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AIRFLOW MODELING AND SIMULATION REQUIRED IN CBRN COLLECTIVE PROTECTION DESIGN

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***Abstract**: Many CBRN agents are very difficult to detect and identify, due to the fact that most technologies, equipment and materials used for their obtainment have also commercial applications. One possibility to counteract such threats, both for military and civilians, is to use systems of collective protection (COLPRO), which must be manufactured from materials that can withstand not only the action of CBRN agents, but, as much as possible, toxic industrial materials (TIMs). The computational fluid dynamics (CFD) study of the atmosphere in the neighbourhood of the COLPRO tent and the air flow dynamics inside the tent give all the necessary data regarding the effect of air circulation on the entire COLPRO system. Based on this study, a favourable orientation of the COLPRO tent may be established relatively to the strategic position of the troops or the civilian groups, versus statistical wind speed, direction and charge.*

Keywords: military protection, Ls-DYNA software, hazardous chemicals

1. Introduction

The new international security environment has brought to public attention, in addition to states or nations participating in wars (with their specific organization), a series of terrorist organizations spread across the globe, who can develop asymmetric capabilities, including weapons of mass destruction, i.e. weapons that use chemical, biological or radioactive or nuclear (CBRN) agents, very hazardous to human beings [1]. Many of the CBRN agents are very difficult to detect and identify, due to the fact that most technologies, equipment and materials used for their obtainment have also commercial applications.

In addition to these military or terrorist threats (including willingness of participants to use CBRN agents or weapons), there is another category of threats arising from the unintentional release of highly toxic industrial chemicals, biologically active agents or radioactive particles that have a direct impact on the population or military units operating in theatres. In military terms, the release into the environment of these categories of materials are called toxic emissions other than attack (EADA) and the generic name of this category of dangerous substances is toxic industrial materials (TIMs).

In case of CBRN agents use or EADA events, the military doctrine recommends avoiding contaminated areas, which is not always possible to adopt. In this case, individual and collective protective equipment is needed, to ensure protection against these contaminants.

Due to this reason, systems of collective protection (COLPRO) for both military and civilian use must be manufactured and made of materials that can withstand not only the action of CBRN agents, but, as much as possible, the TIMs.

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2. Fabrication context and development

Substances that may be in the air and that can induce poisoning by inhalation have different forms: gases, vapours, aerosols. Aerosols may exist in the form of mist, fume, or dust [2].

2.1. Filtration system

The respiratory system is divided into three regions (Figure 1) from the point of view of aerosols depositions:

- upper airways;
- trachea-bronchial area;
- alveolar area.

Liquid and solid particles may become suspended in air and be breathable in their aerosol (Figure 2). Aerosols may have a size between 2 nm and 100 µm or even higher [3].

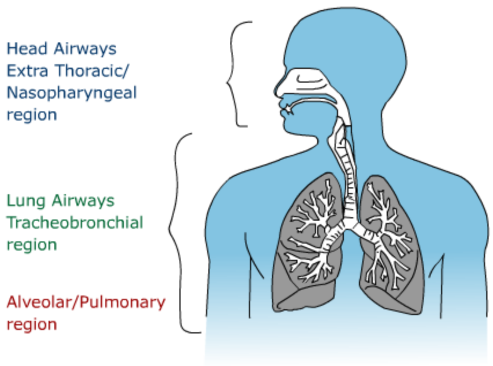


Figure 1: Human respirator y system [4]

2.2. Legislation

In terms of standardization, there are only two documents referring to hazardous chemicals, whose effect must be assessed in the description of a protection system:

a.SR EN ISO 6529:2007 - "Protective clothing. Protection against chemicals. Determination of resistance to permeation by liquids and gases of materials used for manufacturing protective garments" [6] - is an international standard adopted by Romania, which describes how to measure the characteristics of individual protection equipment, but which may apply to any material used for industrial chemicals protection. It includes an Annex A, “List of chemicals recommended for comparing permeation resistance of protective clothing materials”, which includes 12 liquid chemicals and three gaseous chemical compounds;

