Analysis of Forced Ventilation and Conditioning in Summer Conditions

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Abstract **– The research subject of the current work is ventilation and cooling simulations of the laboratory in summer conditions using CFD software. The simulations were made in ANSYS Fluent 14.0. For the validation of the simulation results a series of the measurements were made using computer regulation technique and SIEMENS software. According to the result, conclusions were made about the necessity of the ventilation and cooling simulations and their effect on the thermal comfort of the humans in the closed areas. In the simulation were taken into account not only the primary thermal gains – sun, air temperature but also the secondary thermal gains from the computers, monitors and humans.**

Keywords **– ANSYS Fluent, cooling technique, ventilation, thermal comfort**

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1. Introduction

Air ventilation plays great role not only for the human health but also for comfort as well. Ventilation significantly determines the comfort of housing [1]. Ventilation of housing according to [2][3] is the foundation that determines health, comfort and energy saving. In order to develop modern ventilation systems at home it is necessary, first of all, to understand what it should be in its ideal embodiment [4]. The creation of such ventilation is not an easy task, because its solution is closely intertwined with thermal and vapor insulation of walls, ecology and other [5][6]. At the same time, everything is complicated by a number of contradictions, which are difficult to solve under the traditional approach [2][7].

Ventilation plays great role not only for the heat balance calculation of the building but also for human health [8][9]. Ventilation in winter or summer conditions could significantly affect the temperature comfort not only for the single room but for the whole building [10].

The main purpose of regulating the temperature in the apartment is to create a comfort zone for the people which are living in it [11][12]. However, do not forget that human preferences do not always correspond to the correct temperature regime [13][14]. Overheating of the room, as well as its excessive hypothermia, could adversely affect human health.

Determination of the optimum operating temperature of a domestic or office air conditioning system is influenced by:

- place (apartment, house, office);
- season of operation (in summer - cooling, in winter - heating).

Basically, the optimum temperature for cooling the air conditioner is 22-25°C [15]. The global comfort range is from 19°C to 27°C. This is provided that the difference between the conditioned and outdoor environment is not more than 7°C. Otherwise, according to the [16] [17] when changing rooms, the additional burden on the human body (immune and cardiovascular system) will increase dramatically.

2. Materials and Methods

Room under the study was a laboratory of the renewable energy sources of the Technical University in Kosice. The technical drawing of the laboratory is in picture 1.

In the laboratory was listed the following equipment which can influence the direction and intensity of the air circulation as well as the heat balance of the room what affects what affects the human comfort:

- 2 thermal storage tanks with hot water (800 l and 950 l)
- 1 thermal storage tank with cold water (800 l)
- 6 computer stations with approximate thermal power 0,6 kW (with monitors)
- 2 schematic human bodies with the surface temperature 36°C
- 6 tables

In the upper part of the laboratory are installed ventilation canals for the forced ventilation. Fresh cold air with the temperature 18 °C goes through the floor convectors. Convectors are situated under the windows as it is illustrated in figure 2.

