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Specific Methods for Acquiring Controlled Atmosphere for Clean Rooms Used in Industrial and Medical Domains

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Abstract: *There are industry branches requiring a certain degree of internal air purity where the production process takes place. Consequently, there is a need of arranging special chambers with artificially controlled atmosphere and a high level of cleanliness, named clean rooms used in industry and medicine. Within these cambers the air is introduced by the means of special air plants that realises air treatment and filtration, achieving a continuous filtration and circulation so that the air foreign particles that would endanger the production process are retained and removed. Such special production enclosures are used predominantly in electronics, optics, biotechnology, pharmaceuticals, medical equipment, food industries, where an internal atmosphere with a certain degree of purity is required.*

As a first method of providing optimal parameters for the atmosphere of a protected enclosure, a continuous ventilation of the filtered external air was adopted. A method of designing the interior space and the inlet and outlet orifices that allow a continuous air circulation within a virtual enclosure model is presented in this paper. An air circulation analysis is performed inside the enclosure virtual model, and the results are presented as flow velocity values, as well as specific pressure values on the interior areas of the analyzed fluid region of the enclosure model. Thus, the possibilities of reducing the turbulences occurring during air circulation within the enclosure model are monitored so that the circulation can be close to the laminar flowing range.

Keywords*: Clean rooms, fluid flow, air flow, flow regime, 3D modelling, computational fluid dynamics (CFD)*

1. Introduction

Modern industrial branches whose activity object is the production of goods whose manufacturing process requires a high degree of cleanliness both of the production area and of the atmosphere in which they work, have led to the emergence of clean spaces with a controlled atmosphere where the production process can be carried out in order to obtain optimum results.

Such chambers are specially designed and constructed enclosures with special materials that do not tend to retain foreign particles on the surface, be it walls, floor or ceiling. The air introduced through the air power plants must comply with the purity level of the enclosure's interior atmosphere, without causing any momentary changes affecting the degree of purity.

As a first method used to provide a clean and controlled atmosphere inside an enclosure was the continuous circulation of filtered air inside the enclosure clean room. Various air filter types were used in order to retain the foreign particles from air introduced into the enclosure by means of fans. The method belongs to Florence Nightingale (1895), but inconveniences of this method related to the effect of the temperature difference between the enclosure and the exterior, pressure differences between the enclosure air and the outside air, but also the existence of strong air currents inside the enclosure. [1]

Thus, due to air streams passing through the enclosure in certain directions, particles from the floor are entrained in motion and raised in the room atmosphere. Solutions must therefore be adopted in order to overcome this disadvantage involving the air turbulent flow inside the premises with clean and controlled atmosphere. One of these solutions is to provide the unidirectional air circulation inside the enclosure between the inlet orifices area and the outlet orifices area of the enclosure, with a certain value of the air circulation velocity, thus avoiding unwanted strong turbulent flow.

2. Clean rooms constructive types

Depending on the activity object to be carried out inside the clean room enclosure, there are several types of enclosures classified according to the degree of cleanliness of the indoor atmosphere.

Table 1 summarizes some of the industry branches that require the existence of clean rooms with controlled atmosphere in order to achieve the proposed activity. [1]

Table 1: The industry branches where clean rooms are in use

Current number	Industry Branch	Manufactured products
1.	Electronics	Computers and components
2.	Micro-electronics	Integrated circuits
3.	Optics	Lenses, laser equipment
4.	Pharmaceutical	Pharmaceutical sterile products
5.	Medical equipment industry	Medical equipments
6.	Food industry	Sterile foods
7.	Medicine	Operating rooms, sterile salons

According to international standards ISO 14044/01 a clean room is an enclosure within which the particle concentration contained within the indoor atmosphere is controlled and which is constructed so as to minimize the introduction, formation and storage of foreign particles inside. It is also possible to control other parameters related to the temperature, humidity, pressure inside the enclosure.
Depending on the cleanliness degree of the enclosure indoor atmosphere, clean rooms can be classified. The cleaning degree is given by the number of particles contained in the volume unit of the inner atmosphere. Classification according to ISO standards is based on the following relationship:

$$C_{\max} = 10^{N} + \left(\frac{0.1}{D_p}\right)^{2.08} \tag{1}$$

where:

$C_{\max}$ - maximum allowed concentration;

N - ISO classification number;

D_p - particle diameter in microns;

The ISO, N classification is in the range of 0-9, and each integer within this range represents a cleanliness class for the enclosure internal atmosphere.
The enclosures with controlled atmosphere can be classified according to the type of indoor air circulation introduced by the means of the air plants as follows:

