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Evaluation of overpressure prediction models for air blast above the triple point

L. Ehrhardt[a,*], J. Boutillier[a,b], P. Magnan[a], C. Deck[b], S. De Mezzo[a], R. Willinger[b], S. Cheinet[a]

[a] French-German Research Institute of Saint-Louis, 5 rue du Général Cassagnou, 68300 Saint-Louis, France
[b] Strasbourg University, Icube, UMR 7357 Multiscale Materials and Biomechanics, 2 rue Boussingault, 67000 Strasbourg, France

HIGHLIGHTS

- Original experimental data of blast above the triple point were obtained.
- The method of images features errors on the ground-reflected shock characteristics.
- LS-DYNA's LOAD_BLAST_ENHANCED function improves the predicted characteristics.
- The original fit reduces further those errors.
- A new parameter, the normalized angular distance to the triple point, is introduced.

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ABSTRACT

The increase of blast exposures leads to the need for better assessment of the blast threat. Empirical models describing the blast propagation in ideal conditions as free-field or surface detonations are commonly employed, but in some configurations the ground-reflected shock should be treated explicitly. Empirical models permit the prediction of the blast characteristics with the ground-reflected shock. The present study uses some original experimental data to evaluate the accuracy of the predicted overpressure with time regarding the reflected shock characteristics. Three methods are tested. The first method, called method of images (MOI) and linearly adding a virtual ground-symmetrical source blast to the free-field blast, is quick but lacks accuracy regarding the reflected shock characteristics. The second method, based on the LOAD_BLAST_ENHANCED function of the commercial LS-DYNA framework, better captures the reflected shock compared to the MOI, but the overall differences with experimental data are of the same order of magnitude as for the MOI. An original fit is introduced, based on standard physical parameters. The accuracy of this fit on the reflected shock characteristics, and the better match with the overall overpressure time series, shows its potential as a new empirical blast predicting tool.

1. Introduction

With the increase in number of blast exposures in the battlefield [1] the need for blast threat assessment tools arises. Such tools may be used to evaluate the risks for building integrity and personal security in a given blast scenario. To that purpose, the whole physical chain leading to final damages must be processed. This chain includes the detonation process and generation of the blast wave, the propagation of the blast, the interaction of the blast with the exposed target, and finally the damaging processes. The focus of the present contribution is on the second element of the chain, namely blast propagation, as it still raises major scientific challenges.

Numerical simulations with hydrocodes can be used to predict blast propagation, using either commercial softwares like LS-DYNA™ [2] or self-made models [3,4]. This brute-force approach allows to compute the full overpressure time series, and can account for the relevant, complex and non-linear processes at work. Its main drawback is the intensive computational effort necessary to carry out the explicit computation. For faster blast assessment, other strategies can be considered.

Another, empirical approach is the use of tabulated data, obtained after decades of experiments on blast propagation (e.g. Refs. [5–7]), which still undergoes developments [8]. The tables give the overpressure characteristics and the overpressure-time waveform is reconstructed by assuming that it follows the classical

* Corresponding author.
E-mail address: loic.ehrhardt@isl.eu (L. Ehrhardt).

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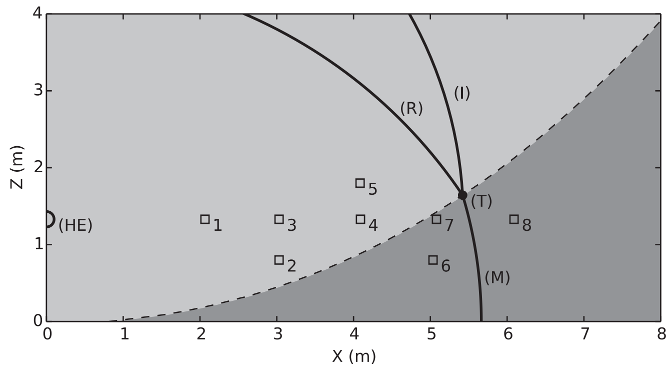

Fig. 1. Illustration of the blast ground reflection phenomena. (HE) is the high-explosive charge, (I) the incident shock, (R) the ground-reflected shock, (M) the Mach stem, and (T) the triple point. The light gray domain is the "simple reflection" regime, and the dark gray domain the "Mach reflection" regime. The border between the two regimes is the triple point path (dashed line). The positions of the sensor used in Section 3 are plotted in squares with the sensor number.

