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THERMAL COMFORT IN OFFICE BUILDINGS

Abstract: *In this paper is studied the thermal comfort in an office room. The first part of the paper presents the state of the art of numerical methods and graphical determination of the thermal comfort in buildings. Using the advanced modelling techniques, in the second part of the paper, the office volume with the ventilation and evacuation systems are modelled. The simulation is achieved using the CFD module from the SolidWorks software, where is assigned the mechanical properties to all components. In this paper are studied three simulation cases. The obtained results from the first case are compared with the results from the second and third case. In the last part of the paper are presented the conclusions of this study.*

Key words: *HVAC, PMV, PDD, CFD simulation.*

1. INTRODUCTION

Due to the evolution and continuous development of the technology a new standard was established, which require building construction with an acceptable thermal comfort for the internal persons [2]. Lately, the CAD design method has become an indispensable tool for engineers, allowing engineering applications to be solved with greater precision and ease than classic methods [3]. For the simulation of the thermal effect in rooms have been developed different software which are using the iterations methods of calculation, with the purpose to quickly finding and precisions optimal construction solution for thermal comfort in the room's geometry.

The optimal thermal comfort it is given by the air temperature from inside and the optimal surface temperature. In this paper, the CAD and CFD of the desk and of the other components are shaped and simulated in SolidWorks software [9].

An air flow visualization study in an office room is simulated to visualize the air circulation in an office room [8]. The office room and the furniture are modelled in SolidWorks. A thermal simulation of the office space is simulated in Theseus-FE. This software is a thermal simulation package that offers models for heat conduction, surface to surface, radiation, etc [7].

Presented study it is realised after an existed model of desk with the purpose of determination and improving the thermal comfort in work period.

Designers and the building engineers must design and control the construction operation, improving the room geometry and the interior design of the furniture component in order to determine the optimal design of the rooms. Thermal perception and the thermal feeling of the comfort depends by the heat of the human body and the heat generated by the furniture objects.

The thermal balance of the human body is given by the next relationship:

$$S = M + W \pm R \pm C \pm K - E \pm Res \quad (1)$$

where:
M – human metabolic rate;
W – mechanical work;
R – radiation;
C – convection;
K – conduction;
E – latent heat of evaporation from skin;
Res – heat loss occurs through respiration.

PMV (Predicted Mean Vote) represent the mean response that can be estimated between the metabolic rate and the thermal load. The thermal load result from the difference between the internal heat of the body and the heat losses in the environments [5].

Relation 2 presents the expression of the PMV:

$$PMV = [0.303 exp(-0.036 M + 0.028)] \cdot L \quad (2)$$

where:
M – human metabolic rate;
L – net thermal load.

Another similarly index is Predicted Percentage Dissatisfied Index (PDD), given relation 3:

$$PDD = 100 - 95 exp \left(-0.03353 \cdot PMV^4 - 0.2179 \right) \cdot PMV^2) \quad (3)$$

The ASHARE and ISO 7730:2005 standards establish the comfort levels; it can be seen in relation 4:

$$-0.5 < PMV < +0.5 < 10\% \quad (4)$$

The comfort level is established according to the values presented below [1]:

- Hot: 3;
- Warm: 2;
- Slightly warm: 1;
- Comfort /Neutral: 0;
- Slightly cool: - 1;
- Cool: -2;
- Cold: -3.

2. CFD SIMULATION

Nowadays, the CAD software has an integrated FEA computing module, enabling to solve the whole process

of the designing, simulation and optimizing process by single engineer [6]. In this research, the CFD simulation of the thermal comfort and the streamline distribution of the air from the office room are realised. To accomplish the CFD process simulation it must be followed the steps outlined in Fig. 1.

