Numerical analysis of a new combat helmet design against ballistic impact.

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Introduction

The use of these materials in combat helmets, body protections and combat vehicles requires an exhaustive analysis of their behaviour in order to satisfy the safety requirements. Personal protections are usually based on fibre reinforced polymer composites, especially Kevlar fibres. The helmet's protective capabilities are commonly evaluated in terms of two parameters: the impact velocity (in general V50 velocity) and the back face deformation (BFD). In this paper, a numerical finite element model was developed in order to predict the response of a combat helmet subjected to ballistic impact.

Objectives

- Development a numerical finite element model able to determine the response of a new combat helmet subjected to ballistic impact.
- Predicted results for the designed helmet under ballistic impact was compared with real impact tests showing the accuracy of the model and its ability to be used as an optimizing design tool.

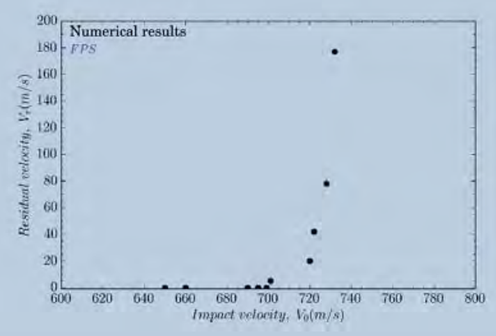
Numerical Model

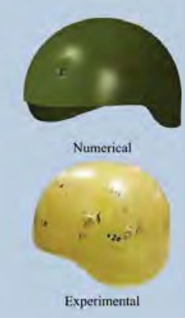
The combat helmet was modeled including the considering both the composite shell and the inner protective foams. Also the headform and the clay used in the experiments were reproduced in the model.
The combat helmet shell analyzed in this work has been recently developed by the company FECSA and the density areal is low, $8.86 kg/m^2$. The mechanical behaviour was described in [1, 2].

Projectiles used was 9 mm full-metal jacketed (FMJ) bullet weighing 8g (124 grain) and 1.1 g (17 grain) FSP with 0.22-caliber (5.5mm diameter).

STANAG 2920 protocol

Eight shoots in different places of the helmet were performed covering a wide range of impact velocities ($663.6 m/s \leq V_0 \leq 732 m/s$) resulting in an experimental V50 of $697 m/s$ (higher than calculated by other researchers). Numerical simulations were carried out with the aim of predicting the V50 velocity with FSP which was found to be around 700 m/s.





NIJ-STD-0106.01 protocol

The analysis of BFD was carried out according to NIJ-STD-0106.01 protocol; five shots (front, sides, rear and top of the combat helmet) were conducted with 9mm full metal jacket bullet, with nominal mass of 8.0 g (124 grain) and velocity of 425 $\pm$ 15 m/s.

The maximum value obtained was 12 mm in the experimental impact at the front of the helmet. This value was lower than 25 mm which is considered the threshold established in the standard [1]. The BFD obtained in frontal impact is twice than that induced in side-lateral impacts.

Position	Impact Veloc. (m/s)	Exp. BFD (mm)	Num. BFD (mm)	Error (%)
Front	427.3	12	10.1	15.8
Right	420.7	6	5.35	10.8
Back	419.7	9	9.67	7.44
Left	433.8	6	5.13	14.5
Top	421.5	11	10.3	6.3
			Average error (%)	**10.9**

The deformed bullets display a classical mushroom shape with diameters of 17.94 mm, 21.36 mm, 17.69 mm for top, frontal and rear impacts, respectively, in the final, permanently deformed state, which was closed to the experimental finding of 15.94 mm, 21.41 mm and 19.99 mm for top, frontal and rear impacts, respectively.

Conclusion

In this work, a numerical finite element model was developed in order to predict the response of a combat helmet subjected to ballistic impact. The experimental work was carried out to calibrate the material properties and validate the ballistic performance of the real helmet presented.

The model has been used as a predictive tool to calculate the ballistic limit on the new combat helmet. The V50 velocity obtained was 697.0 m/s which is higher than values found in the literature for similar configurations. The results of this work have demonstrated that the helmet evaluated in this study has the potential to meet the requirements established by manufacturers for helmet performance against a specific set of ballistic treats

References

[1] Rodriguez-Millan, M. *et al.*, Numerical analysis of the ballistic behaviour of Kevlar composite under impact of double-nosed stepped cylindrical projectiles J Reinf. Plastics and Compos., 35 (2016), 124-137

[2] Rodriguez-Millan, M. *et al.*, Development of numerical model for ballistic resistance evaluation of combat helmet and experimental validation Materials & Design., 110 (2016), 391-403

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