Modeling of information systems

UDC 623.451 **doi: 10.20998/2522-9052.2017.1.01**

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MODELING OF THE HIGH-SPEED PUNCHING DRUMMER BARRIERSAS A SET OF HOLLOW CYLINDERS

Were analyzed the characteristics of damaging elements of artillery systems and small arms. Were analyzed the characteristics and structures of personal Armor protection. Modern protection has layered structure. The main blow of high speed sub munitions takes the hard plate. They can be made of metal or high-strength double-layer panels. At a meeting with the panel the toe of bullet was destroyed. As a result of growing area of interaction between the bullet and the panel, there is a deflection and uncoupling ceramic bullet while destruction. When you hit the drummer in the obstacle created several types of wave perturbations that propagate with different velocities. These effects cause is a complex stress state structure, whose intensity decreases rapidly with time. **The aim of the article** is to investigate the interaction of high-striker with a protective barrier in the form of a set of hollow cylinders. The **methods** that are used: Improving personal armor protection can be achieved by applying the optimum combination of new materials and advanced structural and circuit design. Character penetration drummer an obstacle may change if the obstacle is to imagine a structure that consists of a set of hollow cylinders. Considered the process of interaction, of high-speed impactor, with a protective barrier, in the form of a set of hollow cylinders. In contact with the surface layer drummer obstacles by having an expanded, drummer enters the hollow cylinder, which closely hugs the side surface of the impactor, creating resistance to motion. When moving drummer in the cylinder is converting kinetic energy into energy impactor cylinder and deformation work to overcome friction. Thus, the energy of drummer extinguished intermediate layer and redistributed to the power frame inner layer. following **results** are obtained. The proposed a model to determine the depth of penetration drummer an obstacle in the form of a set of hollow cylinders. There are results of the calculations. It is proposed to further improve the protection of personal Armor achieve by applying the optimum combination of new materials and advanced structural and circuit design.

Keywords: body armor, high-speed hammer, striking element, threat levels, protective barrier, plastic deformation, a hollow cylinder, penetrating power.

Formulation of the problem

Despite the rapid development of modern methods of warfare and the development of weapons based on new physical principles, armed with modern armies are improved traditional means of destruction. Therefore, urgent tasks are the development of modern means of personal body armor.

When conducting modern military operations there are different types of weapons and ammunition, each of which has its own set of characteristics (mass, shape, hardness, speed, etc.), which complicates the solution of the problem of protection against them. The main striking elements are the following:

1) fragments of artillery and rockets, grenades, mines;

2) high-speed bullet;

3) low-velocity bullets.

Fragmental weapons can produce thousands of pieces of small sizes of various shapes, most of which has a mass of about 1 gram. Fragments have an initial speed of 1000-2000 m/s, but with an irregular shape, quickly losing it. They are a source of injury in a large area.

High-speed bullets have greater penetration than fragments [1]. On penetration bullet affects its structure. Bullet with a round toe, the core and the shell of a soft alloy more amenable to deformation in a collision with a protective barrier than steel shards. However, elongated shape still increases its penetration. Heavier bullets with low-speed weighing up to 15 grams of reaching speeds of up to 400 meter per second. Therefore, they have almost the same level of penetration into the protective barrier that of high-speed low mass fragments. With this in mind, personal body armor must meet various requirements for protective characteristics corresponding to different levels of threat. In turn, the threat level is determined by the nature of the fighting, weapons and views used in accordance with this dictates the need for the degree of security of the personnel.

It is known that the armor penetration [2] of bullets of small arms is defined as the maximum thickness for penetration of armor steel, and on the ability of penetration through the protective clothing of various classes of protection while maintaining after-penetration effect action sufficient to guarantee the decommissioning of the enemy. In various countries the necessary residual energy of a bullet or bullet fragments after the breaking of protective clothing is estimated between 80J and more. In general, it is known that, as used in armor-piercing bullets sorts cores after breaking barriers have a sufficient lethal effect caliber core only at least 7.6 mm, and its residual rate of at least 200 meter per second.

