COMPUTER MODELING OF THE LAMINAR BOX VENTILATION SYSTEM

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КОМП'ЮТЕРНЕ МОДЕЛЮВАННЯ СИСТЕМИ ВЕНТИЛЯЦІЇ ЛАМІНАРНОГО БОКСА

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A computer model of air exchange in the working chamber of the laminar box is built. Using the universal software system of finite element analysis ANSYS, the field of distribution of air flows in the working chamber of the laminar box is obtained. The influence of the dimensions of the ventilation holes of the laminator on the parameters of the air flow and pressure loss during the passage of the laminator is analyzed.

Keywords: *laminar box, laminator, ANSYS, ventilation*

Побудовано комп'ютерну модель повітрообміну в робочій камері ламінарного боксу. За допомогою універсальної програмної системи кінцево-елементного аналізу ANSYS отримано поля розподілу повітряних потоків в середині робочої камери ламінарного боксу. Проаналізовано вплив розмірів вентиляційних отворів ламінатора на параметри потоку повітря і втрати тиску при проходженні ламінатора.

Ключові слова: *ламінарний бокс, ламінатор, ANSYS, вентиляція*

Построено компьютерную модель воздухообмена в рабочей камере ламинарного бокса. С помощью универсальной программной системы конечно-элементного анализа ANSYS получено поля распределения воздушных потоков в средине рабочей камеры ламинарного бокса. Проанализировано влияние размеров вентиляционных отверстий ламинатора на параметры потока воздуха и потери давления при прохождении ламинатора.

Ключевые слова: *ламинарный бокс, ламинатор, ANSYS, вентиляция*

INTRODUCTION

In the production processes of various industries, the quality of the finish product is increasingly coming to the fore. To ensure which it is necessary to create controlled and repeatable production conditions. One of the key parameters is the influence of the environment (air) in production areas on the properties of the products. In the pharmaceutical industry, the actions of which comply with GMP requirements, technological operations are carried out under controlled conditions in cleanrooms. Cleanrooms and associated controlled environments provide control of air pollution and, if necessary, surfaces, in order to maintain an acceptable level of contamination in processes [ISO 14644]. To ensure especially critical technological operations, on which there is the possibility of pollution not only of the product, but also of the surrounding space, laminar boxes are often used [1].

ANALYSIS OF THE STATE OF THE PROBLEM AND STATEMENT OF TASKS OF THE STUDY

Laminar box is a high-tech design with an internal limited space of the working area. The use of directional flow technology in the chamber of a laminar box makes it possible to exclude physical contact with the external environment.

Air moves in laminar mode in such types of boxes. The air is cleaned by using the built-in filtration system on the HEPA filter (Fig. 1). Usually the laminar box is closed on the sides and has access to the working area through the front hole [2]. The box maintains a constant overpressure to prevent the ingress of contaminants.

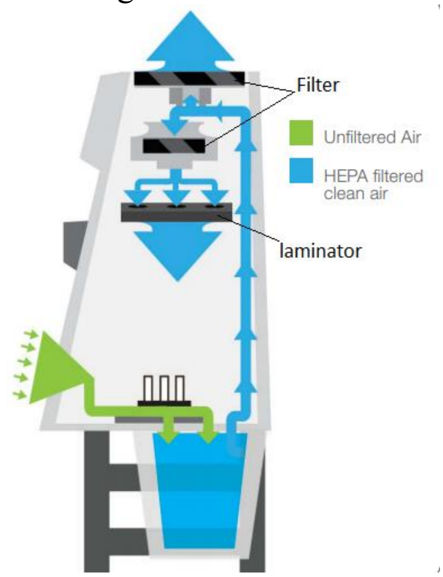

Fig. 1. Scheme of air flow in a laminar box

In accordance with international standards, the following safety classes of laminar boxes can be distinguished (the higher class - the higher protection):

• 1st class of protection – protects the environment and the operator from substances hazardous to health, but does not create sterile working conditions.

• 2nd class of protection –In the laminar, the samples, the operator and the surrounding area are protected from pathogenic and toxic substances. They are used in the manufacture of medicines for working with radioactive and toxic chemicals.

• 3rd class of protection – the operator, samples and the environment are protected when working with highly hazardous materials. Used for safe work with viruses and bacteria of the highest level of danger, carcinogens and isotopes. Laminars of the third class of protection have a completely isolated working area, and are also equipped with a physical barrier between the workplace and the operator.

When designing a laminar, the following basic requirements must be considered:

1. Ensuring air velocity from 0.36 to 0.54 m / s at a distance of 15 cm from the upper filter;
2. The creation of such a design of the air supply elements and its selection, in which the laminar flow of air in the working area is observed.

Each laminar box has an adjustable air supply system and the ability to personalize it for the process. However, computer simulation will reduce the setup time and eliminate the possibility of rejection of the laminar due to its incorrect operation, due to the inability to create a laminar air flow with improper design of internal ventilation systems.

