MODELING OF AIR-FLOW IN ASSEMBLY HALL SUPPORTED BY MECHANICAL VENTILATION SYSTEM

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Summary:
The aim this paper is to present the results of simulations of mechanical ventilation system performance in assembly hall of the Faculty of Environmental Engineering, Lublin University of Technology. Simulation was conducted using Autodesk CFD Simulation 2013. 3D model of the assembly hall was created in Autodesk Revit Architecture application, which is directly connected to CFD Simulation program. There were conducted two variants of simulations: for winter conditions and for the summer performance. Obtained results enable to verify temperature values and air-flow velocities in the modeled room in each place and time. Conducted simulations showed that there are the areas with air parameters do not satisfying the design assumptions, required for thermal comfort and the correction of the applied solutions is needed. Air flow velocity distribution in the examined assembly hall, determining the indoor air parameters depends on many factors that were not considered in the described system solutions. The most important factor is temperature of the external barriers and the particular geometry of the room. Their consideration was only possible after creating the spatial model of the room and the ventilation system.

Keywords: Indoor air quality, Computational Fluid Dynamics, CFD

Introduction

Quickly developing civilization and changing way of human livings caused that most of time people spend in the artificial indoor climate. Currently more pressure is put on creation of optimal indoor air conditions and the possibility to control the microclimate parameters (Afshari A., Bergsoe N.C 2003). Progress of modern technique enables to provide almost all microclimate conditions on suitable level (Fanger, P. Ole, 1974).

Indoor environment designing requires such information as airflow pattern, velocity, temperature, humidity. To study indoor air flow at small-scale or full-scale, suitable models can be built, but they need coefficients for heat transfer and air flow or they are expensive and time consuming. Various numerical methods have been developed to simulate the indoor environment (Chang 2011). The most popular approach of computational simulation is Computational Fluid Dynamics (CFD) methods. CFD can be used for prediction of internal and external flow within and around the buildings.

Autodesk CFD Simulation uses the Finite Element Method (FEM). The space occupied by the fluid is divided into the discrete elements. This allows the temperature, velocity, and other fluid properties to be determined. FEM is used in structural analysis of the solids, but is also applicable to fluids. The FEM formulation has been adapted to be also used for fluid dynamics equations solving (Surana, K.A. et al. 2007, Huebner, K. H. et al. 1995).

The possibility to regulate the indoor air parameters leads to obtain such thermal conditions, that would be satisfying to each person present inside the room. Biological variety of people causes, that it is not possible to guarantee suitable comfort parameters to all individuals, anyhow it should be possible to feel comfortably by the greatest amount of people present. Creation of thermal comfort state is only possible when the neutral status of thermal parameters is obtained which means that men do not require wormer or colder conditions. Anyhow such state does not guarantee thermal comfort (Fanger P.O. et al. 2003, Baker N., Standeven M. 1993).

Still aiming to create thermal comfort is caused by the need to satisfy human needs to feel comfortably. Also, creation of thermal comfort at workplace positively influences work efficiency. Each individual obtains the greatest physical and intellectual efficiency only when suitable thermal comfort status is provided. There were conducted a lot of examinations aimed on determination what conditions were the most satisfactory at particular workplace but it was not determined if thermal comfort is required to maintain the optimal health status of human individuals (Burek R. et al. 2006, Fanger P.O. et al. 2003, Popiołek 2005).

Model assumptions

This paper presents the analysis – simulation of air-conditioning system performance in the room of the assembly hall of the Faculty of Environmental Engineering, Lublin University of Technology. Assembly hall model was elaborated basing on the real object stocktaking and air-conditioning system basing on the executive design of the installation. To create the 3D model Autodesk Revit Architecture 2012 program was applied. Geometry of the assembly hall is presented at Fig. 1. Modeled external envelopes and internal equipment determine the calculation area. Due to the necessity to limit the number of the nodes in the calculation mesh, shape of most of elements was simplified. Such simplifications are widespreadly applied for numerical calculations, because rounded shapes or too many details do not increase calculations quality, but significantly increase the duration of calculations and the volume of the result files (Chang 2011).