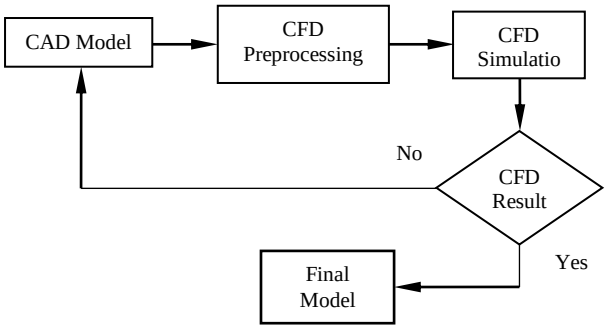

Fig. 1 Flowchart of the iterative CFD simulation process applied.

The start point of the CFD process applied in this paper involves the office room modelling, the furniture components, office desk, computer case, display, radiators, air conditioners system, chairs, light source and the human models, presented in Fig. 2. The dimensions of the office components are shown in the following table:

Table 1

Overall dimensions of the model.

Model	Length x Width x Height (mm)
Office room	6200x5200x3200
Doors	2200x800x100
Windows	1800x1700x100
Display	400x370x500
Computer case	500x500x200
Light source	1200x250x150
Air conditioning	800x280x220
Office desk	1500x750x700
Small closet	540x500x480
Books case	2800x220x600

In the second part, the preparation of the CFD model, the material properties and work characteristics for each office components are attributed. In the third step of the CFD process, the model is computed.

The obtained results are viewed and interpreted in the fourth step of the process. If the obtained results do not satisfy the requirements, the CAD model is improved and the CFD process entering in a loop until the results satisfy the requirements.

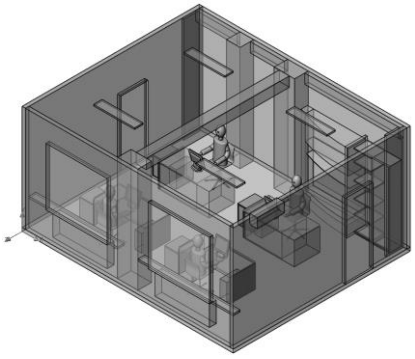

Fig. 2 CAD model of the office room.

The CFD volume of the air is presented below, in Fig. 3. The temperature of the air volume is 18°C.

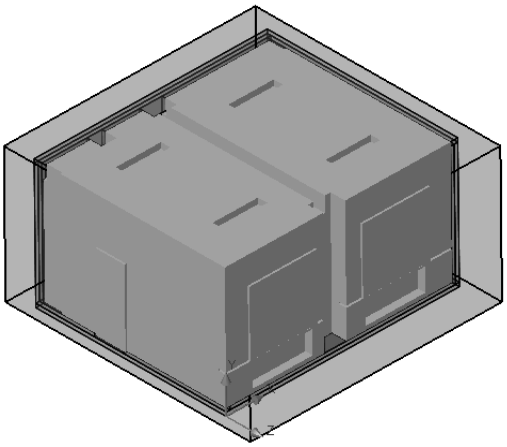

Fig. 3 CFD volume of the office room.

In this research, three case are studied: in first case, the air-cooling system is opened, in the second case the heating radiators are opened and the cooling system is closed and the last case when it is opened the cooling system and the heating radiators.

2. 1. First simulation case

In this case the boundary condition where set for CFD analysis as are presented in table 2 [4]. The value of the inlet volume flow of the cooling system is chosen according to recommendations; the air ventilation from the office room is recommended to be 5-7 m^3/h.

Table 2

Items parameters of the simulation - first case.

Model	Parameters value for one model
Display	Heat generation rate = 30 W/m^3
Computer case	Heat generation rate= 100 W/m^3
Light source	Heat generation rate = 80 W/m^3
Human body	Heat generation rate = 144 W/m^3
Cooling system	Inlet volume flow =0.25 m^3/s Air temperature = 26 °C
Office room wall	Temperature =16 °C
Office room air	Temperature =18 °C

The simulations parameters are chosen to simulate the winter climatic conditions. In this case the cooling system working as a heating system.

2. 2. Simulation results – first case

In Fig. 4, the PMV index is represented to evaluate the thermal comfort from the office room.

The value of the PMV is between -1.75 and -0.86 in the volume area of the human body. The minimum value of the PMV is situated in the evacuation area of the cooling system.

