POLITECNICO DI TORINO

Numerical analysis of blasting: Explosion modeling, FEM code validation and application in explosive metal forming.

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INTRODUCTION

Background. From the theoretical viewpoint, the explosion is an unexpected and aggressive emission of mechanical, chemical or nuclear energy, usually with production of high-temperature and high-pressure gases.Such gases spread in the surrounding environment as shock wave, which in the absence of obstacles, expands like a spherical surface centered in the explosion point. The blast wave is followed by a blast wind of negative pressure, which sucks items back in towards the center. Considering the variation of pressure in time, fixed a point in the space, it change with an exponential law achieving two load stage: the first one is positive duo to overpressure while the second one is negative duo to the depression caused by the explosion winds. (Figure 1)

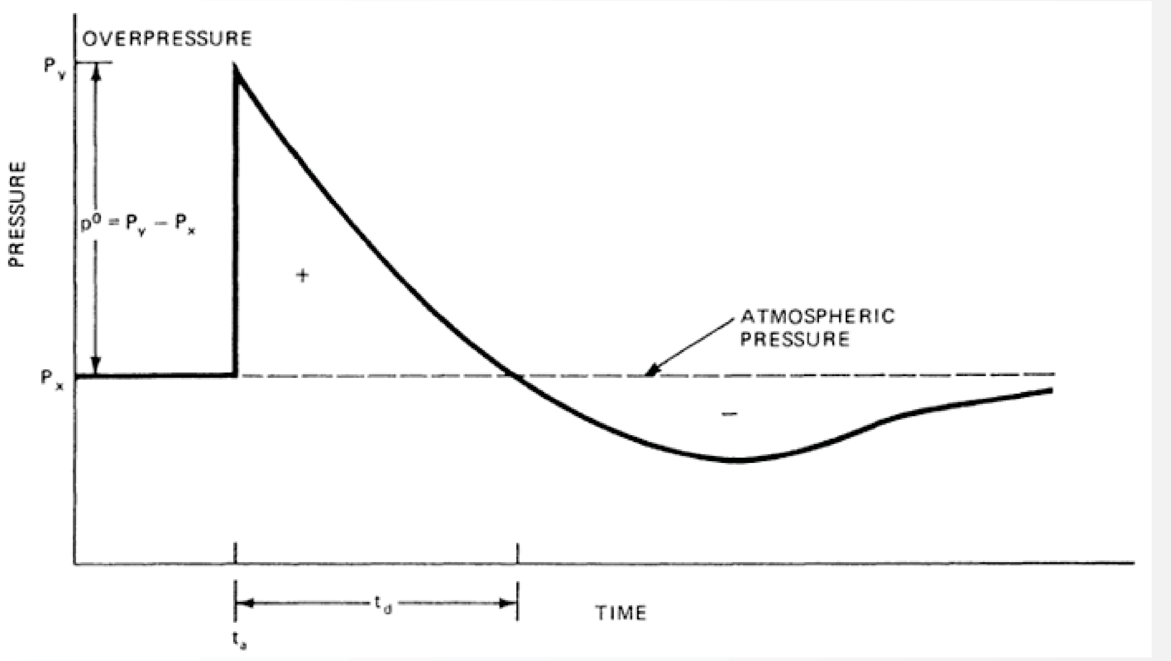


Figure 1: Typical trend of the overpressure

Aim of the study. Realization of a FEM model that describe the evolution of pressure and the behavior of the structures under the effects of dynamics loads with high intensity and short duration, which are those produced by the explosions.

NUMERICAL SIMULATION OF BLAST AND MODEL VALIDATION

LS-Dyna SIMULATION BLAST METHODS

A-Load Blast

This method is based on the CONWEP function and allows the user to simulate bursts using an analytical formulation which depends on the distance from the center of the burst and the amount of the explosive used. The algorithm is based on the equivalent TNT method, indeed, several kind of explosive can be simulated by using an equivalent amount of TNT and appropriate conversion factors. This method allows the simulation of different kind of bursts:

- *Hemispherical surface burst*
- *Spherical air burst*
- *Air burst with ground reflection*
- *Air burst moving non-spherical warhead*

