belongs to Ballistic Level IIIA of NIJ 0101.04 (USA) will correspond to Level 1 of the Russian standard GOST 50744-95. And vice versa, if the armor package has $v_{th} = 445\ m/s$ when impacted by TT pistol bullet, it will have $v_{th} = 445\ m/s \div 0.68 = 652\ m/s$ when hit by Parabellum bullet, therefore the armor package belonging to Ballistic Level IIIA of NIJ 0101.04 (USA) will not correspond to Level 2 of the Russian standard GOST 50744-95. From the above it follows that armor structures with Level 2 of the Russian standard GOST 50744-95 are superior by their ballistic performance to similar structures with Level IIIA of NIJ 0101.04.

Thus, we managed to expand the range of tasks performed with the help of computational model of penetrator/textile armor interaction. We obtained the values of coefficient K for most widely used aramid fabrics manufactured in Russia. We established the correlation parameter of perforation ability of steel and lead bullets against textile armor packages; the parameter can be used to compare the ballistic resistance of armor structures belonging to different classes of Russian and foreign standards.

References

1. *Materials and protective structures for local and personal armouring (text) / V.A. Grigoryan, I.F. Kobylkin, V.M. Marinin, E.N. Chistyakov. – Moscow. Radiosoft Publishing House, 2008*

Investigation of Anti-Ricochet Properties of Body Armor with Steel Armor Panels

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Exploitation of body armor with steel armor panels has shown, that fragments formed in interaction of destructive elements (bullets or high -velocity fragments) with high hardness steel surface are ricocheting and can lead to arm, face or neck injuries. In that case in front of steel armor panels anti -ricochet structure (ARS) is mounted as protective element, providing partial or full localization of secondary fragments.

The aim of the investigation, that included study of the structure of witness plates, their damage criteria, target conditions and real body armor tests, was creation of ARS evaluation procedure and working out of recommendations on ARS composition for body armor with steel armor panels.

0.5 mm-thick aluminum sheet of AMG6 alloy was selected as the witness plate. For confirmation of the right choice of the witness plate, values of V_{50}, energy intensity (ΔE), and energy density E_{den} were determined. Possible effect of test conditions, and in particular of the characteristics of test means – weight

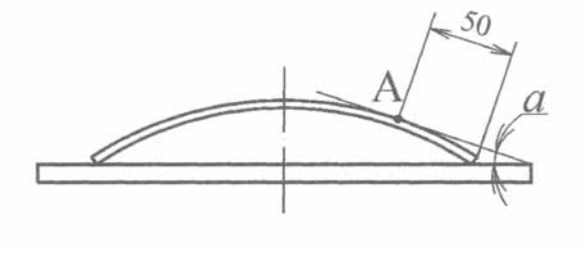

Fig. 1

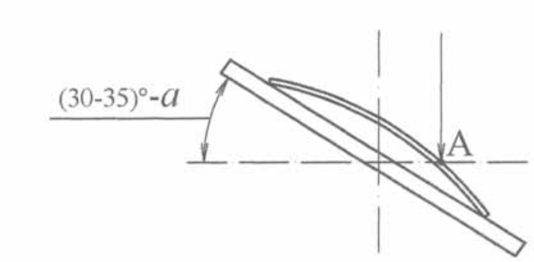

Fig. 2

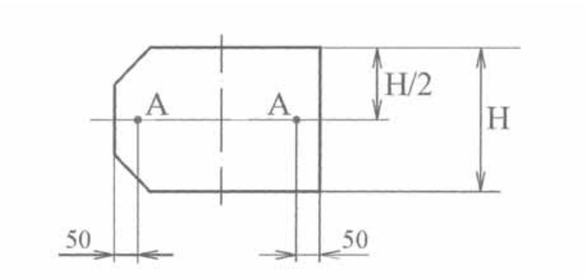

Fig. 3

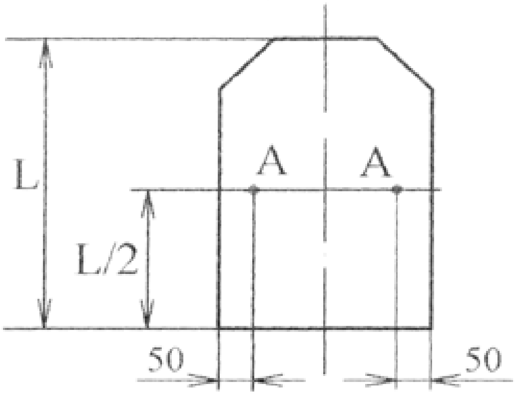

Fig. 4

and material of fragment simulators - on the obtained values of V_{50}, ΔE, E_{den} was evaluated.

