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# 11. Numerical analysis of the temperature distribution in an office room

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**Abstract:** The article sets the temperature distribution for the office room and people in it. The analysis was made on the basis of the numerical solution of the state determined in the ANSYS-Fluent.

**Keywords:** numerical analysis, temperature distribution, thermal comfort

## 11.1. Introduction

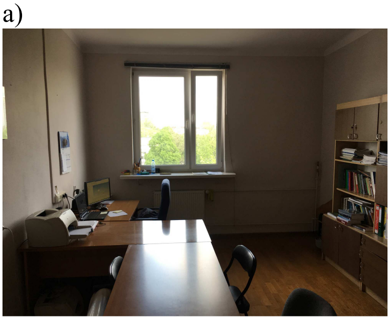
Maintaining thermal comfort at work is recommended not only to ensure adequate employee performance. Employee is obliged to adjust individual air parameters to the standards defined in the Regulation of the Minister of Labour and Social Policy (Rozporządzenie Ministra Pracy i Polityki Socjalnej w sprawie ogólnych przepisów bezpieczeństwa i higieny pracy). According to this regulation, temperature in office rooms cannot be lower than 18°C. Thermal comfort in rooms is felt individually and subjectively. An ideal was the system that guaranteed the lowest percentage possible of people dissatisfied with indoor conditions. Due to the fact that humans spend most of their time indoors, evaluation of these conditions is critical. Thermal comfort in rooms has been examined by numerous researchers, including those conducted by Ravikumar & Prakash 2009, Stavrakakis et al. 2008, Myhren & Holmberg 2008, Fanger et al. 1974. Many researchers have used numerical analyses, with their studies concerning three-dimensional steady-state numerical analysis in a room heated by two-panel radiators (Sevilgen & Kilic 2011), or numerical evaluation of thermal comfort in a room (Embaye at al. 2016) also in a cross-ventilated space with top-hung windows (Deng at al. 2017).

The aim of this study is to present parameters of thermal comfort using the ANSYS Fluent software with the example of the selected office room. The paper presents a three-dimensional numerical analysis of temperature distribution conducted for an office room. A real room heated with a steel two-panel heater was analysed. Furthermore, floor heating and thermal carriers were adopted for comparison. People remaining in this room were also taken into consideration. It was demonstrated that with the computation methods used, it is possible to perform analysis of technological and material solutions already at the stage of design and use of the room.

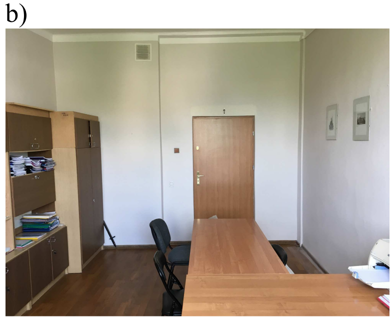
## 11.2. Focus of the analysis

The analysis concerned an office room on the last floor of the building of the Faculty of Civil Engineering, Częstochowa University of Technology in Częstochowa, Poland (Fig. 11.1). Room dimensions are 5.32 m × 3.78 m × 3 m, with a cutout for the chimney channel with dimensions of 0.15 m × 1.6 m × 3 m (Fig. 11.2). There was a wall unit and three desks in the room (Figs. 11.1a and 11.1b).

a)



b)



c)


**Fig. 11.1.** Real view of the analysed room: a) view to the window, b) view to the door, c) front façade of the building

The computations took into consideration three cases of heating. Case 1 reflected the real conditions of heating by means of a two-panel steel heater with dimensions of 0.8 m × 0.6 m, fed from the university's heating plant. Case 2 assumed the use of floor heating, whose heating field is removed from each wall by 0.4 m, with total heating surface of the heating of 12.2 m$^2$. Case 3, the last in the examinations, assumes the use of a two-panel heater with dimensions of 0.8 m × 0.6 m (as in the Case 1) and floor heating with surface area of 12.2 m$^2$ (installed as in the Case 2).

