Conference Agenda

15th ROOMVENT Conference

Session

TC1: Thermal comfort 1

Session Chair: **Manuela Almeida**

Presentations

An experimental study of the influence of a moving person on thermal conditions with diffuse ceiling ventilation

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The influence of occupants' movements should be considered when analyzing local thermal comfort. This study presents the effects of human movement on airflow characteristics and local thermal comfort with diffuse ceiling ventilation by experimental studies. In the experiment, a simulated person moving on track and trolley was used to study human movement in a double layout office. The simulated moving person was designed to go back and forth on a straight track near the workstations. In the tests, three moving speeds were used: 0.3, 0.6 and 1 m/s. The simulated person moved in four cycle patterns: continuous moving and with 5 s, 10 s and 15 s interval breaks between each turn. The heat load was gradually increased from 40 to 80 W/m^2. The effects of heat load level, moving speed and moving frequency on the air flow pattern and thermal comfort were studied. The results indicate that human movement had significant effect on vertical temperature gradient between the floor level and 0.6 m height. However, the moving frequency had no significant effect on the air temperature profile. The mean temperature and velocity increased with heat load. Consequently, also the draught rate, turbulent kinetic energy and the power spectral density increased. It was noted that the moving person created different micro-environments close to work stations and the moving person zone with low-momentum diffuse ceiling ventilation. In all the cases, the mean velocity and draught rate stayed within the acceptable range at occupied zone with different moving speed and moving pattern.

Potential of solar shading solutions for reducing overheating while maintaining acceptable levels of daylight in a refurbished Danish apartment building from the period 1950-1970

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Refurbishment of existing buildings is essential for significant energy savings. Addition of thermal insulation and tightening of the envelope lead to energy savings for heating, but a limited infiltration can cause elevated indoor temperatures during periods with high solar radiation. An excess indoor temperature has been proven to negatively affect health, well-being and productivity.

The paper presents a study focused on the potential of solar shading solutions to reduce overheating without compromising daylight conditions in a typical Danish apartment building from 1950-1970 after refurbishment. The study used coupled thermal and daylight simulations in IDA ICE. The results show that it is possible to obtain acceptable indoor temperatures and maintain daylight levels with use of external solar shading as awning blinds and marquisolette. In case of external or internal venetian blinds, the slat angle and the blinds' colour strongly affect the efficiency of the shading regarding overheating as well as the daylight condition in the rooms

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Experimental study on the draught risk of cold window with demand response

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Decreasing the CO_2 emissions of building stock plays a remarkable role in the mitigation of global warming. The share of building sector from both the global final energy use and CO_2 emissions is about 30%. Demand response of electricity and district heating provides one tool for decreasing emissions in the whole energy system. In the decentralized DR control strategy, heating power of an individual water radiator is possible to adjust separately. With decentralized systems, the local thermal comfort is main issue to consider. The draught risk could increase in workstations adjacent to windows during the decreased heating power mainly because of convection flow of cold window surfaces. This study aims to examine how the demand response of space heating affects the local thermal comfort of occupants. The draught risk during the demand response was investigated by thermal manikin measurements in workstations near windows. The thermal comfort measurements showed that the draught risk increased in workstations adjacent to windows during the decreased heating power. The window surface temperature depends on the outdoor air temperature, wind, solar radiation, indoor air temperature, window construction and properties in addition to room conditions like air flow patterns. The increase in draught risk was noticed when the window surface temperature dropped below 15 °C while the heating was turned OFF. To prevent the draught risk, a window surface temperature restriction shoud be implemented in the MPC control algorithm, then its influence on the demand response potential could be investigated with different properties of windows.

Assessment of thermal conditions perceived in clean high-tech laboratories

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A thorough design of cleanrooms together with best practices in cleanroom operation enables to minimize the concentration of airborne particles and create the desired environment of high-tech laboratories for precise manufacturing or research. In common practice, the thermal comfort of users is put aside in favour of the achievement of suitable environmental conditions required by installed technologies and ongoing processes.

