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Measurement of impulse from the close-in explosion of doped charges using a pendulum

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Abstract

This paper presents an investigation into the use of a pendulum device for evaluating the energy and hence the impulse transferred to structures from detonating doped and undoped high explosives at ranges of generally less than 0.5 m. For such close-in explosions, evaluating the load delivered by either computer modelling techniques or experiments involving the use of electronic pressure transducers may not be possible. This is because adequate mathematical representation of the events close to a detonating charge may not be available and the expense associated with the use of instrumentation that would be at risk of destruction or at least severe damage could be prohibitive.

In the study reported here, a robust pendulum was designed that could be used repeatedly to provide an evaluation of explosive charge output at close range. Once its effectiveness had been demonstrated with standard condensed high explosive charges, it was then used to study the effects of incorporating different materials in the explosive. The purpose of doping the charges in this way was to determine whether the system was capable of discriminating between different charge formulations and, if so, to assess how the additives used for doping affected explosive performance. It was found that doping with fine particles of either barium sulphate or copper oxide increased the amount of energy and impulse delivered to the pendulum from the charge. In contrast, however, doping with dolomite reduced the amount of energy and impulse transferred.

Keywords: Impulse; Close-in; Explosion; Pendulum

1. Introduction

1.1. Close-in explosions

There are several methods for predicting the loading produced by an explosive material detonating at some distance from a structure. These include empirical methods such as those available in the program ConWep [1]

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or numerical simulation using codes such as AUTODYN [2] or Air3d [3]. However, for charges detonated at very short range to a structure ('close-in explosions'), the methods noted above becomes less reliable.

Effects that make close-in explosive loading more difficult to assess include both the proximity of the structure limiting the atmospheric oxygen supply needed by some explosive materials for efficient detonation and the possible attendant alteration of the pressure within the fireball. Also, at short range, unconsumed explosive may be present in the atmosphere if the explosive does not detonate fully; this may occur with improvised devices. It may also be possible for a device to break up and cause explosive material to impact on a nearby structure before detonating. If there was inert material contained within the explosive, either deliberately or unintentionally, this could provide a source of primary fragments in the form of fine particles or small objects. All of these factors could influence the resultant loading and its effect on a proximate structure.

The presence of unconsumed explosive or the inclusion of other solid particles in the blast wave resulting from detonation will alter the method of energy transfer from the explosion to the structure. Instead of the blast wave being the only transport mechanism, there will be solid particles present that will also transfer energy and momentum. Thus, two apparently identical charges may not produce the same effect even under identical atmospheric and detonation conditions. Part of the work reported here was to assess how the inclusion of small particles altered the energy and momentum transfer from a close-in explosion to a structure.

1.2. Measurement systems for close-in explosions

Making physical measurements of pressure or impulse at short range from an explosion could place expensive instrumentation at high risk of severe damage or destruction. Historical evidence suggested that the solution to this problem lay in the design and construction of a device based on the principles of the pendulum. The first recorded used of a pendulum, for measuring the speed of a projectile, was in 1742. A device built by Benjamin Robins had, attached to the pendulum's swinging 'bob', a wooden target into which projectiles were fired to allow comparison of the performance of different gun and charge designs. Later in the same century, Rumford [4] modified Robins' design in order to carry out similar experiments. Known as an 'eprouvette', this system had both the target and the gun freely suspended. 'Ballistic pendulums' of this general form have been in continual use since and a number are currently employed for a range of impact and explosive loading studies. For example, Krauthammer [5] uses pendulums for simulating vehicle impacts, Nurick [6] has used small pendulums for explosive loading studies for a number of years and Bergeron and Tremblay [7] use a large pendulum for assessing the loading produced on vehicles by landmines.

For this study, therefore, a pendulum device was needed capable of operating effectively even after being subjected to repeated explosive loading and that would allow reliable measurement of the impulse transferred to it from a variety of charges at relatively small stand-off distances.

2. Pendulum systems design and performance

Two pendulums were designed and constructed for the Fortifications Section of the former Defence Evaluation and Research Agency, Chertsey (now part of QinetiQ, Farnborough). The first, Pendulum A, was installed at a range near Kirkcudbright, Scotland where the first part of the experimental programme was conducted and the second, Pendulum B (an improved version of Pendulum A), was installed at Shoeburyness in Essex where the second part of the programme was implemented.

Pendulum A, shown in Fig. 1a with a charge in place ready for detonation, was built as a frame using $200 \times 100 \times 16$ mm thick box sections to produce a structure that was 3.79 m high, 6.70 m long and 1.84 m wide. It was equipped with a bob which rotated around a static axle supported by the frame. Attached to the bob was a circular target plate 1000 mm in diameter and 30 mm thick whose centre was located 2 m from the axis of rotation. The target plate was designed to be removable to allow for repair or replacement as a result of any damage. Behind the target plate was a 1000 mm diameter, 50 mm thick support plate. With target plate and support plate in place, the bob had a mass of 1.43 tonnes. Over a tonne more could be added to this by attaching masses to the rear of the bob in the form of 10 mm thick square steel ballast plates (each of mass 38.5 kg to allow for ease of handling) supported on four bars equipped with threaded ends, which protruded