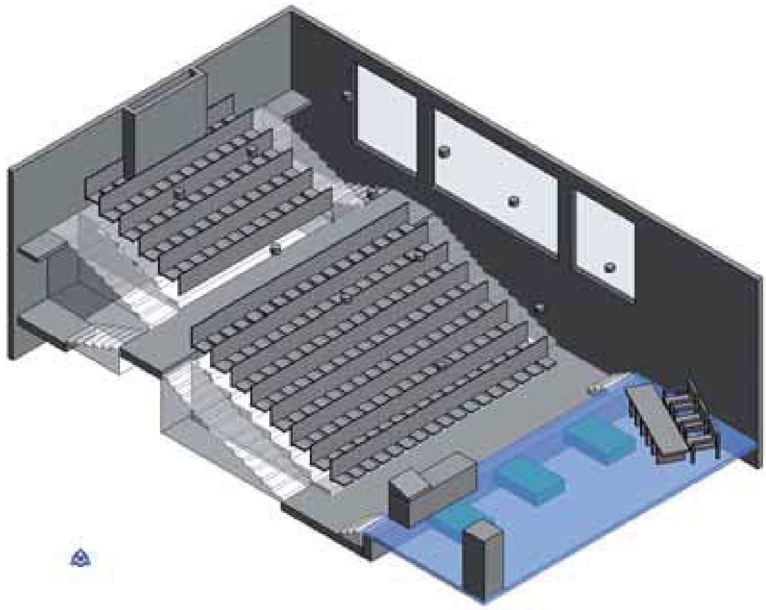

Fig. 1. Three dimensional model of the described assembly hall

The dimensions of the assembly hall are the following: 11m × 20m and the room height depends on place. Maximum height is about 7m and minimum height – 2.5m.

According to fire regulations, in the design it was assumed the maximal number of people inside the room n = 150 persons. Air ventilation is supported by the inlet-exhaust central unit. Ventilation unit productivity is 7200m^3/h. Inlet elements are TROX VDR 315 type ventilators. They are assembled at the suspended ceiling. These ventilators have the possibility to change slope angle of the delivered air. Depending on position the ventilators have the following slope angle: 45°, 65°, 75°, 90°. Each of 12 ventilators delivers the same amount of fresh air equal to 600m^3/h. Single exhaust is placed below the stand for the lecturers. It removes totally 7200m^3/h of polluted air and consists of three exhaust grills made by TROX, AWT type.

System of air-conditioning of the assembly hall should enable maintenance of temperature level at 22°C during winter season and 23°C in summer (Fanger P.O., et al., 2003).

Materials and methods

The basic tool used in the described paper is Autodesk Simulation CFD packet which can be used for thermal analyses and fluid mechanics simulations. It consists of tools enabling simulation of turbulent flows but also heat conduction and convection (Chang 2011).

To create model for simulation procedure it is necessary to determine the types of materials of the modeled object and assign the suitable parameters like temperature etc. Next step is determination of points of air delivery and the exhaust. For simulations of indoor thermal comfort the most important is to present air temperature and velocity distribution. To obtain this results it is required to assign such values as: the amount of air delivered to the room, the amount of exhausted air but also its temperature and velocity. Intake air velocity can be omitted, but only if the dimensions of intake and exhaust ventilators are suitably defined – in these cases the program will calculate suitable velocities of air intake and exhaust itself. In rooms with equal amount of delivered and exhausted air it is not required to set the amount of the exhausted air by the ventilator, it is only required to sign this element with 0 Pa air flow. The final step to be defined before simulation procedure is to set up the calculation mesh. CFD Simulation packet has a very big potential for calculation mesh settings. The only criterion that limits the extend of the details is the CPU computational efficiency and thus duration of calculations but also the size of the outcome file, which great dimensions sometimes disable the possibility to verify the results even on very effective computers.

Described application enables to present the obtained results in many formats: for example the diagrams with averaged results from the default period of calculations, results in graphical form for any layer of the room, particular place or the area. From generated graphics it is also possible to create animations.

Available computer efficiencies enabled to conduct simulations reaching 120 minutes of simulated process with possibility to visualize every 10 minute steps in the most significant stage of air conditioning system – start of the process.

Simulation was divided into two variants: one for winter period and the second one for summertime:

– Winter, empty room, intake air temperature 22°C, windows temperature 10°C, external envelopes temperature 18°C,
– Summer, empty room, intake air temperature 19°C, windows temperature 40°C, external envelopes temperature 22°C (Fanger P.O., et al., 2003).

Results analysis

The aim of the conducted simulation was to verify the possibility to provide suitable values of temperature and air velocities in the people's zone in the assembly hall of the Faculty of Environmental Engineering, Lublin University of Technology.