Modern protective equipment (Fig. 1) has a layered structure [3]. The basic personal protective equipment material is resistant to high-energy shock fabric fibers made of synthetic, special composition and structure. This fabric is used in the form of a package of several layers, delays and low-speed bullet splinters. To keep the high-speed sub munitions used rigid plate. Furthermore, for cushioning, the cushion layer is applied.

The main hit of high submunitions perceives rigid plate. They can be made of high strength metal or double-layer panels. Upon impact with the panel, bullet sock destroyed. This increases the area of interaction of the bullet and the panel comes deflection and splitting ceramics while fracture the bullet.

Fig. 1. Types of body armor

In the scientific literature, most attention is paid to the definition of required thickness barrier, depending on the impact velocity [4–7]. It is noted that the reaction of the hammer with the barrier with low speed inertial forces are negligible compared to the strength characteristics of the elements. Deformation covers the entire structure and has is mainly elastic character. At medium speeds the hit force of inertia can be impact comparable with the static penetration resistance, deformation is local and is characterized by high values of the plastic deformation and its speed. At high speeds, the hit becomes more prevalent inertial forces within the material interacting elements close to hydrodynamic.

Different researchers have produced a variety of empirical formulas which take into account the basic parameters of the impact [4, 5] (formula by Petri, Nobile, Saatchi and Kruppov, Havre, Thompson, Davies, Berezanskaya and ets.), based on experimental data obtained during shelling of armor plates at different conditions, which narrows their field of application.

However, most studies have paid attention to the mechanical characteristics of materials, much less design parameters evaluated barriers. Common to the known studies is that the protective barrier provided in a plate (kit plate), while one of the components of firearms is a mechanical system consisting of a striker (bullet) and barrel (sheath).

Thus, these data suggest that the theory of the mechanical interaction of projectiles from obstacles [8] of various kinds has not received its completion, the processes occurring in hit interaction of elements of mechanical systems is not fully understood, and applied models and methods of calculation depend on the necessary the accuracy of the results, while not measured structural parameters barriers. It is suggested that further improvement of personal body armor can be achieved by applying the optimum combination of new materials and modern design-circuit design.

Processes occurring in the punching of barriers are very diverse and depend on many factors. The main ones are: the speed and direction of impact, size and shape of drummers, the design and manufacturing technology of protective equipment, the physical and mechanical properties of materials and drummers protective barriers.

The reliability of the forecast of the results of impact interaction drummer barrier rises comparing the results of the analytical and numerical modeling, and data field tests. A comprehensive experimental- design study features of the interaction of projectiles with targets is essential for a reliable forecast of the results of the interaction of the elements and can significantly improve the efficiency of development of constructive solutions. This research scheme (the study of the behavior of structural elements under real conditions of dynamic loading, numerical and experimental modeling) allows you to create a basis for the development and justification of recommendations for the rational design and selection of materials and their structural condition, to enhance the effectiveness of their use in designs.

The scientific basis for studying the process of breaking down barriers by high-speed strikers are theory of elasticity, ductility and strength of materials, theoretical framework for ensuring the survivability of personnel departments in the conduct of hostilities, the theory of reliability models, mathematical modeling, mathematical design of experiments.

The aim of the article is to investigate the interaction of high-striker with a protective barrier in the form of a set of hollow cylinders.

The Main material

The process of penetration of the striker in the traditional protection barrier which is integrates several physical mechanisms. In this case, there is a stage associated with apart of the target material and the stage of knockout plugs (scabbing).

When you hit striker on the barrier there are several types of perturbation waves traveling at different speeds. These disturbances cause design complex stress state, the intensity of which decreases rapidly in time.