The following tests were conducted:

- steel ball, diameter 6.35 mm, weight 1.05 g;
- steel ball, diameter 5.0 mm, weight 0.514 g;
- steel ball, diameter 6.3 mm, weight 1.56 g;

During experimental investigations real body armor was tested. The test item was fixed tightly to a hard flat support with a technical band. A wooden panel made from 50mm-thick softwood boards was used as a support.

To provide the required impact angle of the bullet with the protective structure, the support with fixed test item could rotate around the vertical axis either to the right (clockwise), or to the left (anticlockwise), and also rotate to 90 degrees in vertical plane, perpendicularly to the line of sight.

The test item was fixed to the support with a shift to the left edge of the support (when the support turned to the right) or to the right edge of the support (when it turned to the left). The distance from the edge of the support to the edge of steel armor panel along the central line, on which the impact point was supposed to be, did not exceed 20 mm.

To provide the required impact angle of the bullet with the protective structure of the body armor, the correction angle a was determined which took into account the geometry of the steel armor panel surface curvature in the supposed impact point.

The correcting angle was calculated on the basis of nominal sizes, indicated in construction documentation. (Fig. 1)

Taking into account the correcting angle, the support with the attached test item was turned to the angle equal to $\{(30\text{-}35)^\circ - a\}$ (Fig. 2)

Protective characteristics of the anti-ricochet structure were evaluated by bullet impacts in four directions (from the left, right, above and beyond relating to the front surface of test item). Impacts were provided to the left and to the right with consistent turn of the support with the attached test item relating to the vertical axis. Then the support (test item) was turned to 90° in the vertical plane, perpendicular to the line of sight, and the impacts were provided again to the left and to the right with consistent turn of the support relating to the vertical axis.

The supposed impact point on the steel armor panel was to be situated on the horizontal central line of the steel armor panel (irrespectively of spatial position of the test item) at a distance of 50 mm from the steel armor panel left edge (when the support turns to the right) or from the right edge (when the support turns to the left) (Figs. 3 and 4)

The witness plate, by the integrity of which the type of anti-ricochet structure was determined, was made from AMG6 alloy with thickness 0.5 mm (Federal standard GOST 21631-76), height 500 mm, length 600 mm and was mounted into a hard skeleton frame.

The witness plate was mounted vertically from the left (when the support turned clockwise) or from the right (when the support turned anticlockwise) side

Table 1. Values of energy density of aluminum witness plate depending on the test means

Fragment material	Fragment weight, g	V_{50}, m/s	E_{50}, J	E_{den}, J/sm^2
Steel	0.5	131.1	4.42	22.5
Steel	1.05	106.7	5.66	18.9
Lead	1.56	91.7	6.39	20.5

