CFD modeling of air exchange in a room using a textile air duct with microperforations

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Abstract. The article is devoted to the issue of increasing the energy efficiency of ventilation systems and improving the air quality in the working environment of the premises of communication personnel for the maintenance of transport infrastructure when using a new types of air distribution devices. These include textile air ducts made of polyester. This material allows you to cut micro-holes. The advantage of diffusers with microperforation is the possibility of even distribution of air throughout the premises without creating drafts in the working area. The results of the analysis of literary sources on the issue of improving air quality in public buildings are presented. The data on the results of a comparative CFD modeling of the air distribution in the room with two supply air supply schemes: through the supply openings and with the help of a textile air duct with microperforation are presented. In the course of numerical calculation, the distribution fields of temperature and air velocity in the working area of the room were obtained. It is concluded that the textile air duct copes with the task of removing excess heat more efficiently than the traditional ventilation system.

1 Introduction

The issue of improving the efficiency and cost-effectiveness of ventilation and air conditioning systems in buildings for various purposes is given great attention all over the world. Modern theoretical and experimental studies [1-5] are aimed at finding ways to improve existing ventilation systems, research new types of air distribution devices: microperforated textile air ducts [6-8]. Air ducts of this type provide supply air with quick-extinguishing micro-jets, creating normalized and comfortable parameters of the microclimate in the working area of the room without drafts.

The supply air supply system using microperforated textile air ducts has a number of advantages compared to a galvanized steel air duct: low air speed, light weight, easy installation and disassembly, corrosion resistance, easy transportation, reduced noise during operation, the ability to wash and disinfect, etc.

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In the modern reference literature, there is no method for calculating the air distribution using microperforated air ducts made of polymer materials. This issue is relevant and currently there are attempts to find a relevant solution.

In order to study the characteristics of air flow in Denmark, Nielsen and co-authors [2] conducted a comparative experimental study in a chamber where the air supply was carried out using three types of air distributors: textile air duct, ceiling and wall diffusers.

The results of the experiment showed that under the same conditions, the flow of air flowing from the textile air duct provides more comfortable environmental parameters (low air velocity in the working area, a small temperature gradient in height) compared to other types of air ducts.

To analyze the impact of pollutants on people in a room ventilated with a textile duct, Nielsen et al. [3] conducted a full-scale experiment using mannequins that reproduce human breathing.

It was concluded that individual ventilation based on a textile air duct helps to improve the air quality in the area where humans breathe.

Similar conclusions were made by Pinkalla [4], who noted that the use of textile air ducts in practice reduces the amount of pollution in the indoor air environment.

As a result of the analysis of the considered works, it can be concluded that there are attempts to experimentally and theoretically study air distribution using textile air ducts, but the issue of air supply using microperforated textile air ducts by means of micro-jets remains unexplored.

Thus, the purpose of the work is determined: a comparative numerical calculation of the main parameters of the air environment of an office space when air is supplied using supply holes and using a microperforated textile diffuser.

The effectiveness of solving problems in the field of ventilation and air conditioning is directly related to the use of numerical modeling.

CFD (computational fluid dynamics) is successfully used for predicting air movement, temperature and heat flow distribution, concentration of pollutants in the room environment, and determining the pressure and intensity of turbulence.

Numerical modeling of hydro-gas dynamics problems in the environment of specialized software systems is considered in detail by the authors [5, 9-16].

In order to compare the efficiency of the organization of air exchange in the office space under consideration, two variants of numerical calculation were performed:

1. modeling of forced convection in a closed volume of the office space under consideration with heat sources when air is supplied through the supply openings and removed through the exhaust openings.

The air is cooled using a split system.

2. Modeling of forced convection in a closed volume of the office space under consideration with heat sources when air is supplied through a microperforated textile air duct and removed through exhaust vents. The air is cooled using a split system.

2 Materials and methods

A comparative calculation of the air distribution in a room (Figure 1) when supply air enters through ventilation grilles and through a microperforated textile air duct was performed using the *STAR-CCM+* software package.