Type 1 - a clean room enclosure inside which there is a turbulent airflow introduced in several directions;

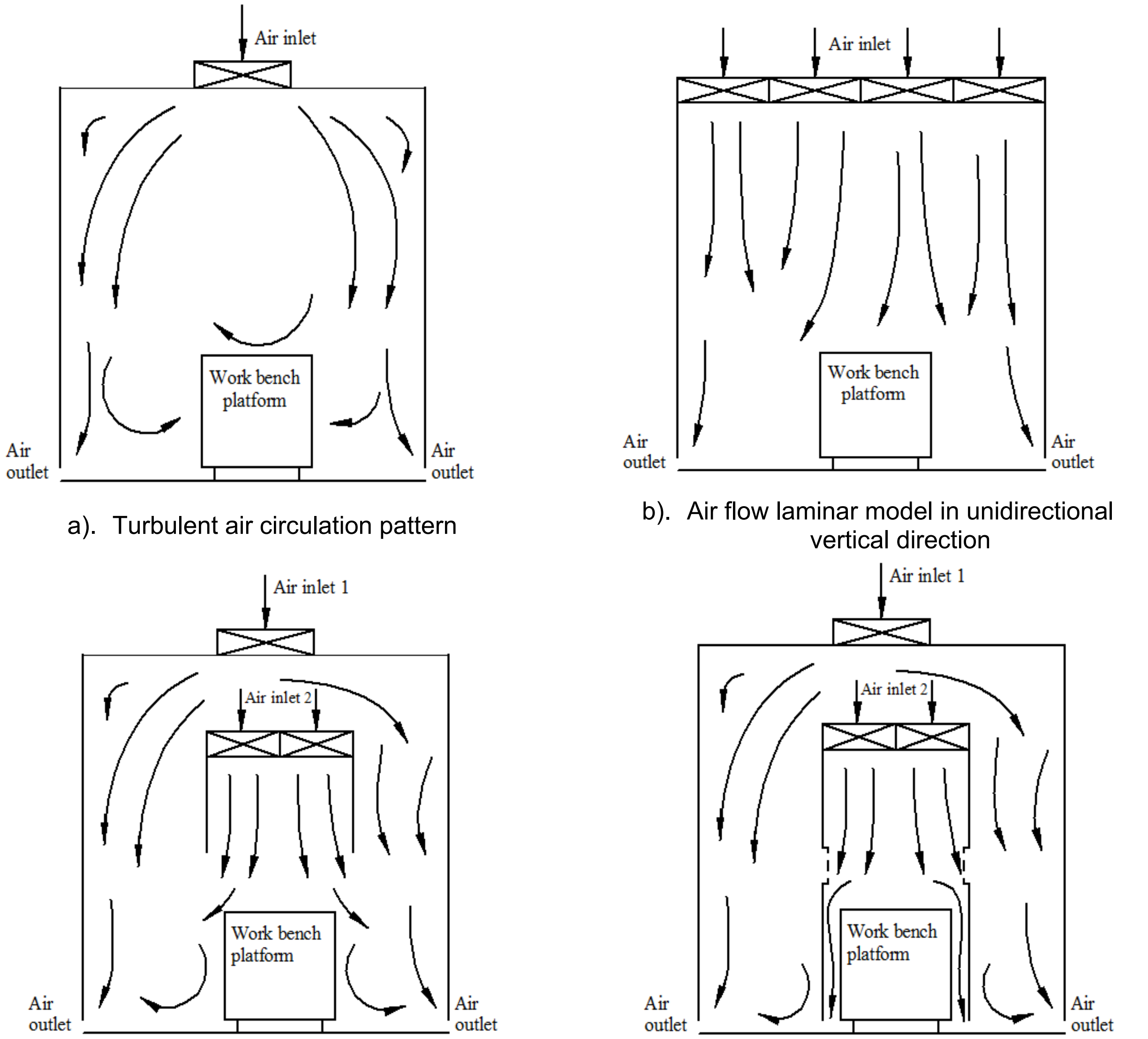
Type 2 - clean room enclosures inside which the air circulation is laminar unidirectional, using high-efficiency filters;

Type 3 - clean room enclosures inside which there is a mixed air circulation;

Type 4 - laminar and unidirectional air circulation within enclosures having insulating walls.

Both in the industry and also in the medical field, clean room standards must be strictly respected. These spaces are clean rooms with a controlled atmosphere, which can be arranged according to the requirements of the proposed activity object. Such enclosures are made of special materials of the walls, floor, or ceiling, to which the particles in the atmosphere can not adhere and with the air intake devices a permanent air circulation is maintained inside the enclosure. Air circulation is achieved between the inlet orifices positioned on the ceilings or the walls and outlet openings positioned at the base walls or even in the floor inside the enclosure.
By means of filters the foreign particles from external air is retained from the outdoor air introduced into the enclosure.