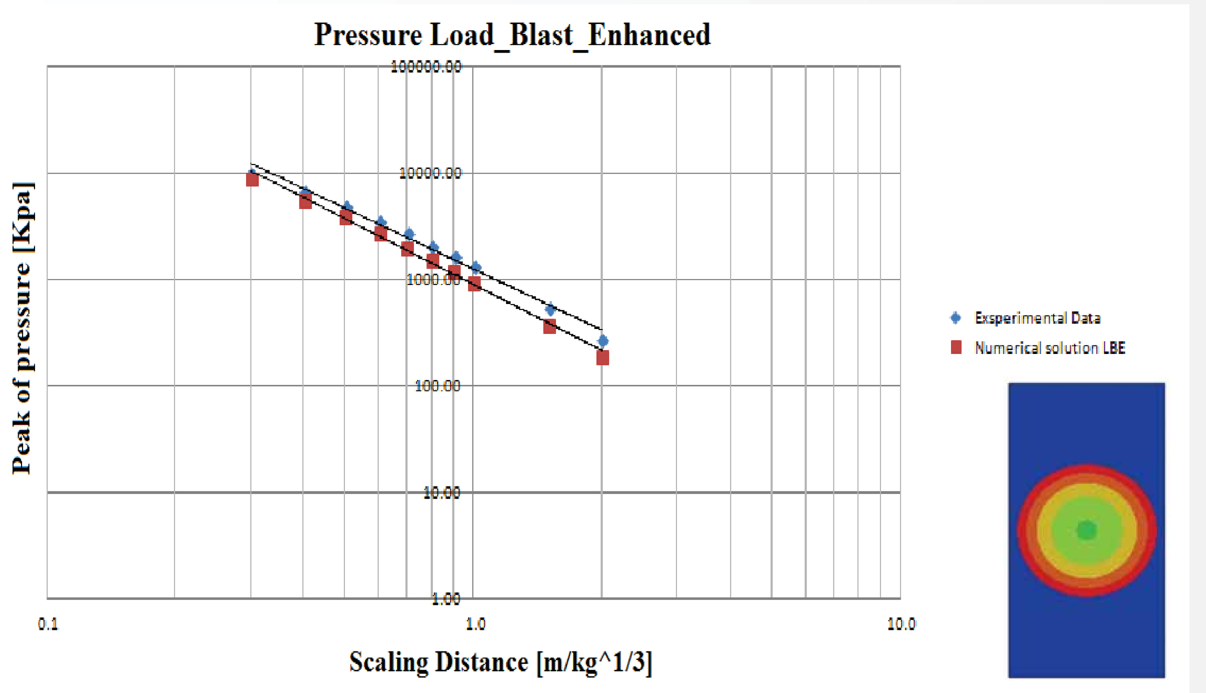


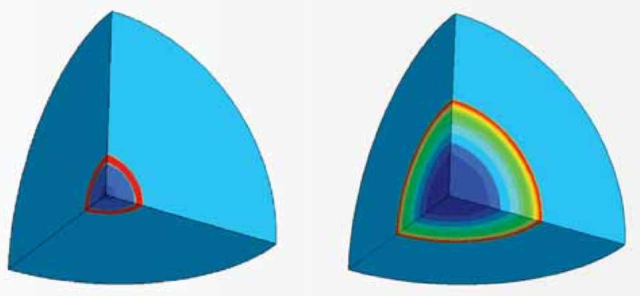
Figure 2: LBE overpressure valitation

The convenience of this method is its low computational cost, but it does not take into account the reflections due to possible presence of objects situated between the explosive charge and the target. The presented numeric method has been utilized for the simulation of a free-air-spherical-burst: the results have been validated by the comparison with experimental data taken from Kingery and Bulmash (Figure 2)

B-Multi material ALE (Arbitrary Lagrangian Eulerian)

The name of the method, *Multi-Material*, derives from the fact that different domains are involved, respectively for the modeling of the explosive and those of the shock wave propagation medium.