The initial stage of penetration of the striker in the barrier [9, 10] is determined by the point in time during which the drummer penetrate the barrier at a depth of about two of it diameters. During this period, for the non-deformable drummer with conical warhead changes the character of the movement and the stress-strain state of the target material, and the penetration force reaches a steady state value other than efforts in the surface layers. (In the case of interaction between striker with a relatively strong barrier at the initial stage of an intensive deformation of the head of the striker and the formation of its new form).

After reaching a certain critical penetration depth of the crater size ceases stop change and starts to form the main channel of the cavity. The final stage of penetration barrier is considered part of the process, which starts with the approach striker to the back surface of the barriers to a certain critical distance, and ends with the release of the striker obstructions. Achieving the specified distance associated with access to the back surface of the plastic zone, it causes a change in the stress-strain state of the interacting elements.

When approaching striker to the back surface of the barrier, there arises the tensile zone of radial and tangential stresses and σ_r and σ_φ as expanding conical funnel. As a result of these stresses in the material can be damaged or cracked. Further movement of striker leads to mechanical damage of the target material.

The nature of striker penetration into the target may change if the barrier will be a structure consisting of a set of hollow cylinders (Fig. 2).

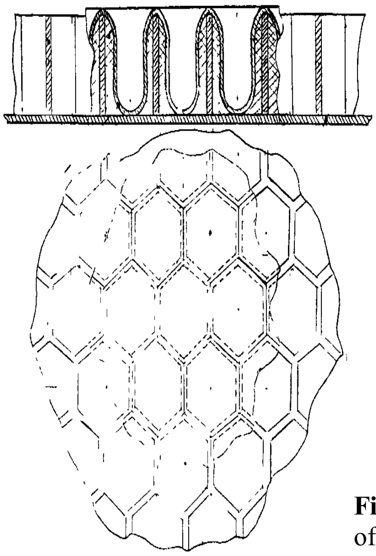

Fig. 2. The construction of the barriers

Structurally, the protective barrier of this type may comprise outer, intermediate and inner layers [11]. Wherein the outer layer is made as a set of interconnected hollow cylinder with a closed bottom and a top part which extending and made of materials possessing ductility property. The inner layer is a frame structure in the form of spatial lattice consisting of a plate connected to the placed perpendicular to the reinforcement ribs, the distance between which is greater than the outer diameter of the cylinder of the outer layer. The outer and inner layers are interconnected by means of an intermediate layer of adherently-elastic material. The construction of outer protective barrier layer can convert the kinetic energy of striker to the work by plastic deformation of the cylinder. Application of the inner layer as the power frame, allows striker to redistribute energy over a larger area. The use of an intermediate layer of adherently-elastic material can reduce the energy transmitted by drummer to inner layer of protective barriers.

Upon contact with striker outer barrier layer, by having the divergent upper part, the hammer falls in a hollow cylinder that fits tightly the lateral surface of the moving striker, which creates a resistance to its movement. When moving striker in the cylinder of the kinetic energy is converted into energy of striker cylinder and a deformation work to overcome the friction force. In this case, part of the energy striker is extinguished intermediate layer and redistributed on the frame structure of the inner layer.

Consider the process of interaction between the hammer (bullet) with thick-walled hollow cylinder (tube) (Fig. 3), using the elements of the theory of plastic deformation of thick-walled pipes which are under internal pressure pi created penetrated into the cylinder drummer. At the same time, ri - the inner radius of the cylinder, ro - the outer radius of the cylinder.