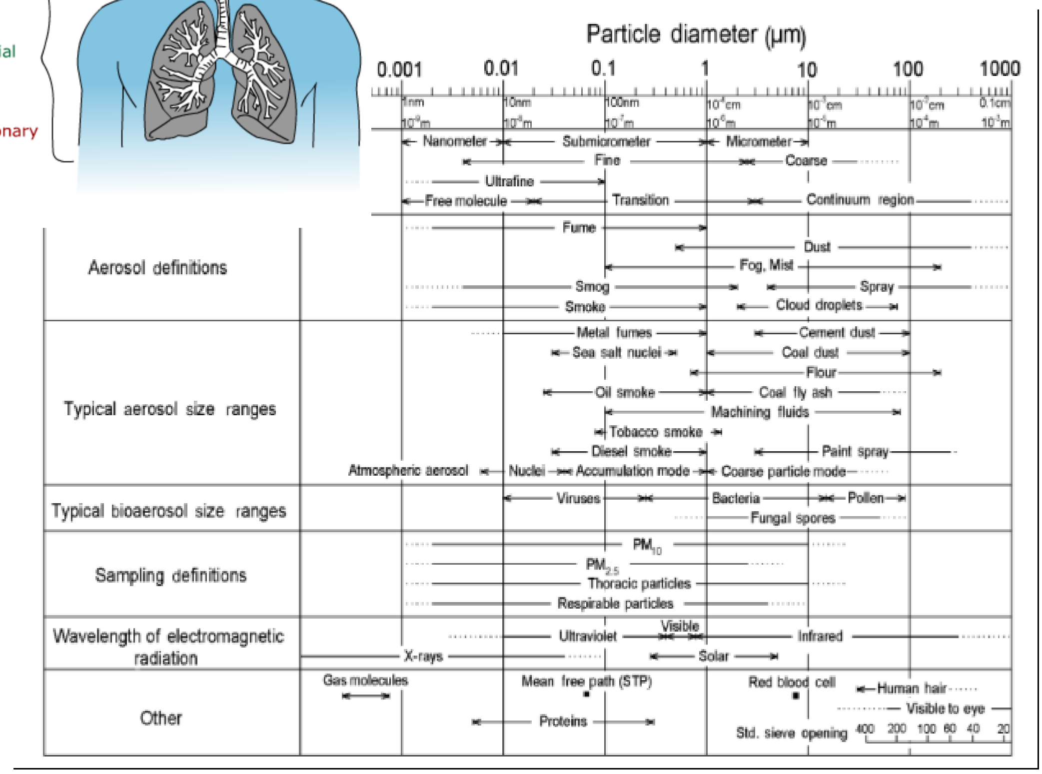


Figure 2: Types of aerosols versus size range [5]

b. AEP-38 - “Operational requirements, technical specifications and evaluation criteria for CBRN protective clothing" [7]. This document is a NATO manual to define requirements and test methods for protective CBRN equipment. Annex C of this manual defines a list of 17 chemicals that must withstand military CBRN protective materials.

3. Results

An extended analysis of air movement inside and outside the COLPRO system tents is needed to establish design and operating conditions in the most various climatic conditions. Analysis of air flow, both inside and outside the tent, using aerodynamic calculation methods, materializes into a set of information and useful data.

Identification of aerodynamic processes and phenomena is performed separately on the two fluid areas in contact with the tent, outside and inside.

3.1. Outside field

External air flow produced by the wind under certain conditions, adversely affects the mechanical stability of the tent. The pressure forces developed by the wind on the COLPRO system components vary versus wind direction and intensity.

To analyse the mechanical stability of the tent supporting system, in weather conditions specific to the area in which it is used, it is necessary to establish the worst load regime and the intensity of the forces that occur in these conditions. Aerodynamic forces caused by wind, together with the other forces acting on the system, such as weight of snow on the roof and other payloads, have as consequence the mechanical stability decrease of the pressurized (inflatable) supporting structure.