The study assessed thermal conditions experienced in laboratories by both a measurement and a post-occupancy evaluation. Not only the general perception of thermal conditions but also the local discomfort and uniformity of indoor conditions were assessed to examine possible sources of discomfort. Determination of fundamental problems of indoor conditions can positively affect the user's well-being and possibly reduce the energy consumption of cleanroom operation.

According to the results, the specific environmental conditions of cleanrooms such as high air change rates, temperature levels and the necessity of cleanroom garments resulted in the frequent discomfort of users. The most occurred sources of dissatisfaction were high air velocities and local heat gains perceived as a draught and temperature variations among workplaces respectively. The excessive built-up of the space with technologies and equipment was considered as a significant source of uneven indoor conditions as well as a possible source of increased risk of space contamination. With a view to the better thermal comfort, more than 90 % of users adapt their behaviour. However, some of their actions do not correspond with the cleanroom policy.

Evaluation for Heatstroke Risk Using Thermoregulation Model JOS-2

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In this study, the reduction effect of heatstroke risk by the counter-measures in hot environments was analyzed using thermoregulation model JOS-2.

The summer outdoor environmental conditions in Japan are becoming increasingly worse owing to the urban heat island and climate change phenomenon. Exposure to hot outdoor environmental conditions can cause not only thermal discomfort but also heat illness. Heat illness is a general term for disorders caused by excessive heat stress on the human body, which are classified as heat syncope, heat cramps, heat exhaustion, and heat stroke, depending on the mechanisms and symptoms of occurrence. The wet-bulb globe temperature (WBGT) has been widely used as an indicator of heat stress to prevent heat illness. However, the problem with the WBGT is that human factors such as metabolic rate and clothing insulation are not thoroughly examined, and exposure time to the environment is not considered.

This study aims to verify whether countermeasures in hot outdoor environments can reduce the risk of heat stroke from the viewpoint of thermophysiology using the human thermoregulation model JOS-2 developed by our research group. First, the prediction accuracy of JOS-2 was validated against our own experimental data and from the literature. Second, leafy shade, solar shielding with a metal roof and parasol, pavement watering, and heat-shield pavement were chosen as typical countermeasures in hot environments. A literature survey on the effects of these measures was conducted. Finally, the effectiveness of these countermeasures in reducing heat stroke risk according to activity level was analyzed using the thermoregulation model JOS-2.

Based on previous studies, the core temperature of above 38.3 °C and amount of perspiration above 2% of body weight were set as the criteria for evaluating heat stroke risk. The acceptable exposure time was defined as the time until the core temperature or volume of perspiration exceeded the criterion value.

As a result of numerical study, in cases of standing and walking, it was found that solar radiation shields (i.e., leafy shade, solar shielding with metal roof and parasol) prevented the rise in core temperature and significantly reduced heat stroke risk. On the other hand, heat-shield pavements accelerated the rise in core temperature owing to the increasing reflected insolation from the ground. In cases where there is air flow such as walking, pavement-watering promoted core temperature rise because the latent heat dissipation from sweating was suppressed by the increased humidity from watering. In cases of high metabolic activity such as heavy outdoor work, the acceptable exposure time is within 1 h, and purely environmental measures could not sufficiently reduce heat stroke risk. Therefore, it is necessary to manage physical conditions and exercise duration along with environmental improvements.

Evaluation of outdoor thermal comfort under building external wall surface materials with different reflective directional characteristics by CFD

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Recently, urban heat island (UHI) is becoming more intense due to the increase of artificial constructions in the city. In addition, for many office buildings in big cities of Japan, except for indoor workplace, some outdoor workplace has been provided on the rooftop or space surrounding the building to better improve productivity of the people. Therefore, it is considered as an important topic to create a comfortable outdoor thermal environment. It has been reported that about 40% of urban anthropogenic heat comes from buildings in large cities, and the heat emitted from building external walls accounts for much larger ratios of anthropogenic heat from buildings, compared to outdoor unit such as air-conditioner.

