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CFD SIMULATION OF CARBON DIOXIDE DISPERSION DYNAMICS IN CLOSED SPACES

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Abstract: *Carbon dioxide is a suffocating gas resulting either from industrial activities from combustion or explosion. There may also be carbon dioxide deposits under pressure, quartered in porous geological formations. This gas can show slow or violent releases with accumulation at ground level. Carbon dioxide is a gas that is both toxic and asphyxiating. This gas can accumulate in closed spaces and when it exceeds the concentration of 12% vol. it becomes lethal. For the protection of working personnel, it is necessary to identify and apply the most effective preventive measures. This requires an understanding of carbon dioxide's behaviour during the build-up phase. The research gives a CFD analysis for determining the dynamics of carbon dioxide dispersion in a confined enclosure.*
Keywords: *CFD, dispersion, gas dynamics, asphyxiating gas, carbon dioxide, closed spaces*

1. Introduction

For the study of complex physical phenomena, including fluid flow, specialized programs known as CFD technique are used as a top technique [1, 2, 3, 4]. In order to simulate gases, the CFD technique and physic-mathematical equations for fluid flow [5, 6, 7, 8, 9, 10, 11]. At the international level, experiments and modelling were performed with the CFD technique to identify the peculiarities that occur in the flow of gases including carbon dioxide [12, 13]. However, the analysis of the dispersion dynamics of this gas, indoors, can bring additional information in order to establish preventive measures [14, 15, 16, 17, 18, 19, 20].

2. Technique used description

The CFD technique for modelling of suffocating and toxic gas used the ANSYS MULTIPHYSICS software package.

The ANSYS package taken into account as follows: Export skills of discretization to the solvents contained in the package, but also to other solvents (such as: Abaqus, Flotran, Nastran, Patran, UGrid, TGrid, etc); Pre and post processors for multiphysics and mechanical solvers; Interface / connection, Pro / ENGINEER, One Space Designer, etc.; Graphical working interface for assembling and interacting mechanical, fluid, electromagnetic systems, geometries and discretization; Parametric generation and modelling application of solids (2D and 3D); Data resources (databases) comprising the technical characteristics of materials mainly used in industry, of toxic and explosive gases and liquids; Ability to automatically discretize (including TGrid) the generated geometries, depending on the type of solver used; Pre- and post-processing for mechanical, structural, thermal and magnetostatic systems; Ability to simulate cyclic loading on the product to anticipate lifespan; Generation and import from Nastran of finite element

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models; Processing the dynamics of rigid and rigid / flexible bodies; Ability to load and manage a batch of solutions. Parallel processing within the package is based on a variational technology applied to static or transient solutions for thermal and structural analysis. The application allows the administration and storage of data from computer simulations.

3. Conditions for modelling

For the modelling regarding the dispersion of carbon dioxide in a closed enclosure, the CFD technique was used on a computerized model, fig. 1, [21, 22].

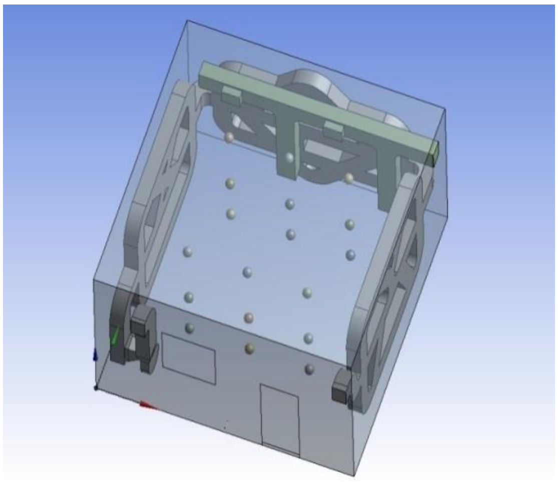

Fig. 1. Site modelling

At the level of the modelled enclosure, three sets of points were formed, as shown in Table 1, at altitudes of 0.5, 1.5, and 3m from the floor (fig. 2). Set points are used to regulate the evolution of gas concentrations during simulation.