The purpose of this study is to simulate the process of air exchange in a laminar box, as well as to determine the effect of the design of the laminator (air supply system) on working conditions in the laminar box.

To achieve this goal, it is necessary to solve the following tasks:

1. The construction of the geometry of the internal space of the laminar box.
2. Building a computer model of the air exchange process in a laminar box.
3. Analysis of the effect of the geometry of the laminator on ensuring the optimal mode of operation of the laminar box.

MODELING THE AIR EXCHANGE PROCESS IN A LAMINAR BOX

The computer model was built in the universal software system of finite element analysis ANSYS, CFX solver.

To reduce the load on the computing power of the computer, a part of the internal space of the laminar was simulated. The geometry of the computational domain is shown in Fig. 2.

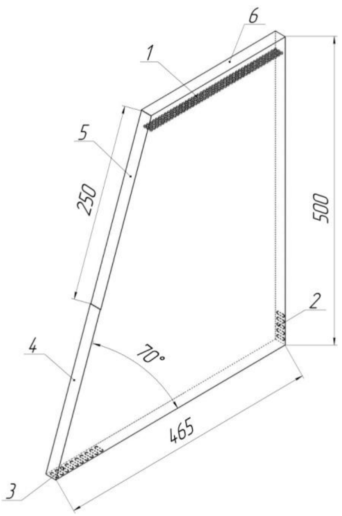

Fig. 2. Geometry of the computational domain:
1 – laminator; 2, 3 – openings for air outlet; 4 – window for manipulation;
5 – protective glass; 6 – supply of purified air

The laminator is a perforated barrier on the air flow path, designed to create a uniform laminar air flow (Fig. 3). The diameter d of the hole of the laminator took the following values: 2 mm, 3 mm, 4mm.

The computational domain was divided into a mesh using the Mesh module. The mesh was created for CFD solvers, based on triangular prisms. The maximum element size is 26.7 mm, the minimum is 0.267 mm. The number of nodes is 531590, elements – 2914235. A higher quality mesh was created near the holes, where it is necessary to more accurately capture the change in flows.

The K-e turbulence model was chosen as the solver model, which has good accuracy in solving problems of fluid motion, both in turbulent and laminar modes.

The problem was solved in a stationary state, since it was necessary to determine the steady state air flow in the box.

Material "Air" from the library was chosen as the working medium, the parameters of which correspond to the properties of air at 20 °C.

The following boundary conditions were specified for the model:

- at the upper end (pos. 6, Fig. 3), the inlet of purified air is provided - the boundary condition "Inlet", the velocity of the medium is 1 m/s;

- through the manipulation window (item 4, Fig. 3) free air flow is possible - the boundary condition “Opening” is set, with pressure of 1 atm;

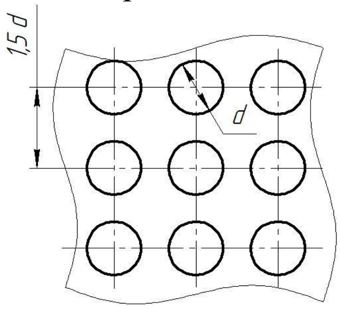

Fig. 3. Laminator hole location

- exhaust air is sucked out through the outlet openings (pos. 2, 3, Fig. 3), due to the presence of a fan in the system, the outlet pressure is reduced to 0.995 atm – the boundary condition is “Outlet”;
- to reduce the duration of the calculations, only a part of the internal volume of the box is allocated, therefore, the condition "Symmetry" is set on the side faces;
- for all other surfaces, the boundary condition of the “Wall” is set.

RESULTS

The results of computer calculation for the diameter of the holes of the laminator 2 mm are shown in Fig. 4 - 5. To assess the degree of adequacy of the constructed model to the real process, a visual assessment of the velocity distribution in the working area of the laminar box was carried out (Fig. 4).