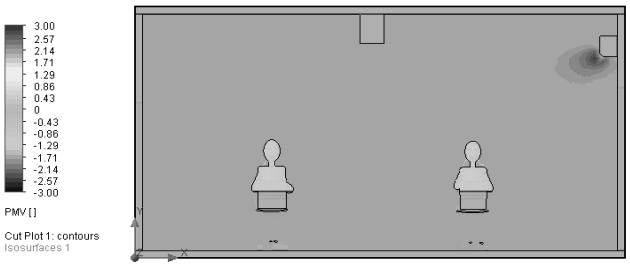

Fig. 4 PMV index in the office room.

It can be seen that the thermal comfort of the persons from the office desk is lower.

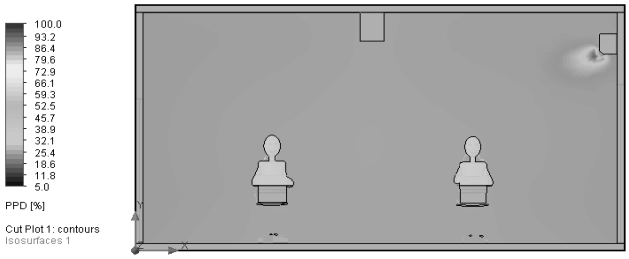

Fig. 5 PPD index of the thermal comfort.

In Fig. 5 is represented the air distribution with the PPD index procent.

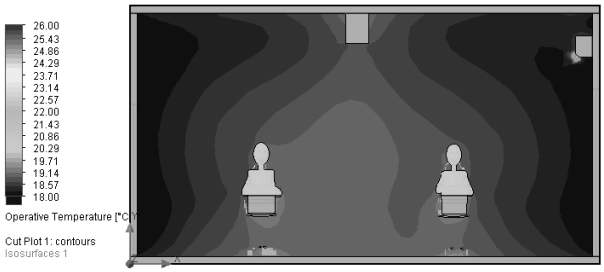

Fig. 6 Operative temperature on the office room.

In Fig. 6 is presented the operative temperature on the office room. It can be seen that the temperature is between 18-21 °C. In the area of the persons the temperature is 20 °C, that is the optimal temperature for working.

2. 3. Second simulation case

In this simulation case, the parameters of simulation are chosen as a winter condition. The values of the parameters are presented in table 3.

Table 3

Items parameters of the simulation - second case.

Model	Parameters value for one model
Display	Heat generation rate= 30 W
Computer case	Heat generation rate= 100 W
Light source	Heat generation rate= 80 W
Human body	Heat generation rate= 144 W
Heat Radiator	Temperature = 70 °C
Office room wall	Temperature =16 °C
Office room air	Temperature =18 °C

In this case, the air-cooling system is off. For heating the room air volume were placed on the wall two radiators set to temperature of 70 °C.

2. 4. Simulation results – second case

In Fig. 7 is presented the PMV index value. In can see the range between -1.29 and 0.43. The thermal comfort of the office is better to work, is acceptable thermal comfort.

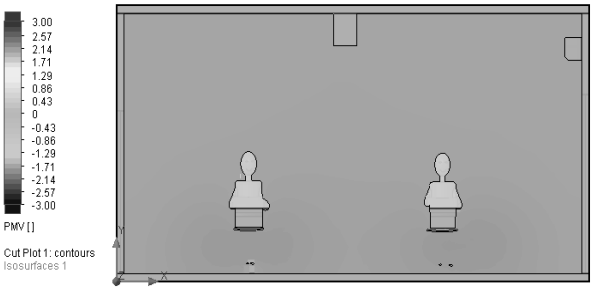

Fig. 7 PMV value of the second case.

The PPD index id it is presented in Fig. 8.

