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# Modeling of the microclimate in the work environment with the use of numerical methods

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Abstract: The article presents modeling of the work environment microclimate using numerical methods. The numerical models adopted for the calculations were based on an office located in the building of the Faculty of Civil Engineering of the Czestochowa University of Technology. Six computational variations were made that differed in the heating method, air supply and ventilation. The results of the numerical analysis for one of the models were compared with the test in the assumed measuring point recording temperature and relative humidity. The per-formed numerical analysis allows for a relatively quick assessment of the influence of the adopted boundary conditions on the formation of the microclimate in the work environment.

Keywords: computational fluid dynamics, CFD, numerical modeling, work environment microclimate

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## Introduction

In a specific man-made closed space, the microclimate is defined as a set of air features. The microclimate parameters in the workplace, such as air temperature, humidity and air flow speed, affect the employee's feeling of thermal comfort. Thermal comfort is the most favorable microclimate in which the employee feels good, not feeling too cold or too warm, and the heat management of their body is at its most economical (Major & Kosiń, 2019; Major et al., 2018). According to article 94 no. 4 of the Labor Code, the entrepreneur is obliged to ensure safe and hygienic working conditions and conduct systematic training of employees in the field of occupational health and safety (act. Labor Code, 2021). This provision

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refers, inter alia, to ensuring the thermal comfort of employees. Providing employees with the right microclimate can improve their efficiency, well-being, and also their safety.

The aim of the article was the numerical modeling of issues related to the microclimate produced in the working environment during the heating season. The parameters taken into account in the conducted analysis were temperature and relative humidity. For this purpose, six computational models of the office were adopted. The models differed in the method of heating, air supply and ventilation. For model I, the results of temperature and relative humidity obtained from the numerical analysis were compared with the readings of these parameters made in the office using a temperature and humidity sensor (Kosiń & Pawłowski, 2017; Major & Kosiń, 2019; Major et al., 2018).

## 1. Description of the analyzed models

The office on the basis of which the calculation models were built is located on the third floor of the Faculty of Civil Engineering at the Czestochowa University of Technology (Fig. 1a). The interior of the room, measuring 3.78 m wide, 5.32 m long and 3 m high, is shown in Figure 1b. In the wall opposite the window there is a ventilation duct measuring 0.2 m x 0.2 m (Fig. 1b). Based on the actual condition of the office, six calculation models were created that differed from each other in the boundary conditions presented in Table 1. The source of wall heating was a two-panel steel radiator with dimensions of 0.8 m x 0.6 m, and in the case of underfloor heating, the heating surface was 10.8 $m^2$. The external air was supplied through a window vent with dimensions of 0.4 m x 0.03 m.

The construction of the models was done using the ANSYS Research 2021 Design Modeler, which is a parametric modeling application allowing the creation of CAD geometry. The CAD model of the office was discretized according to the solutions presented in the works (Fluent, 2019; Kosiń, 2021; Major & Kosiń, 2016). The Fluent module of the ANSYS Research 2021 software was used for the flow calculations.

For specific numerical models, boundary conditions were assumed in the form of mass inlet area, mass outlet area, and walls resistant to mass flow. The radiator panel simulated operation at a temperature of 70°C, while in the case of underfloor heating the temperature was assumed to be 30°C. The air temperature at the inlet of the diffuser was set at 4°C, the air speed at the inlet of the diffuser was assumed to be 3.8 m/s, which corresponds to the wind pressure of approx. 10 Pa. Using a plot of the transformation of humid air (Mollier plot), the mass fraction of water vapor (4.17 g/kg) in the air at the inlet of the diffuser was read. For the human model, the mass fraction was assumed to be 10 g/kg, corresponding to a cut temperature of 33.4°C. The air outflow took place through gravity ventilation with dimensions of 0.2 m x 0.2 m located at a height of 2.7 m and a gap leading to the corridor under the door with dimensions of 0.9 m x 0.02 m. A pressure boundary condition was applied at the outlet. For the window, temperature boundary conditions corresponding to 15°C were used, for vertical and horizontal partitions, the heat transfer coefficients were assumed in accordance with the requirements of the legal regulations (Journal of Laws, 2021).