It is based on the numerical solution ALE in which one mesh is a *Lagrange-type-mesh* and the other one is an *Euler-type-mesh.* One domain is created for representing the shock wave propagation phenomenon and it is modeled according to the material of the burst event environment; the second material, which is the Lagrange-type one, is used for simulating the explosive domain. Both domains do have an assigned material which allows the modeling of the kind of explosive and those of the shock wave propagation space. Furthermore, a pressure propagation equation is used to characterize the shock wave propagation environment. This method is appropriate for simulating enclosed bursts, ground-level-bursts and free-air-spherical-bursts taking into account the interactions (the reflections) with secondary objects placed between the explosive charge and the simulation main object. The same free-air-spherical-burst simulation has been conducted using this technique and also in this case the results successfully validated the Load_Blast data-method (Figure 3)



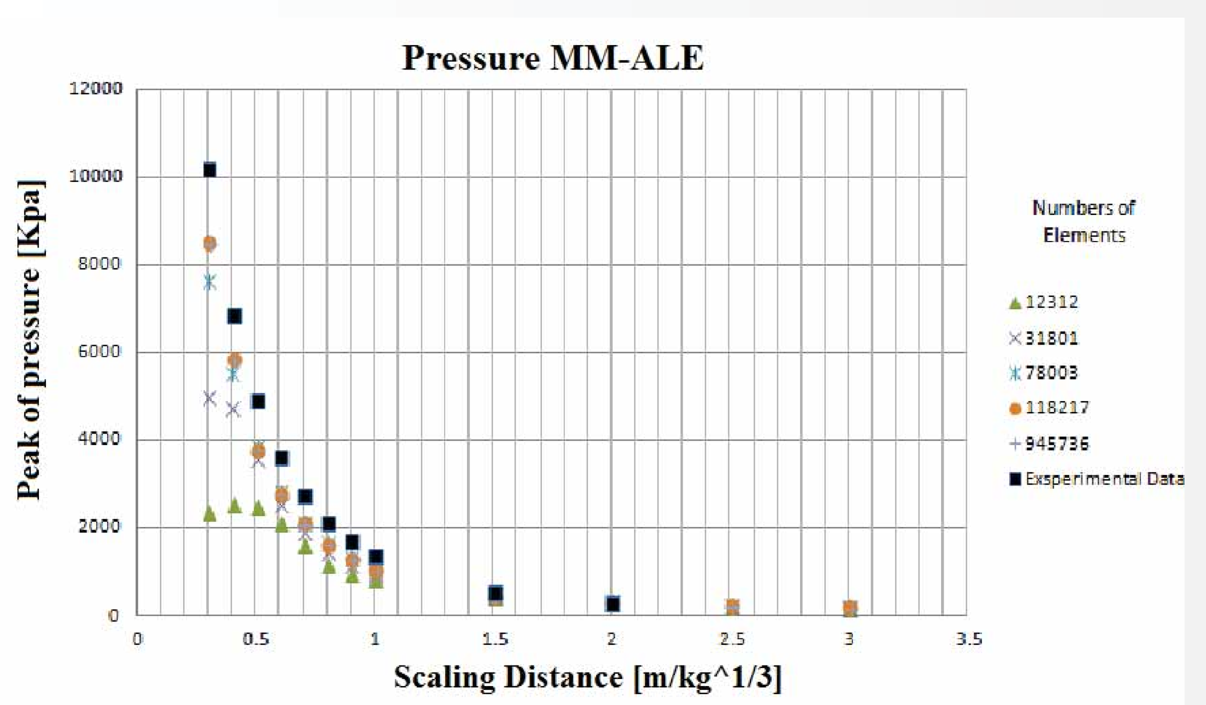
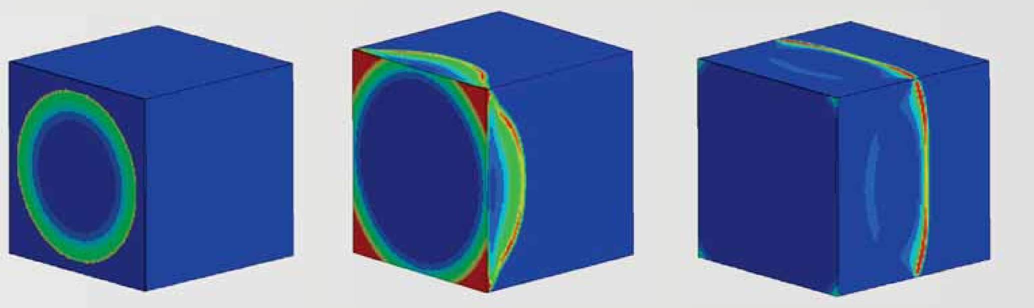