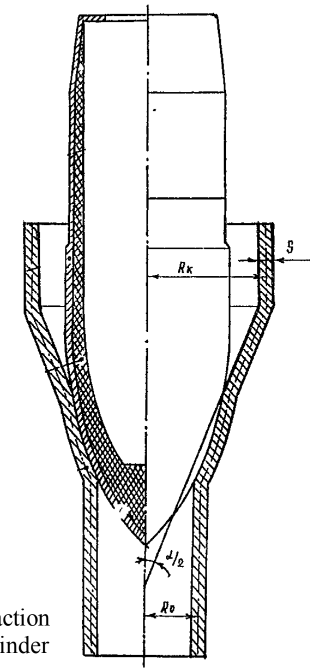

Fig. 3. Scheme of the interaction of the bullets with a hollow cylinder

Of the three principal stressesσ_θ, $\sigma_я$, σ_r, occurred at the same time in the cylinder design according to the results given in this article [12], the most important is the voltage σ_θ, and the smallest σ_r. In this case, the plasticity of the condition can be written as:

$$\sigma_\theta - \sigma_r = 2\,k, \tag{1}$$

where $k = 0.5\ \sigma_t$ – the criterion of plasticity of Saint-Venant.

From the analysis of the expression for σ_θ in solving elastic problems for thick-walled pipes [12] that the greatest tension will be in the interior of the pipe. With increasing internal pressure p_v in the plastic state will go first inner layer. In order to determine the value p_v, where plastic deformations appear in the inner layer, substitute the plasticity condition (1) and the expression for σ_θ and σ_r, obtained by solving the plane problem of elasticity theory, denoting the internal pressure corresponding to the start of plastic deformation of p_t:

$$\frac{r_v^2 \cdot p_t}{r_n^2 - r_v^2} \cdot \left(r_n^2 / r_v^2 + 1 \right) + p_t = 2 \cdot k.$$

hereof

$$p_t = \frac{r_n^2 - r_v^2}{r_n^2} \cdot k.$$

Consider a case in which the internal pressure $p_v > p_t$. The internal portion of tube section will be in a plastic state, and external - in the elastic. The boundary between the plastic and elastic zones is a cylindrical surface of radius r_t. On the border of this layer is radial stresses σ_r, which is denoted by q. Thus, it is determined by the formulas [10] to the outer layer of the pipe with an inner radius ri, pressure q and an outer radius r_o of voltage σ_r and σ_θ :

$$\sigma_r = -\frac{r_t^2 \cdot q}{r_n^2 - r_t^2} \cdot \left(r_n^2 / r^2 - 1 \right);$$

$$\sigma_\theta = \frac{r_t^2 \cdot q}{r_n^2 - r_t^2} \cdot \left(r_n^2 / r^2 + 1 \right).$$

To determine these values, consider the inner layer of the pipe is a pipe under internal p_v and external p_n pressures. The inner radius r_v of the pipe and the outer r_t. This pipe is entirely in the plastic state. Therefore, in addition to her equilibrium differential equation:

$$\frac{\partial \sigma_r}{\partial r} + \frac{\sigma_r - \sigma_\theta}{r} = 0. \quad (2)$$

Have plasticity condition (1).

After substituting this condition in (2) we get:

$$\frac{\partial \sigma_r}{\partial r} = \frac{2k}{r}.$$

After integrating this equation we obtain:

$$\sigma_r = 2k \cdot (\ln r + C). \quad (3)$$

The integration constant C we find the condition that at $r = r_{vn}$, $\sigma_r = - p_v$, then $2k \cdot (\ln r_{vn} + C) = - p_v$,where

$$C = -(\ln r_{vn} + p_v/2k).$$

After substituting the integrating for C (3)

$$\sigma_r = 2k \cdot \ln\left(r/r_B \right) - p_B. \quad (4)$$

From plasticity conditions

$$\sigma_\theta = 2k(\ln\left(r_t/r_v \right) + 1) - p_v. \quad (5)$$

Thus, for plastic (internal) stress area defined by the formulas (4, 5). At the boundary between the elastic and plastic zones, i.e. at $r = r_т$, voltage σ_r and σ_θ, defined by the formulas for the elastic ($\sigma^у_r$,$\sigma^у_\theta$) and plastic ($\sigma^п_r$,$\sigma^п_\theta$) zones should be the same, that is, to determine the unknown q and $r_т$ are the following conditions: when

$$r = r_т \sigma^п_r = - q, \quad \sigma^п_\theta = \sigma^у_\theta,$$

the first condition:

$$q = -(2k \ln\left(r_t/r_v \right) - p_{‰}),$$

from the second condition, we obtain:

$$2k \cdot \left(\ln\left(r_t/r_v \right) + 1 \right) - p_v =$$
$$= \left(p_v - 2k \ln\left(r_t/r_v \right) \right) \cdot \left(r_{n'}^2 + r_t^2 \right) / \left(r_{n'}^2 - r_t^2 \right).$$

