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MODELLING ASSESSMENT OF CERAMIC/COMPOSITE ARMOUR UNDER BALLISTIC IMPACT

Djalel Eddine Tria(*), Ballout Ali, Harouche Karim
Laboratoire Génie des Matériaux, Ecole Militaire Polytechnique, Alger, Algeria
(*)*Email:* djaleleddine.tria@gmail.com

ABSTRACT

The design of new composite layered personal armour requires both numerical modelling and experimental validation in order to balance between requirements posed by weight, cost and effectiveness. To develop lightweight solutions, ceramic and composite materials were used to defeat small arms ammunition. In this study, the ceramic material, which is the front plate, has been made of Alumina Al_2O_3-98, Al_2O_3-99.7 or Boron Carbide B_4C, and composite back-up plate were composed of Kevlar reinforced. We used a finite element analyses with constitutive relations implemented in LS-DYNA to simulate the impact tests with real ammunition. Johnson Holmquist (JH2) and pseudo-geological model were used for ceramic tiles, while Chang-Chang failure model was used for composite plates. Experimental work involving impact tests on ceramic-composite at 830 m/s using 7.62X51 mm bullet. The Back Face Signature (BFS) was measured and cracking damage in recovered ceramic plates was characterized. The obtained results provided real data for the assessment of material parameters and the accuracy of the developed finite element model. The simulations successfully matched details of the cracking patterns and revealed the damage evolution in the ceramic tiles. Also, the B_4C wasn't found only to provide the lowest trauma effect, but also the lightest structure in comparison to Al_2O_3 -98 and Al_2O_3-99.7.

Keywords: terminal ballistics, ceramic fracture, composite impact, finite elements.

INTRODUCTION

The non-metallic materials, such as ceramics and composites, have been increasingly incorporated into more efficient lightweight armour (Ong, 2011), (Tria, 2017). When a projectile impact onto ceramic/composite, the projectile is first eroded or flatted by the hard ceramic and the reflected tensile wave breaks the ceramic in tension. The backing composite layer deforms to absorb the remaining kinetic energy of the projectile (Feli, 2011), (Forquin, 2015).

The objective of this study is the development of a 3D finite element model for the simulation of ceramic-composite armour when it is subjected to FMJ bullet at the ordnance velocity. The cracking damage of ceramic tiles, failure based on fibre fracture, matrix cracking and delamination of composite materials, and erosion of FMJ bullet during perforation have been considered.

RESULTS AND CONCLUSIONS

When the projectile impacts the ceramic front plates made of Al_2O_3, a fragmented ceramic conoid breaks from ceramic tile (see Fig.1). Also, cracks were propagated until the free plate edges. However, the ceramic conoid wasn't seen in B_4C tiles with a narrow cracked zone in comparison to Alumina tiles. Also, the smaller BFS was obtained by the use of tiles made of B_4C (see Fig.2).

Fig.1 - Front side of damaged Al_2O_3-98 ceramics

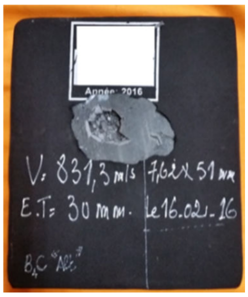

Fig. 2 - Front side of damaged B_4C ceramics

Fig. 3 - BFS measurement on plastilina

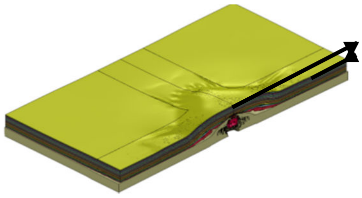

Fig.4.- Penetration of the bullet in the armour

The FE simulations (Fig.4. 5 and 6) successfully matched details of the cracking patterns and revealed the damage evolution in the ceramic plates. Also, composite delamination was predicted and the obtained BFS was in correspondence to the measured BFS. From the computed bullet residual velocity, B_4C tiles showed the highest kinetic energy absorption level, which justifies the lowest trauma effect.

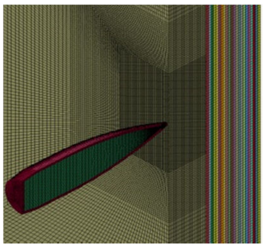

Fig. 5 - Initial meshing of 7.62X51 mm bullet and ceramic-composite armour

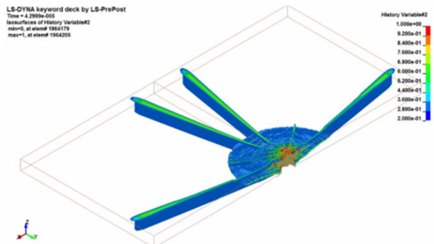

Fig. 6 - Cracking patterns and damage evolution in the ceramic plates made of Alumina.

REFERENCES

[1]-Ong C.W, Boey C.W, Robert S, Jose O. Advanced layered personal armour. International Journal of Impact Engineering 38 (2011) 369-383.

[2]-Tria D.E., Trębiński R. Methodology for experimental verification of steel armour impact modelling. International Journal of Impact Engineering 100 (2017) 102-116.

[3]-Feli S, Asgari M.R. Finite element simulation of ceramic/composite armour under ballistic impact. Composites: Part B 42 (2011) 771-780.

[4]-Forquin P. Barthélémy J, Zinszner L, Erzar B. On the characterisation of the dynamic compressive behaviour of silicon carbides subjected to isentropic compression experiments. EPJ Web of Conferences 94, 01072 (2015).