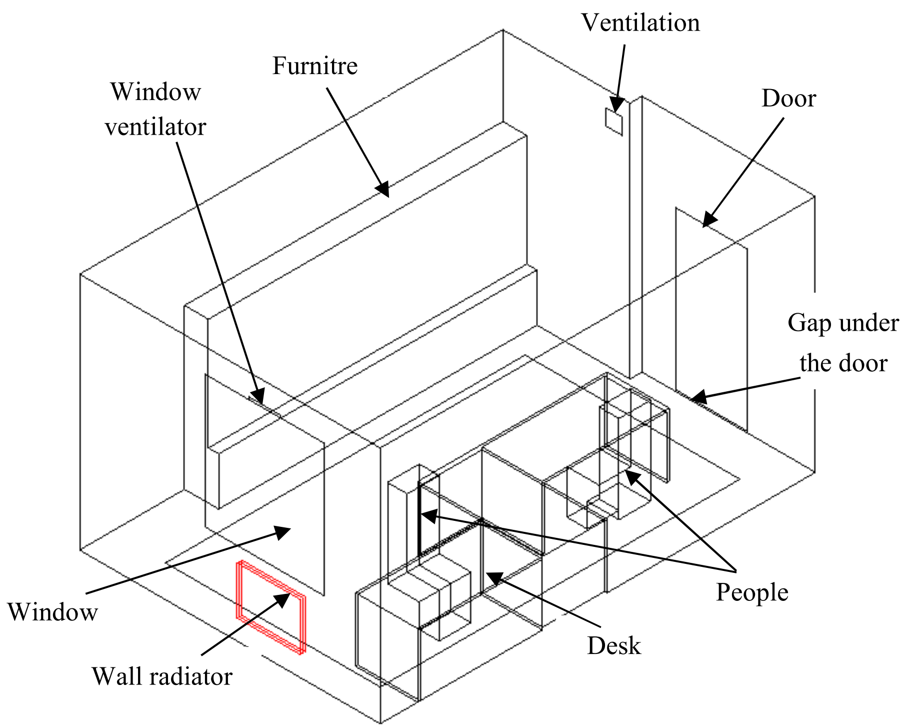



**Fig. 11.2.** Model of the room analysed

## 11.3. Numerical model and case study

ANSYS - Fluent software was used for numerical analysis (comp. Major & Kosiń 2016 or Major & Kosiń 2017). A source of heat adopted for computations was one of the cases (Case 1, Case 2 and Case 3) and heat from two people. Temperature of heating devices was 70°C for the wall heater and 29°C for floor heating. Due to the clothing, the temperature generated by humans was adopted as 33.7°C.

The external air temperature of -20°C was adopted for the analysis. The temperature of air flowing from the rooms adjacent to the building was 20°C. Numerical analysis did not take into consideration the heat gains from solar radiation.

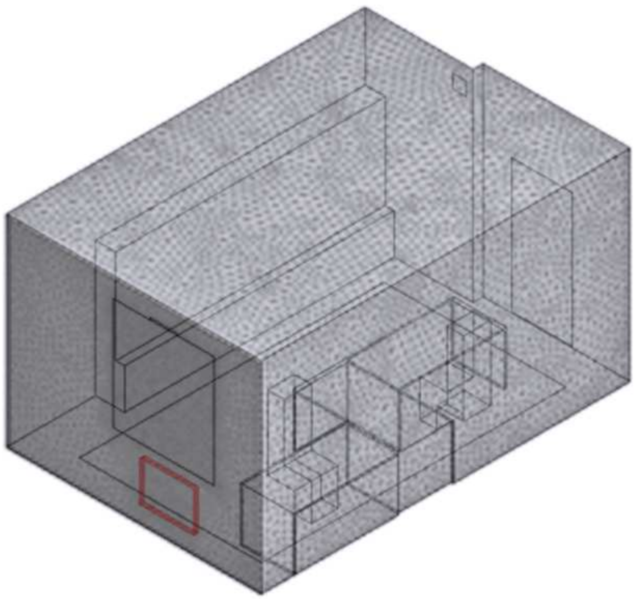


**Fig. 11.3.** The view of the generated net of finite elements

Inflow of air from the outside occurred through the window air inlet, for which entire value of ventilation air flux was 0.007 kg/s. Furthermore, air outflow was ensured by gravitational ventilation outlet with dimensions of 0.2 m × 0.2 m and a gap under the door (0.9 m × 0.02 m) leading to the building corridor.