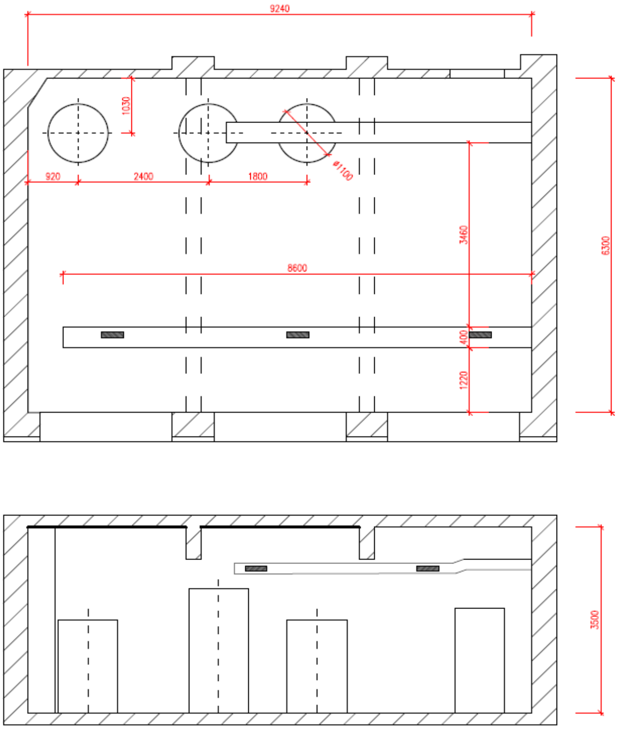

Figure 1.Laboratory under the study

Figure 2.Convectors location

According to the literature the temperature in the laboratory must be around 20-25°C to satisfy the conditions of the comfort being. The outdoor temperature was 35°C what is appropriate for the summer conditions in the eastern Slovakia climate.

Thermal characteristics of the windows, walls, floor and ceiling were chosen according to their technical documentation.

- Thickness of the internal walls is 200 mm and the temperature is 22°C.
- External wall has 500 mm thickness and temperature in the middle of the wall is 27°C.
- Thickness of the windows is 100 mm and the external surface temperature is 30°C.
- Celling and floor have 300 mm thickness and the temperature is 24°C and 22°C respectively.

The laboratory has south orientation so it has significant thermal gains from the sun. Also some heat is achieved through the thermal storage tanks. The tanks are isolated by special fibrous material of 10 cm thickness. The surface temperature during the day of the first tank (in the corner) is around 24.5 °C, the second – 23.5°C, the third — 21°C. The temperature of the water inside the tanks is approximately 37.5°C for the first tank, 32°C — the second, 8°C — the third.

3D model was made in ANSYS design modeller to provide stable calculation and to eliminate inaccuracy in the geometry. ANSYS mesh solver was chosen for the mesh making purpose to eliminate mistakes and to decrease the total simulation time. Other mesh settings were: proximity and curvature advanced si-ze function with fine relevance center, active assembly initial size seed, high smoothing and slow transition. According to the settings, the model had 2,958,471 elements.

3. Simulation

Simulation of the cooling was made in ANSYS Fluent 14.0. As a setting for FLUENT was used the energy equation model, standard K-epsilon model and radiation p1 model [14] [18]. To simplify the simulation model and decreased the calculation time, the convectors were replaced by the velocity inlet according to the technical documentation and the real measurements [19] [20]. The results of the measurements are in table 1. The convectors have only 4 possible work modes, the first is 0% power, the second - 33% power, the third - 66% power, and the fourth - 100% power.

Table 1. Work characteristics of the convectors

Power	Air velocity, m/s	Air temperature, °C
33%	6,5	15
66%	7,0	15,4
100%	7,5	16

Inlet type of the convectors was chosen as velocity-inlet with velocity magnitude and temperature according to table 1. For outlet was chosen the pressure outlet type. All the parameters were chosen according to the technical documentation of the cooling technic and the norm of the thermal comfort. The results of the simulation are in the picture. At the picture are results of the simulation as streamlines of the air from the convectors and temperature contours of the laboratory (figure 3 and figure 4).

