EVALUATING NUMERICAL APPROACHES IN EXPLOSION MODELLING USING A SURFACE-LAID MINE

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Abstract. Within the mine-blast research community, there is an increasing desire to enhance the efficiency and efficacy of mine-resistant vehicles, albeit in a cost-effective way. An approach that mirrors this requirement is presented in this paper. The explosion of an antitank mine is modelled and analysed by using the non-linear dynamics analysis software, AUTODYN. The initial simulation setup consisted of a hemispherical charge laid on a 'perfectly reflective' plane. Two equations of state for explosive products were studied, with the first one being the commonly used empirical equation of state, Jones-Wilkins-Lee (JWL). The second study applied the ideal gas equation of state, often used for simplification in complicated models. The mesh sensitivity study was carried out. Two parameters of blast waves, namely maximum pressure and specific impulse, are evaluated and compared with accessible experimental data obtained from CONWEP. Consequently, an explosion of a mine laid on sand was modelled using JWL EOS and blast parameters were compared with the previous model.

INTRODUCTION

It is estimated that up to 60 million mines lay strewn in some 70 countries all over the world. Approximately 26 000 civilians are killed or maimed every year in minefields [1]. The medical, psychosocial, environmental, and economic impacts inevitably scale up further tension and armed conflict in the affected areas. In mine-affected countries, scarcity of adequate medical services, safe water and food has led to dependency on the international community for humanitarian and development assistance. Mine contamination of infrastructure disrupts relief supplies from reaching their intended destination. Therefore, appropriate transport for successfully negotiating minefields must be developed in order to make international assistance more far-reaching and cost-effective.

In addition, the military aspect of the mine threat cannot be omitted in this domain. In World War II, 20% of tank casualties were attributed to mines. In Vietnam, US armour casualties attributed to mines increased to 70% and French forces lost about 85% of tanks in Indo-China [2]. In the more recent conflicts, US military losses attributed to landmines were 59% in Persian Gulf War and 60% in Somalia [3].

In recent years, some initiatives have been undertaken to study and understand mine blast and loading behaviour in order to enhance the design of vehicles used in mine-affected zones. This study is split into experimental and numerical approaches, whose results are often complementary to the others. The two approaches can be summarised in brief as follows:

Experimental activities. Experiments have been conducted to investigate the response of a vehicle subjected to a mine explosion in order to (i) analyse the gross motion and damage to the vehicle, (ii) to assess effects on occupants (iii) and to evaluate attenuation materials [3–6]. These experimental results have led to design proposals, such as deflector plates fitted under the wheel wells and fuel tank placed in the rear section. Experiments, studying explosion output, have shown that mine deployment and soil compositions have significant effect on the magnitude of vehicle loading. The most severe loading is obtained from explosion of mines buried in cohesive soil, such as clay [7–9].

Numerical simulations. The finite element method is widely used in defence related engineering analyses, such as high-velocity impact and penetration. In preliminary works, explosion was implemented in simulation using empirical formulae [10,11]. Recently, bespoke numerical procedures have been developed which allow the study of the explosion process from the initiation of explosive charge [12–14].

In conventional use, a mine is generally laid above, flush with, or buried in soil (commonly categorised between sand and clay). Upon initiation, the detonation wave propagates through the explosive material, generating high pressures and temperature in the detonation products. These products expand violently, forcing the surrounding material (soil and air) out of the occupied volume and create a pressure shock-wave propagating through the surrounding material in all directions from the charge. As soil is pressed out forming ejecta, the detonation products break through the surface. Soil gains kinetic energy and moves upwards. After impinging on the target, soil falls back and forms the apparent crater surface.

It is to be noted that the detonation products expand to a scaled radius of about 0.8 m.kg$^{-1/3}$ [15], where scaled distance is defined as $Z=R/W^{1/3}$, R [m] is the distance from charge centre and W [kg] is the TNT equivalent charge mass. The whole of the compressive wave propagates in air beyond a scaled radius of 1.6 m.kg$^{-1/3}$. Hence analyses focusing up to this region must take into account both the explosive products and air.

This paper reports on the initial analysis of a mine explosion phenomenon using the latter approach. An explosion of an anti-tank mine laid on the ground surface was analysed using commercially available software AUTODYN to evaluate the feasibility of an equation of state for explosive products and optimum cell size.

The remainder of the paper is organized as follows. The next section covers the rudiments of explosion process modelling in some detail. Subsequent sections discuss the simulation framework proposed and the numerical results obtained from the simulation runs. The paper concludes with discussion of results.

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