Sensor positions – are there good or bad ones?




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Numerous data of simulation at different climate control concepts in a simplified office room provide information about a useful positioning of a temperature sensor in a room with regard to optimum performance and thermal comfort. The optimum sensor position depends on the installed ventilation system and the temperature-controlled surface.

Keywords: sensor position, energy performance, thermal comfort, coupled simulation, CFD

To operate building energy systems in an efficient way, it is necessary to acquire data of the most important quantities of the building. The more precise these data are, the more accurate the building control can operate.

Latest developments in sensor technology and electronics, together with decreasing prices, offer new opportunities for data acquisition and control of indoor air conditions [EnOcean, 2015]. Unfortunately, there is no uniform indoor air climate in a room which raises the question where the room temperature sensor should be positioned with regard to optimum performance and thermal comfort.

Figure 1 shows the temperature distribution of the wall temperature as well as of the operative temperature. The air temperature shows diff–erences of about 1.5K depending on the position of the working place. This means that the sensor position in a room will have an impact on thermal comfort as well as on energy consumption. Additionally, the type of the sensor as well as the type of the heating/ventilating/air-conditioning systems and the weather conditions are analyzed to make statements about good or bad sensor positions.

In the following numerical simulations should provide information about the influence of the location and type of the sensor, the operation mode of the system (heating/cooling) and the type of ventilation system (mixing, displacement and personal ventilation).

Methodologies and boundary conditions

Various simulations of the room air flow structure in a model room are done under different boundary conditions. The model room (see **Figure 2**) is 8 m long, 3.92 m wide and 2.84 m high.