Due to the shortening of the computation time, a grid with four-wall components was generated (Fig. 11.3). Details of grid generation and solutions were derived from the literature: Ansys Fluent 12 User's Guide 2001 and Major & Kosiń 2016. The computational domain was composed of nearly three million nodes.

## 11.4. Solutions

For the analysed cases (1 to 3), the figures below (11.4a-c and 11.5a-c) present isotherms on the plane parallel to the floor and on the vertical plane. The assumed planes parallel to the floor were placed, respectively, at the floor level (height: 0.00 m), over the desk (height: 1.00 m) and at the level of the head of a sitting person (height: 1.4 m).

Figs. 11.4d and 11.5d illustrate distribution of temperatures in the vertical plane passing through the centre of the window air inlet (compare Fig. 11.2).

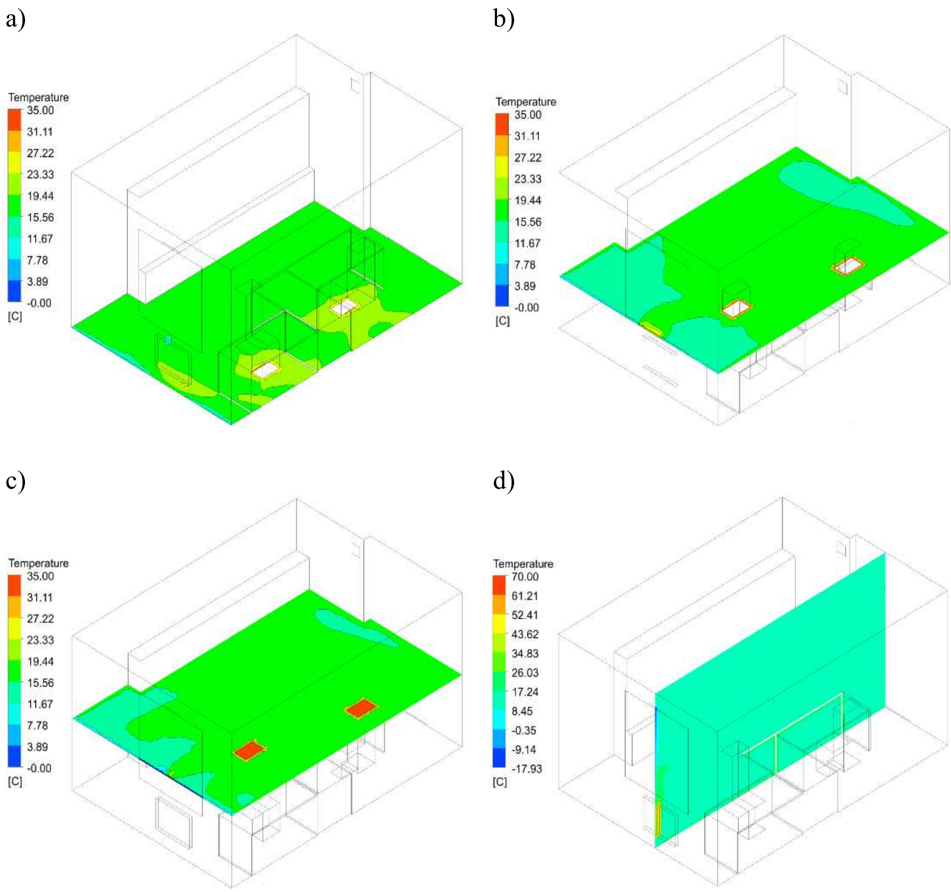



**Fig. 11.4.** Distribution of temperature: Case 1: a) level of floor of 0.00 m, b) level over the desk 1 m, c) level of the head 1.4 m, d) vertical plane passing through the centre of the air inlet

In the Case 1, moving planes show a disturbed distribution of temperature at the side of the wall with the window and wall with the door (Fig. 11.4b, c). The change in the temperature fields occurs also in the area of sitting people (Fig. 11.4a). Fig. 11.4a shows heat radiation from the heater and the effect of low temperature from the window part (Fig. 11.4d).