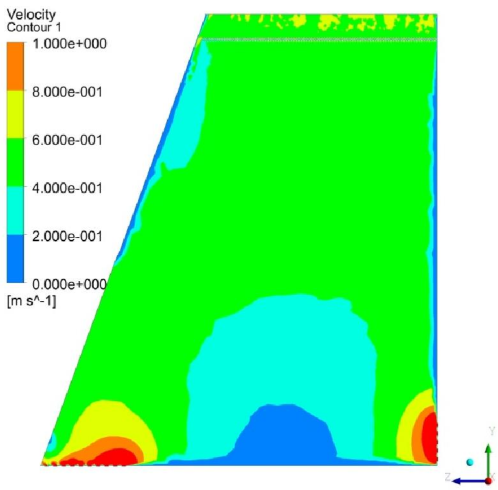

Fig. 4. The diagram of velocity contours

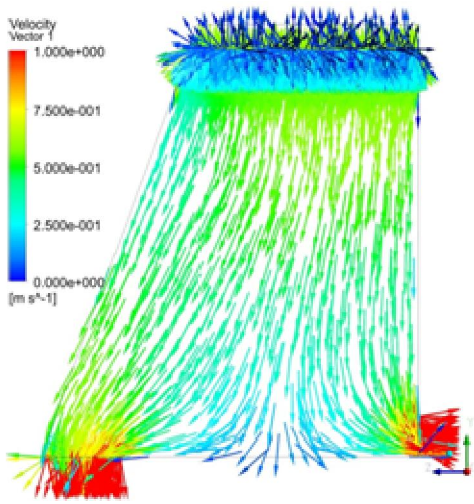

Fig. 5. Speed vectors

At the outlet of the laminator, the air flow has a desired velocity and uniform distribution of fluid, motion mode – laminar. When approaching the outlet, the speed increases, which is associated with a decrease in the cross-sectional area. At the same time, there is a slight outflow of air through the manipulation hole (Fig. 5).

When changing the diameter of the hole of the laminator, the following is observed:

1. In the assessment area, the velocity distribution is more uniform with a hole diameter of 2 mm. Speed decreases with increasing diameter. The lowest speed is observed in the protective glass zone, although it is within the required value (Fig. 6)

2. The pressure loss to overcome the laminator when changing the diameter does not change significantly: from 0.281 Pa at a diameter of 2 mm to 0.234 Pa at 3 and 4 mm.

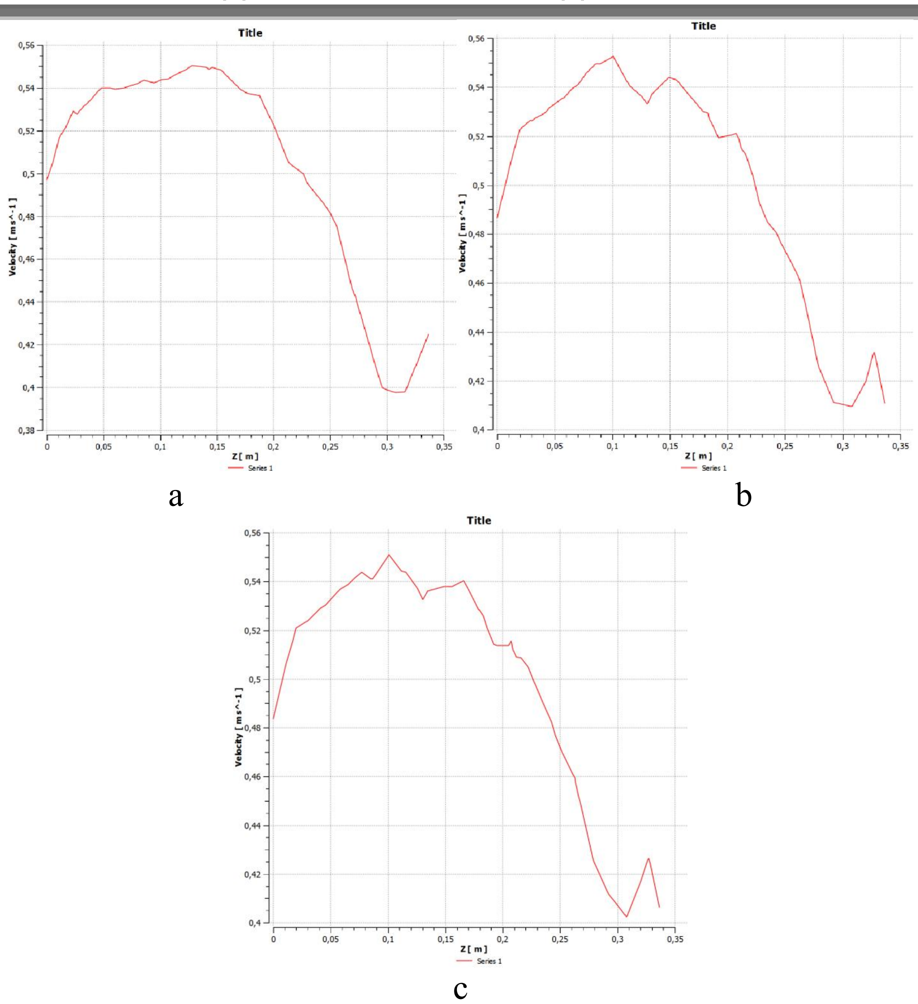

Fig. 6 Changes in speed at a distance of 15 cm from the upper filter:
a – diameter of the holes of the laminator 2 mm; b – diameter of the holes of the laminator 3 mm; c – diameter of the holes of the laminator 4 mm

CONCLUSIONS

1. The constructed computer model makes it possible at the design stage of the laminar box to determine the limits of use and the necessary parameters of the ventilation system
2. Reducing the diameter of the holes of the laminator will make it possible to evenly supply air to the working area, while the pressure loss does not increase significantly, only 0.281 Pa
3. Depending on the created vacuum in the air exhaust zone and the excess pressure in the supply zone, different conditions can be created: protection of the operator or raw materials, depending on the needs of the production.

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