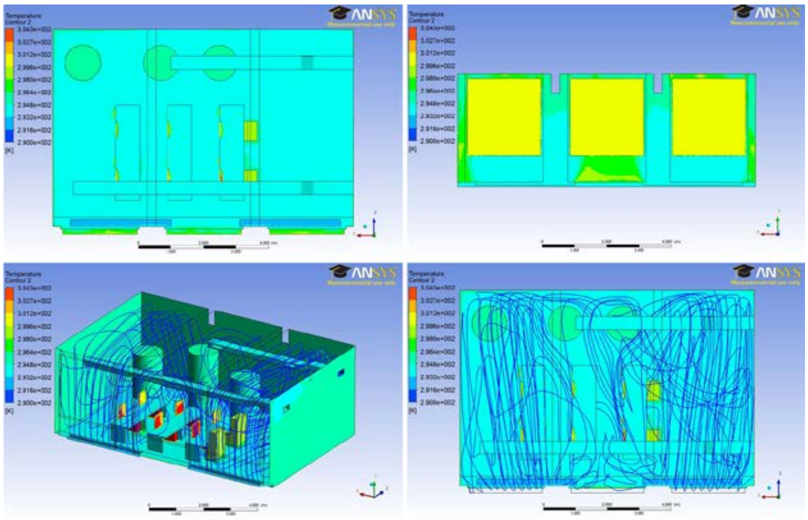

Figure 3.Results of the simulation, temperature contours

According to the simulation results, the temperature inside the laboratory is 21.5 – 23.1 °C depending on the air layer high. Nevertheless, the temperature difference between the floor and 2 m high air layer is 1.2°C what is appropriate according to the EN 12831.

The main heat sources of the room are the external walls and the windows as they have south orientation. Despite this fact and due to the convectors' location, the external wall has the lowest internal surface temperature 19.5 – 20.3°C comparing with other surfaces. The temperature of the side walls is 21.9 – 23.4°C, and the wall behind the water tanks is 22.3 - 23.6°C. Higher temperature of the last wall is caused by the higher temperature 25°C inside the common room (corridor) due to its small surface and big thermal gains in summer period.

The temperature of the celling surface is 23 - 24°C and the lowest temperatures are in the areas close to outlet as the average outlet temperature is 20°C.

The temperature of the floor is 20 – 22°C with the lowest temperatures in the areas close to the convectors. In figure 4 are shown the air velocity streamlines.

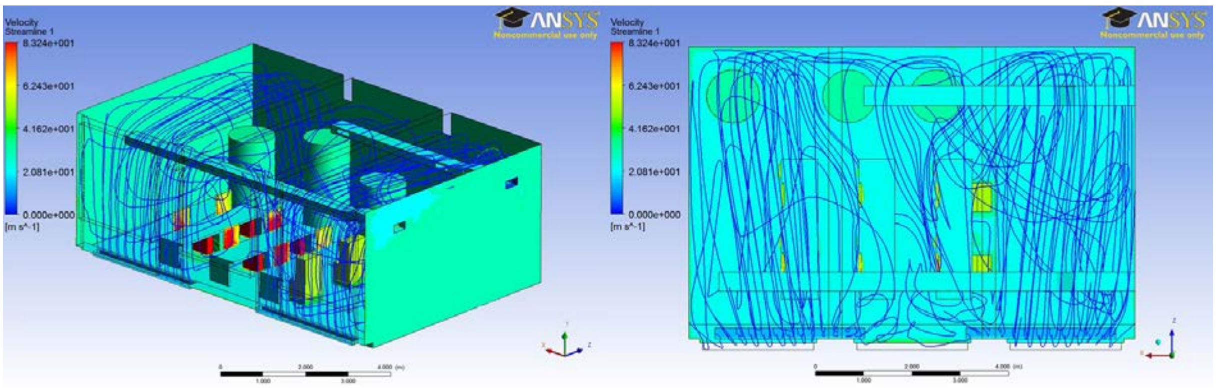

Figure 4.Results of the simulation, air velocity

According to figure 4, the laboratory can be divided by three main parts of the air flow type to understand air circulation.

The first part represents area with one convector which is located in front of the water tanks. Owing to the high inlet velocity (table 1) of the cold air it goes up to the celling where after mixing with the hot air it falls down to the tanks. Then the volumes of the coldest air flow between the barriers as are tables and computers and are cooling them. Air mases in the middle part of the room play a great role in heat and mass transfer between the different parts of the laboratory.

The second part represents area with the other convector which is located close to the humans. This part has approximately the same scheme of air circulation except the area near the wall which is opposite to the convector. In this area, the air masses have the worse mixing as they do not have any barriers.

The third part represents the area between the two convectors. In this area, the cold air masses from the previous two parts have lower intense of mixing with hot air due to a lot of different barriers and smaller air velocity.