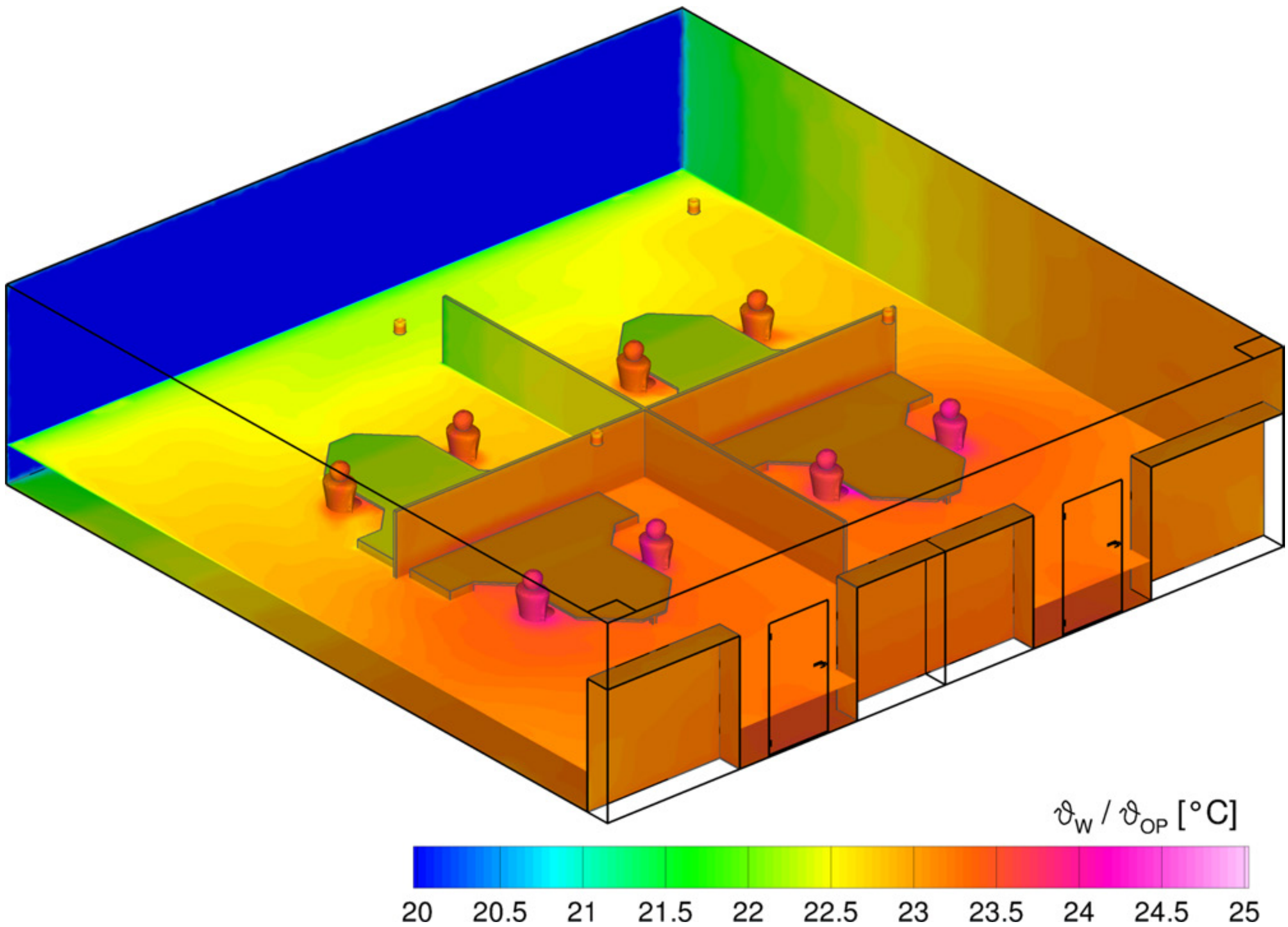

Figure 1. Temperature distribution in an open plan office.

The model room represents a typical situation in an office with two office workers with an occupancy time between 8 am and 6 pm. The wall structures are similar to typical office buildings with the exception of special windows which are used to guarantee the optical access from outside. There are four window segments on the north side of the model room and two window segments on the east side (see **Figure 2**, red surfaces).

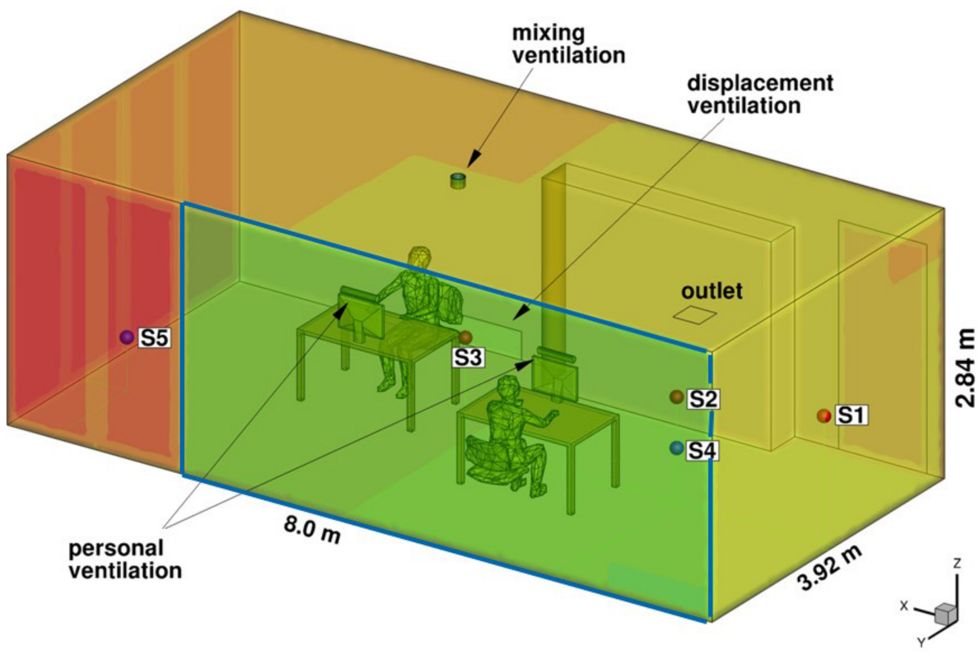

Figure 2. Geometry of the investigated office room with two work places, different sensor positions (in m: S1: x=0.05, y=1.96, z=1.40; S2: x=1.80, y=1.84, z=1.10; S3: x=4.20, y=1.84, z=1.10; S4: x=1.80, y=1.84, z=0.60; S5: x=7.49, y=2.65, z=0.60) and three different types of ventilation systems.

Three different ventilation systems (mixing, displacement and personal ventilation) were analyzed in the model room, which are briefly described in the following. In the case of mixing ventilation, a swirl diffuser in the center of the ceiling is used to supply air into the model room. The diffuser of the displacement ventilation is positioned at the bottom zone at one of the both long sides of the model room. The diffuser is 1.2 m wide and 0.3 m high. In the case of personal ventilation, the diffusers were installed directly above the monitors. All systems are mainly used for the ventilation, not for cooling of the office. As shown in **Figure 2**, the position of the outlet diffuser is in the right corner of the ceiling. This is the case for all ventilation situations.

