DAMAGE OF CERAMIC ARMOURS SUBJECTED TO HIGH VELOCITY IMPACT BY STEEL SPHERES

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Abstract. Two grades of armour ceramic have been subjected to high velocity impact by small steel spheres. The depth of penetration, crack formation and the extent of comminution have been characterised. In particular the formation of the Hertzian-type conical fractures has been analysed and compared with other experimental results. A ranking method has been employed to calculate the relative mass advantage of using a ceramic over an aluminium material. It is found that, for this experimental programme, using a harder alumina of lower fracture toughness provides better protection than that given by a softer, tougher grade. However, the advantage of using this ceramic diminishes as the impact velocity is increased. This paper will be interest to the armourer who is concerned with high explosive fragmenting ammunition.

INTRODUCTION

Ever since the 1960's, ceramics have been well known for their ability to stop high velocity projectiles. Their high compressive strength, high hardness and comparatively low density make them ideal candidates to form part of a lightweight armour system. Today, ceramics are used in many types of armour systems ranging from the personal protection of troops to appliqué armour systems for Main Battle Tanks, all of which are subjected to a wide variety of threats. One example of such a threat is Armour Piercing Fragmenting Ammunition, such as that which can be found in various mines and grenades. These weapons explosively propel small fragments or pre-formed steel or tungsten spheres at high velocity that can cause extensive damage to lightweight armour systems.

This paper examines the effect of such a threat on ceramic armours. The damage caused by firing steel spheres in the velocity range 0.8-2.2 kms^{-1} into two grades of ceramic is characterised. The depth of penetration, size of the crater and the extent of fracture are analysed.

EXPERIMENTAL TECHNIQUE

To obtain velocities within the range 0.8-2.2kms^{-1}, two different methods of firing were used. For the lower velocities of impact, a sabotted steel sphere was fired from a 7.62mm proof barrel. A single stage of a two-stage light gas gun was used to attain higher velocities. In all cases the projectile was a 6.35mm diameter steel (SAE 52100) sphere, nominally weighing one gramme. The ceramics used in this experimental programme were Morgan Matroc Sintox-FA and Sintox-CL (Alumina).

The material properties [1] of the aluminas are stated in Table 1.

Alumina	Purity (%)	Grain Size (μm)	ρ (kg/m^3)	Hv 2.5	E (Gpa)
Sintox-FA	95	5	3694	1250	308
Sintox-CL	98	3	3840	1640	382

Table 1. Alumina material properties.

A number of experimental firings were also carried out into thick Aluminium Blocks (ASME 6082 T6) to provide a baseline for the penetration results. In each case, the level of confinement was the same. The ceramic blocks and the Aluminium were confined within a steel jig and clamped to a steady surface. In all cases, the targets were considerably thicker than the penetration depths. The impact side surface dimensions was kept constant between targets (100×100mm).

After impact, the ceramic samples were cut using a slow diamond saw and examined using both an optical and a scanning electron microscope (SEM).

RESULTS

All targets exhibited qualitatively similar cracking patterns; however, the density and the orientation of the cracks varied with impact velocity.

The first damage area of interest is directly below the impact crater. This area is identified as the 'residual comminuted zone' [2]. Using an optical microscope at ×40 magnification the structure of the comminuted zone was compared with an area of unaffected ceramic. Under the optical microscope the structure of the comminuted zone contains many inter-granular cracks, compared with that of the remainder of the target block. Figure 1 shows the extent of micro-fracture close to the impact surface in comparison to material further away.

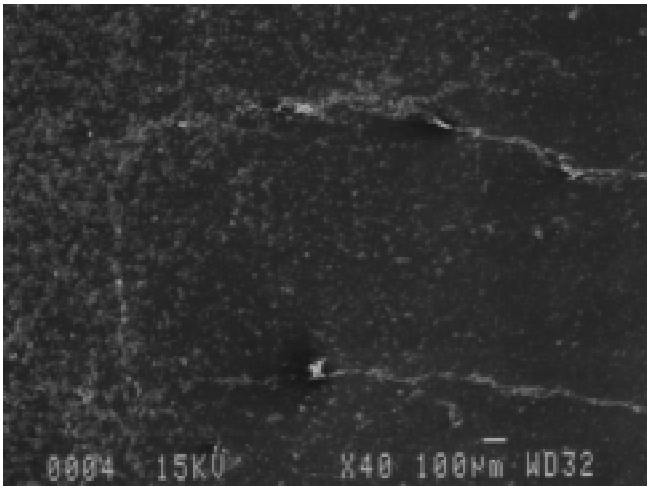

Figure 1. Comparison between Comminuted and Non-Comminuted Material (Comminuted to the left).

The same sample was also scrutinised using a scanning electron microscope, under which the individual grains could be observed. The structure of the non-comminuted zone was fairly uniform, with only a little porosity and macroscopic cracking. In the comminuted zone the