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LAMINAR FIELD OPTIMIZATION IN CONNECTION WITH THE CURRENT PANDEMIC SITUATION CAUSED BY COVID-19

OPTYMALIZACJA Z WYKORZYSTANIEM POLA LAMINARNEGO W ODNIESIENIU DO OBECNEJ SYTUACJI PANDEMICZNEJ SPOWODOWANEJ PRZEZ COVID-19

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Abstract

COVID-19 is constantly spreading around the world. Doctors, nurses and medical staff spend more time providing their professional help than usual. It is especially important to provide them with a suitable working environment. Therefore, in the following article we will deal with the design of a computational model of a laminar field in a clean room using CFD methods.

Keywords: tlaminar field, clean room, air flow, CFD model, outlet

Streszczenie

COVID-19 nieustannie rozprzestrzenia się w świecie. Lekarze, pielęgniarki i personel medyczny spędzają więcej czasu niż zwykle niosąc, profesjonalną pomoc. Jest zatem szczególnie istotne, aby zapewnić im odpowiednie środowisko pracy. Dlatego też w prezentowanym artykule zajęto się zaprojektowaniem modelu komputerowego pola laminarnego w czystym pomieszczeniu z wykorzystaniem metod CFD.

Słowa kluczowe: pole laminarne, czyste pomieszczenie, przepływ powietrza, model CFD, wywiew

1. INTRODUCTION

Just a few of us realize that the air which a person inhales indoors contains a lot of dirt, it can even be more polluted than outdoors air. Pollution is caused by being in the room and the materials that surround us in the indoor environment, such as the materials of the walls, floors or ceiling. Elevated levels of chemicals in the interior can lead to the so-called Sickbuilding Syndrome (SBS). This is manifested by worsening of central nervous system reactions, headaches, impaired concentration, asthma and respiratory problems. One has a feeling of discomfort and discomfort in such spaces. Elevated levels of CO_2 in the air have a number of adverse effects on human health. These may include headaches, dizziness, tiredness, restlessness, difficulty breathing, sweating, increased heart rate, or high blood pressure. Seeing that a person spends more than 85% of his time indoors, it is very important when choosing materials to make sure that they contain as few harmful chemicals as possible. There are such rooms where this situation is unacceptable, because due to their specifics, the final purity of the air flow is necessary. We are talking about clean rooms.

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High demands on the cleanliness and quality of the indoor environment are placed in particular in the field of healthcare, especially in operating theaters intended for demanding operations such as transplants, heart and joint operations, vascular operations, neurosurgical operations, and also in intensive care units. The arrangement of ventilation systems is an essential part of clean rooms and air conditioning to ensure a suitable microclimate. Ventilating very clean rooms is one of the most challenging tasks a HVAC designer can face. In most cases, the aim of ventilation and air conditioning equipment is to ensure thermal comfort and the required air quality for the occupants. In clean rooms, requirements for indoor environment parameters such as humidity, temperature, flow rate and especially air purity are very important.

In clean rooms, 2 types of flow can occur – laminar and turbulent. We can say that laminar flow is better, but also more expensive. Its main advantage is that the air flows in parallel streams in one direction, in contrast to the turbulent one, in which the particles perform a disordered motion and it is possible to create stagnation zones from which no pollution is removed [4].

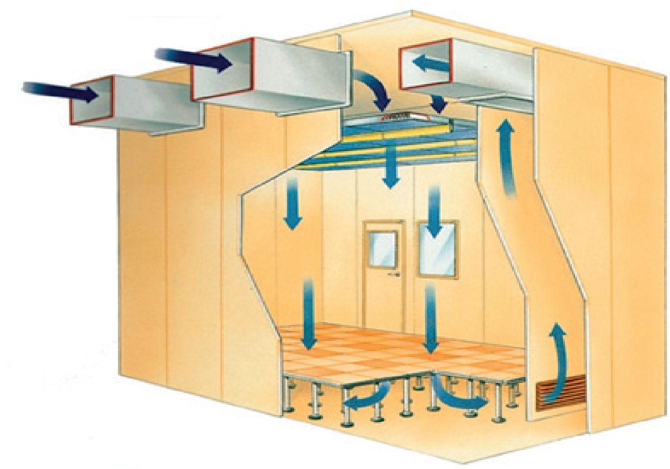

Fig. 1. Laminar flow in clean rooms with closed compact filter cartridges. Source: www.elfa-filtr.cz

