The analysis of selected parameters of thermal comfort in the classrooms using CFD technique

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ABSTRACT

The microclimate parameters, such as temperature and air velocity, have a large influence on the sensations, as well as on the effectiveness of the student learning. Therefore, the heating, ventilation and air conditioning systems are designed to provide such parameters of the internal environment, which will guarantee thermal comfort for people staying in classrooms. The analysis of selected air parameters was realized based on the two rooms located in the building of Faculty of Civil Engineering, Architecture and Environmental Engineering at Lodz University of Technology. For this purpose, the DesignBuilder program was used to obtain the temperature and air velocity distributions in the students presence zone.

\textbf{Keywords:} thermal comfort, air parameters, CFD technique

1. INTRODUCTION

Classrooms are rooms which are characterized by a large number of people staying in them in relation to their surface area [1]. The heat and moisture gains derived from people have an impact on microclimate by changing the ambient temperature and relative humidity [2]. Maintaining appropriate air parameters in classrooms should be provided by heating, ventilation and air conditioning systems. It is necessary to take into account the irregular use
of this type of room in the systems working in order to ensure that the students feel thermal comfort from the very beginning of class [3]. The parameters of the internal environment should provide thermal comfort to the people staying in the rooms, i.e. the neutral sensation associated with the microclimate [4]. The main physical parameters which form thermal comfort are: air temperature, radiation temperature, relative humidity and air velocity. The large impact on fluctuations in these parameters have, inter alia, additional heat sources located inside the rooms, construction of the building partitions, surfaces temperature and air infiltration [3]. Ensuring adequate heat conditions is also essential because of their impact on the effectiveness of learning. Fluctuations of microclimate parameters, which exceed the recommended ranges, cause reduction of work productivity [5].

Indoor air parameters should be adapted to the intended use of rooms, i.e. to provide the suitable conditions for carrying out the activities by the people who stay there [6]. In the standard, PN-EN ISO 7730: 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 [7], there are presented design criteria for spaces in the different types of buildings. Due to the similar use of classrooms in schools and in university, the requirements for this type of space are shown in Table 1.

**Table 1.** Design criteria for classroom space at an activity level of 70W·m$^{-2}$.

<table>
<thead>
<tr>
<th>Season</th>
<th>Summer</th>
<th>Winter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>Operating temperature [$^\circ$C]</td>
<td>24.5 ±1.0</td>
<td>24.5 ±1.5</td>
</tr>
<tr>
<td>Maximum average air velocity [m·s$^{-1}$]</td>
<td>0.12</td>
<td>0.19</td>
</tr>
</tbody>
</table>

The decrease in the effectiveness of learning also occurs in rooms with poor air quality [5]. Therefore, during the evaluation of the indoor environment, air quality is an important factor, which can be impaired by dust, bacteria, fungi, and substances emitted by furnishings and building materials. Mechanical ventilation and air conditioning systems, which also have a big impact on air quality, can lead to the increased pollution in the building in the result of improper maintenance. The level of impurities and microbes not exceeding the permissible values testify to the optimum indoor air quality [8]. The content of gases is an important element in assessing the purity of the internal environment [9]. For rooms such as classrooms, where people are the main source of air pollution, carbon dioxide can be used as an indicator of pollution level [5]. Increasing the carbon dioxide concentration above 1000 ppm (Pettenkofer number) results in a decrease in the efficiency of work, but such content is not harmful for people. With the further rise in the carbon dioxide levels, the well-being of the people becomes impaired and the negative impact on their health is exacerbated [9-11].
The assessment of air quality and room conditions can be performed using computational fluid dynamics. CFD modelling enables to perform an analysis of airflow and indoor air parameters in relation to fulfillment of thermal comfort conditions [1]. Computer calculations, based on CFD technique, are also used in the design of systems, mostly in the design of smoke extraction system [12].

2. RESULTS

The analysis of temperature and air velocity was carried out for the two classrooms located on the second floor of the building of Faculty of Civil Engineering, Architecture and Environmental Engineering at Lodz University of Technology. Figure 1 presents the geometric model of the room A. Room A is an exercise room where the experimental stand of the ventilation and solar systems and gas boiler are located.

![Figure 1](image-url)  
**Figure 1.** The geometric model of room A.