From whence

$$p_v = k \cdot \left(2 \ln\left(r_t/r_v \right) - r_t^2 / r_n^2 + 1 \right).$$

If the plastic zone will occupy all the cross-section, the bearing capacity of thick-walled tube is exhausted. The value of the internal pressure limit is determined by the formula:

$$p_{пр.} = 2\, k \ln\left(r/r_v \right). \quad (6)$$

The force P acting on the annular element unit width of thick-walled pipes is determined by the expression:

$$P = 2\pi\, r\, p_{пр.}. \quad (7)$$

The force causing the tangential stresses in the cylinder, with the proviso that the plastic zone will occupy all of the cylinder section and carrying capacity is exhausted:

$$P = 2\pi\, r_k\, \delta\, \sigma_\Theta, \quad (8)$$

where r_k – final (after deformation) radius of the cylinder;

δ – the thickness of the cylinder.

The force pulling the striker within the cylinder defined by the formula:

$$P_1 = f_1 \cdot P, \quad (9)$$

where f_1 is effective coefficient of friction.

Drummer energy expended on overcoming the forces of friction and deformation of the cylinder:

$$E_\Sigma = \Delta E_{тр.} + \Delta E_{деф.}.$$

The path traveled by the striker inside the cylinder, by the formula:

$$E_\Sigma = P_1\, h, \quad (10)$$

where we find h

$$h = \frac{E_\Sigma}{P_1}. \quad (11)$$

Determine the magnitude of the penetration depth of BSC-43 bullet weighing 7.9 g, and the initial speed of 715 meters per second with a steel core Kalashnikov (AKM) in a steel cylinder, provided that the plastic zone will occupy all of the cylinder section and carrying capacity is exhausted.

Substituting in the formula (6)–(11) the following parameters:

$r_k = 0{,}0038$ m;

$\delta = 0{,}01$ m;

$\sigma_\Theta = 1{,}22 \mathrm{x} 10^9$ H/ m^2;

$f_1 = 1{,}2$; bullet energy

$E_\Sigma = 2019$ J.

As a result, the calculations we get: $h = 0{,}007$ m.

Results of field experiments confirm the fundamental possibility of stopping bullets barrier of a set of hollow cylinders (Fig. 4).

Calculation of breaking the plate thickness of the same material from the formula by Thomson gives the following result.

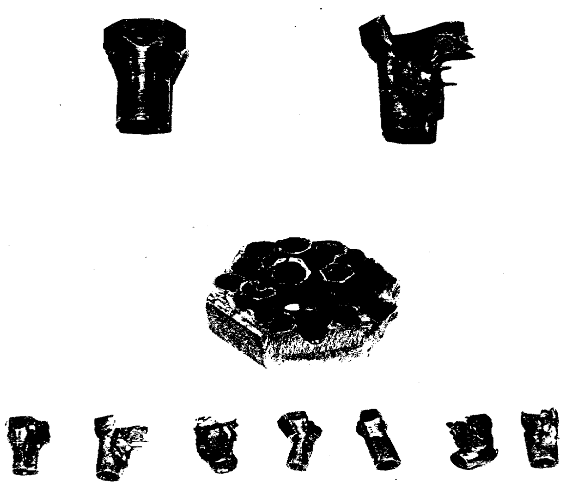

Fig. 4. Experimental results

The total energy absorbed by the plate during its plastic deformation during expansion hole is defined as follows:

$$E_{\Sigma} = \pi R^2 h \cdot \left[\sigma/2 + \rho \cdot uR/L\right],$$

where R – caliber of the bullets, m;

h – thickness of a punched layer barrier, m;

σ – limiting stress for the environment, MPa;

ρ – density of the fluid kg / m^3;

u – bullet speed, m/s;

L – length of the bullet head, m.

