Numerical modeling and experimental validation of ballistic panel penetration

Beata Jackowska-Zduniak*

Institute of Information Technology, Warsaw University of Life Sciences, Str. Nowoursynowska 159, building 34, 02-776 Warsaw, Poland

ORCID 0000-0001-9332-9275

Abstract. In the paper, the model of a protective panel ensuring the 3rd level of ballistic protection according to STANAG standards was proposed. Adequacy of proposed approach to the problem was tested on the example of a selected type of armor-piercing projectile 7.62x54R B32. The scope of paper included preparation of numerical models formulated using axi-symmetric and three-dimensional descriptions. Built models were validated and verified using experimental results. Conducted multi-variant numerical analyzes show that the developed numerical model satisfyingly corresponds to the real course of the perforation process for assumed experimental conditions. At the model validation stage, an error in determining the residual velocity of the projectile in the range of 0.8-2% was obtained. As a result of verification, the final result of simulation was obtained in accordance to experimental observation.

Introduction

The tasks that Armed Forces around the world are currently facing define the minimum requirements for a ballistic panel necessary to protect light combat vehicles involved (STANAG 4569 normative documents - protection levels for logistic crews and light armored vehicles). The challenge faced by people designing such a protective panels is to minimize the threat to combat vehicles in result of fire from small-caliber weapons with the use of 7.62x54R B32 armor-piercing projectile. Protective elements should be characterized by low weight, due to the dynamic characteristics of the vehicle, and a sufficiently high ability to absorb impact energy. The research included i.a. features of the system of protection against the effects of a small arms projectile, such as the modular structure of the armor. Such construction of the ballistic panel allows easy assembly and quick replacement of the armor part, if the protective plate is partially damaged. Computer modeling methods have been an important tool in the research process for years. Popularity of computer simulations is related to the fact that they are an intermediate link between theoretical analytical considerations and experimental research. The review of the literature shows that in numerical models a simplified description of the phenomenon of perforation/penetration is used, and the projectiles used do not meet the standards of a specific threat level. Experimental verification of the obtained results is also often not carried out.

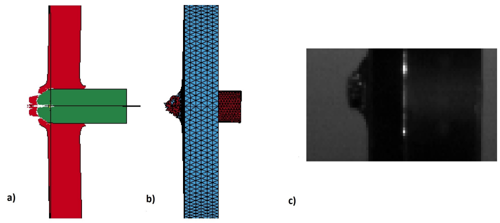

Figure 1: Comparison of the disc perforation at the same moment of time for the numerical model (a) 2D, (b) 3D and (c) experiment.

Result and discussion

The model validation and verification stage showed a satisfactory level of correctness of obtained modeling results. The maximum error due to the residual velocity of the projectile reached 2% for the validation variant of the axisymmetric model and 0.8% for the three-dimensional model. For verification variants, both 2D and 3D, obtained from the simulation, the residual velocity was 0 m/s, the same as in the experiment. It is worth noting that the way of cracking and fragmentation of ceramic tiles and the presence of a cork in the axial symmetric variant for the ARMOXA disc is consistent with experimental observations. On the other hand, it was not possible to obtain a cork for the 3D variant, which is related to the selection of failure parameters for the Johnson-Cook model. As mentioned earlier, this model is not able to reproduce all the physical behavior of the material, similarly to the cracking of the cork in the axisymmetric model. The visual consistency of the final form of shield destruction with the results obtained on the basis of the simulation is visible in Figure 1. The obtained results prove: correct adoption of the basic assumptions of the model, properly performed spatial discretization of models, proper selection of constitutive models of materials with appropriate material data, acceptable method of describing damage / damage and material erosion.

References

[1] Scazzosi R., Giglio M., Manes A. (2021) Experimental and Numerical Investigation on the Perforation Resistance of Double-Layered Metal Shield under High-Velocity Impact of Armor-Piercing Projectiles. *Materials* **14(626)**.

[2] Dey S., ClausenA. H., Børvik T. (2006) A preliminary study on the perforation resistance of high-strength steel plates *in EURODYMAT - 8th International Conference on Mechanical and Physical Behaviour of Materials under Dynamic Loading*.