THE EFFECT OF CERAMIC TYPE ON THE PERFORMANCE OF CERAMIC-FACED METALLIC ARMOUR

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Abstract. Depth-of-penetration tests are used to compare a number of different ceramic types when impacted by tungsten and tungsten-carbide-cored ammunition. These results are then compared to ballistic limit test results on commercial armour systems incorporating the same set of ceramic materials and using high-hardness steel or aramid composite backings. The depth of penetration test are shown to broadly predict the performance of the ceramics when subsequently used in practical armour systems although penetrator erosion is also shown to be a significant factor which needs to be taken into account.

INTRODUCTION

There is an increasing demand for armour on previously un-armoured vehicles and increased armour protection on light armoured vehicles. Most in-service light armoured vehicles use rolled homogeneous steel armour, high-hardness steel or aluminium alloys to protect against artillery fragments and soft-cored ammunition from light weapons. More recent requirements often include protection against hard-cored projectiles and larger-calibre weapons

Increasing the protection level of such systems can follow a number of approaches; typically these are appliqué armour packs of steel, ceramic-faced composite, or complex armour. These may be used in combination with spall liners within the vehicle. Appliqué systems can be stand-alone armour systems or they can rely upon the base armour as an integral part of the protection solution.

A number of studies have shown that ballistic performance of ceramic-faced armour scales to some extent with hardness of the ceramic. It has also been shown that the ceramic must have a hardness that is significantly greater than that of the projectile [1]. For steel-based projectiles, which are common in light armour-piercing ammunition, alumina-faced armour has sufficient hardness to achieve adequate performance. However tungsten-carbide-cored ammunition has a hardness level equal to or greater than some alumina compositions [2]. Therefore, where such hard-cored projectiles are a threat there is a need to choose the correct ceramic material.

This paper describes the characteristics of an integrated armour system consisting of ceramic tiles bonded to a high-hardness steel armour. The selection process for ceramic type is described and the system is compared to similar composite-backed systems.

CERAMIC TYPE

Three ceramic materials were tested: a 95% alumina, a 98% alumina and a reaction-sintered silicon carbide. The basic properties are given in Table 1. It should be noted that a proprietary reaction-sintering route was used to produce the silicon carbide. This represents a simpler and potentially cheaper production method than conventional hot-pressed silicon carbide, but produces a slightly lower strength and hardness.

BALLISTIC TESTS

The depth-of-penetration (DoP) technique as described by Anderson [3] was used to measure the performance of the armour materials. In this method a test projectile is fired into a block of metal of density ρ_B and the depth of penetration P_B is recorded. A ceramic tile of thickness t_C and density ρ_C is then placed against a similar block and the residual depth of penetration P_R of a similar projectile is recorded. From these measurements it is possible to derive a number of indices of ceramic performance. In this work the following indices have been used: the mass efficiency factor (*MEF*), and the calculated critical ceramic tile thickness (t_{crit}) to just defeat the projectile.

$$MEF = \frac{P_B \rho_B}{\rho_C t_C + P_R \rho_B} \qquad (1)$$

$$t_{crit} = \frac{t_C P_B}{(P_B - P_R)} \qquad (2)$$

The backing block was an aluminium 7039 alloy having a hardness of HV 120. The ballistic tests used two types of ammunition: 7.62×51mm AP FFV and 0.50” Saboted Light Armour Piercing (SLAP). Salient details of these rounds are given in Table 2.

Material /property	95% Alumina	98% Alumina	Silicon Carbide
Manufacturer/grade	Morgan Matroc Ltd Alumina Grade FA	Morgan Matroc Ltd Alumina Grade CL	Advanced Materials Enterprises PTY
Density (g/cc)	3.7	3.84	3.18
Hardness (HV_{30})	1100	1500	1900
Fracture toughness ($MPam^{-1/2}$)	4.6	3.5	3.0

Table 1. Mechanical properties of armour ceramics.

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