For steel barriers with parameters

σ = 1200 MPa; ρ = 7800 kg/m^3;

characteristics bullet

u = 715 m / s; R = 0.00762 m; L = 0.012 m,

the energy

$$E_{\Sigma} = 2019 \text{ J}$$

the thickness of the punched of barrier layer

$$h = 0{,}018 \text{ m}.$$

Dependence of thickness of the broken through layer of barrier of h on the thickness of cylinder δ, presented on a Fig. 5.

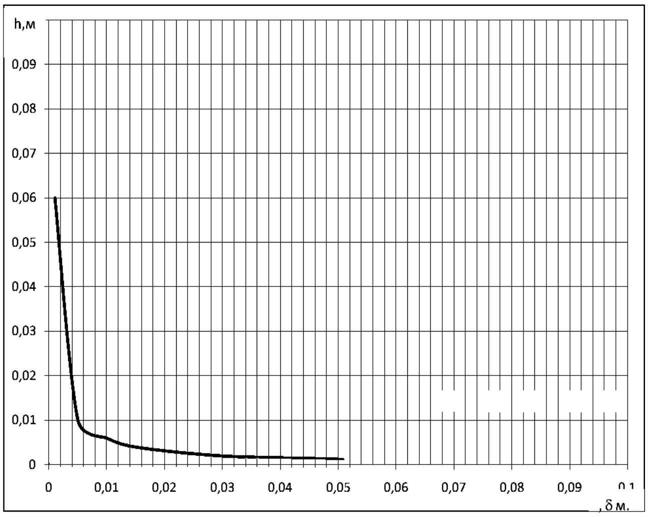

Fig. 5. Dependence of thickness of the broken through layer of barrier on the thickness of cylinder

Conclusions

1. Investigated the process of the interaction of high-drummer (bullet) with a protective barrier in the form of a set of hollow cylinders.

2. Propose a model for determining the depth of penetration of high-speed drummer into the hollow cylinder.

3. The calculation of the depth of penetration of bullets of BSC-43 weight of 7.9 grams and an initial velocity of 715 m/s with steel core from a Kalashnikov (AKM) in a steel cylinder, provided that the plastic zone will occupy all the section and bearing capacity of the cylinder is exhausted.

3. The calculation of the depth of penetration of the BSC-43 bullets from a Kalashnikov (AKM) in a plate of the same material from the formula Thomson.

4. Further studies are related to taking into account the violation of the structural integrity of the bullet with steel core and a lead jacket, the possibility of which must be considered when designing the protective armor constructions.

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Надійшла (received) 31.01.2017
Прийнята до друку (accepted for publication) 18.04.2017

Моделювання процесу пробивання високошвидкісним ударником перепони у вигляді набору порожнистих циліндрів