The original solid-state 3-D model of the office space (Figure 2) was created using the CAD (Computer-Aided Design) graphic software package CATIA.

Fig. 1. Office space.

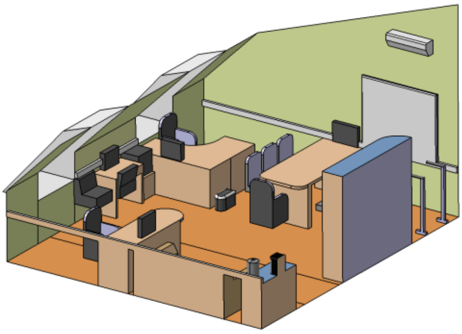

Fig. 2. Geometric model.

When modeling the problem of heat and mass transfer in an office space, the following assumptions were made:

- the problem is solved in a stationary three-dimensional formulation;
- the turbulent non-isothermal movement of air in the volume of the room under consideration is considered;
- heat and mass transfer in an office space occurs as a result of forced convection, taking into account the influence of Archimedean forces.
- a gas is a "Newtonian", incompressible, viscous medium;
- the SST turbulence model was used to simulate the turbulent regime in a room [16].

In the first version of the calculation, fresh air is supplied to the upper area of the room using two supply holes (300x400 mm) and removed by means of two exhaust holes (Figure 4).

The area of the live cross-section of the holes is $f=0.084$ m^2.The ventilation system capacity is $L=300$ m^3/h.

The supply air velocity is $v=0.49$ m/s.

In the second version of the calculation, the supply air is supplied by a microperforated textile air duct (Figure 5), and the removal is carried out using two exhaust vents.

Characteristics of microperforated textile air duct: $d=0.25$ m, length $l=5.7$ m, level of location relative to the floor surface – $h=2.2$ m (Figure 5).

The average air flow rate from the duct surface is $v=0.025$ m/s. The length of the perforated section is 4.5 m.

The volume flow rate is L=324 m3/h.

Air cooling for the two calculation options is performed using a split system (t=15°C, v=2 m/s).

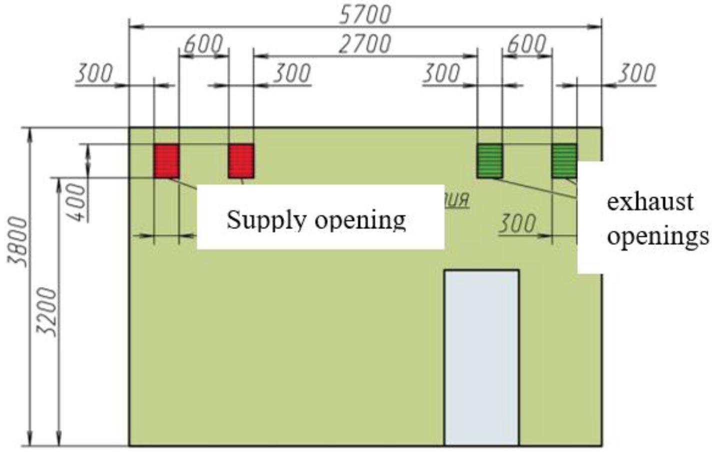

Fig. 3. The scheme of location of supply and exhaust openings.

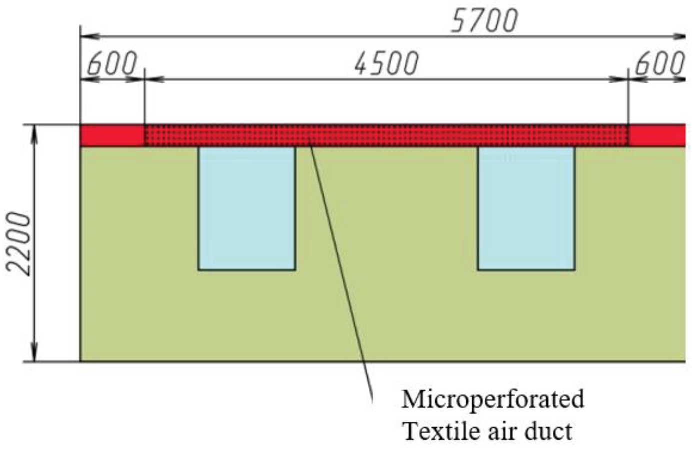

Fig. 4. Layout of Microperforated textile air duct.