4. Measurements and discussion

The series of measurements were made to approve the results of the simulation. The regulating and measuring equipment were fully controlled by the DESIGO program. This program was developed by Siemens to control the thermal comfort and record the data as well as to control the heating equipment of the whole building. View of the DESIGO program is in figure 5.

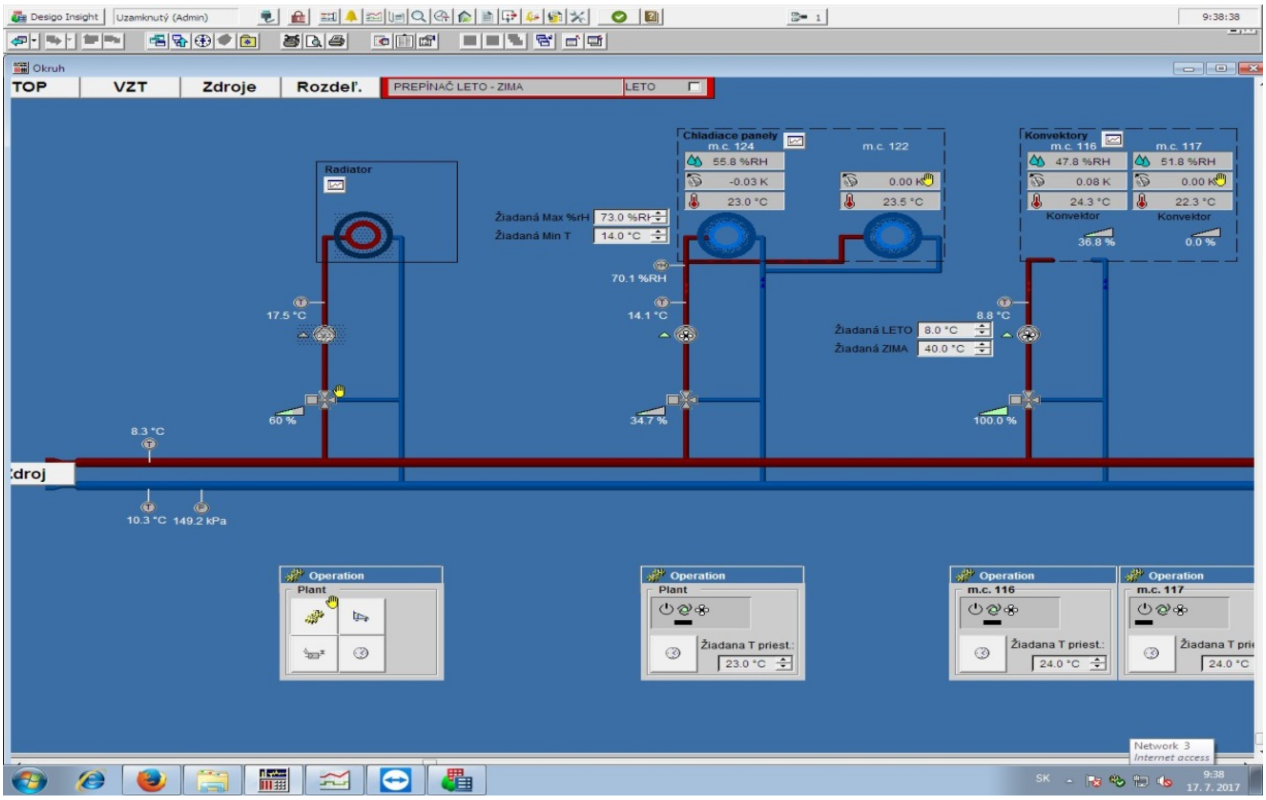

Figure 5. DESIGO program

Owing to DESIGO, were recorded and managed the temperatures inside and outside the laboratory as well as inside the room (Figure 6 and 7).