Figure 3: MM_ALE overpressure valitation

C-**Mixed Method LBE-ALE**

As a last validation test, a mixed method has been adopted. It has been developed by considering the two previously described simulation techniques: the *LBE* and *MM_ALE* methods. The idea is to simulate flat shock waves which derive from being at long distances from the detonation center. In this way the computation gets faster if compared to a pure ALE method simulation and this allows employing a smaller number of finite elements within the numeric method. In the domain which is not modeled by using finite elements, the shock wave is simulated with the LBE method, while for the modeled domain, the *ALE_MULTI_MATERIAL method* is employed. To simulate the air flow moved by the shock wave within the ALE domain, some *receptor* solid elements have been employed; they have the task of feeling the shock wave load which is computed by the LBE numeric method. At a later stage, they propagate within the rest of the air domain which, in turn, is also modeled with solid elements. The receptor elements and the air domain make up the *Multi-Material Domain* .The same free-air-spherical-burst simulation has been conducted using this technique and also in this case the results successfully validated the Load_Blast and ALE data-method (Figure 4)



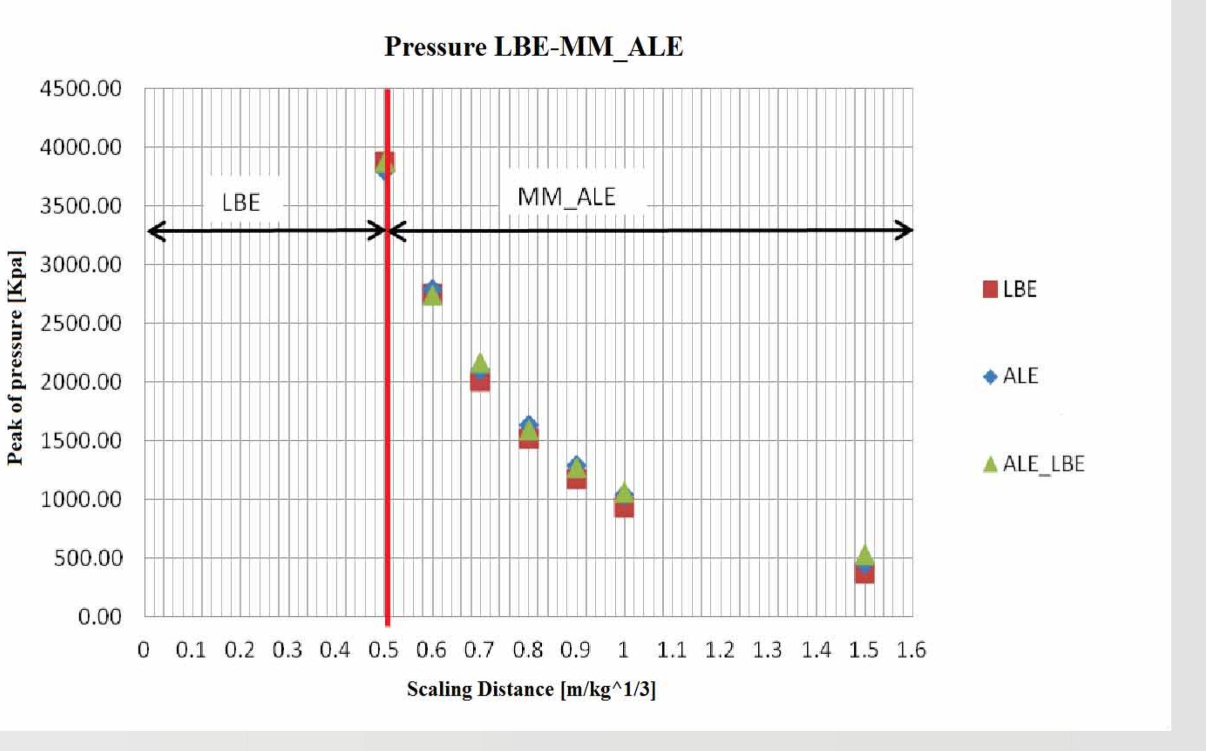
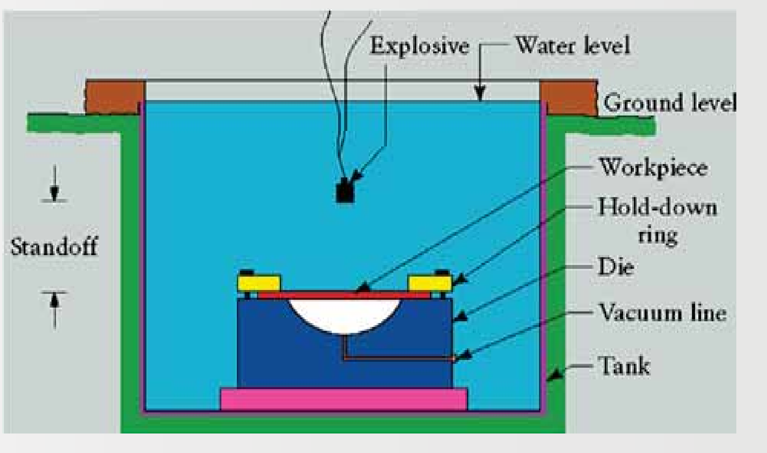