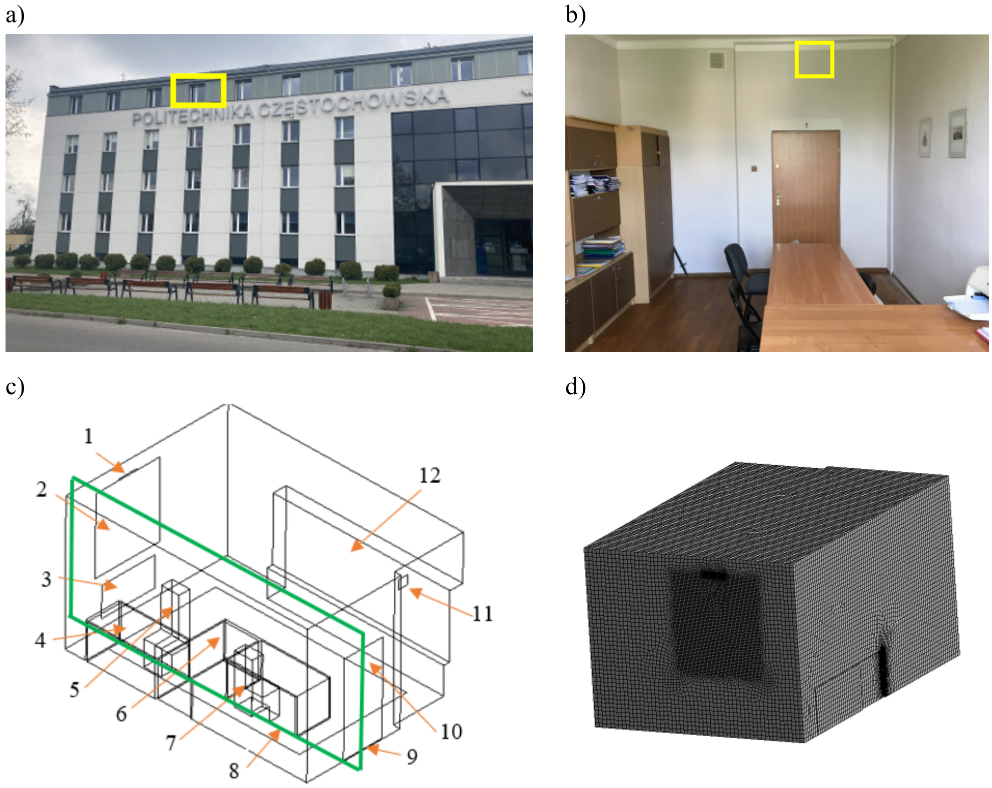


**Fig. 1.** The analyzed room: a) marked location of the analyzed room in the building of the Faculty of Civil Engineering of Czestochowa University of Technology, b) view of the interior of the room in question with the ventilation duct marked, c) computational model of the analyzed office – the plane of the presented results marked in green (1 – window ventilator, 2 – window, 3 – wall radiator, 4 – desks, 5 – person 1, 6 – measuring point, 7 – person 2, 8 – floor radiator, 9 – gap under the door, 10 – door, 11 – ventilation, 12 – furniture), d) mesh (*own research*)

**Table 1.** Adopted calculation models with different boundary conditions (*own research*)

| | Wall radiator | Floor radiator | Window ventilator | Ventilation |
|---|---|---|---|---|
| Model I | YES | NO | NO | YES |
| Model II | YES | NO | YES | YES |
| Model III | NO | YES | NO | YES |
| Model IV | NO | YES | YES | YES |
| Model V | YES | NO | NO | NO |
| Model VI | NO | YES | NO | NO |

## 2. Presentation of the results

The performed validation of the numerical calculations of temperature and humidity for model I in the designated area reflects the nature of the measurements made with the use of relative humidity and temperature sensors (Fig. 2a). The variation in the specified parameters is 8% for temperature and 12% for moisture. Taking into account the influence of many factors determining the prevailing environmental climate in the analyzed office, the obtained differences between the numerical calculations and the actual measurements can be regarded as satisfactory. The results of numerical calculations present maps of temperature and relative humidity distribution in the vertical plane of the longer side of the analyzed room. The measurement plane passed through desks and people's models (Fig. 1c).

a) b)

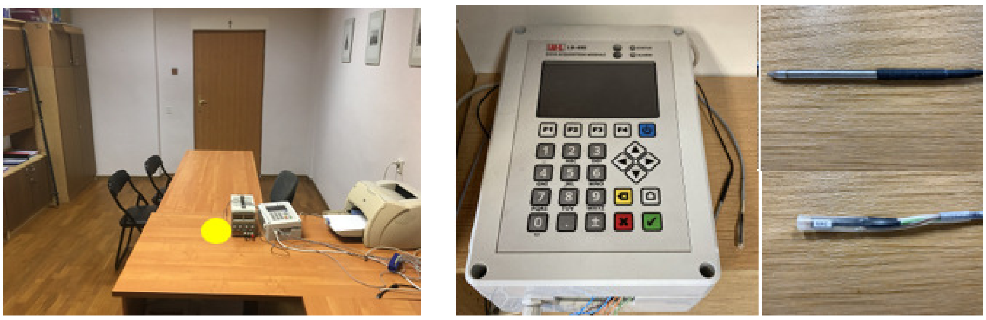

**Fig. 2.** Measurement of the compared parameters (temperature and humidity of the microclimate): a) measurement site, b) LB 490 recorder with a HIH 4000 humidity sensor and TL2 temperature sensor (*own research*)