The computational fluid dynamics (CFD) study of the atmosphere in the neighbourhood of the tent is able to give all the necessary data regarding the effect of external air circulation on the COLPRO system. Based on the same study, a favourable orientation direction of the tent may be established relatively to the local direction, and prevailing wind statistics.

3.2. Inside field

Air circulation inside the tent is a consequence of the air introduction through the ventilation system by forced circulation, and to a lesser extent the natural flow.
Arrangement of air holes and objects placement inside the tent, input parameters – air pressure, velocity and temperature, are the elements that determine the internal air flow.

The achievement of a proper air flow in all areas inside the tent ensures proper quality of breathable air.

A continuous homogenization inside the tent and air composition maintaining in the prescribed parameters are the most important objectives for designing the COLPRO ventilation system.

3.3. Mechanical stability of the pressurized support system

In COLPRO systems, tent's stability and rigidity are provided by the pressurized inflatable support system. In general, these systems can take important tasks on preferential directions, proportional in intensity to the working pressure. In real-world use of COLPRO systems, forces that act on the tent vary in position, intensity and direction. In this situation, efforts produced by specific charges in the support system elements are complex, including all the six components.

The equations that govern fluid mechanics have differential expression and conservative character:

- equation of continuity or conservation of mass;
- equations of impulses conservation;
- equation of energy, if necessary.

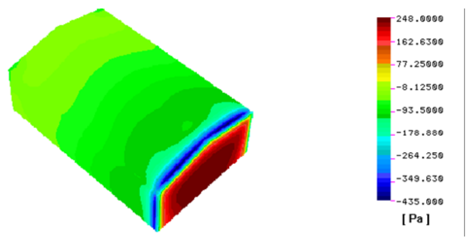
For compressible fluids, an equation of state is added to the equations of conservation.
For turbulent movements, a turbulence model is attached to the differential system of equations.

Each issue of the mechanics of fluids is customized by boundary conditions, on the boundaries and initial.
In general, an analytic integration of the system of differential equations, for the specified boundary conditions, is virtually impossible for most of the fluid mechanics problems. Solutions in finite terms are obtained only for very simple patterns. Problems encountered in the simulation of processes and phenomena related to air movement inside and outside COLPRO systems can be solved in Ls-DYNA, FLUENT or AUTODYN software.

The models analysed are defined in the incompressible turbulent movement field. For the acoustic analysis, the compressible gas model is used. Several samples of the solution obtained by CFD are shown in Figure 3, which represents the wind pressure distribution on the outer surface of the body in two particular cases of orientation, at a 20 m/s wind speed.

For the solution presented, simplified models of COLPRO system were used, without obstacles and other items.

Examples of CFD have been introduced to demonstrate the usefulness and the strength of solving various numerical simulation methods for the analysis of processes and phenomena produced in the aerodynamic exterior and interior of the tent.



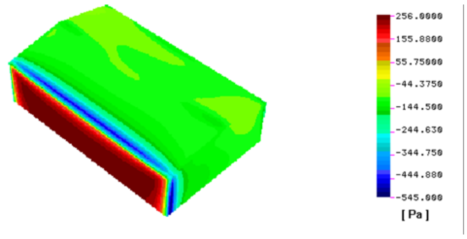


Figure 3: Distribution of the pressure produced by the wind on the outer surface of the tent (downstream and transversally)

4. Conclusions

Knowing aerodynamic processes and phenomena that occur inside and in the vicinity of the COLPRO systems, their quantitative approach has favourable effects on their design activity and on the establishment of operating conditions.

Numerical simulation techniques implemented in the commercially available software are means of investigation and detailed knowledge of phenomena in continuum mechanics (structures and fluids).

The application of numerical simulation methods in conception, design and use of systems of any nature shortens the periods of project design, products fabrication and testing.

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