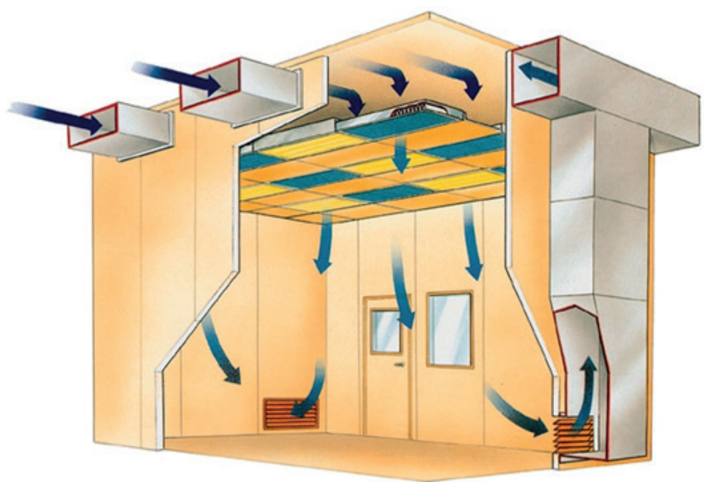

Fig. 2. Turbulent flow in clean rooms with closed compact filter cartridges. Source: www.elfa-filtr.cz

2. MEASUREMENT METHODS

Our goal was to design and model a CFD laminar array suitable for a clean room, to evaluate the benefits and possibilities of this array and, above all, to find out how the variable air supply via the laminar array affects air quality in a clean room.

Laminar field is a technically advanced solution consisting in the installation of ceiling fans with a large surface area. This device provides the whole room with high cleanliness and suitable physical parameters with a low degree of turbulence and elimination of pollutants emitted in the room [1].

Thanks to its construction, the laminar field creates a constant flow of air at a low velocity under the entire supply surface. With this solution, it is not necessary to extract air through the floor, but the diffusers in the side walls will suffice [2].

The simulation software Ansys Fluent was chosen as a program for creating a CFD model of a laminar field in a clean room, the main advantage of which is accurate calculations and graphical outputs in the form of images. Using this CFD model, an analysis of the air flow in the designed clean room was subsequently performed. The results were determined for the area above the operating table.

In the calculation, we considered that the supply air has the same temperature as the air located in the operating room. Our calculation includes a comparison of the velocities of individual air flows for the case where the air extraction is ensured evenly by all 12 outlets.

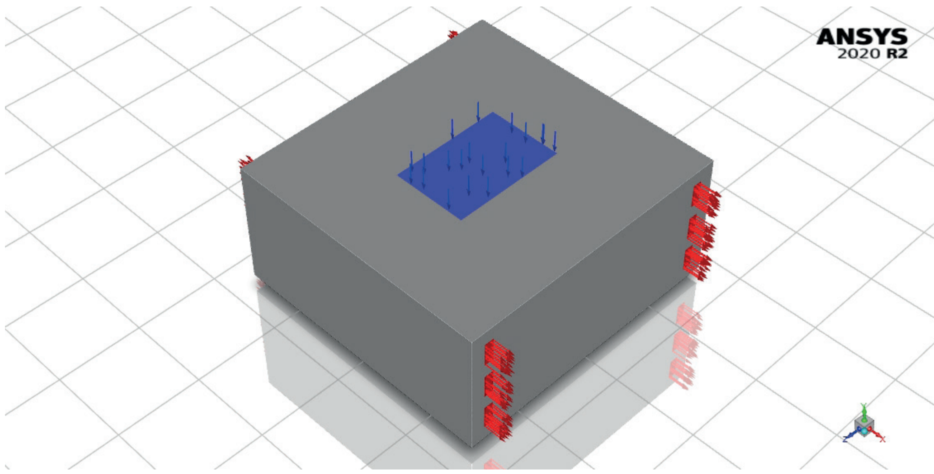

Fig. 3. CFD model of laminar field in the designed clean space (own source)