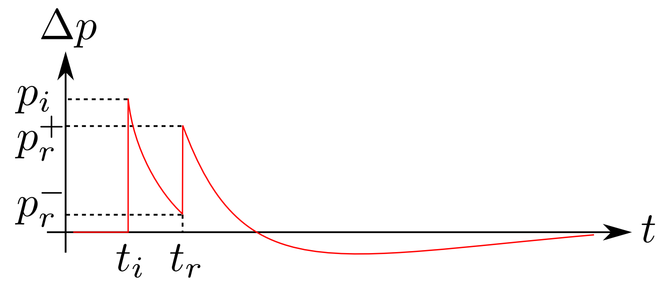

Fig. 2. Idealized overpressure-time curve and its characteristics for a spherical blast in the simple reflection regime.

Friedlander shape. This approach is for example used in the well-known ConWep software [9]. Tabulated data can be found in many references (e.g. Refs. [10,11]). The drawback of this approach is in the assumption on the waveform, which points to the restriction of matching the scenario of the tabulated configurations.

The available tabulated data have been mainly evaluated in three scenarios: spherical blast propagation in free-field, hemi-spherical blast propagation with ground (hemispherical charge located on the ground), and air blast propagation with ground (spherical charge above the ground). In the latter case, however, the blast propagation is more complex as there are two distinct regions where the overpressure-time curve strongly differs (see Fig. 1). The shock reflected by the ground ("R" in Fig. 1) travels faster than the non-reflected "incident" shock ("I"), as it propagates in hotter, previously shocked air. Close enough to the ground the two shocks merge, leading to the so-called "Mach" stem ("M") (see e.g., Refs. [12,13]), while high enough above the ground, the two shocks are distinct. The "triple point" ("T") is the intersection between the incident, reflected, and Mach shocks, and its path with time describes the separation between the "Mach reflection" and "simple reflection" regimes. In the standard tables, no Friedlander characteristics are provided for the simple reflection regime. This largely limits the blast propagation scenarios that can be addressed.

Some approaches exist for assessing the blast characteristics in the simple reflection regime, but they lack a well-documented, publicly available experimental evaluation. A reason may be that although some experimental data are available in the literature for blast above the triple point (e.g., in Refs. [2,14]), the volume of the public databases is not sufficient to perform a generic evaluation.

The purpose of the present study is to assess the performance of those approaches, on the basis of original, systematic experimental data, for spherical detonation above ground in the simple reflection regime. Besides two approaches proposed in the literature, an alternative fit will be introduced and evaluated.

The paper is composed as follows. Section 2 presents two standard approaches available in the literature. The experiments realized to evaluate these strategies are presented in Section 3. In Section 4, the experimental fit used to complete the evaluations is presented. Finally, the evaluations are realized and discussed in Section 5, and some conclusions and perspectives are given in Section 6.

2. Available empirical approaches

In the simple reflection regime, the overpressure-time waveform follows the shape depicted in Fig. 2 (see e.g., Ref. [12]). This idealized waveform can be characterized by the time of arrival of the first incident shock t_i, the overpressure just after this shock p_i, the time of arrival of the (second) reflected shock t_r, and the overpressures p_r^+ before and after this second shock, respectively p_r^- and p_r^+. The rates of pressure decay between those points must also be provided to fully describe the waveform.

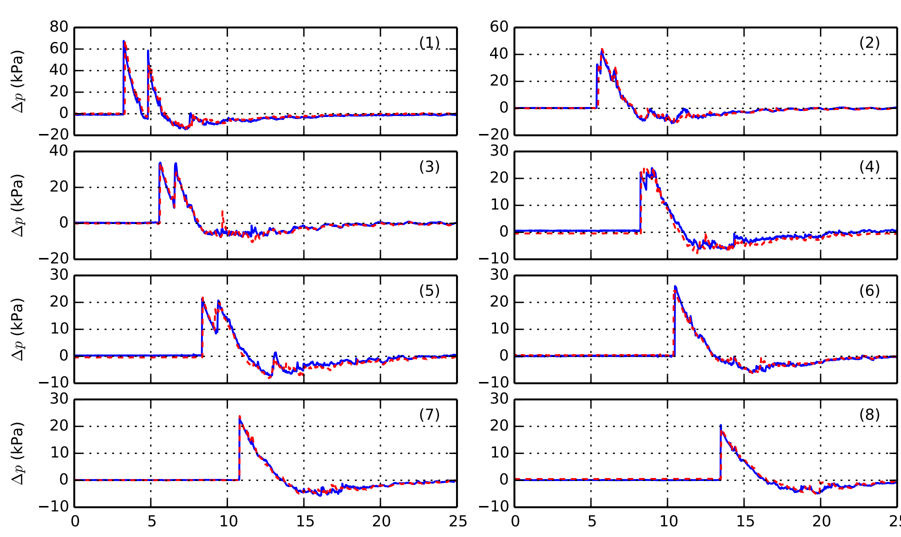

Fig. 3. Overpressure with time, for a 200 g charge at HoB = 66 cm. The top-right number indicates the sensor number. (–) 1st, and (- -) 2nd repetition.