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Influence of Boundary Conditions on Ceramic/Metal Plates under Ballistic Loads

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Abstract

Ceramic/metal plate is one of the most widely used light weight armors, especially to protect armor piercing (AP) bullet. Experimental investigation of projectile penetration mechanism into the ceramic/metal plate requires costly sensitive equipment to capture impact phenomenon that completes within microseconds. Alternatively, the impact mechanism can be efficiently investigated using numerical simulations. Among recent investigations on the protective capability of this ceramic/metal plates, few only discussed the influence of the boundary effects on the ballistic protection. This study thus aims to examine the effect of boundary conditions by changing shapes of the plate, border constraints and bounded materials in numerical simulation. Material models of the ceramic and the backing metal plate made of aluminium 2017-T6 are selected. The 7.62 AP projectile's core was modeled by a solid cylinder. The initial projectile velocity was 940 m/s. The plates are represented by either a square or a hexagonal tile. The edges of the plates were fixed or enclosed by a soft epoxy. To investigate the effect of backing plate, a small gap was introduced between some of the ceramic and aluminum interfaces. The results showed that the hexagonal tiles reduce the deformation of the backing plate. The plates bounded by the epoxy exhibit inferior performances compared to the fixed plates. Finally, the small gap between the ceramic and the aluminum interfaces significantly increases the time to stop the projectile.

Keywords: Ceramic armor; Boundary condition; Impact behavior.

1. Introduction

One classical armor material is monolithic steel i.e. Rolled Homogeneous Armor (RHA). This material disperses the impact energy from projectile through its plastic deformation. The limitations of steel armors are their high density, maximum deformation and low protection against Armor-piercing (AP) bullet. For these reasons, composite armors have been developed. Ceramic/metal is one of the widely used composite armor materials. Ceramic/metal armor has less areal density compared with the monolithic steel. As a result of increasing capability of payload and vehicle maneuverability, the armor vehicle performance is improved. Besides, the hardness of ceramic face help to erode the AP projectile head, reduce its stability and slow down the projectile speed. The penetration efficiency of the blunted AP projectile was also reduced because the energy disperse to the backing plate on larger area. With the same amount of energy, plastic deformation of backing plate hit by blunted projectile has small depth compared with that of the sharp one which decreases damages behind the backing plate.

Failure of ceramic tile under the high velocity impact is caused by the stress wave in the material. When the projectile hits the ceramic face, the shock wave, which is compressive wave, will transfer from the ceramic front surface to its back. At the connecting surface between the ceramic and the backing plate, some of the shock wave will continue moving into the steel and the remaining shock wave will reflect back to the ceramic. This wave reflection creates tensile wave in the material. Since brittle materials have low tensile strength, the ceramic starts to crack under the tensile wave.

The crack from this impact has conical shape which is called conoid. The dimensions of the conoid have been widely studied because the radius of the cone base has an effect on the energy dispersion from the ceramic to the backing plate.

The ballistic performance of the ceramic protection depends on various parameters. P.J. Hazell et al. [1] found that increasing the density of the ceramic compact for given thickness yields better result in ballistic resistance than increasing the thickness of a given density.