Depending on the cleaning class requirements for enclosure atmosphere where the production process takes place the work rooms types with different configurations in terms of working space and air circulation may be arranged as shown in the models presented in Figure 1.



a). Turbulent air circulation pattern

b). Air flow laminar model in unidirectional vertical direction

c). Model of air circulation in laminar in the work site and turbulent for the enclosure

d). The laminar air flow pattern inside the work area isolated from the enclosure

Fig. 1. Schematically representation of air flow within clean room enclosure types

Depending on the enclosure clean atmosphere class, different configurations are provided with respect to the positioning of the work space, which can be placed both in the enclosure and inside a protected area with unidirectional overflow circulation of the air streams within the enclosure where the operator has access by the means of special access slots.

3. The air flow analysis for the clean room enclosure model

A three-dimensional model for a virtual clean room was built with a length of 7 meters, 5 meters width and 3 meters height. The openings that represent the air inlet and outlet orifices areas are also initially designed on the enclosure model. For the air inlet were made 4 rectangular orifices (60x70 cm), placed on the enclosure ceiling and for the outlet a number of 12 rectangular orifices (70x10 cm), placed at the bottom of the chamber walls, were adopted. The model was introduced into the ANSYS CFX flow analysis and for the working fluid was selected air at 20 degrees Celsius.

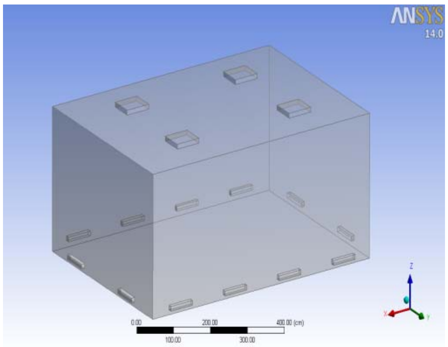
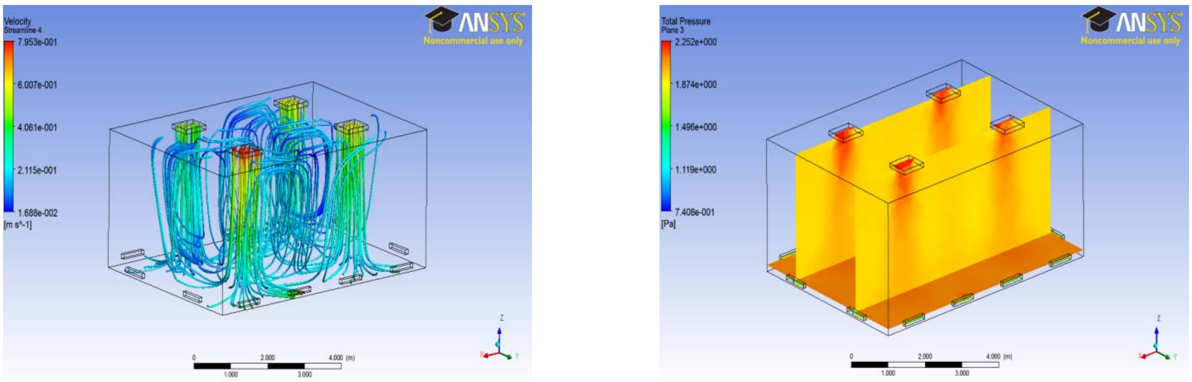


Fig. 2. Enclosure model fluid region

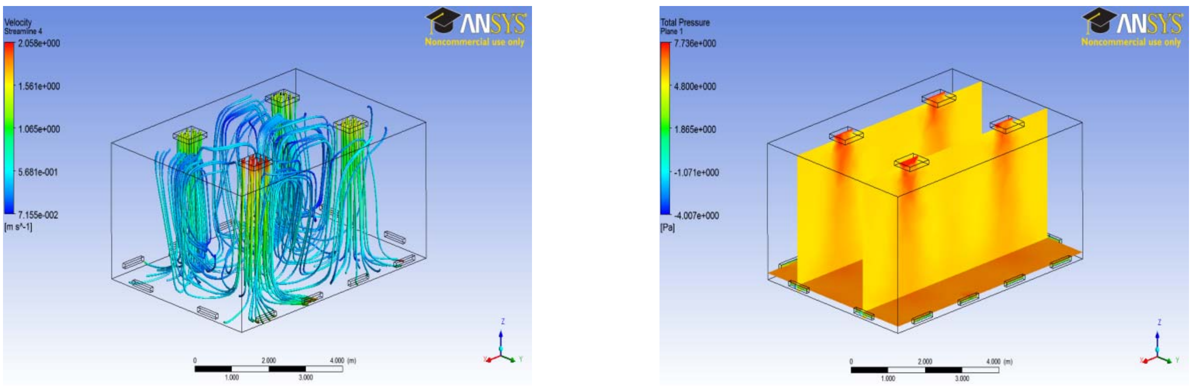
Four distinct cases were analyzed with different air flow rates values declared at the inlet orifices. The obtained results highlight the air circulation model inside the enclosure by the described pathlines having different velocity and pressure values at the analyzed fluid regions. It can be noticed that the flow model is generally turbulent but with different values for the air movement velocity. Table 2 describes the initial values regarding air flow rate declared for each analyzed case.