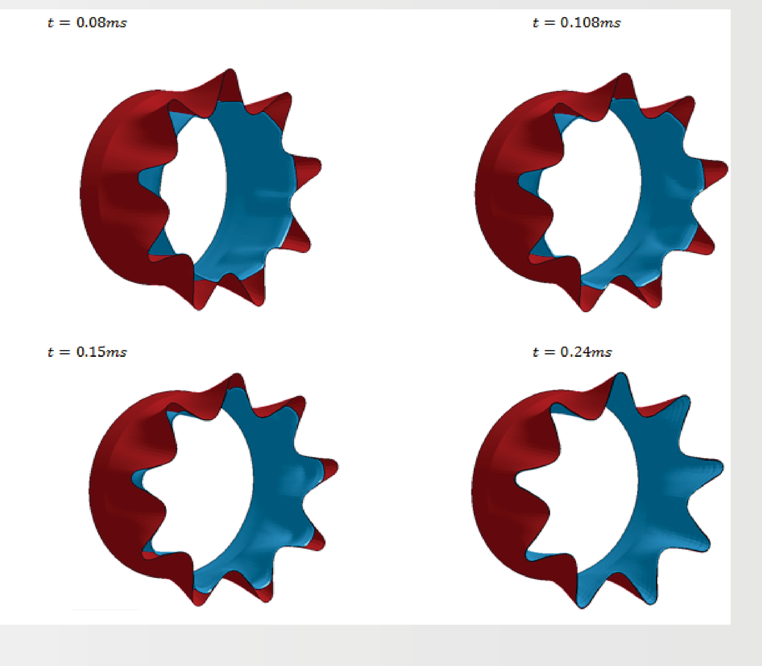
Figure 4: LBE-MM_ALE overpressure valitation

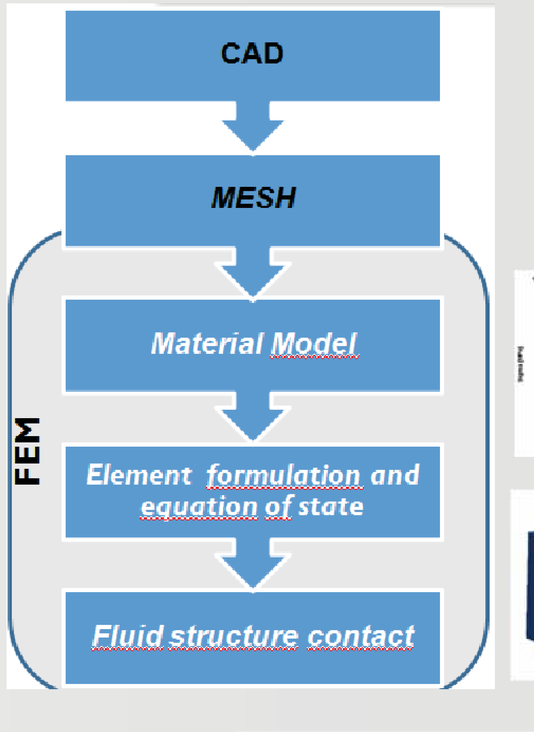
EXPLOSIVE METAL FORMING

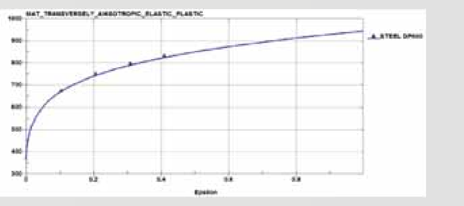
The explosive forming technique is a material processing method where a shock wave is generated by an explosion and propagated through a suitable pressure medium, such as water or air, and deforming a metal plate, tube, or other object. It provides very high straining of the material and also a suitable plastic deformation. The method tested is called shock bulge forming. The advantages of shock bulge forming are reduced spring back and a high strain rate material processing. The material processing at high strain rate leads to an extremely high deformability of the aluminium based alloys.