Obtained simulation results unequivocally show places where calculated indoor air parameters significantly differ from the assumed ones, which were required to satisfy the thermal comfort conditions. Air temperature distribution in winter period after 120 minutes of system start is not satisfactory – areas with unfavorable temperature below 20°C can be found in the people's zone. Fig. 2 presents temperature distribution at the level of ankles of the audience. In the middle part of the hall there are visible the areas with temperature 18°C which is unacceptable (Fanger P.O., et al., 2003).

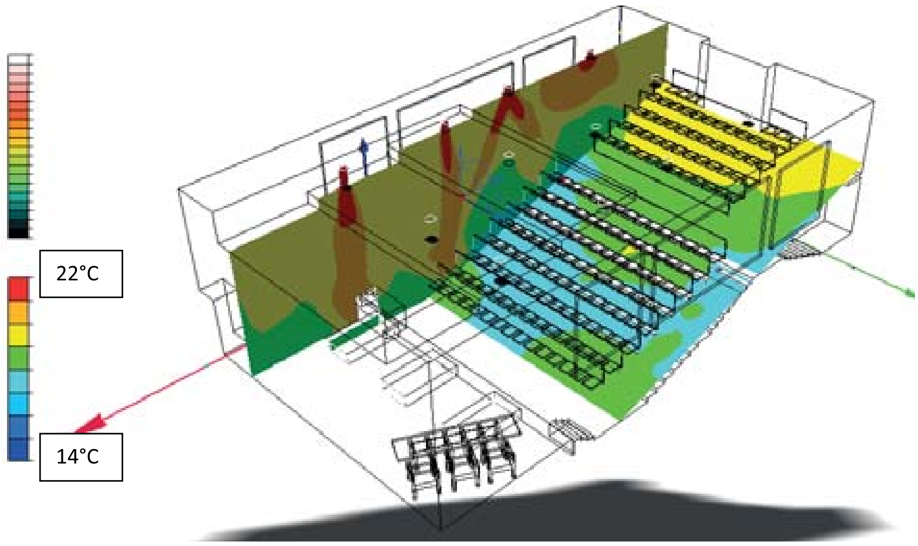

Fig. 2. Air temperature distribution at the level of ankles in the 120 minute of air-conditioning system working

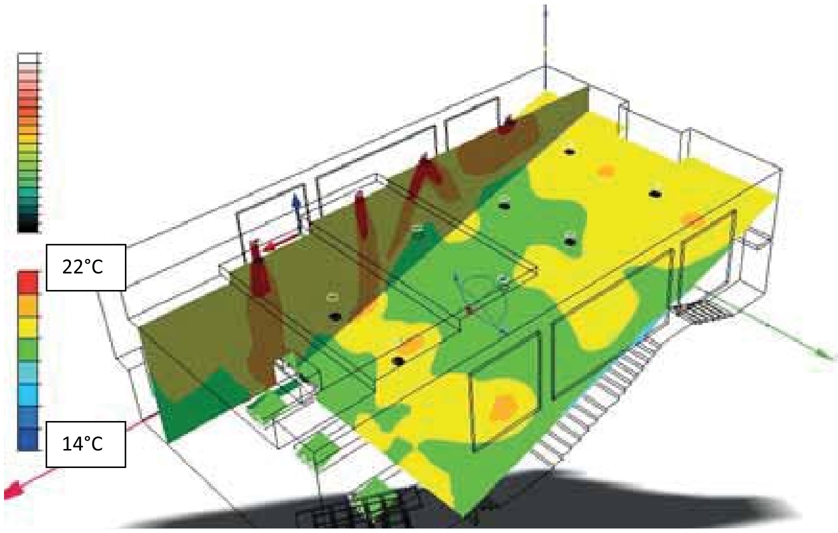

Fig. 3. Air temperature distribution at the level of heads in the 120 minute of air-conditioning system working

In winter period, air velocity at the level of head of sitting people maximally equals 0.6 m/s (Fig. 4) with temperature 19°, which is unfavorable phenomenon from the point of view of thermal comfort (Fanger P.O., Popiołek Z., Wargocki P. 2003).