А. В. Ковтун, В. О. Табуненко

Проаналізовані характеристики вражаючих елементів артилерійських систем і стрілецької зброї Проаналізовані характеристики и конструкції індивідуальних засобів броне захисту. Основний удар високо швидкісних вражаючих елементів приймають жорсткі пластини. Вони можуть бути виконані з високоміцних металів або двошарових панелей. При зустрічі з такою панеллю, носок кулі руйнується. В результаті зростає площа взаємодії кулі і панелі, виникає прогин і розчеплення кераміки при одночасному руйнуванні кулі. При ударі ударника по перешкоді в ній виникає декілька типів хвиль збурювань, які поширюються с різними швидкостями. Ці впливи викликають в конструкції складний напружений стан, інтенсивність якого швидко знижується в часі. **Мета статті** – досліджувати процес взаємодії високошвидкісного ударника із захисною перешкодою у вигляді набору пустотілих циліндрів. **Методи дослідження.** Удосконалення засобів індивідуального броне захисту може бути досягнуто шляхом застосування оптимального поєднання нових матеріалів і сучасних конструктивно-схемних рішень. Характер проникнення ударника в перешкоду може змінитися, якщо перешкода буде уявляти собою конструкцію, яка складається з набору пустотілих циліндрів. Розглянуто процес взаємодії високо швидкісного ударника з захисною перешкодою у вигляді набору пустотілих циліндрів. При контакті ударника з поверхневим шаром перешкоди, за рахунок наявності розширеної верхньої частини, ударник попадає в пустотілий циліндр, який щільно обіймає бокову поверхню ударника, що створює супротив його руху. При русі ударника в циліндрі проходить перетворення кінетичної енергії ударника в енергію деформування циліндра і роботу по переборенню сили тертя. При цьому частина енергії ударника гаситься проміжним шаром і перерозподіляється на силовий каркас внутрішнього шару. **Результати.** Запропонована модель визначення глибини проникнення ударника в перешкоду у вигляді набору пустотілих циліндрів. Наведені результати розрахунків. Пропонується подальше удосконалення засобів індивідуального бронезахисту досягати шляхом застосування оптимального поєднання нових матеріалів і сучасних конструктивно-схемних рішень.

Ключові слова: бронезахист, високошвидкісний ударник, що вражає елемент, рівні загрози, перешкода, пластична деформація, порожнистий циліндр.

Моделирование процесса пробивания высокоскоростным ударником преграды в виде набора полых цилиндров

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Проанализированы характеристики поражающих элементов артиллерийских систем и стрелкового оружия проанализированы характеристики и конструкции индивидуальных средств броне защиты. Основной удар высоко скоростных поражающих элементов принимают жесткие пластины. Они могут быть выполнены из высокопрочных металлов или двухслойных панелей. При встрече с такой панелью, носок шара разрушается. В результате растет площадь взаимодействия шара и панели, возникает прогиб и расцепления керамики при одновременном разрушении шара. При ударе ударника по препятствиям в ней возникает несколько типов волн возмущений, которые распространяются с разными скоростями. Эти воздействия вызывают в конструкции сложное напряженное состояние, интенсивность которого быстро снижается во времени. **Цель статьи** - исследовать процесс взаимодействия высокоскоростного ударника с защитной преградой в виде набора пустотелых цилиндров. **Методы исследования.** Совершенствование средств индивидуальной броне защиты может быть достигнуто путем применения оптимального сочетания новых материалов и современных конструктивно-схемных решений. Характер проникновения ударника в препятствие может измениться, если препятствие будет представлять собой конструкцию, состоящую из набора пустотелых цилиндров. Рассмотрен процесс взаимодействия высоко скоростного ударника с защитным препятствием в виде набора пустотелых цилиндров. При контакте ударника с поверхностным слоем препятствия, за счет наличия расширенной верхней части, ударник попадает в пустотелый цилиндр, плотно занимает боковую поверхность ударника, что создает сопротивление его движения. При движении ударника в цилиндре проходит преобразования кинетической энергии ударника в энергию деформации цилиндра и работу по преодолении силы трения. При этом часть энергии ударника гасится промежуточным слоем и перераспределяется на силовой каркас внутреннего слоя. **Результаты.** Предложенная модель определения глубины проникновения ударника в препятствие в виде набора пустотелых цилиндров. Приведенные результаты расчетов. Предлагается дальнейшее совершенствование средств индивидуальной бронезащиты достигать путем применения оптимального сочетания новых материалов и современных конструктивно-схемных решений.

Ключевые слова: бронезащита, высокоскоростной ударник, поражающий элемент, уровни угрозы, препятствие, пластическая деформация, полый цилиндр.