise even though two smart ventilation systems were operated. The smart ventilation system should be improved the airtightness to prevent unplanned the outdoor air inflow.

Personalized Work Environment Improving Individual Performance

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In recent years, in Japan, there is a concern that the labor force will decline due to a decrease in the working population in an aging society and a decrease in working hours by work style reform. In order to improve the productivity of the entire organization, it is first necessary to create an environment that maximizes the capabilities of individuals. In addition, there are individual differences in environmental preferences, so by creating an environment suitable for individual differences and work content, there is a possibility that productivity can be further improved. In this study, we created a Personalized Work Environment (PWE) that can provide an environment corresponding to individual differences. By using PWE, a subject experiment was conducted to demonstrate the effectiveness of workplaces that respond to individual differences in improving productivity, gaining knowledge about personal environment preferences to be considered when providing the environment, and gaining knowledge about realizing environmental control by sensing. The PWE in this study includes thermal control (air conditioning set temperature, air volume, wind direction), light environment control (illuminance, color temperature of task ambient lighting), sound environment control (5 types of music, volume), opening control (curtain opening and closing), and subjects could freely control these environments when using PWE.

In the experiment, the subjects were first categorized into office preference type and personality diagnosis by Big5 through a preliminary survey, and the subjects were classified into 4 types, and 5 personalities (extraversion, coordination, openness, diligence, neurotic tendency) was evaluated. Based on the results of the preliminary survey, personality and space preference were analyzed for each individual.

Next, subjects were selected for each of the 4 preference types, and an experiment was conducted in which tasks were performed in three spaces (open-type office, personal booth, and PWE) that resemble the office. The experiment was performed in three spaces with two types of tasks: typing that assumed information processing and mind map that assumed knowledge creation, a total of six conditions. In addition, Measurements of physiological quantity, psychological quantity, concentration, and physical environment of laboratory environment were performed. The experimental procedure is: test / measurement preparation and psychological quantity declaration 1 (20 min), task work 1 (30 min), psychological quantity declaration 2 (10 min), task work 2 (30 min), psychological quantity declaration 3 (10 min), these 100 minutes were taken as 1 set, and 3 sets were made for each subject for a total of 300 minutes.

As the results, the general environmental satisfaction by using PWE was 92.9%, and it was shown that the environmental satisfaction can be improved by self-regulation of environmental factors. From the subjective evaluation, PWE was evaluated as a space where people could concentrate and not to be fatigued. From the objective evaluation, it was confirmed that the tendency of concentration and fatigue in each space differed depending on the type of space preference. The results of this study suggest that it is possibile to improve environmental satisfaction and productivity by providing space according to environmental preference and space preference.

Measuring and visualizing the flow supplied by personalized ventilation

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This study investigates the flow supplied by personalized ventilation (PV) by means of anemometer measurements and schlieren visualization. The study was conducted using a thermal manikin to simulate a seated occupant facing a PV outlet. Air velocity was measured at multiple points in the flow field; the collected velocity values were used to calculate the turbulence intensity. Results indicated that PV was supplying air with low turbulence intensity that was able to penetrate the convective boundary layer of the manikin to supply clean air for inhalation. The convective boundary layer, however, obstructed the supplied flow and reduced its velocity by a total of 0.26 m/s. The PV flow preserved its value until about 10 cm from the face where velocity started to drop. Further investigations were conducted to test a PV diffuser with a relatively large outlet diameter (18 cm). This diffuser was developed using 3d-modelling and 3d-printing. The diffuser successfully distributed the flow over the larger outlet area. However, the supplied velocity and turbulence fields were not uniform across the section.

Operational evaluation of the D-type Cool and Heat chairs

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At the office, employees have different comfort levels based on their clothes, physical condition, and activity level. Moreover, they have different values for thermal comfort. Therefore, it is difficult to reduce employee frustration when using a homogeneous thermal office environment created by traditional air conditioning systems. The system introduced in this research is called "Personal Air Conditioning System" and has been attracting attention. We focused on the office chair and designed it as a "Cool Chair" with its own air conditioning system.The "D-type Cool and Heat chairs" was developed based on the knowledge obtained by continuing the research and development of "Cool Chair".As a function of the air conditioner, this chair has two fans under the seat, exhausts on both sides of the seat, and a heater inside the seat.In order to confirm the effect of this chair, we asked people to actually use it in the office and conducted a questionnaire to those who used the "D-type Cool and Heat chairs" and those who did not.We also measured the time they spend in their chairs and how they use their features.Both heating and cooling functions were widely used throughout the year, but some people did not use them. This is probably because each adjusts the air conditioning function according to the individual heat demand.Those who used the "D-Type Cool and Heat chairs" in summer and winter answered that they were more comfortable in the thermal environment than those who did not.In addition, a large percentage of people who used the chair answered that they were satisfied with the function of the chair.From these facts, it can be considered that the "D-type Cool and Heat chairs" can flexibly respond to individual thermal environment requirements and contribute to improving the comfort of employees.