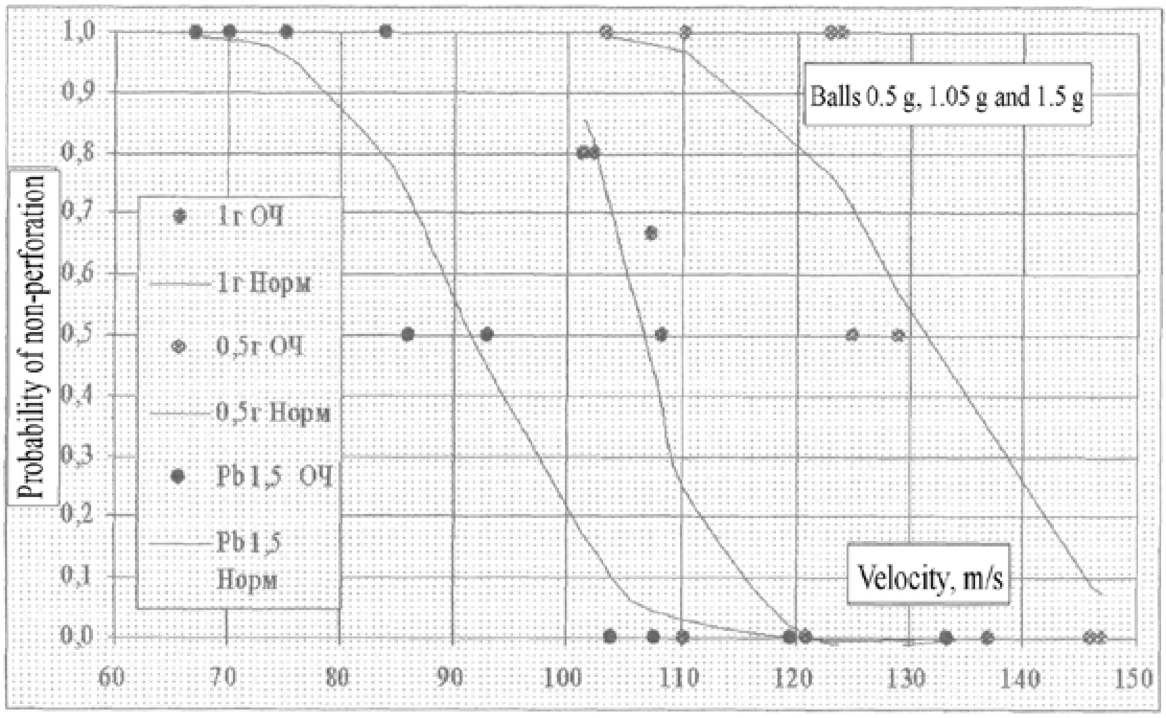

Fig. 5. Test-means-type dependant perforation/non-perforation frequency of the aluminum witness plate graphs.

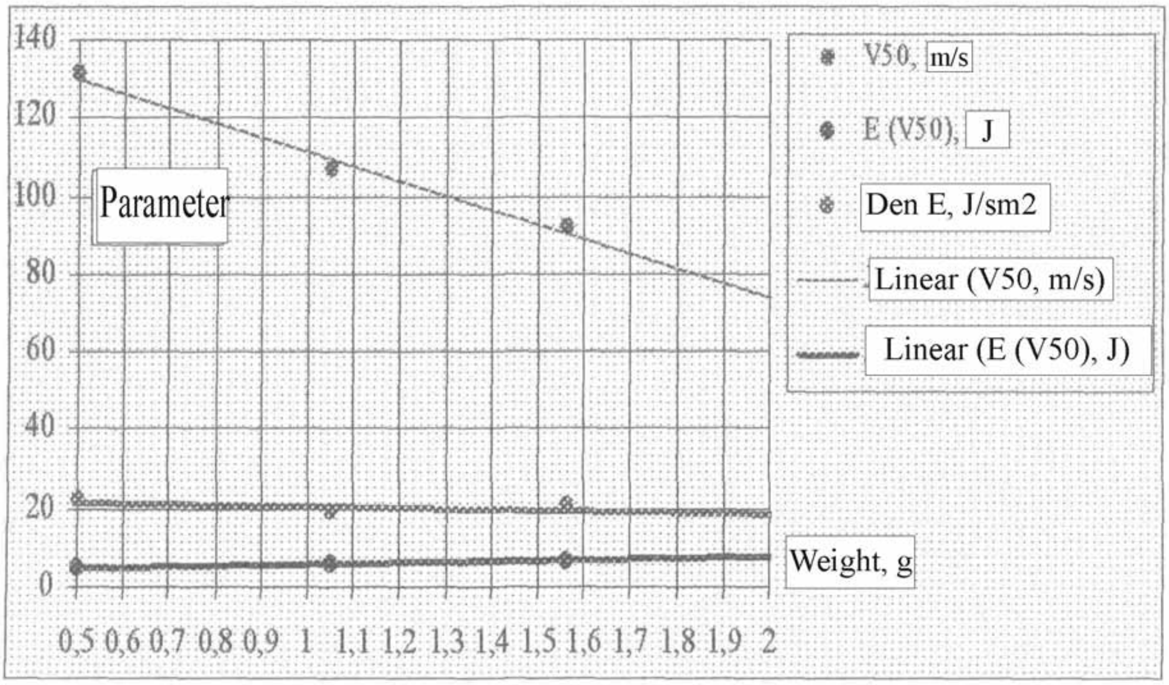

Fig. 6. Dependency of defense properties of the control aluminum screen parameter from splinter type (weight) diagram

of the support with the attached test item. Furthermore, the witness plate was mounted in the vertical plane, parallel to the line of sight, at a distance of 50-100 mm from the steel armor panel edge. The center of the witness plate was to be situated in the line of the expected slug and secondary damage fragments outlet.