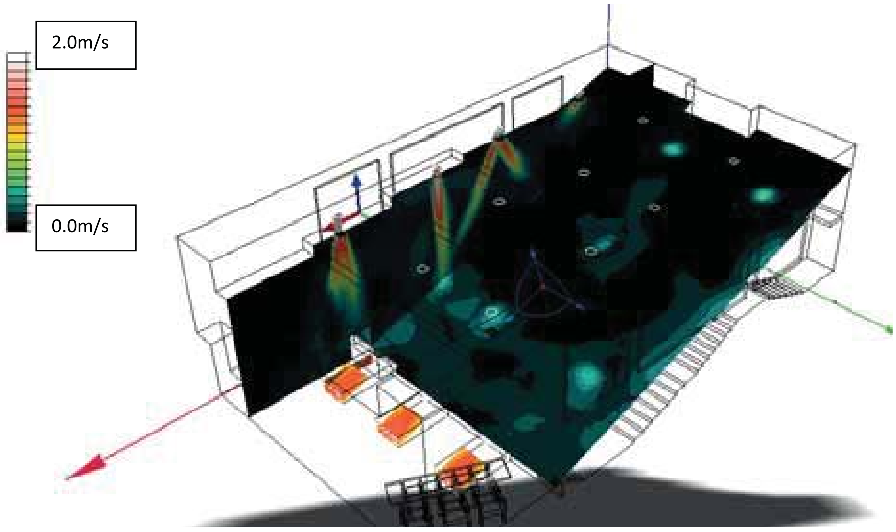

Fig. 4. Air velocities distribution at the level of head after 120 minutes of system functioning

Unfavorable conditions were also noticed in the lecturers podium – air velocity exceeds the maximal values (Fig 5).

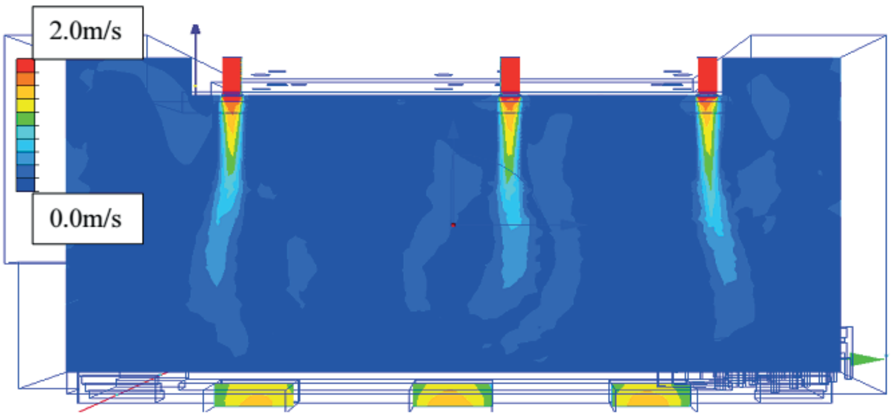

Fig. 5. Air velocities distribution at lecturers podium

In summertime temperature distribution at whole room is suitable and is equal about 27°C, with the assumed outdoor temperature equal 36°C. Unfavorable conditions spread close to the intake ventilators with the following inflow angles: 75° and 90°, where air flow velocity close to people's heads is significantly too high and reaches about 1.3 m/s (Fig. 7) and air temperature equal 29°C (Fig. 6).