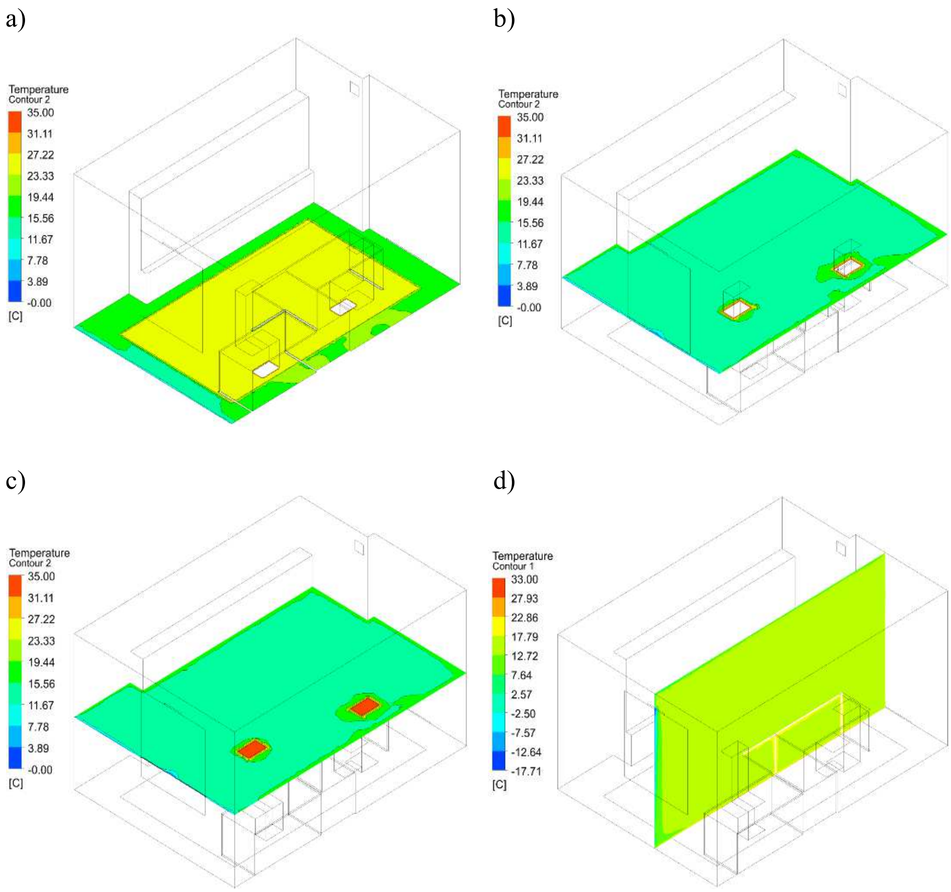



**Fig. 11.5.** Distribution of temperature: Case 2: a) level of floor of 0.00 m, b) level over the desk 1 m, c) level of the head 1.4 m, d) vertical plane passing through the centre of the air inlet.

The isolines at the floor level in the Case 2 show variable fields of temperatures near the external wall and in the area of feet of the people sitting at desks (Fig. 11.5a). In other vertical planes, distribution is not homogeneous, with light disturbances near people sitting in the room (Fig. 11.5b, 11.5d). The window zone, presented in Fig. 11.5d, contains a band of cooler temperature over the height of the external wall.

For the Case 3, with mixed heating, including heating with a two-panel steel wall heater with the dimensions of 0.8 m × 0.6 m and floor heating with the surface area of 12.2 m$^2$, distribution of temperature at the floor level (Fig. 11.6a) differs significantly from the Case 2. The vertical plane shows greater changes in temperatures in the area near the window (Fig. 11.6d).