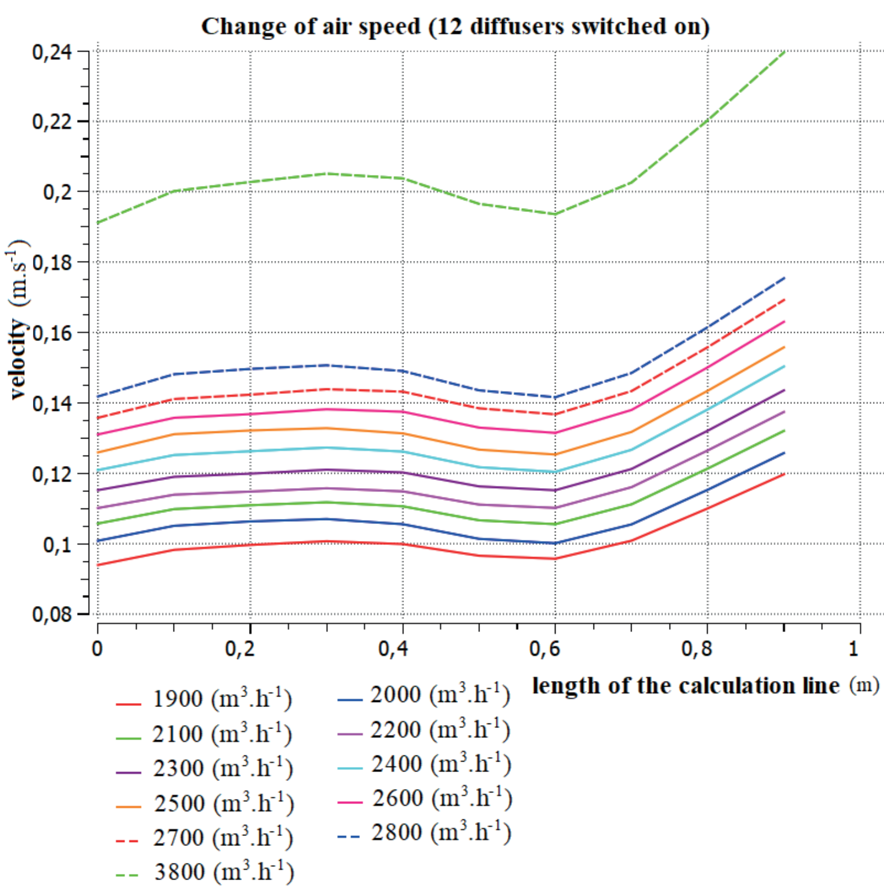

Fig. 4. Analysis of air extraction at constant temperature through 12 diffusers (own source)