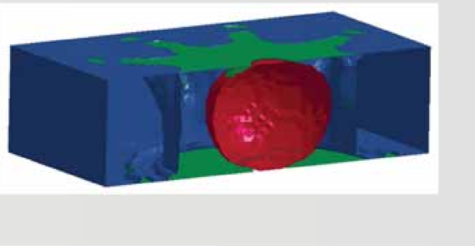
Forming of a gas mixer for gas turbine engines

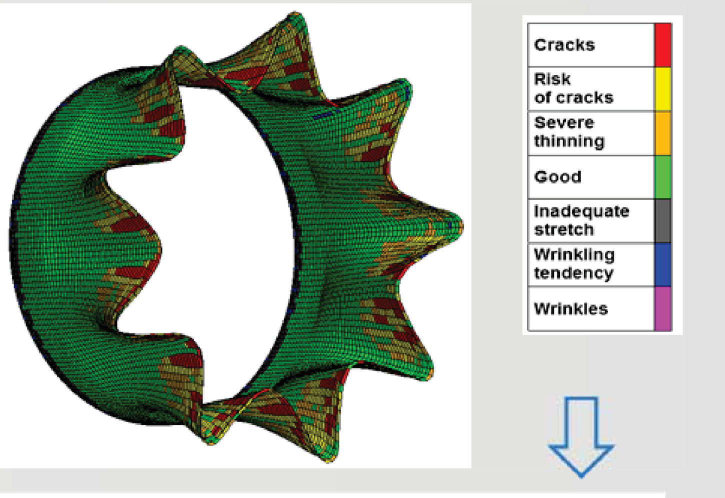












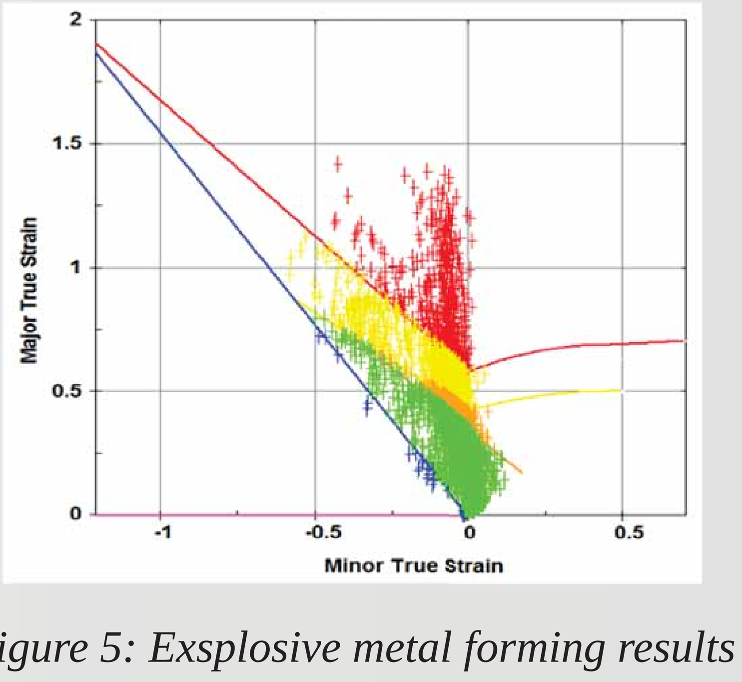


Figure 5: Exsplosive metal forming results

CONCLUSION

The graphics above show that numerical and experimental results have a good correspondence about an spherical charge explosion in air. With Explosive Metal Forming application, has been also simulated the fluid-structure interaction.

Currently industrial safety are imposing stricter laws about the explosions, therefore numerical simulation can be an important support in order to make safe the structures near high-danger detonation areas.