

SIMULATION OF PLATE STRUCTURE SUBJECTED TO ANTI-TANK MINE BLAST

Adisak Showichen,¹ Amer Hameed, Michael J. Iremonger, and John G. Hetherington

Abstract: A brief literature review of anti-tank mines and relevant theories is described in this paper. A numerical simulation of a single plate subjected to blast loading in the air, was developed using LS-DYNA and compared with the available experimental results. There appeared to be good correlation between the two, considering that there were many variables that could influence the results. Double-plate structure simulations with an air-filled gap subjected to mine blast were then developed. The experimental and numerical simulation results have shown that using air between the two plates has little influence on either plate (in this work, air is not restrained). The bottom plate deforms mainly due to the impact of the top plate, which deforms more than the gap between the two plates. The simulation without air may then be used as a cheaper alternative. In addition, the numerical results, using CONWEP loading, seemed to be comparable with the experimental results. This analysis has provided skills necessary for future study into the development of numerical simulations in LS-DYNA, which will be crucial for modelling more complex structures.

INTRODUCTION

It is believed that one of the most dangerous weapons in the world during the 20th century was the landmine because of its versatility and cost-effectiveness. In 1994, in a report by the US Department of State, it was estimated that there were around 60 million buried landmines around the world [2]. Buried landmines can remain active for more than 50 years after being laid [3]. Since 1975, landmines have killed or injured more than one million people [4]. The estimated number of landmines and unexploded ordnance (UXO) casualties of both military and civilian personnel is between 15 000 and 20 000 per year [5]. It was estimated that 20% of tank losses in World War II were from mines [6] and 70% in the Vietnam War [7]. Landmines can also cause disruptions to the logistic supply routes, which will prevent or delay the advance of the military on the ground. A single mine costs as little as £2 but the damage caused by a mine, could cost thousands of pounds to repair the structural damages [8]. Apart from direct costs, these mines can cause other impacts, such as to medical and environmental resources, and so on.

A mine is defined as an explosive material, normally encased, designed to (i) destroy, damage or disable vehicles, boats and aircraft, or (ii) designed to wound, kill, or otherwise incapacitate personnel [1]. It may be detonated by the action of its target, the passage of time or by controlled means. Anti-tank (AT) mines are typically larger and contain several times more explosive material than anti-personnel (AP) mines—the typical amount of explosive contained in AP blast mines is 0.003–0.25 kg, while in AT blast mines is 1.5–10 kg [1]. Hence AT mines are the most likely cause of damage to vehicles and their occupants, in comparison with AP mines. It is estimated that around 80% of the mines likely to be encountered are blast mines [9]. This paper therefore only concentrates on the effect of mine blast.

Nowadays, some UN peacekeeping forces and other humanitarian agencies are working in the vicinity of anti-vehicle mines: it is therefore very important to ensure the safety of vehicle crews. New improved protection vehicles being researched, will undoubtedly involve experimental tests, which are usually very expensive and time consuming. Numerical analysis is being introduced to reduce the number of experimental tests required and hence it could provide a more economical method of development.

The vehicle structure used in mine-blast experiments and numerical simulations may range from a simple plate structure to a real vehicle. Results from the experiments are normally classified and subsequently there is limited literature available in this area. Moreover, experiments are cost-prohibitive and previous experimental results are difficult to find and correlate because some of the parameters affecting the results might not have been well-defined. Often a simple structure such as a mild-steel plate is used for testing and validation of numerical simulation. The present work reports on the development of numerical simulation relating to damage assessment of a plate subjected to mine blast. In order to validate the model the relevant experimental results are taken from Boyd [16].

The preliminary model was based on a simple plate subjected to an exploding charge in the air. The simulation was developed in LS-DYNA software LS DYN4 [21]. The modelling of the blast was implemented using blast-modelling software CONWEP [10], which is an empirically based loading model within LS-DYNA. The CONWEP blast model was developed based on Kingery and Bulmash [11] and Technical Manual TM5-855-1 [12]. The blast loading model was implemented based on the report by Randers-Pearson and Bannister [13] to reduce the process of explicitly simulating the progress of the shock wave from the high explosive through the air and its interaction with the structure. It should be noted that the loading model does not take into account any confinement or tunnel effects and should not be used for analysing such problems. The CONWEP code in LS-DYNA can be used in two cases: the first one being in the free air detonation of a spherical charge and the second case in the surface detonation of a hemispherical charge. The surface detonation is the preferred option in the case of mines buried 5–20 cm deep. However, it should be noted that in reality the depth of the burial has a significant effect on the energy released from the explosive through the ground and onto the target. Other variables such as moisture content and soil type can also affect how the energy is transferred to the structure. Those below-ground effects are not included in the CONWEP blast model.

TNT EQUIVALENT

In LS-DYNA, the keyword *LOAD_BLAST needs an input of TNT explosive charge. If the charge used is not TNT then

¹ Engineering Systems Department, Cranfield University, The Royal Military College of Science, Shrivenham, Swindon, SN6 8LA, United Kingdom.