Figure 2 presents the geometric model of room B. Room B is the classroom in which the laboratory classes are carried out with the use of desktop computers.
In the analysed classrooms there is a mechanical ventilation system with the supply and exhaust air handling unit with plate heat exchanger (CNW). In the room A (Fig. 1) there are two supply air diffusers (N1 and N2) and two exhaust air diffusers (W1 and W2). In the room B (Fig. 2) there are two supply air diffuser (N3 and N4) and the air is removed from room B through the ventilation grille in the door to the room A, and also through leaks in the building partitions.

The geometric models of rooms A and B were created in DesignBuilder program. The structure of the rooms, furnishing and ventilation and heating elements were made in the “3-D modelling” module. After generating the computational mesh, the following boundary conditions were introduced into the program: the interior surface temperature of interior partitions equal 21 °C, the interior surface temperature of outside partitions equal 19 °C, the interior surface temperature of windows equal 17 °C and supply air temperature equal 21.5 °C. After the calculations, horizontal sections of rooms with temperature and airflow velocity distributions were generated from the program. Cross-sections at a height of 1.2m were selected for analysis, because this high correspond to the height of the head of seated person and during the classes in selected rooms students are sitting for the most of the time.

Figure 3 presents the air temperature distribution at the height of 1.2m in room A. The air temperature is in the range from 20.5 °C to 24.3 °C. In the part of the room intended
for students staying during the class this temperature is about $21 \, ^\circ\text{C}$. Increasing the temperature to about $22 \, ^\circ\text{C}$ is noticeable in areas of direct impact of diffusers N1 and N2 (Fig. 1). Much higher values of temperature are visible above the radiators located near to the outside wall under the windows, which results from convection.

![Figure 3. The distribution of air temperature in the room A.](image)

Figure 4 presents the air velocity distribution at the height of 1.2 m in room A. The air velocity is in the range from $0.1 \, \text{m} \cdot \text{s}^{-1}$ to about $0.8 \, \text{m} \cdot \text{s}^{-1}$. The air velocity exceeding $0.2 \, \text{m} \cdot \text{s}^{-1}$ is observed only in the area of direct impact of the diffuser N1 and N2 (Fig. 1). The velocity increase is also noticeable over the radiators, which results from the convection effect there. For the most part of the room the air velocity equals $0.1 \, \text{m} \cdot \text{s}^{-1}$.

Figure 5 presents the air temperature distribution at the height of 1.2 m in the room B. The temperature approximately equal $22.5 \, ^\circ\text{C}$ has been observed in almost the entire cross-sectional area. Significant rise of temperature, to over $24 \, ^\circ\text{C}$, has been noticed in the immediate area of desktop computers. This is the result of the heat gains to the environment generated by these devices. The higher temperatures were obtained near the radiators, as in the case of room A (Fig. 3).

Figure 6 presents the air velocity distribution at the height of 1.2 m in the room B. The air velocity does not exceed $0.1 \, \text{m} \cdot \text{s}^{-1}$ in the best part of the classroom. The air velocity values which exceed $0.2 \, \text{m} \cdot \text{s}^{-1}$ are observed mainly in the area of direct impact of the diffuser N3 and N4 (Fig. 2) and in the vicinity of radiators.
Figure 4. The distribution of air velocity in the room A.

Figure 5. The distribution of air temperature in the room B.
3. CONCLUSIONS

Obtained by computer calculations air parameters, such as temperature and velocity, enable to evaluate the conditions in the students presence zones in classrooms A and B. The received air temperature values, in the areas definite for students, are complied with the design criteria of the standard PN-EN ISO 7730: 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 [7]. After comparing the average temperatures values in analysed classrooms, it can be observed that in the room B the temperature is higher by about 1.5 °C than in the room A. It can be caused by the desktop computers which are localised in the room B, which generate additional heat gains. Lack of exhaust mechanical ventilation system in this room may forbid the proper air exchange.

During the analysis of the air velocity distribution in the classrooms, it is visible that the air velocity, in the almost entire area of students staying, does not exceed the maximum permissible air velocities presented in the standard PN-EN ISO 7730: 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 [7]. The air velocity exceeds the mentioned above designed criteria only in the areas of direct impact of supply air diffusers.

Comparing the received air parameters distribution to the thermal comfort conditions, it can be seen that students, who stay in the occupied zone, should feel thermal comfort.

Figure 6. The distribution of air velocity in the room B.
Only students, who stay in the area of direct impact of supply air diffuser, may experience low discomfort associated with elevated air velocity. The use of CFD technique enables to analyse air parameters in any point in a building. It facilitates determination of zones where people may feel discomfort and implementation of changes of existing systems or at the stage of their design.

References


(Received 10 April 2017; accepted 06 May 2017)