Influence of gender, age and BMI on human physiological response and thermal sensation for transient indoor environments with displacement ventilation

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Providing high thermal comfort in indoor environments is one of the main objectives of air conditioning and ventilation systems. The concept of displacement ventilation is often used to handle high thermal loads and to maintain low draft rate at the same time. To evaluate such systems in the design phase, a simulative approach can be used by a CFD-analysis coupled to a thermo-physiological human comfort model. On the one hand, these models have to be calibrated for a wide range of boundary conditions. On the other hand, knowing the target groups for the particular application, an adaptation of the human model concerning gender, age or BMI to the target group can provide results that are more reliable.

This paper presents results from a 300 min test study in the climate test bench “Aachen Comfort Cube” (ACCu) with 48 subjects. The separation of the whole subject group into eight subgroups with six subjects each, which have controlled characteristic attributes regarding gender, age and body-mass-index (BMI), allows a statistical evaluation of each attribute with a quantity of 24 versus 24 subjects. The test begins with an acclimatization phase of 60 min at 20.5 °C outside the test bench. In this phase, we measured the subject’s body parameters (height, weight, body fat). In addition, we equipped each subject with 25 skin temperature sensors at different body parts. After the acclimatization phase, the subjects entered the ACCu. The temperature at 0.6 m height was set at 18 °C for the first hour, then increased to 28 °C for two hours and finally decreased back to 18 °C for the last hour. The vertical temperature gradient was constantly set to 2 K/m. Two subjects participated each test run and evaluated their overall and local (16 body parts) thermal sensation as well as thermal comfort on a questionnaire. Additionally, their body core temperature was measured with an in-ear temperature sensor. All subjects have worn a pre-defined clothing combination (underwear, socks, normal shoes, long trousers, t-shirt) during the whole test run.

For each attribute, the metric data (e.g. age or skin temperature) were analyzed with the T-test. The ordinal-scaled data (e.g. thermal sensation) were analyzed with the Wilcoxon-rank-sum-test. Thus, we can identify statistically significant deviations for gender, age and BMI. In the context of thermo-physiological comfort modeling, the results show, that it is required to find different logistic functions for the described attributes to predict the thermal sensation based on the skin temperature.

Development of Combined Convection-Radiation air conditioning system

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The Japanese Government proposed to achieve ZEB on an average of new buildings by 2030. In the same year, SDGs including 17 international goals such as energy and wellness were adopted. In recent years, it has become stronger as a social demand to promote energy saving performance of buildings and improvement of occupants’ comfort and productivity. TABS is attracting attention as an air conditioning system that meets these demands. Advantages of TABS include heat storage and reduce air transport energy. On the other hand, there are disadvantages such as the increase of slab thickness, weight and low responsiveness to variation in heat load.

In this development, we propose a combined convection-radiation air conditioning system to solve the disadvantages of TABS. The radiant panel and convection-enhanced spot fan (hereinafter, refer to as the spot fan) were installed under the slab whose ceiling surface was surrounded by concrete beams (hereinafter, refer to as waffle slab). The spot fan blows toward the ceiling, and the airflow flows over the surface of the radiant panel, reaches the side of the beam, it falls into the living space. The slab thickness can be reduced by not burying the water pipes, and the responsiveness can be improved by the spot fan. In addition, contact radiation fins (hereinafter, refer to as the fin) were installed for homogenization of the airflow which hits the human body. The balance between the heat storage in the slab and the heat release into the room was adjusted by these fins, in addition the airflow velocity reaching the living space mitigated.

An experimental facility was built to verify the thermal environment formed by the spot fan and the fins. In this experimental facility, the airflow improvement effect by changing the spot fan diameter and introducing fins was verified using a three-dimensional ultrasonic anemometer. In addition, we conducted an experiment using a thermal manikin that can evaluate the thermal environment of the whole body and each part, and verified the cooling effect using the equivalent temperature, skin surface temperature, and heat loss.

By changing the diameter of the spot fan 350mm to 400mm and installing the fins, the velocity of the descending airflow falling from the corner portion of the waffle slab was weakened, and the difference in the velocity between the upper and lower portions in the living space became small. As a result of the thermal manikin experiment, it was confirmed that the cooling effect was improved by using the radiant panel and spot fan together and changing

the fan operation from weak to strong. The installation of fins improved the non-uniformity of the airflow in the living space, and the cooling effect of the human body was able to reduce the difference between body parts.

The thermal environment in this system can form homogeneous heat radiation and airflow environment, and can be used effectively as spot airflow conditioning. This paper can provide useful data for consideration of personalization and control methods to individual characteristics.