Table 2: The initial values for air flow rates

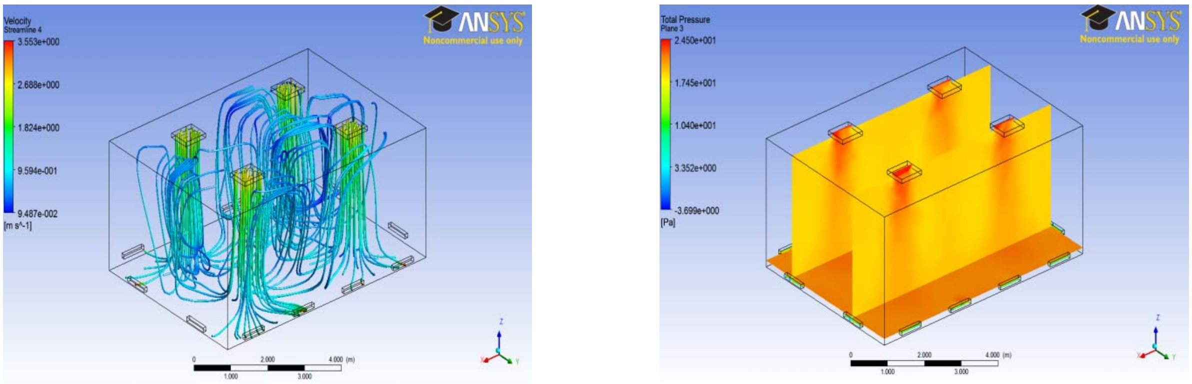
Case number	Air flow rates [kg/s]	Air flow rates [m3/h]
Case 1	0.3	896.2656
Case 2	0.7	2091.286
Case 3	1.3	3883.817
Case 4	2	5975.104