Comparing model I (Fig. 3a) and model II (3b), which created the variation of the boundary conditions (Table 1), with wall heating, ventilation and a diffuser, a difference in temperature distribution between these models can be observed. In the case of model II with an air inlet (Fig. 3b), you can see the inflow of cooler air concentrated in the lower part of the room.

a) b)

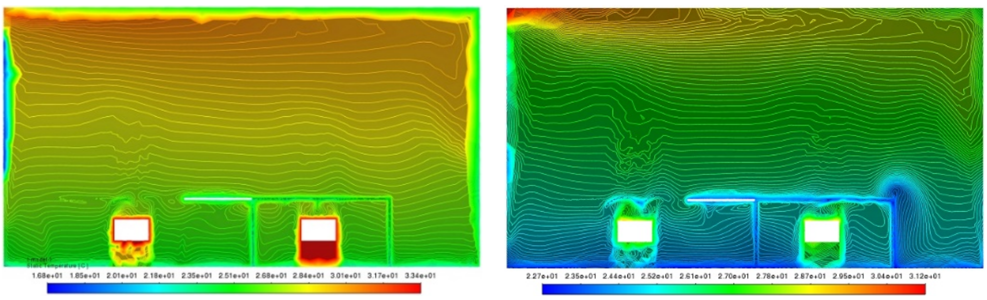

**Fig. 3.** Temperature distribution: a) model I, b) model II (*own research*)

Also for models with underfloor heating (model III – Fig. 4a and model IV – Fig. 4b), the influence of the blown air results in lowering the temperature, especially in the perimeter of the model of a person closer to the window. In the case of comparing the models, taking into account ventilation and its absence in the analyzed plane, there are no visible changes in the temperature distribution (Fig. 5).

a) b)

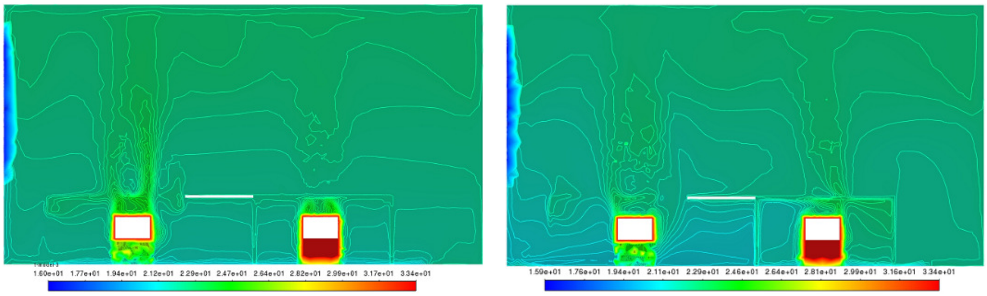

**Fig. 4.** Temperature distribution: a) model III, b) model IV (*own research*)

a) b)

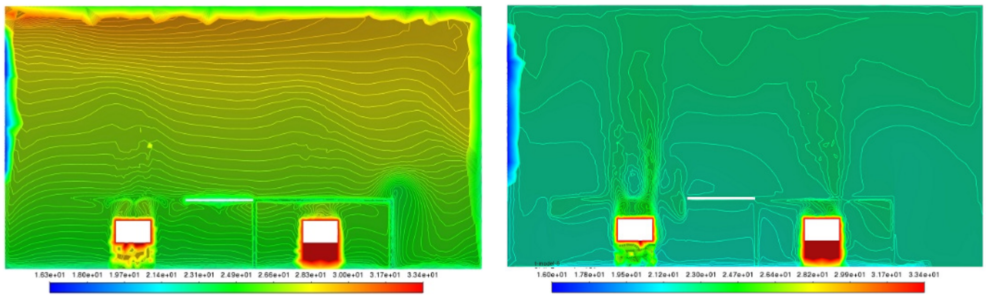

**Fig. 5.** Temperature distribution: a) model V, b) model VI (*own research*)

Observing the relative humidity in the case of models with wall heating (model I – Fig. 6a and model II – Fig. 6b) and underfloor heating (model III – Fig. 7a and model IV – Fig. 7b), there are significant differences in its distribution. In the case of model II and model IV with diffusers, three zones of relative humidity distribution can be distinguished. The first with increased humidity located in the area near the window, the second covering the central part of the room indicating lower humidity, and the third, dry at the wall opposite to the window. Models without diffusers and ventilation (model V – Fig. 8a and model VI – Fig. 8b) are characterized by low humidity in the entire plane of the presented results.