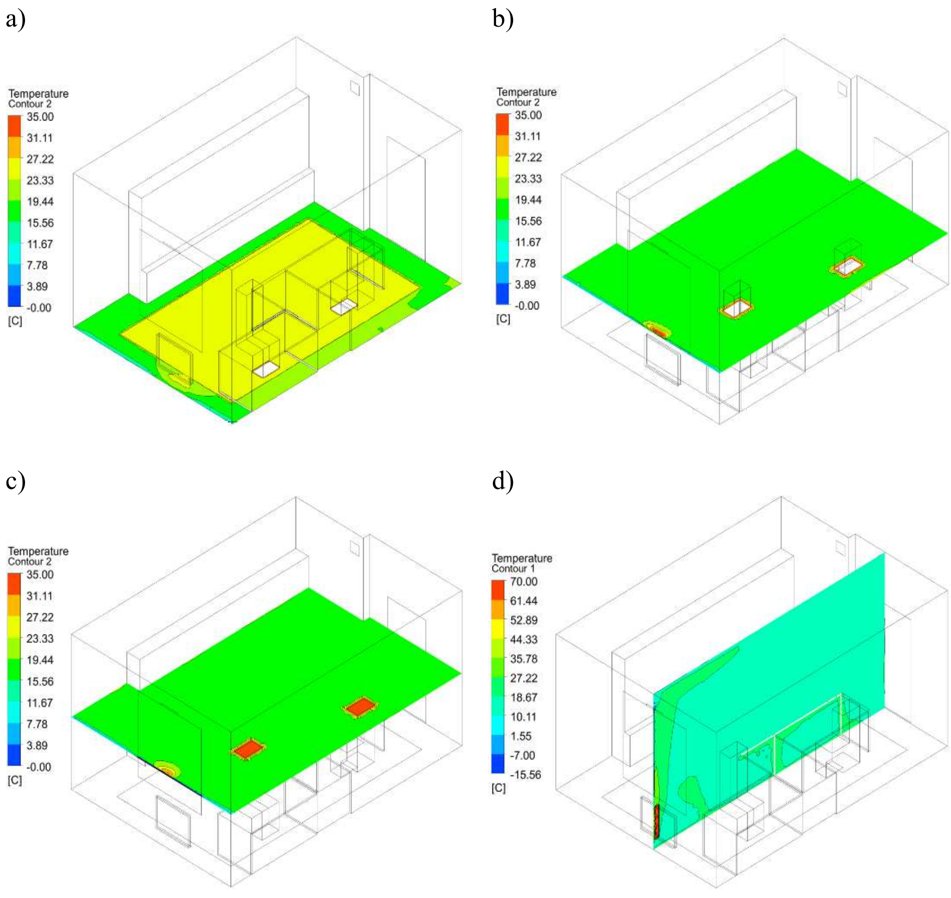



**Fig. 11.6.** Distribution of temperature: Case 3: a) level of floor of 0.00 m, b) level over the desk 1 m, c) level of the head 1.4 m, d) vertical plane passing through the centre of the air inlet.

Other figures (Figs. 11.7 – 11.9) showed isolines of the velocity of air moving in the analysed room. In the first case, the most intensive air stream can be observed in the part of the room located nearest the heater (Fig. 11.7). Different situation is observed for the Case 2 and 3, where substantially greater changes occur in the area near the floor i.e. near the person sitting nearest the window (Figs. 11.7c and 11.7d, 11.8c and 11.8d).