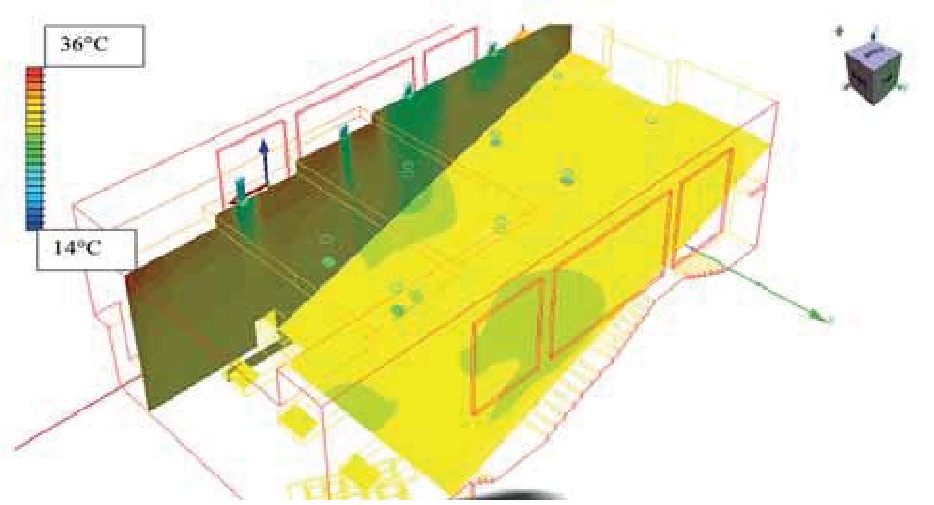

Fig. 6. Temperature distribution at heads level, summertime period

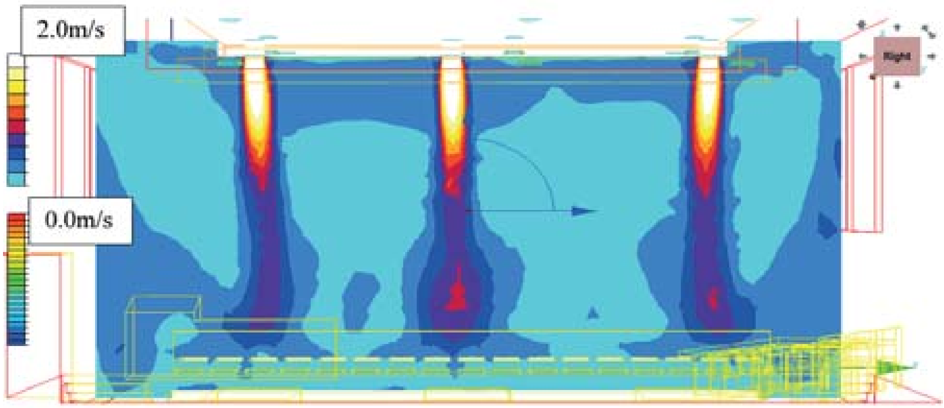

Fig. 7. Air velocity distribution at lecturers stage

At the upper part of the assembly hall, under the intake ventilators with blades angle equal 45° there occur places with air flow velocities equal zero, which also, especially during summertime, may result in discomfort sensation (Fig.8).

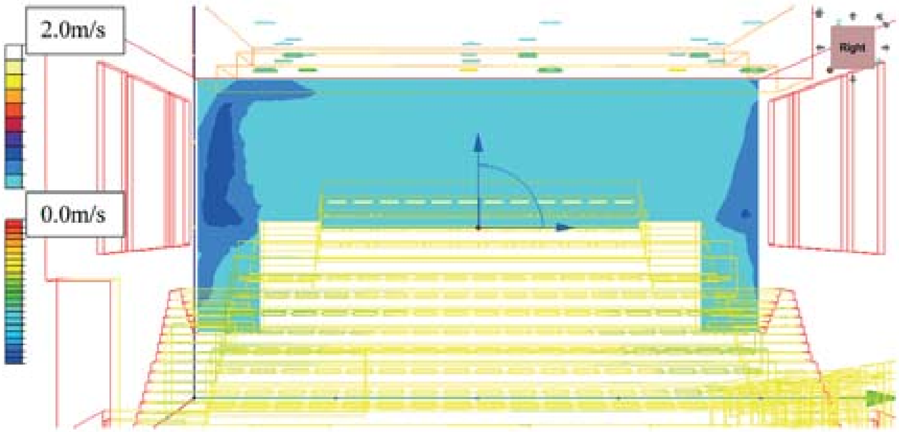

Fig. 8. Air velocity distribution in the last row of the seats

Air temperature and velocities at the rest part of the assembly hall are at the suitable levels. Main factor which would enable to obtain suitable temperature and air velocity in the whole people's zone would be to set different blades angle of the intake ventilators or application of a different type of ventilators.

Conclusions

Simulation of functioning of the air-conditioning installation in the assembly hall of the Faculty of Environmental Engineering, Lublin University of Technology designed in the traditional way, according to all assumed rules revealed the possibilities of occurrence of situations, when the designed system does not fulfills its assumptions. Disturbances of the described system performance were not possible to be predicted at the stage of designing. Air velocity distribution determining the maintenance of thermal comfort depends on many factors which were not considered at the designing stage, but were possible to be considered in presented simulations. The most important factors are: temperature of external envelopes and the detailed geometry of the room itself. Their consideration was only possible by creation of the spatial model of the room and thus installation. Due to the benefits provided by modeling, computer simulation will become obligatory stage of the whole building designing process and installations.

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