Therefore, highly reflective (HR) materials are applied to external wall surface of buildings to increase the solar reflectivity of external wall surface as to finally reduce the heat emitted from building external walls. These applied HR materials basically have diffuse or specular reflective directional characteristics.

It is considered that different kinds of reflective materials have different effect on the outdoor thermal comfort surrounding urban buildings. Thus, this study aims to use the Computational Fluid Dynamics (CFD) analysis method to predict the outdoor thermal comfort by using diffuse HR building coating and specular reflective building coating. A total of three thermal sensation indices including outdoor air temperature (Ta), wet bulb globe temperature (WBGT) and new standard effective temperature (SET*) with consideration of outdoor solar radiation effect are used to evaluate the outdoor thermal comfort under diffuse and specular reflective building coatings in this study.

Analytic model for solar air heaters performance assessment

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Towards to zero energy consumption buildings, designers are seeking ways to: a) minimize the energy consumption of the buildings for heating, cooling and lighting and b) to exploit the available renewable energy sources either passively, through bioclimatic design, either actively for heating and/or power production.

Many passive construction elements' configurations have been suggested using solar radiation in order to provide and/or storage heat during winter and enhance the ventilation during summer reducing the cooling loads.

Solar Air Heater is a quite simple low maintenance device capable to increase fresh air temperature and thus, it can be used in a number of applications requiring low to moderate increase in temperatures such as space heating, drying etc. Solar Heating systems have been used for many years, but the first SAH system was designed by E. Morse in 1881.The technology used was rather simple while the achieved heating energy savings were depending from the size of the system in comparison of the space attached to it.

Although, numerous software tools has been developed by many researchers, it is located a small gap for user friendly computational tools that can guide the design teams during early stages of design. Though, the simulation of these systems is possible (EES, T*SOL, TRANSOL) their use is not straightforward, a fact that prevents techno-economic assessment. The other two alternatives are the use of CFD which requires special knowledge, software and computational time and is not adequate for early stage designing, neither can be used by all the designers. Another alternative is the use of analytical models. The existing analytical models suffer from two shortcomings: The first is that even in the case of a monthly time step require iterations and thus some kind of programming effort, the second is that they require the knowledge of data like heat transfer coefficients and dynamic parameters for which the standards give some much generalized values.

In the present paper, user friendly simplified analytical models is developed, based on the concept supported by ISO 13790:2009, for the prediction of performance of three glazed SAHs. The addressed configurations will be:

a) Opaque element with transparent insulation without thermal mass for heat storage, b) Trombe-Michel configuration with the appropriate mass thermal storage wall and c) Opaque element with transparent and heat storage system away from the opening for day – night operation.

The heat transfer through radiation and convection and the heat storage will be described for steady state conditions and the dynamic phenomena will be taken into account according to the instructions of the ISO 13790. Those models will provide an easy tool for engineers in order to assess the energy savings from those passive systems at the first stage of the design without the use of special software for simulation of annual behaviour.

Evaluation of The Bedroom Thermal Environment and Analysis of Sleep Quality based on Individual Basal Metabolic Rate

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In this study, we comprehensively evaluated the thermal environment in a bedroom by considering the individual basal metabolic rate (BMR) and investigating the relationship between the thermal environment and sleep quality. Individual variations in thermal sensation are thought to be attributed to the BMR. Therefore, this study uses the human heat load (L_m), which is related to individual BMR, to assess the impact of the thermal environment on sleep. From July 16 to September 29, 2018, we conducted sleep surveys and BMR measurements. The subjects were 10 young men, 5 young women, 1 middle-aged man, and 3 middle-aged women. The sleep survey was conducted over five consecutive days for each subject. The metrics were physical quantities including six thermal elements, physiological quantities such as brain waves and heartbeats, and psychological quantities including sleep satisfaction. Subjects were asked to measure their body composition four times, and the average value was used. The average BMR for all subjects was 0.70 met. However, male values were significantly higher than female values, and adolescent values tended to be higher than middle-aged values. Considering individual BMR, most subjects were in a thermally neutral environment during sleep using L_m. Furthermore, more neutral thermal environments lowered the incidence of sleep arousal. In conclusion, the thermal sleep environment was evaluated in greater detail by considering individual BMR differences. Sleep quality was shown to likely improve when human heat load is near neutral.