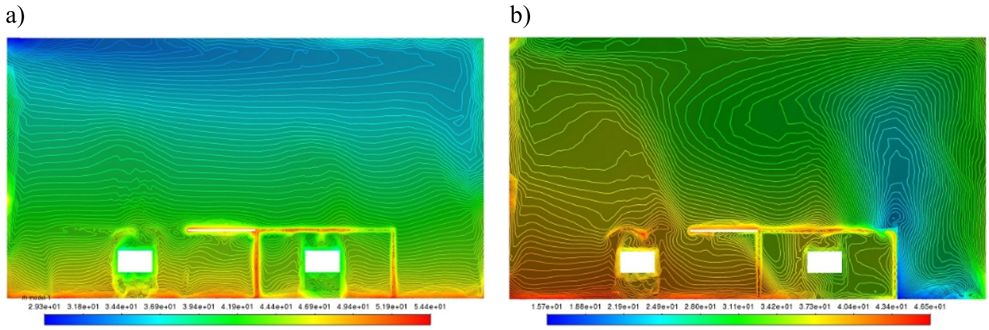

**Fig. 6.** Relative humidity: a) model I, b) model II (*own research*)

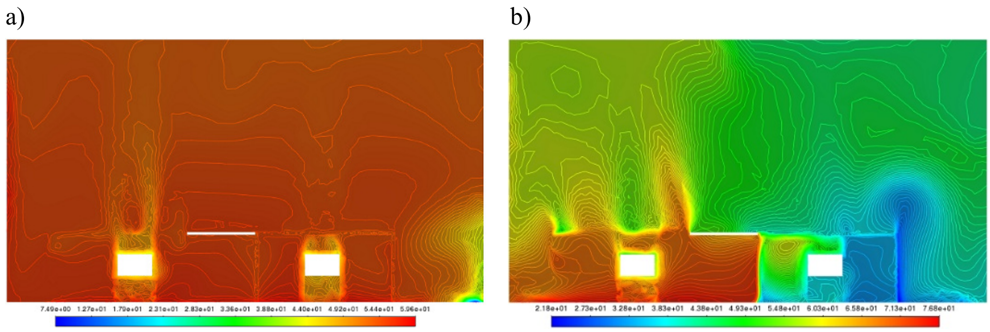

**Fig. 7.** Relative humidity: a) model III, b) model IV (*own research*)

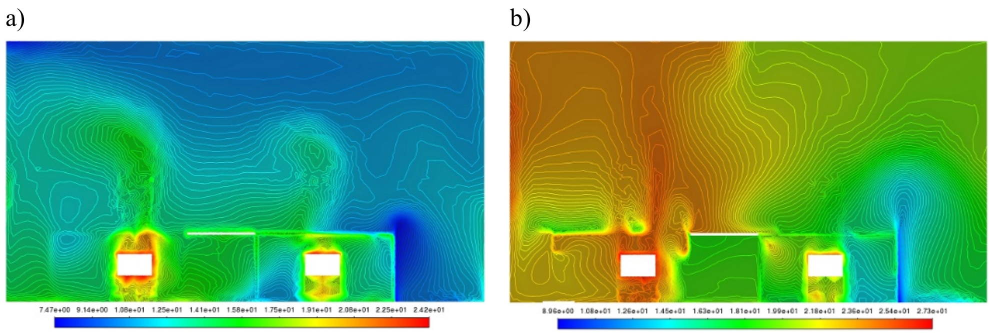

**Fig. 8.** Relative humidity: a) model V, b) model VI (*own research*)

## Conclusion

The aim of the article was to present the application of numerical calculations to evaluate selected parameters creating the microclimate in the work environment. The analysis focused on the comparison of temperature and relative humidity, taking into account the combinations of the assumed boundary conditions. The presented variations of the created calculation models provide information on the parameters of interest. The graphic presentation of the results at the design stage allows for an analysis of the solutions adopted, in this case that shape the microclimate in the work environment. An example of this may be in the conducted analysis computational models taking into account the influence of window diffusers on the temperature and relative humidity distribution. It can be concluded that the installation of window ventilators increases the relative humidity of the room and slightly lowers the temperature. The installation of window ventilators (model II) increases the relative humidity by approx. 5% compared to the room without ventilators and with wall heating (model I). In the compared room variations, the temperature for model I was 23.5°C and for model II 22.7°C. Relative humidity and temperature were read at the measuring point shown in Figure 2a. The possibilities offered in this case by the Ansys program used for calculations are much greater and in further studies they will be presented by the author in the field of shaping the environmental climate. From the point of view of numerical calculations, it is appropriate to validate them with experimental research. In the presented work, the comparison of the results obtained on the basis of numerical analysis with the results of direct measurements of relative humidity and temperature is satisfactory.

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*Rozporządzenie ministra infrastruktury z dnia 12 kwietnia 2002 r. w sprawie warunków technicznych, jakim powinny odpowiadać budynki i ich usytuowanie.*

*Ustawa z dnia 26 czerwca 1974 r. Kodeks pracy.*