Quantity of test items has been determined in dependence on the surface of steel armor panels. If the steel armor panel surface didn't exceed 0.02 m^2, one impact was produced. When the steel armor panel surface exceeded 0.02 m^2, two impacts were produced.

During the tests perforation or non-perforation of the body armor protective structure was determined and also the integrity or quantity of perforations in the witness plate.

The impact is considered fair, if numerical values of bullet velocity and shooting range are equal to the values set in Federal standard GOST R 50744, the body armor protective structure is not perforated, and the achieved impact point is spaced not more than 10 mm from the supposed impact point.

On the basis of processing of the received data on perforation (non-perforation) velocities (speeds) of the witness screen by different test weapons, the following data were determined and created:

- probabilities of normal distribution (frequency curves) of impact on the aluminum witness plate
- parameter of protective properties of the aluminum witness plate vs splinter type (weight) diagram

On the basis of the obtained data the values of velocity for 50% non-perforation (V_{50}, m/s), energy intensity (E_{50}, J) and energy density (E_{den}, J/cm^2) were determined, rated on the basis of obtained value of 50% non-perforation (V_{50}, m/s).

The obtained data is represented in Table 1. From the obtained data it follows:

- the energy intensity of the aluminum witness plate in the investigated range of velocities and weights of the selected fragments does not practically depend on the type (weight) of the fragment and at the average is equal to$E_{den\ 50}$ (20.5±2) J/sm^2;
- the obtained value of the aluminum witness plate energy density sufficiently correlates with biomedical tests data on injurious effect of fragments formed when bullets ricochet from the steel armor panel of body armor (safe criteria – 10-11 J/cm^2, fatal – 100 J/cm^2 and more) (Projects of S.M. Kirov Military medical academy and N.N. Priorov Central institute for scientific research of traumatology and orthopedics)

In accordance with experimental findings evaluation of ARS has been proposed by three-type qualitative assessment of witness plates.

Anti-ricochet structure is classified as Type 1 if there are no perforations recorded in witness plates after all impacts on test items from the types of weapons declared in technical documentation.

Anti-ricochet structure is classified as Type 2 if there is no more than one perforation in each witness plate.

Anti-ricochet structure is classified as Type 3 if there is more than one perforation in each witness plate.

During the investigation it was found out, that for armor steel protective panels the following amount of material in body armor ARS basically solves the problem of localization of secondary fragments: 6 layers of art. 56319 for Protection Class 2, 16 layers for Protection Class 3 and 18 layers for Protection Class 5, mainly for secondary fragments localization task.

Risk Analysis in Designing of Body Armour

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INNOVATIVE ECONOMY
NATIONAL COHESION STRATEGY

EUROPEAN UNION
EUROPEAN REGIONAL
DEVELOPMENT FUND

Key Project No. POIG 01.03.01-10-005/08 entitled: „Modern ballistic body armours and covers for transportation means as well as for buildings made on a basis of textile composites”.

Introduction

The risk analysis and an ocean of potential threats arising from the process of designing, manufacture as well the experience resulting from post-manufacture stage of ballistic body armours’ life cycle are helpful tools for providing the functionality of the products, and the adequate, acceptable security level to their users.

The risk management has been approved and implemented i.a. as basic requirement for the medical products according to the provisions of European Directive 93/42/EWG [1] and defined in the standard PN-EN ISO 14971:2007 [2] and PN-EN ISO 22442-1:2008 [3]. The tool is versatile so much, that there are possibilities of applying it directly to the designing, manufacture and marketing.

General rules concerning applying the risk analysis

At the stage of designing the modern ballistic body armour the selection of most suitable and optimum technical, technological and design solutions for pro-