In addition, **Figure 2** shows the position of the five temperature sensors which are integrated into the model room. All five sensors are used to acquire the air temperature, the operative temperature and the predicted mean vote according to EN ISO 7730 (2005). Sensor S1 is used to control either the operative temperature or the air temperature. Sensor S2, S3 and S4 are used to control the operative temperature.

In order to consider all relevant phenomena and influencing factors, such as climatic conditions, wall and window constructions, sensor positions, air inlet types, positions and numerical simulations were performed as coupled transient calculations of both, a dynamic building, system simulation and a Computational Fluid Dynamics (CFD) simulation [Lube et al. 2008].

Numerical simulations are done for the heating mode as well as for the cooling mode. The ceiling and one of the wall surfaces were taken into account. The wall surface surrounded with a blue frame in **Figure 2**. The cooling capacity is 1.6 kW, the heating capacity ranges up to 1.5 kW.

The weather conditions for the cooling mode represent a period of hot summer days with temperatures up to 33°C. In case of the heating period, the ambient temperature is set to a constant value of –5.0°C. The window is equipped with an intelligent shading system, which avoids 90% of the direct solar radiation.

Two surface areas and three different ventilation systems, which are analyzed for the heating as well as the cooling mode in each case, result in a number of 30 simulations. The simulation model has been validated by measurements in a climate chamber of the same dimensions by the Institute of Air Handling and Refrigeration (ILK) Dresden, Germany [Kandzia et al. 2015].

Results

In all cases and for all sensor positions the criteria of the thermal comfort fulfill the demands of category A, given in EN ISO 7730. Thermal comfort for a room can be selected from three categories. In the case of category A, the predicted mean (PMV) vote should have a value between –0.2 and +0.2.

Figure 3 gives an overview about the best possible option of the difference of daily energy demand between two different sensor positions. The energy demand of the heating and cooling surfaces is summed up for 24 h sections for every simulation run. In the case of the wall as temperature controlled surface, the differences of the daily energy performance depending on the sensor position are much higher in the cooling mode. The difference between the sensor positions reaches more than 20% in the case of displacement ventilation. But contrary to heating mode, the optimum sensor position is always S4. In heating mode, it is not possible to define an optimum sensor position that fits for all three types of ventilation. In case of displacement ventilation, the lower position of sensor S4 is beneficial.

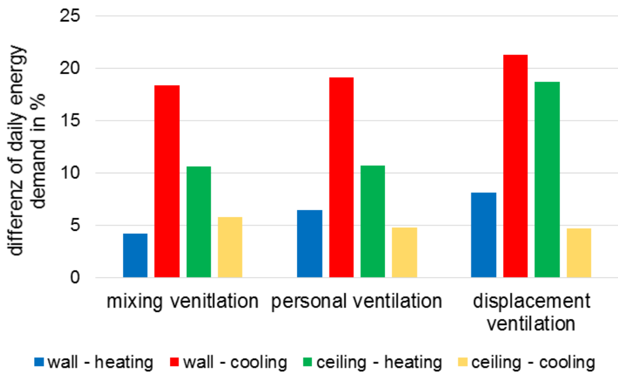

Figure 3. Comparison of possible energy savings depending on the ventilation systems as well as on heating or cooling mode.

Some savings arise in all situations by measuring operative temperature instead of air temperature. In the case of the ceiling as temperature-controlled surface, the possible energy savings are higher in the heating mode.

In no case neither the sensor position S1 nor S5 is the optimum position. Both sensors are located outside of the occupied zone. Hence, they were exposed neither the influence of the temperature controlled surface nor the different ventilation system. They respond much slower to changes in the room and this affects adversely to the energy savings.

Conclusions and outlook

In the specific example examined here, it makes sense to position the sensor as low as possible in the room in the case of the wall as temperature-controlled surface. However, in the case of the ceiling as temperature-controlled surface the sensor should be positioned close to the ceiling. In the cooling mode, it is possible to define sensor S2 as optimum sensor position, but, it is not possible to specify an optimum sensor position in the heating mode. **Table 1** gives an overview about the optimum sensor position depending on the cooling concept.

Sensor S2 as well as sensor S4 are not located in the occupied zone. This means that the permissible temperature at these positions is reached later than in the occupied zone. This effect causes a higher temperature level in the whole room. Consequentially, sensor S4 has the optimum position in the cooling mode by using the wall as temperature-controlled surface. ■

Table 1. Optimum sensor position.

	wall		ceiling	
	heating	cooling	heating	cooling
mixing ventilation	S2	S4	S2	S2
personal ventilation	S2	S4	S3	S2
displacement ventilation	S4	S4	S2	S2

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