Table 1. Coordinates of control points

	P1A	P1B	P1C	P1D	P1E	P1F
X_1	1.5	2.8	4.1	1.5	2.8	4.1
Y_1	1.5	1.5	1.5	4.0	4.0	4.0
Z_1	0.5	0.5	0.5	0.5	0.5	0.5
	P2A	P2B	P2C	P2D	P2E	P2F
X2	1.5	2.8	4.1	1.5	2.8	4.1
Y2	1.5	1.5	1.5	4.0	4.0	4.0
Z2	1.5	1.5	1.5	1.5	1.5	1.5
	P3A	P3B	P3C	P3D	P3E	P3F
X3	1.5	2.8	4.1	1.5	2.8	4.1
Y3	1.5	1.5	1.5	4.0	4.0	4.0
Z3	3.0	3.0	3.0	3.0	3.0	3.0

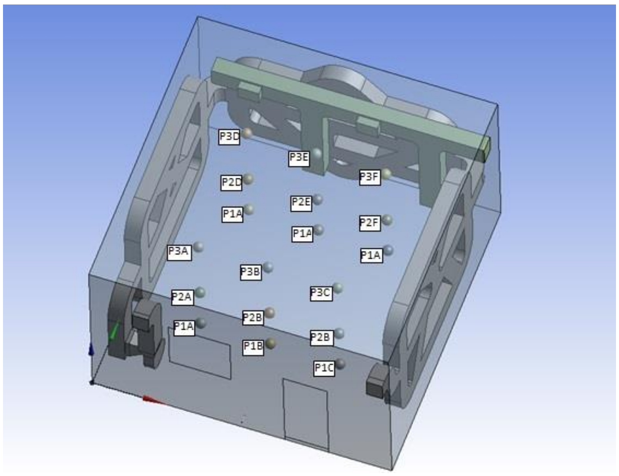

Fig. 2. Location of control points

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4. CFD modelling

The conditions imposed for modelling were:

Carbon dioxide has maximum concentration;

The carbon dioxide introduction device was placed 0.15 meters from the floor;

Carbon dioxide is introduced using an 8 mm diameter hose;

The gas flow rate introduced is 4.5 l/min;

Modelling time was 10 minutes;

The maximum value of carbon dioxide was established at 1% Vol.

Following the simulation of carbon dioxide, the results are presented at the levels 1, 2 and 3.

The evolution of carbon dioxide concentration at level 1 is shown in Figure. 3.

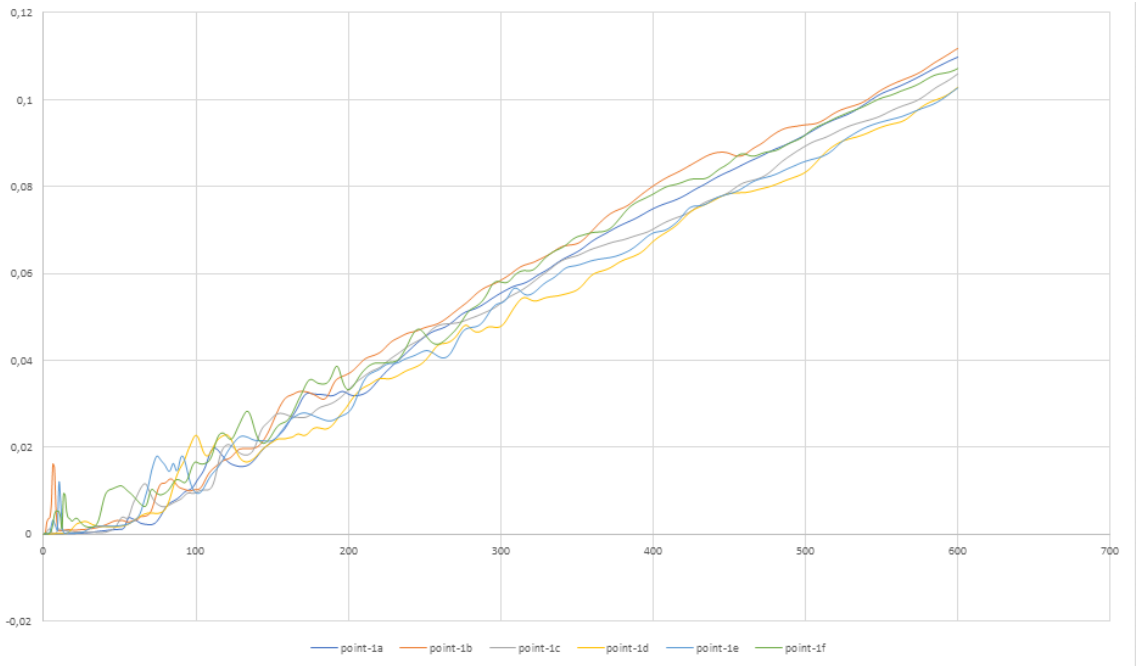

Fig. 3. Dynamics of carbon dioxide dispersion at level 1

The evolution of carbon dioxide concentration at level 2 is shown in Figure 4.

