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Computer modeling of process of projectile's penetration into discrete-element armor panel

V. Kartuzov, I. Kartuzov, O. Mikhailov

Frantsevich Institute for Problems in Materials Science NASU, Krzhizhanovsky str., 3, Kyiv, 04680, Ukraine

Abstract

This effort is to bring the results of numerical experiment to resolve a problem of projectile's penetration into hybrid (sandwich) armor panel with absorbing layer made from discrete elements.
Modeling was performed at two scales. Deformation of each discrete element was considered in terms of continuum approach, the hybrid armor panel was represented by a big number of discrete elements with the given law of interaction. Numerical experiment consisted in variation of micro porosity of Al form damping particles and variation of projectile shape and velocity as well as a variation of material and shape of discrete reinforcing elements.

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1. Introduction

Acceptance of a new concept of employment of lightweight dissipative layers made from materials with cellular structure in armor panels [1-4] which was suggested in the beginning of the third millennium, greatly contributed in armor development. Starting from 2005 year this new conception has been actively developed, being based on theoretical investigation which predicted high impact resistance of armor hybrid panels with cellular layers if compared with monolithic materials [5-7]. Further the results of numerical and analytic investigations were published in monograph [8].

* Corresponding author. Tel.: +38-044-424-01-02; fax: +38-044-424-01-02.

E-mail address: vvk@ipms.kiev.ua

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Performed studies confirmed an expediency of presence of absorbing layer from Al foam [9] in armor panels. Porous aluminum is characterized by the ability to absorb a significant amount of energy upon impact. At the same time, it has a little resistance to mechanical action. To increase the protective properties of multilayered panels requires a presence of discrete reinforcing elements, for example a layer of ceramic cylinders or hexagonal prisms with spherical vertices [10,11]. The elevated efficiency of this design is due to a fact that in addition to common mechanisms of energy dissipation, there is one more mechanism associated with oscillation of reinforcing elements.

If compare with commercial ceramic armor panels the advantages of hybrid panel with single discrete-ceramic absorbing layer (Liba trade mark) are: less cost, easy repair and replaceability, lowered "boundary effect" in 3-4 times and rather high survivability [12-14]. Looking for the optimum design of hybrid armor panels, a various alteration of layers and ceramics and non-ceramic (steels, rubbers, foamed metals, polymers, etc.) inserts were tried [7]. Experimental works were combined with numerical and analytic modeling to substantiate an expediency to include the layers made from Al foam in hybrid panels.

This effort brings the results of numerical experiment as to solution of a problem of projectile's penetration into hybrid armor panel with absorbing layer which includes discrete elements. Behavior of armor panel with reinforcing elements has been also considered.

2. Problem set up and methodology of modeling

This armor design consists of two metal plates (material - steel or aluminum), among which an absorbing layer made from discrete particles is disposed (see Fig.1). Material of particles was varied and was represented by porous Al, compact Al and ceramic SiC.

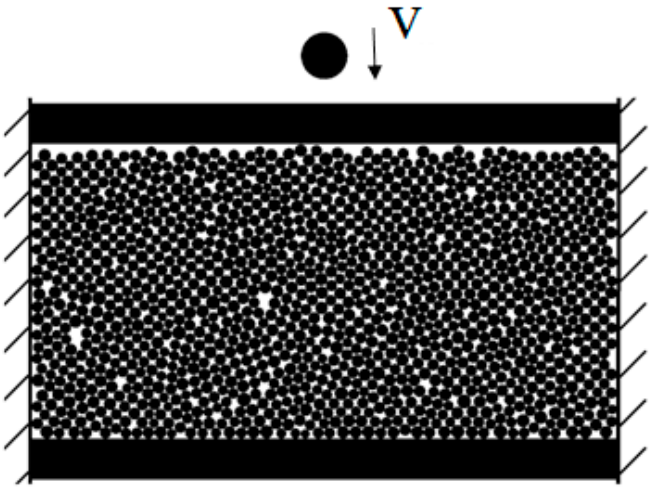

Fig. 1. Impact scheme

Upper and bottom plates are rigidly fixed. Horizontal movement of particles is limited by side walls. Dynamic impact is made by a steel projectile which moves vertically. Projectile's velocity was 870 m/s and 1000 m/s and shape was varied as well.

We considered 2D formulation of a problem (plane-deformed state). Shape of packed particles in plane of section was of two kinds - in the form of a circle and a square. Packing of particles was both free filling and regular. When generating particles, the approach proposed and implemented as in [15], was used. In order to compare a character of compaction of porous material in different regions of armor panel, it was assumed that the initial micro porosity of all particles was the same.

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