3 Discussion of results

The results of calculating the temperature distribution over the height of the working area of the office space (from 0.1 to 1.5 m) are shown in figures 6-7; changes in air velocity (v, m/s) are shown in figures 8-9.

The calculated cross-section passes through the workplace of a person.

The temperature jump in the range from 0.4 to 1 m (figure 7) is associated with heat access from humans and office equipment.

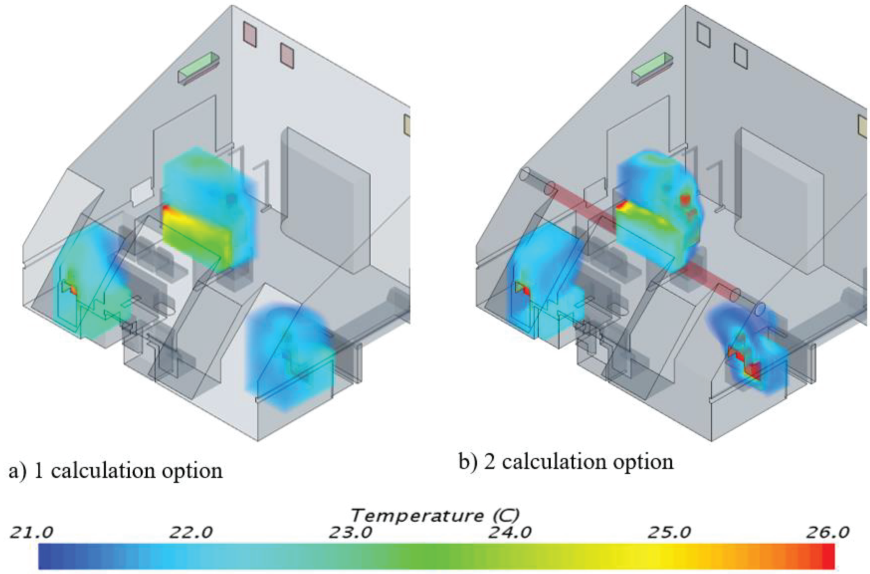

Fig. 5. Temperature fields in the working area based on the results of two calculation options.

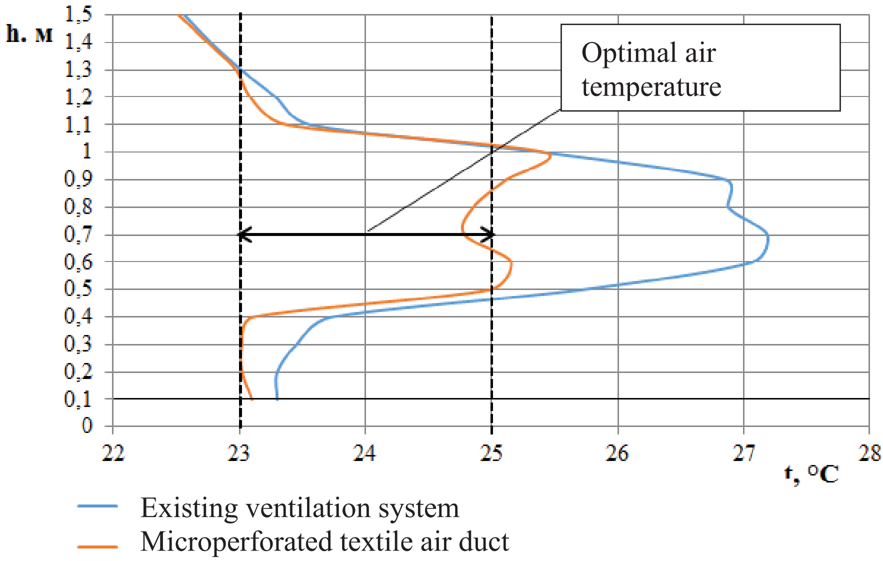

Fig. 6. Temperature change in the height of the serviced area of the office space based on the results of two calculation options.