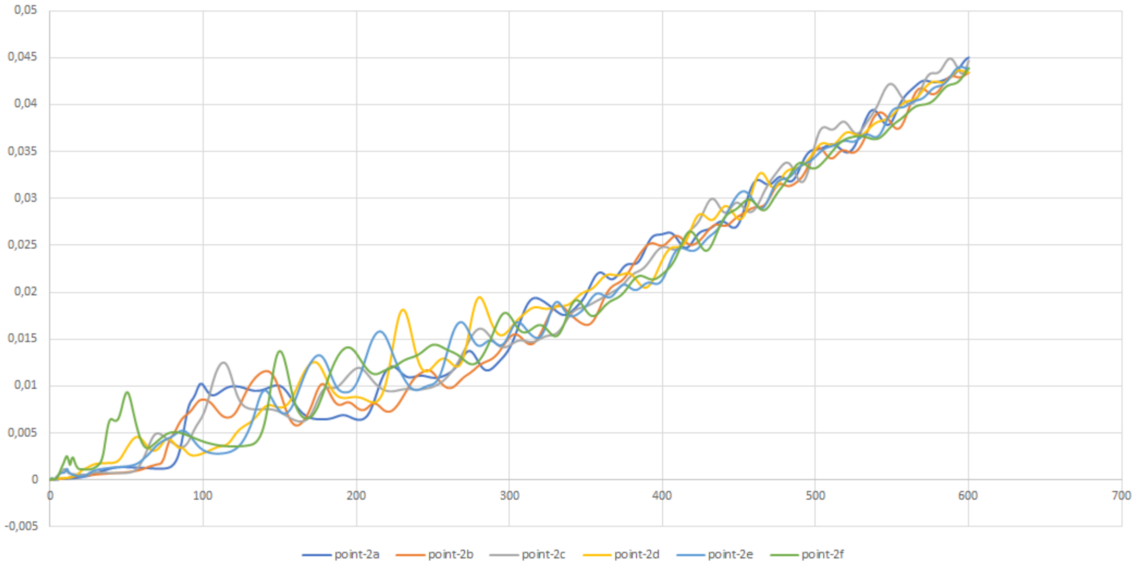

Fig. 4. Dynamics of carbon dioxide dispersion at level 2

The evolution of carbon dioxide concentration at level 3 is shown in Figure 5.

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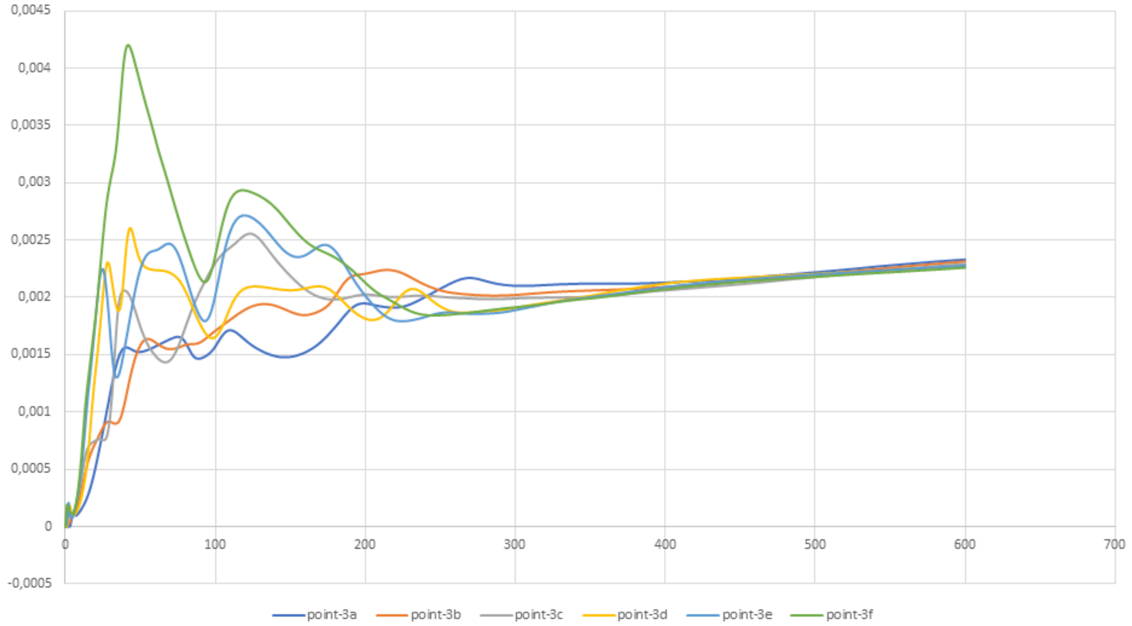

Fig. 5. Dynamics of carbon dioxide dispersion at level 3

The results are shown graphically in Figures 6-9.

In Figure 6 at 1 min., in Figure 7, at 2 min. the carbon dioxide disperses parallel to the floor facing of opposite wall.

Additionally, the jet of carbon dioxide rises on the opposite wall up to half its height and diffuses slowly.