Comparison of Thermal Comfort In Operating Rooms for Different Ventilation Systems

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Background

In German operating rooms (ORs) either laminar air flow (LAF) or turbulent mixing ventilation (TMV) are suggested by DIN 1946-4:2018-09 [1]. In the research project "Energy efficient ventilation in operating rooms", which is performed at the Hermann-Rietschel-Institut (HRI) at Technische Universität Berlin, different ventilation systems are compared. Besides LAF and TMV also a displacement ventilation (DV) is used as a fundamental concept.

A previous study [2] showed that the requirements regarding thermal comfort of the personnel are different. The surgeon is performing physically demanding activities, whereas the anesthetist is sitting at rest, therefore they would prefer different air temperatures. A comfortable environment for all persons with similar clothing regulations was not possible with the investigated ventilation systems.

The thermal comfort in ORs with DV shall be presented in this paper.

Methods

The global thermal comfort as well as the draught risk were evaluated with regard to DIN EN ISO 7730:2005-06 [3]. The research OR at the HRI was equipped with a realistic load configuration, including person simulators with different heat loads and further equipment. The air temperature and the velocity were measured at heights of 0.1 m, 1.1 m and 1.7 m and the globe temperature at 1.1 m. The thermal comfort was evaluated for a surgeon, a scrub nurse and an anesthetist. For the patient the thermal comfort and the draught risk were not evaluated, but the energy consumption of the normothermia system was measured.

Results

Whereas in ORs with LAF the draught risk (DR) is 37 %, which is above the limit of the comfort levels regarding DIN EN ISO 7730: 2005-06 [3], in TMV (DR = 12 %) level B can be reached.

With DV, the velocity and turbulence intensity at the ankle can be uncomfortable for the personnel. Furthermore, the temperature at the ankle can also limit the global thermal comfort of the OR staff members.

The energy consumption of the normothermia system to keep the surface temperature of the patient constant in case of DV is similar to the case with TMV.

Conclusions

For the thermal comfort in rooms with DV especially the velocity and air temperature at the ankle are critical. In an OR the staff is wearing light shoes and tunics, whereas it should be avoided that cold air is introduced under the tunic and result in discomfort of the personnel.

At the OR table, where the patient has to undergo the surgery, the air is already warmed and the energy consumption of the normothermia system is similar to TMV.

Literature

[1] DIN 1946-4: 2018-09: Ventilation and air conditioning – Part 4: Ventilation in buildings and rooms of health care

[2] Hartmann A., Hofer V., Rotheudt H., Zielke B., Kriegel M. (unpublished): Thermal comfort in operating rooms with laminar airflow systems and turbulent mixing ventilation. Healthy Buildings 2019 Asia, 22.10-25.10.2019, Changsha

[3] DIN EN ISO 7730: 2006-05: Ergonomics of the thermal environment – Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria

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Measurement of metabolic rate in Japanese subjects for different activity using indirect calorimetry

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Metabolic rate was measured in 45 young Japanese subjects while sitting quietly, sitting and typing, standing quietly, standing and typing, and walking. Indirect calorimetry was used to determine the metabolic rate from the expiratory volume and expiratory composition of the subjects. It was found that the mean measured metabolic rates were lower than the reference values presented in the ISO 8996 (2004) international standard for all activities. Moreover, the metabolic rates in women were lower than those in men, and gender differences of approximately 10% were found in the metabolic rates for sitting and standing. These results indicate that metabolic rate depends on individual differences, such as race and gender.