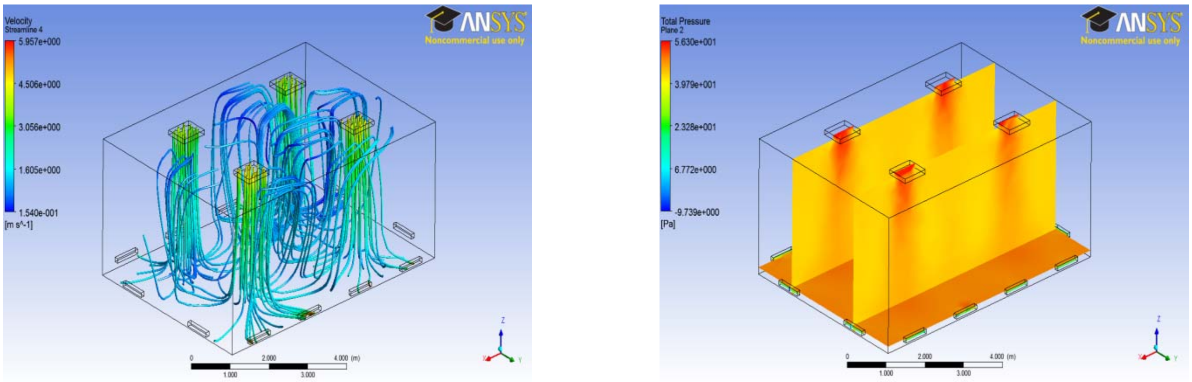
a). The obtained values for Case 1



b). The obtained values for Case 2



c). The obtained values for Case 3

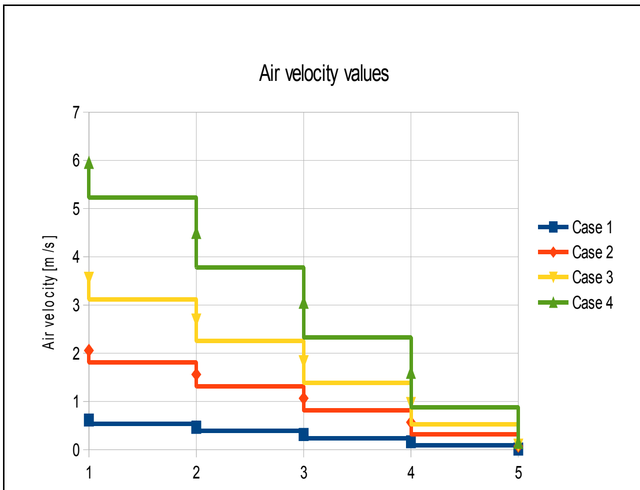


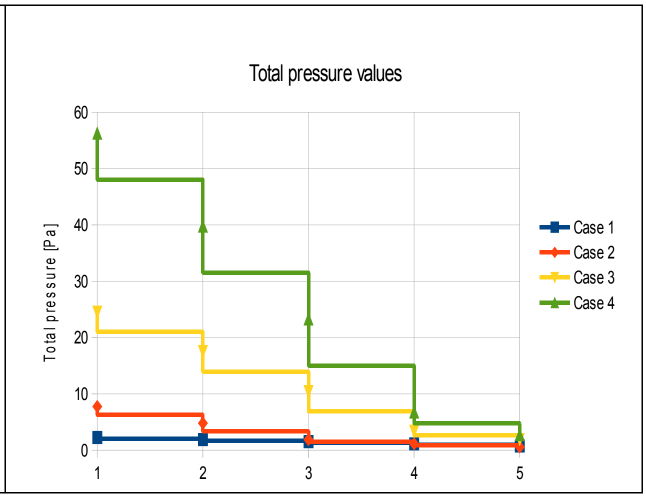
d). The obtained values for Case 4

Fig. 3. Fluid velocity and total pressure values for the analyzed cases

Using the obtained result values from the analyzed cases, the diagrams corresponding to the air velocity and total pressure values were plotted, presented in Table 3.

Table 3: Air velocity and total pressure diagrams





The diagrams show the minimum and maximum values in which the velocity and total pressure ranges inside the analyzed fluid region for all 4 analyzed cases.
Generally, for a clean room with a controlled atmosphere with a certain class of cleanliness, the circulated air velocity values are limited at values ranging between 0.2 - 0.5 m/s, for the turbulent air flow model inside the enclosure and the optimal values for pressure ranges from 7 to 20 Pa. [2]

Air circulation velocity values are limited in order to prevent particles entrainment in circulating air, while a reduced air circulation velocity can create the deposition of these particles on the clean room surfaces.
The pressure values must be higher than the external environment pressure in order to prevent particle infiltration from the enclosure outside environment.
Thus, basing on the requirements for air velocity and pressure values correlated with the values obtained from air flow analysis within the virtual model of the analyzed enclosure model, the case 2 (air flow of 0.7 kg/s) values presents the closest terms for air velocity and pressure values.

4. Conclusions

Clean rooms with controlled atmosphere have arisen due to the existing needs in both the industry and the medical field, regarding the cleanliness of both the enclosure and the air present on the premises. Specific cleaning classes have been developed that describe the premises used in various branches of industry and medicine.
The presence of foreign particles in the clean rooms atmosphere can not be avoided but can be reduced by number based on the specific construction procedures and the introduction, circulation and filtration of indoor air.
A virtual enclosure model was built and analyzed regarding the air circulation mode in this paper.
Four distinct cases were considered for which different air flow rates were declared at the inlet orifices. The results show the air circulation mode within the analyzed fluid region, with the specific recorded values for the velocity and total pressure.
The flow model is of turbulent type as the air stream pathlines for all analyzed cases are presented.
Based on the recommended values for clean room enclosures, Case 2 was chosen as the optimal case, as the values obtained for the air circulation velocity and the pressure values inside the enclosure model are the closest to the recommended values.
Values for airflow velocity inside the enclosure must be limited for practical reasons in order to reduce the turbulences created and to ensure an optimal degree of comfort for human operators working in such premises.
Regarding the pressure values, the highest pressure value must be ensured for the higher cleanliness class from clean room standards in order to avoid external contamination of this enclosure.
In addition to the air circulation velocity, an optimal level of temperature and humidity values inside the clean rooms premises with controlled atmosphere are also provided, depending on the technological process that takes place in the enclosure.
Further conditions of sterility of the clean room enclosures must be provided that describe the level of microbial contamination directly related to the microorganisms and particles from the enclosure indoor air atmosphere which are added to the total particle number that provides the specific cleaning class for the clean room enclosure. [2]

References

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