Fig. 6. Carbon dioxide dispersion at 1 minutes

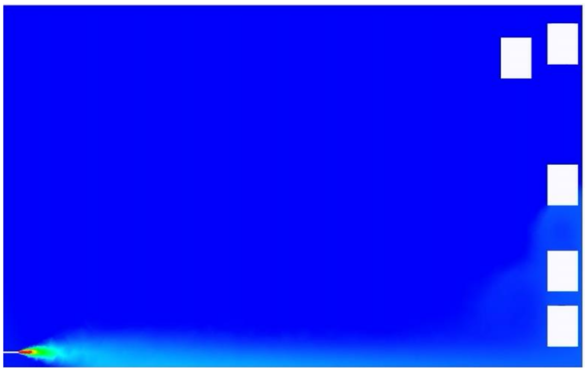

Fig. 7. Carbon dioxide dispersion at 2 minutes

In Figure 8 and 9, at 9 min. respectively 10 min., carbon dioxide disperses parallel to the floor going up the opposite wall towards the ceiling. In addition, the carbon dioxide jet rises firmly on the opposite wall to half its height. From the floor, carbon dioxide diffuses progressively vertically, evenly, in a firmly established stage, up to about half the height of the enclosure.

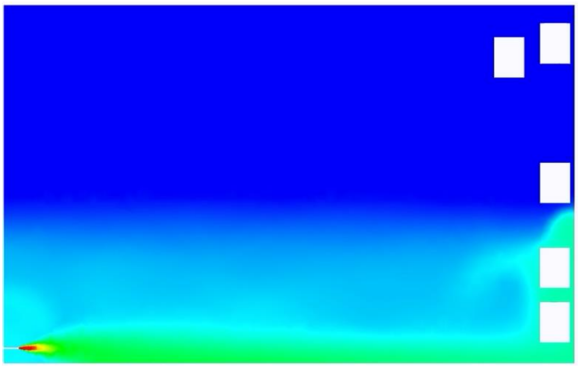

Fig. 8. Carbon dioxide dispersion at 9 minutes

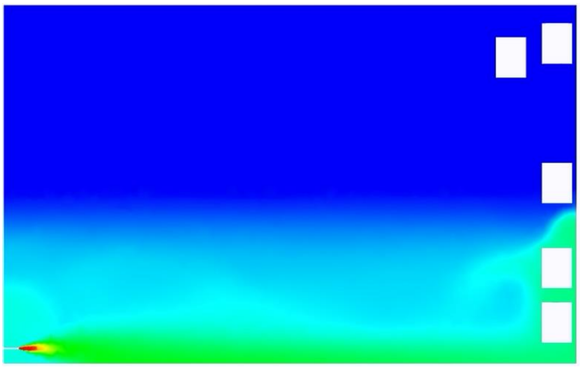

Fig. 9. Carbon dioxide dispersion at 10 minutes

5. Discussions

From modelling indoor asphyxia gas dispersion we can formulate the following observations:

The carbon dioxide dispersion was monitored on 3 levels: Lower Level 1, Middle Level 2, Upper Level 3;

The gas dispersion at first level has a variable evolution in the initially turbulent phase. The flow becomes laminar as the flow process stabilizes;

The gas dispersion at second level has a variable evolution in the medium turbulent phase. The flow initially becomes turbulent as the flow process stabilizes;

The gas dispersion at third level has a variable evolution in the highly turbulent phase, but it becomes laminar as the flow process stabilizes;

The Gd parameter that characterizes the degree of dispersion showed a variable evolution as follows:

Gd at first level vary from 4.217 to 4.526% Vol./h;

Gd at second level vary from 1.717 to 1.855% Vol./h;

Gd at third level vary from 0.088 to 0.092% Vol./h;

CFD simulation of carbon dioxide revealed a dispersion phenomenon oriented along the flow direction. Carbon dioxide disperses in the form of a flat jet attached to the floor, up to the level of the opposite wall. Vertically, the gas is diluted unevenly.

The carbon dioxide concentration gradually decreases and becomes relatively uniform and reduced in the accumulation area at floor level. If the carbon dioxide were to disperse continuously, the atmosphere inside the enclosure would be displaced from the floor to the ceiling.

6. Conclusions

For the study of the dispersion dynamics of asphyxiating gases, the modelling of the dispersion of carbon dioxide was carried out using the CFD method;

At first level, second level and third level, the flow has a variable evolution in the early, medium and strongly turbulent phase. The flow becomes laminar as the flow process stabilizes;

The Gd parameter that characterizes the degree of dispersion showed a variable evolution and presented value between 0.088 and 4.526 % Vol./h;

The simulation of carbon dioxide presented a dispersion oriented in the direction of flow, presenting the shape of a jet stuck to the floor up to the level of the opposite wall. The gas disperses unevenly vertically from the floor level.

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