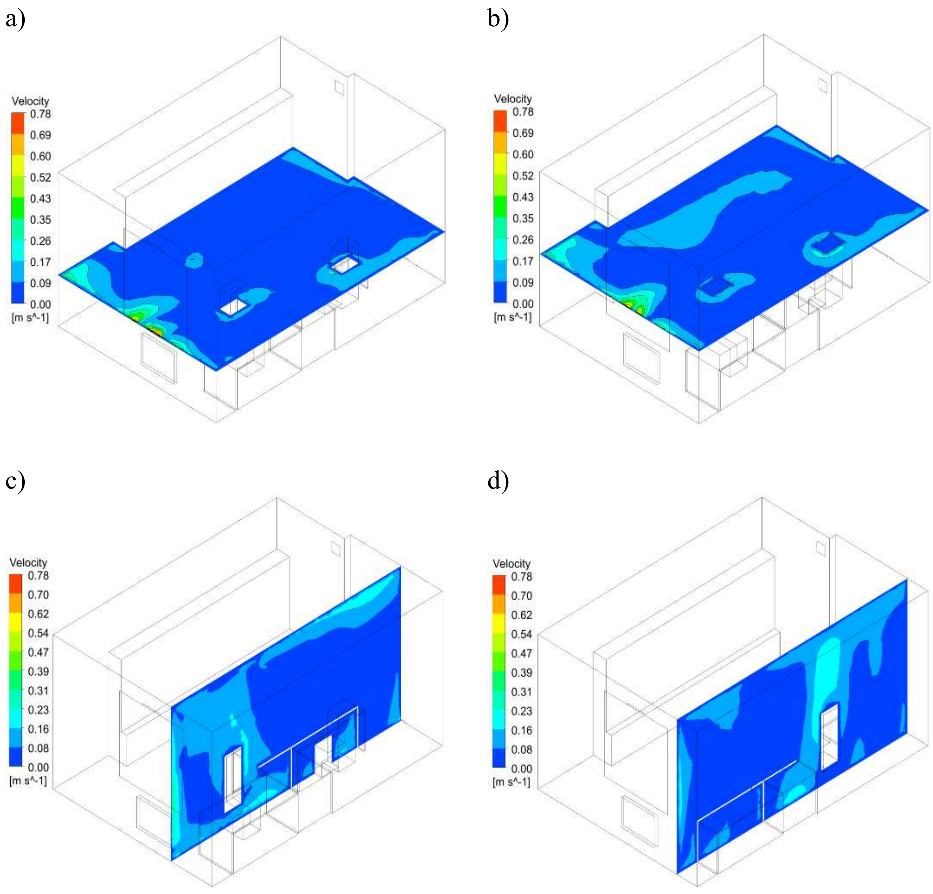



**Fig. 11.7.** Velocity isolines: Case 1: a) horizontal surface over the desk (1m), b) horizontal plane at the height of the head (1.4 m), c) vertical plane passing through the person sitting nearest the window, d) vertical plane passing through the person sitting further from the window

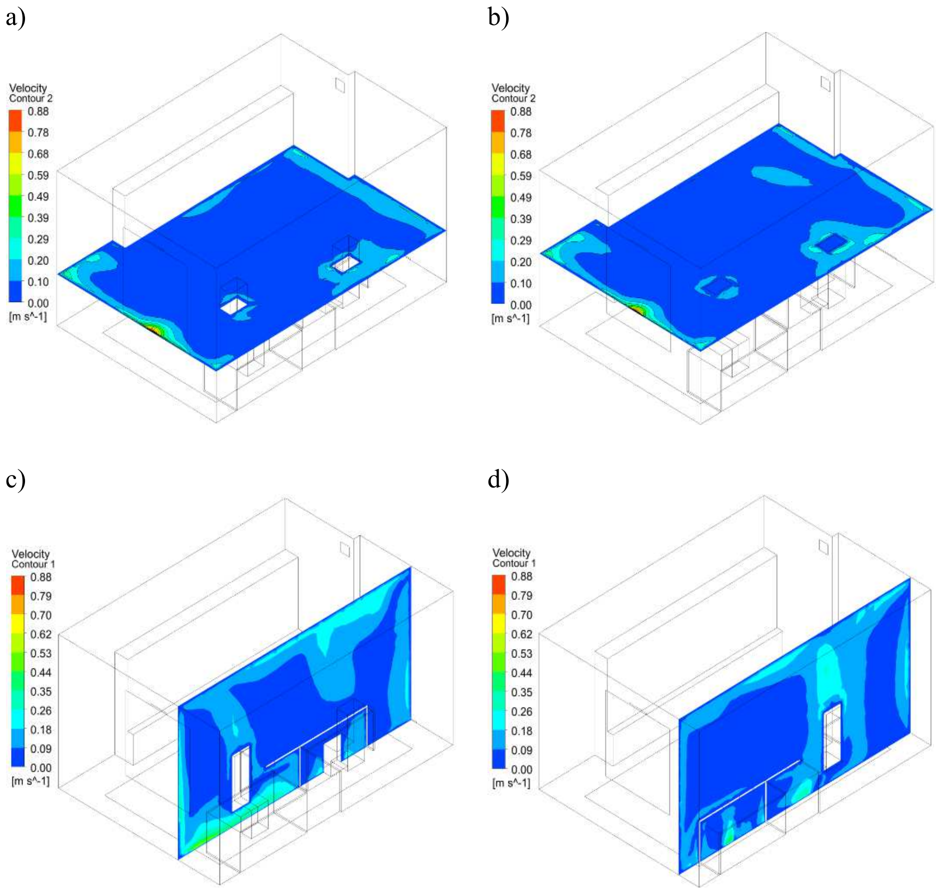



**Fig. 11.8.** Velocity isolines: Case 2: a) horizontal surface over the desk (1m), b) horizontal plane at the height of the head (1.4 m), c) vertical plane passing through the person sitting nearest the window, d) vertical plane passing through the person sitting further from the window