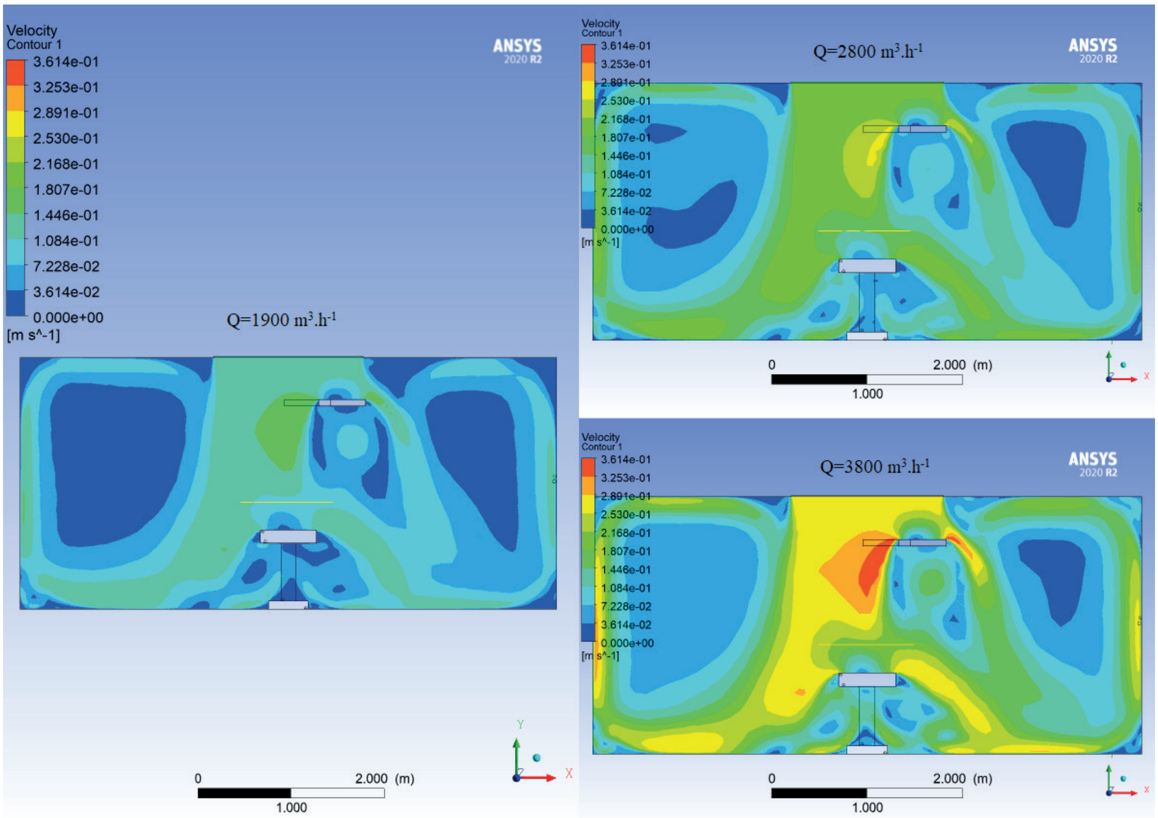

Fig. 5. Simulation of air extraction at constant temperature through 12 diffusers (own source)

3. RESULTS OF THE CLEAN ROOM

As we can see at the pictures (Fig. 4 and Fig. 5), provided that the air extraction from the room is ensured evenly by all 12 outlets, there will be no air turbulence, air flow rates will be low (up to 0.25 $m \cdot s^{-1}$) and with minimal differences in input and output.

The flow of 3800 $m^3 \cdot h^{-1}$ (green dashed line) serves as a control value, which is already beyond the permissible limit and shows us how the curve should no longer look (significant ripple) and at what values it should no longer move. Thanks to the low temperature difference of the supplied air and the low degree of turbulence, the air flow is completely imperceptible. Controlled pressure flow ensures that no airborne contaminants enter the work area of the operating team. The clean air first flows around the patient evenly and only then is they dispersed into the surrounding space.

4. CONCLUSIONS

Although the laminar field has been known in the world for decades, the aim of this work was to modify it and thus reduce the risk of infection of the patient and doctors in the operating room. This innovation could help to make transplants more successful, as operating room conditions play a key role in transplants. By more optimal airflow, we can prevent bacteria and viruses from entering the open wound and thus eliminate the risk of infection.

Since the laminar field is an energy-intensive device, it was necessary to analyze this device from an economic point of view. Since all calculated airflows in the range 1900-2800 $m^3 \cdot h^{-1}$ will ensure the required standardized air exchange, from the point of view of energy intensity, it seems to be the most advantageous option to use lower exhaust air flows, which are also sufficiently efficient. After an overall evaluation of the results, we found that the most advantageous solution is the case where the air extraction is evenly provided by 12 outlets and the flows for air exchange in the operating room will be selected in the range from 1900 $m^3 \cdot h^{-1}$ to 2200 $m^3 \cdot h^{-1}$. These flows ensure the most stable air flow over the operating table with the least turbulence and are also the least energy intensive.

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