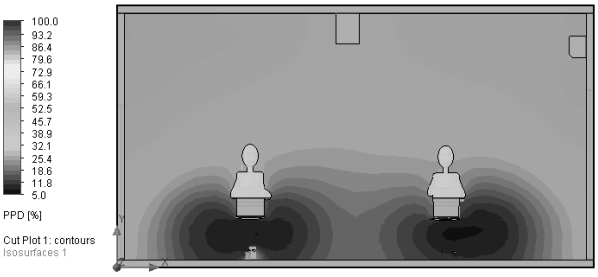

Fig. 8 PPD index of the thermal comfort.

The operative temperature of the room space it is presented in Fig. 9.

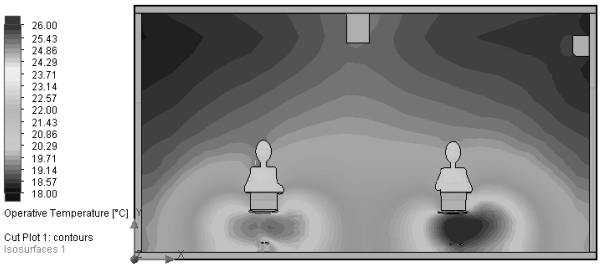

Fig. 9 Distribution of the temperature.

2. 5. Third simulation case

In this simulation case, the air cooling and heating radiator it is on. The value of the item parameters is the same as for the first and the second case.

The result of the third simulation case is presented below. In Fig. 10 is presented the PMV thermal comfort.

The comfort for the persons is better, the value of PMV is between -12.9 and 0.43. The best comfortable space is situated around the persons.

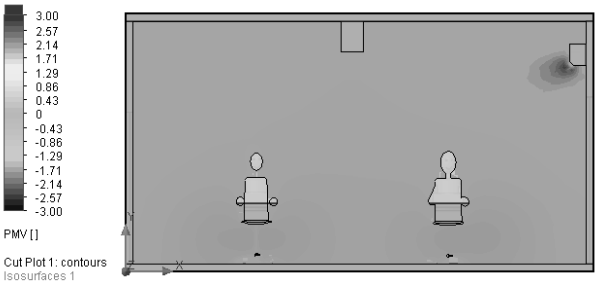

Fig. 10 PMV value of the third case.

The PPD index is presented in Fig. 11, in which can be view the distribution of the thermal comfort.

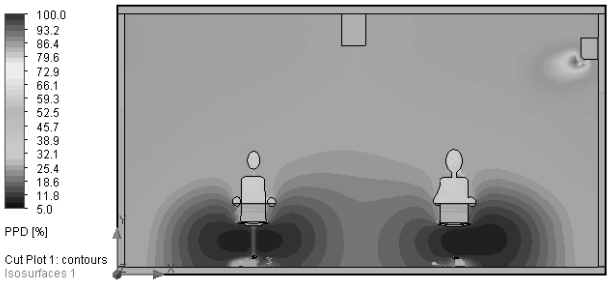

Fig. 11 PPD index of the thermal comfort.

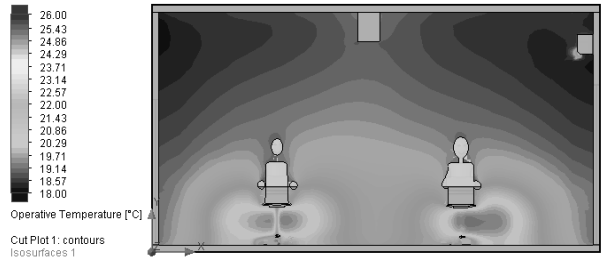

Fig. 12 Distribution of the temperature.

The temperature of the environment presented in Fig. 12 is a little bit higher than the comfortable working conditions.

The CAD models and CFD simulations from this study where made on a graphical workstation HP Z400, Intel Xeon processor, 16 GB RAM and Nvidia Quadro Graphical card.

3. CONCLUSIONS

In this paper, three CFD simulations were made to determine the comfort in an office room. After interpreting the results, it can be seen that the best thermal comfort it is presented in the third simulation, where the value of the PMV index represent the best thermal comfort from these three cases. This type of the CFD studies is recommended to be made before the construction of the office building in order to optimise the volume space to a higher thermal comfort.

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