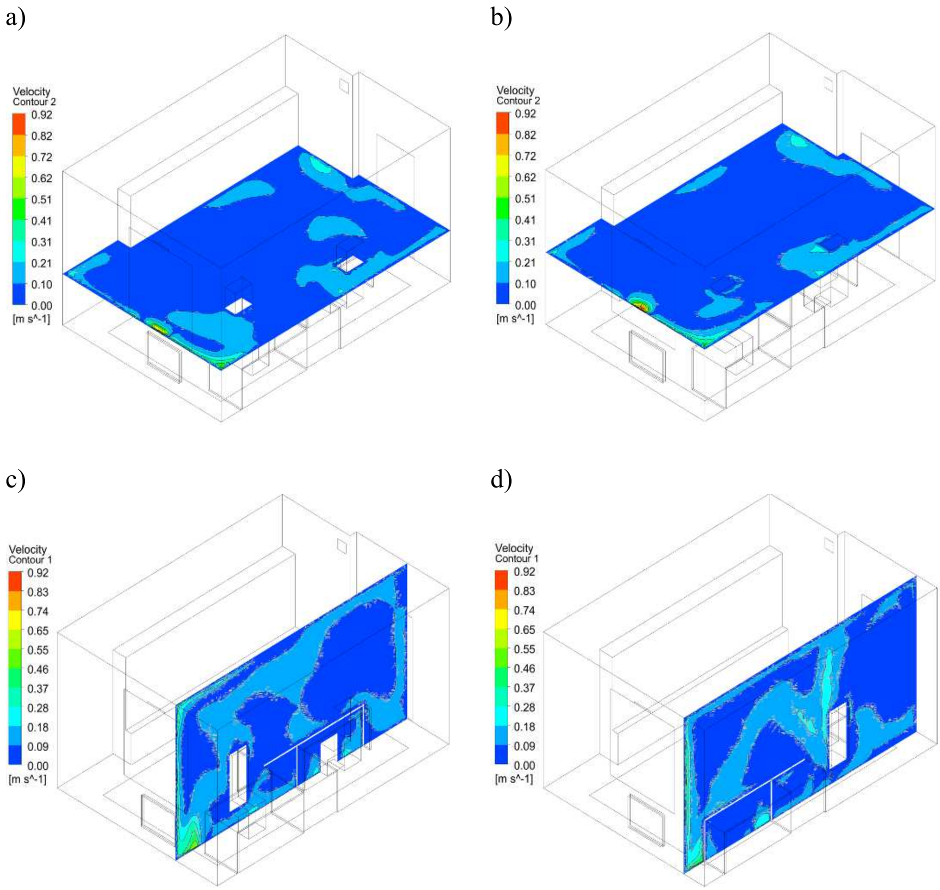



**Fig. 11.9.** Velocity isolines: Case 3: a) horizontal surface over the desk (1m), b) horizontal plane at the height of the head (1.4 m), c) vertical plane passing through the person sitting nearest the window, d) vertical plane passing through the person sitting further from the window

## 11.5. Conclusions

The aim of this study was to model the problems connected with the evaluation of the temperature distribution for various heat carriers by means of numerical methods. The use of numerical software allows for a relatively fast evaluation of the adopted methods of room heating and allows for verification of the adopted solutions. Numerical computations provide both information about the parameters of concern and they allow for a graphical representation of the distribution of these parameters in the room analysed. Consequently, analysis of technological and construction solutions can be made at the design stage, which has a substantial effect on the functional properties of the building. This allows for an effective designing of solutions and assessment of the thermal comfort in the room where humans are expected to spend time, whereas their individual sensations will determine their work performance. One should strive to ensure that the system that guarantees thermal comfort in a room should meet the expectations of people remaining inside. Since humans spend most of their time indoors, numerical analysis of the thermal comfort is a very important and desired form of evaluation of the expected solutions. This can be performed using 3D software such as ANSYS - Fluent.

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