THE EXPLOSIVE ATMOSPHERE CONDITIONS REQUIRED TO CARRY OUT AN IMPROVISED EXPLOSIVE DEVICE AND NUMERICAL SIMULATION OF DETONATION

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ABSTRACT
The purpose of this article is to study the conditions in which an explosive atmosphere of LPG-air may be set up as part of an improvised explosive device. The main effect generated as a result of explosive atmosphere is the overpressure in the shock wave front. In this article I will study the detonation of an explosive atmosphere made from liquefied petroleum gas - air, in a room of a building, using numerical modeling in 3D with software product ANSYS-AUTODYN.

KEYWORDS: AUTODYN, confined space, explosivity limits

1. Introduction
It was used LPG-air mixture as explosive atmosphere because from statistical analysis resulted that most accidents are of this type [1].

For numerical simulation, I chose a mixture of 8 % propane and 92 % butane, which falls within the boundaries of the constituents of the LPG, as defined in the SR 66:2007 [2]. This mixture of fuels, is initially in liquid state, bottled in containers under pressure. LPG will be disseminated in the air to form an explosive atmosphere.

Explosivity limits fall between 1,9 % – 8,5 % for butane and 2,2 % – 9,5 % for propane [3]. These percentages are calculated as a holding volume in air.

Using the C.E.A. program (program for calculation of chemical compositions, characteristics at equilibrium) it was calculated the detonation parameters of the explosive atmosphere of LPG-air (Table no. 1). The method used to obtain the detonation parameters Chapman-Jouguet is described by Zack and Gordon, in several stages [4, 5]. It was noted that the maximum pressure obtained correspond to a mixture of 4 % LPG in vapor state and 96 % air.
### Table no. 1

<table>
<thead>
<tr>
<th>LPG-air</th>
<th>Vol.% gas in air</th>
<th>Detonation pressure</th>
<th>Temperature</th>
<th>Detonation velocity</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>19.422 bars</td>
<td>2814.44 °K</td>
<td>1830.6 m/s</td>
<td></td>
</tr>
</tbody>
</table>

It was disseminated a quantity of gaseous mixture inside an enclosure having multiple rooms, to detonate it and then analyze the effects.

2. **Explosive Atmosphere Detonation using Modeling in Ansys – Autodyn**

It was defined an one-dimension numerical model of LPG-air mixture, having a predefined geometry type “wedge”, for a spherical explosive charge in open space, with a radius of 4250 mm (Figure no. 1).

![Fig. no. 1 Two-dimensional numerical model](image)

The model has been realized by using the solver “Euler multi-material”, specific to problems in which are modeled gases, fluids or solids that will undergo large deformations. This model has been saved as a part, in order to be loaded into the 3D model.

For modeling the structure walls it was used SolidWorks software, and the result was saved as a part in order to be imported in Ansys-Autodyn.

Using Ansys Workbench, it was created a project, consisting of analytical interconnected systems. With the help of these systems it has been implemented the geometry and the mesh of that domain in which it was defined the structure.

In order to create numerical models have been used the following materials, existing in AUTODYN library: AIR, CONCRETE-35MPA, CONCRETE-140MPA [6, 7]. The walls were modelled using CONCRETE-140MPA material and floor was modeled using CONCRETE-35MPA material.

Using Workbench, the structure was implemented in AUTODYN. It was defined an AIR volume (15000 mm × 15000 mm × 2000 mm), which enclose the structure of the building. The wall thickness is set to 400 mm. The structure of the building consists of 7 rooms (C1-C7), three of them having exterior.

Inside room C1 was set the charge of LPG-air, implemented as part of the 2D (Figure no. 2). The volume of the gaseous mixture is represented by a cylinder section with the 4250 mm radius and height 2000 mm. After making calculations resulted 113,49 m³ gaseous mixture. Knowing the high densities of butane and propane in liquid state, and their chosen participation % in LPG, it was calculated that 18,549 liters of LPG is needed to get the amount of 113,49 m³ explosive atmosphere.
Inside the rooms were disposed seven virtual transducers, six transducers to measure the overpressure in the direction of door arrangement (Gauge 1-6), and one (F) near window as presented in figure no. 3.

Liquefied petroleum gas is bottled in containers under pressure, which can exceed 80 litres, the chosen quantity being relatively easy to disseminate. To disseminate the gas throughout the entire building it has to be covered a volume of approximately 74 litres of LPG.

To be able to achieve an explosive atmosphere, the volumes of fuel and oxidizer must fall between explosivity limits, which is very difficult to control, since it has to be ensured also the homogeneity of the mixture. Thus, the
outdoor achievement of an explosive atmosphere is very difficult to obtain.

To form an explosive mixture it is necessary to disseminate it in a closed room and also the volume to be released must be between the percentages of participation corresponding to explosivity limits.

Below is shown the shock waves front evolution after 3.07 ms and 13.5 ms, to analyze the propagation mode, how they compose due to reflection from walls (Figure no. 4) and also the direction of movement of the front by using vectors.

Fig. no. 4 The evolution of the shock wave front after 3.07 ms and 13.5 ms

In the C1, C2, C4, C6 and C7 rooms, overpressures exceed 6 bars, which is the pressure value that causes 100% lethality [8]. Overpressures are much increased in the directions of doors and in areas where they were composed, due to reflections from walls.

In front of window were registered pressures in the bars, so if they had been equipped with double-glazed windows, these would have been broken producing secondary fragments.

In Figure no. 5 is presented the evolution of overpressures corresponding to each set virtual transducer, depending on time.
The virtual Gauge transducers 2 and 4 recorded values of 4 bars, respectively 2.15 bars, the values which won’t cause lethality, but people who are subject to such overpressure can suffer piercing of eardrums and trauma at head or internal organs, particularly to lungs [9].

The virtual transducer Gauge 1 recorded a pressure of more than 8 bars because was set in the direction of the door of the room C7.

From the overpressures analysis it has been concluded that to be able to inflict significant damage, the explosive atmosphere must be disseminated in a volume as larger as possible.

Mixture initiation must be made using a small amount of explosive so that the initiation energy to be big enough that explosive aerosol could enter detonation.

We can notice that the inside the explosive atmosphere, the overpressure is approximately constant, around the value of 19.5 bars. As a result of reflections with walls were formed higher overpressures. The LPG takes up a huge volume compared to a shattering classic explosive, basically the aerosol needs to be disseminated within an enclosed space to preserve its homogeneity.

3. Conclusions
To be able to achieve an explosive atmosphere, the volumes of fuel and oxidizer must fall between explosivity limits, which is very difficult to control, since it also has to be ensured the homogeneity of the mixture. The possibility of forming an outdoor explosive atmosphere is small due to the conditions to be fulfilled, the homogeneity being one of them.

To form an explosive mixture it is necessary for the gaseous mixture to be disseminated in a closed room, and the released volume to be between the percentages of participation corresponding to the explosivity limits.

Mixture initiation can be made by heat or by using an explosive, which confers a bigger energy. Considering the fact that it is quite difficult to achieve homogeneity of the mixture, it is recommended to use a small quantity of explosive to initiate the aerosol explosive.

To achieve an improvised explosive device using an explosive atmosphere, first must be rated the enclosure/building volume where it will be disseminated to, and in the container under pressure to preserve a gas quantity that will occupy a volume falling, mixed with air, between the limits of explosivity.

The damage incurred as a result of an explosive atmosphere detonation is mainly inside it, the gaseous mixture acting as an explosive with a much larger volume.
REFERENCES