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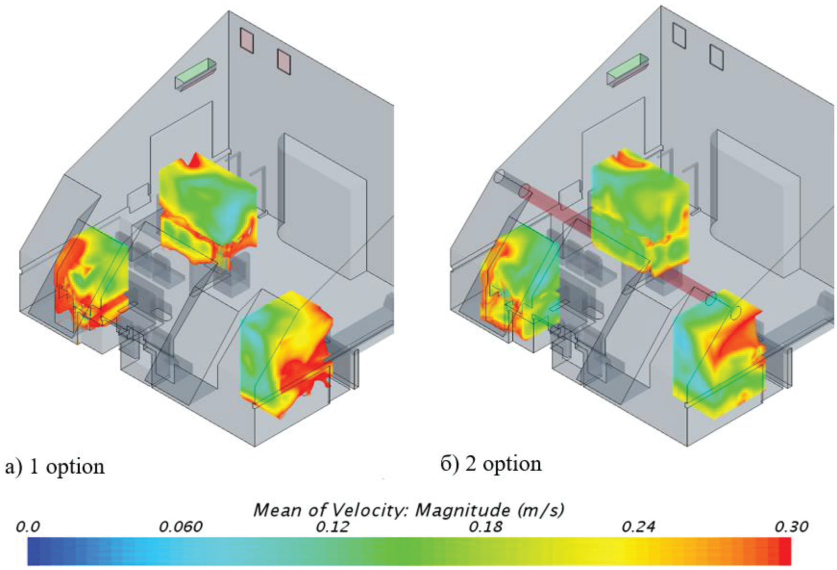

Fig. 7. Fields of the speed module in the working area based on the results of two calculation options.

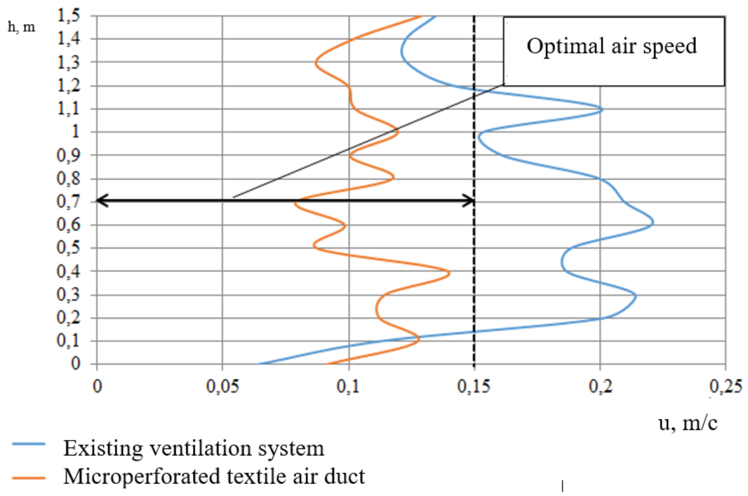

Fig. 8. Change in air velocity over the height of the office space.

4 Conclusions

As a result of the analysis of literature sources, it is established that there are experimental and theoretical studies of air distribution using textile air ducts, but the question remains unexplored regarding the supply of supply air using a microperforated textile air duct by means of micro-jets.

A comparative numerical calculation of the distribution of supply air in an office space when the supply air enters through the supply ventilation grilles and through a Microperforated textile air duct is performed.

The analysis of obtained numerical results it is concluded that microperforations textile duct effective job of removing excess heat and the formation of a high-speed mode in the present office space.

The practical use of textile air ducts with microperforation makes it possible to form the required air parameters of the working area of the room, increasing the efficiency of the ventilation system and the assimilation of heat surpluses.

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