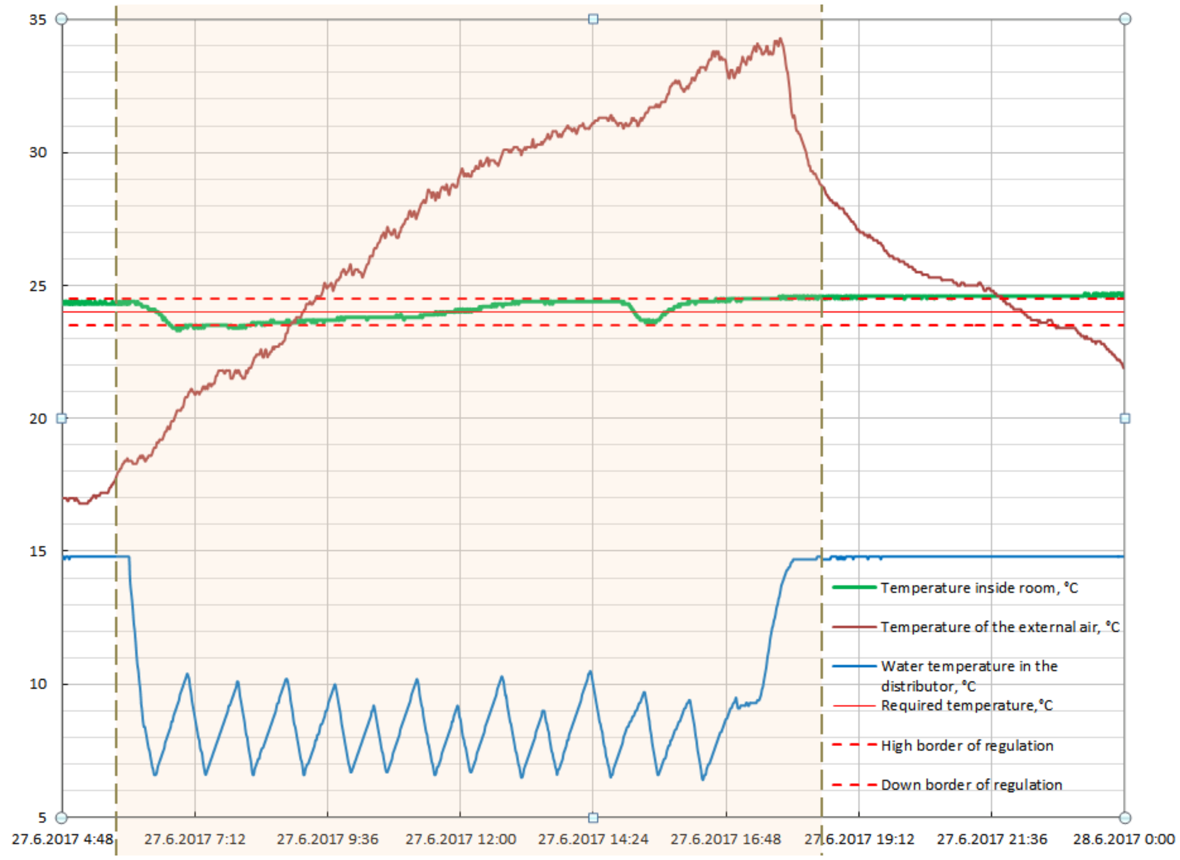

Figure 6. Recorded data from DESIGO on27.06.2017

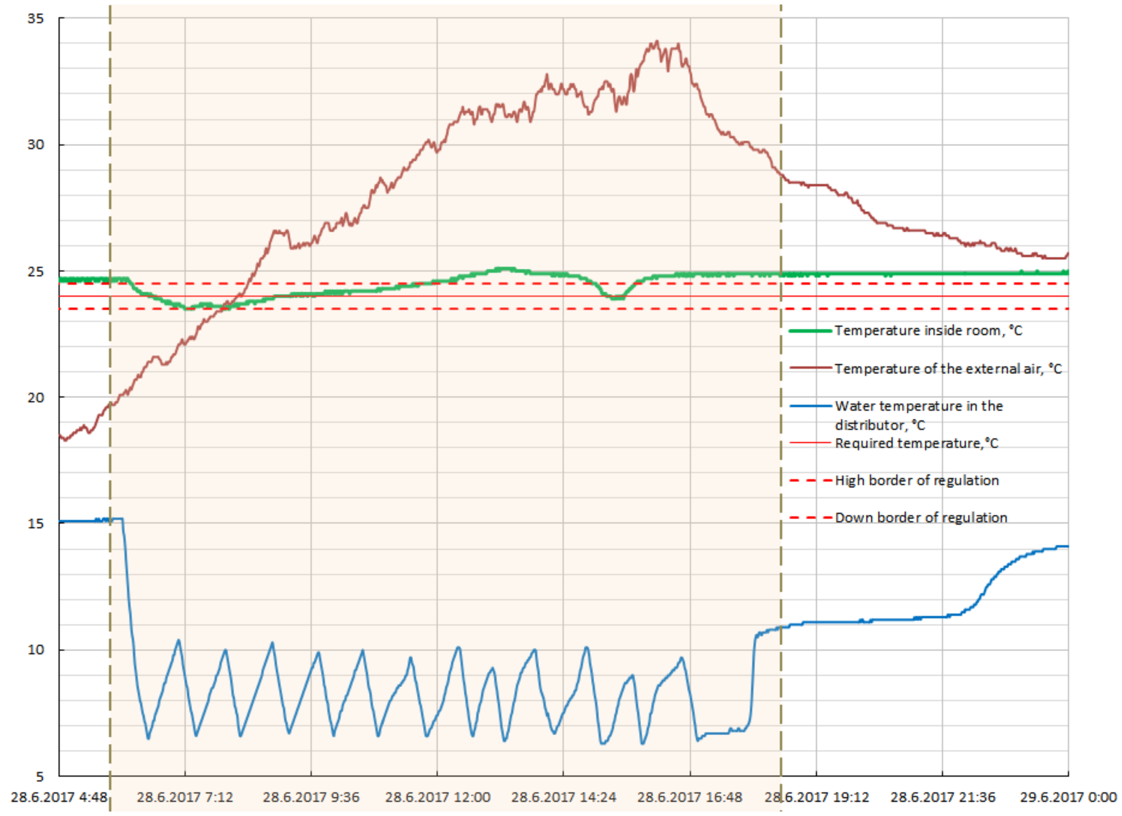

Figure 7. Recorded data from DESIGO on 28.06.2017

To validate the results of the simulation were chosen 2 days – 27th and 28th of June 2017 as the exterior air temperature in working hours was approximately the same 22.3 – 35.2°C (average 29.2°C) and 21.7 – 34.5°C (average 28.9°C) respectively.

Internal thermometer is placed on the wall at 1.6 m between the windows. According to the measured data, the average temperature inside the laboratory is 24 – 24.8°C during the day. The results of the simulation and measured data should be compared in the period when the exterior temperature was 30 ±1°C. Such conditions were from 12:00 till 14:20 at 27.06.2017 and from 11:35 till 13:50 at 28.06.2017. At these periods, the average internal temperatures were 24.5°C on 27.06.2017 and 24.8°C on 28.06.2017. The difference between the simulation and the measurements is approximately 1.2 – 1.8°C.

5. Conclusions

The main idea of the current work was to make simulation and analysis of the room which is cooled by floor convectors in the summer period using the CFD software such as ANSYS Fluent. Owing to the CFD simulation an analysis of flow of the air masses was made in closed area as well as an analysis of the thermal comfort in the laboratory with the respect to the European Norms [16-20]. The conclusions of the study are as follows:

1. It is necessary to make the simulation of the air ventilation systems of the building not only to understand its efficiency but to know how it affects the thermal comfort of humans.
2. It is sufficient to use general CFD software for the simulation and analysis purpose of the ventilation and conditioning systems. The difference between the CFD simulation and the real thermal comfort according to this work is approximately 1.2 – 1.8°C. Such difference can be explained by the uncertainties around the walls, celling and floor composition what lead to the differences between the real and the calculated heat flow. So this simulation mistake can be eliminated if the exact composition of the building elements is known.

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