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Design and commissioning of a semi-confined blast chamber

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Abstract

This paper presents the design, test and analysis of a scaled cylindrical blast chamber. The blast chamber is a one-fifth dimensional size replica of the full-scale blast chamber (Emily). The blast chamber is semi-confined as one end is open. The scaled blast chamber is used to test concepts for closing the open end and allows the gas to vent at the same time. ANSYS AUTODYN calculated the pressure time histories for different closure scenarios. Comparing the results suggested a viable scenario, namely a structure consisting of a circular disc and a frame positioned at the open end of the blast chamber. The structure and cylindrical blast chamber were subjected to scaled blast tests and the pressure results are presented and discussed.

Keywords: Confined blast; Similarity scaling; Impulse

1. Introduction

The CSIR has been involved in the field of blast research for some time in an effort to characterise and understand threats mainly to advise the SANDF [1]. The blast research at LS of the CSIR included characterisation of explosive charges in free air where high speed photography, pressure transducers and momentum sensors were used to characterise the dynamic parameters such as peak overpressure and impulse of the charges [2]. Data from this work enabled the researchers to characterise the output of different explosives and to evaluate their damage potential.

Researchers have recently been more interested in blast compositions with additives that enhance the overpressure, impulse and/or thermal output (see for example Trzciński et al. [3]). The reason for this interest is the increase in incidents of terror combined with improvised explosive devices and the need to understand the threat. As the open-air setups of the blast experiment cannot easily differentiate the full effect of the additives in explosives, testing in a more enclosed environment is needed according to Mostert and Du Toit [4]. In an open-air setup, Fig. 1 shows a typical overpressure time history of 6 kg spherical TNT charge captured at a 2 m standoff distance.

In order to evaluate the potential output of an explosive charge entirely it is necessary to evaluate its performance in varying confinement. Whereas an explosive such as TNT with a negative oxygen balance requires additional aerobic interaction to fully combust (so-called afterburning, due to mixing with the surrounding air), other explosive compositions contain additives that react proportional to the dynamic pressure and temperature in the aerobic phase. By introducing confinement near an explosive charge, the volume of by-product (fireball) expansion, and therefore the inherent pressure distribution and heat dissipation in the gasses, is dynamically changed.

For a characterisation of enhanced explosives, an open-air setup may prove difficult to quantify the effects of additives. Secondary reactions are more prominent when reflected waves re-compress the detonation products in a confined environment. Additionally a more confined environment offers retention of the detonation products within the reach of the sensors and hence a detectable reaction process between the additives and available air. An enclosed setup enables detailed quantifications of the enhancement of the blast parameters.

However, an enclosed environment adds complex features to the overpressure–time profile. The enhanced blast output and the reverberation of shock waves in the chamber complicate the characterisation and ranking of explosives in an enclosed environment. Evaluating conventional charges without any additives provides a baseline so that the expected behaviour of additives can be quantified.

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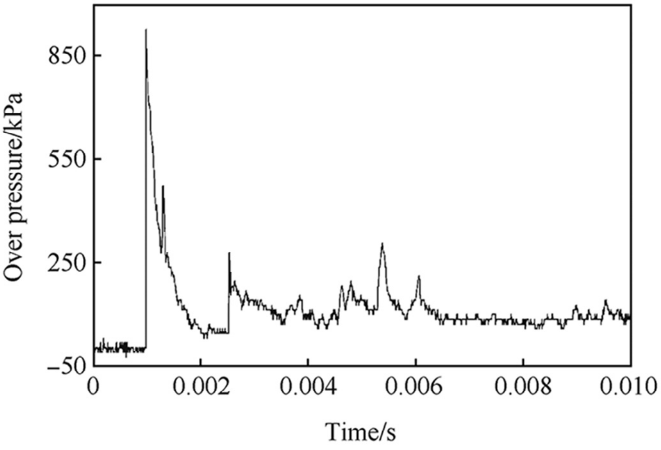

Fig. 1. TNT side-on overpressure time history at 2 m.

At the CSIR, earlier studies of enhanced explosives were conducted in a smaller confined environment, which implied the use of smaller charges. From these studies, it became apparent that the smaller size of the charges (<1 kg) limited the reaction of the additives within the explosives with the available volume of air [4]. The CSIR embarked on a programme to acquire a larger chamber that enables testing of up to 3 kg of explosive charges. With the support from ARMSCOR, CSIR acquired a section of the decommissioned Daphnè class submarine, Emily Hobhouse, transported it to the DBEL test facility. The semi-confined blast chamber consists of the section of the decommissioned submarine and a solid wall at one end while the other end is open. To commemorate the design, the blast chamber is named Emily.

Emily allows testing of charges in the mass range of 0.5–3.0 kg [5] and is approximately 6 m long with 5 m diameter (Fig. 2(a)). Emily has measurement ports for installing pressure sensors and momentum gauges. By comparing the overpressure and/or the impulse between different explosive charges, Emily supported the study of the effects of explosives with or without additives in a semi-confined environment. Fig. 2(b) shows the pendulum door that enhances the confinement of detonating charges.

While Emily allowed excellent analysis of the effect of explosives in semi-confined conditions, it does not allow the evaluation of the explosive output in full confinement [6]. The open side of Emily allows detonation products to escape from the reaction volume. In order to achieve an environment of higher confinement, researchers at LS have designed and tested a scaled model of a partially enclosed Emily called SEmily. The aim of the design was to evaluate the feasibility of a dynamically vented enclosed design of Emily without compromising the full-scale design during such an evaluation exercise. The confinement of the detonation products in Emily was only required to a maximum time of three milliseconds after detonation. The chamber is then allowed to vent.

SEmily is a 1:5 scaled blast chamber model of Emily with ports for mounting transducers and it is equipped with a door that acts as a pendulum during the blast to allow ventilations (Fig. 3(a)). The dimensions of SEmily are 1.2 m in length and 1 m in diameter. The door only covers 76% of the opening, which minimises damage of the chamber, while at the same time allowing extra confinement (Fig. 3(b)). The curved and back wall of SEmily consists of a 10 mm thick commercially graded mild steel. The pendulum door weighs 53 kg, also manufactured from commercially graded mild steel [7].

(a) Without the pendulum door

(b) With the pendulum door (side view)

Fig. 2. The blast chamber Emily.

This paper deals with the design and testing of the closure of the scaled model SEmily. The design considerations are discussed briefly in Section 2. Section 3 discusses the computational analysis and determines the closure, while at the same time allowing the door to swing in and out without touching the inside. The design and manufacturing is briefly discussed in Section 4. The next section discusses commissioning, additional experiments conducted with SEmily and a computational analysis with results that confirm the findings of the experiments. The scaled results compare favourably with the full-scale results as discussed in Section 6.