Механіка, машинознавство та електропостачання

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PROJECTILE RICOCHET ENERGY REDUCTION PROCEDURE

Security forces weapons' designing is an actual problem since antiterrorist and law enforcement activities appear more important issues in modern conflicts. Meanwhile, police and other security forces over the globe still apply combat weapons while providing law enforcement, antiterrorist, and other force domestic actions. Probable injuring of irrelative persons is well known problem of law enforcement and other security forces' firearms usage practice. The ways to advance firearms usage safety when there is risk of ricochet are considered. It is determined that projectile's material density influences on ricochet velocity. The procedure to provide safe after ricochet parameters of a projectile by projectile's material matching is designed. Common dependencies and methods of external and terminal ballistics are applied.

Keywords: *firearms, security forces, weapon usage safety, ricochet, conditional restoration coefficient.*

Introduction

Problem statement and analysis of recent researches and publications. When security forces personnel apply their weapons, it is extremely important to avoid lethal injuring of other servicemen, hostages or those who are not law breaking participant (they can be denoted as irrelevant persons). Let's denote such conditions as weapon apply safety (WAS). Probable projectile reflection from various surfaces (installations, pavement, water surface, etc.) and its further unpredictable move can seriously affect WAS [1]. Security forces personnel usually have to apply their weapon within settlement, inside installations or transport facilities where, as usual, irrelevant persons are present and can be injured. There were many evidences of injuring or death of irrelevant persons due to ricochet when military or security forces servicemen had applied their weapon [2–4]. To enhance WAS in probable ricochet conditions, projectile ricocheting velocity must be reduced providing non-lethal level of remaining projectile's kinetic energy (RKE) E_{rem}. Recent ricochet researches [5–6] are mainly devoted to defining ricochet parameters of projectiles in combination with various target materials and surfaces. Mechanical properties of projectile affect RKE as it is reported in [7]. Dependences of the remaining projectile's velocity after hitting steel obstacle on its initial before collision velocity for various projectile materials are also represented there.

Purpose of the article. To meet WAS demands it is necessary to define weapon ballistic parameters that would provide safe projectile ricochet velocity and required projectile target meeting velocity to be matched. This is the task with internal contradiction because the projectile velocity must be large enough providing target to be hit and simultaneously it must be low enough providing ricochet safety. To solve this contradiction a special procedure should be designed.

Exposition of basic material

WAS demands remaining projectile's kinetic energy must not exceed the certain value that we denote as safe projectile kinetic energy E_{saf} ($E_{rem} \leq E_{saf}$).

Projectile hitting effect achieving needs two conditions to be realized. The first one is projectile specific energy $E_{sp} \geq 0{,}5$ J/mm^2 (to provide target penetration) [8], the second one is $E_k \geq 30$ J (to provide required target destruction) [8]. The most wide applied security forces guns and machineguns calibers are 7,62 mm and 9 mm (with 7,62×25TT, 9×18PM, and 9×19Par. cartridges). Therefore these cartridges are taken to be researching samples in the article. To provide hitting effect (with respect to E_{sp} required), it is necessary $E_k \geq 30$ J for the 7,62 mm projectile and $E_k \geq 32$ J for the 9 mm projectile. Let's accept assumption of WAS providing energy is 1 J less then minimal hitting energy mentioned above.

Minimal projectile muzzle kinetic energy E_{km} necessary to provide target hitting effect depends on projectile ballistic coefficient C and target distance. Dependences of necessary projectile muzzle kinetic energy on target distance for three gun projectiles regarding their C values ($C_{7,62}$=9,63 m^2/kg, C_{9PM}=12,48 m^2/kg, C_{9Par}=7.69 m^2/kg) are represented at fig. 1. From (1) and (2) is obtained (3).

$$E_k = \frac{m \cdot V^2}{2}, \qquad (1)$$

where E_k – projectile kinetic energy, J; m – projectile mass, kg; v – projectile velocity, m/s.

$$V_X = V_m \cdot e^{-kCX}, \qquad (2)$$

where V_x – projectile velocity at X distance from muzzle, m/s; V_m – projectile muzzle velocity, m/s.

$$E_{km} = E_{kt} \cdot e^{2kCX_{aim}}, \qquad (3)$$

where E_{kt} – projectile kinetic energy when it riches target, J; $k = 3{,}29 \cdot 10^{-4}$ – air resistance coefficient, kg/m^3; C– projectile ballistic coefficient, m^2/kg; X_{aim} – weapon aimed distance, m.

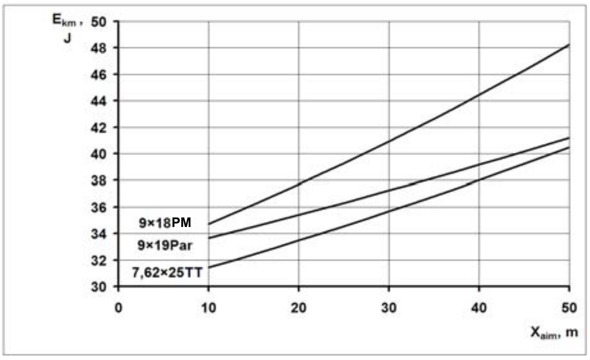

Fig. 1. E_{km} versus X_{aim} for gun projectiles 7.62 mm and 9 mm

Providing WAS it is necessary projectile after ricochet kinetic energy to be reduced to E_{saf} level. The longer aiming distance the larger E_{km} value necessary to provide target hitting effect (fig. 1). WAS demands must be fulfilled for all distances including X_{aim}. Thus, simultaneous providing of target hitting effect and WAS is as complicated as large X_{aim} value is. As well X_{aim} value growing as bigger E_{km} and E_{saf} difference to be compensated by means of conditional restoration coefficient K_r [7] adjusting. At the same time conditional restoration coefficient of projectile materials can not be substantially small while remaining projectile hitting properties. Therefore, when technical specifications for security forces weapons are being designed, it should be mentioned aiming distance not to overrate if not necessary. Dependences of necessary conditional restoration coefficient value on aiming distance for mentioned gun projectiles are depicted on fig. 2.

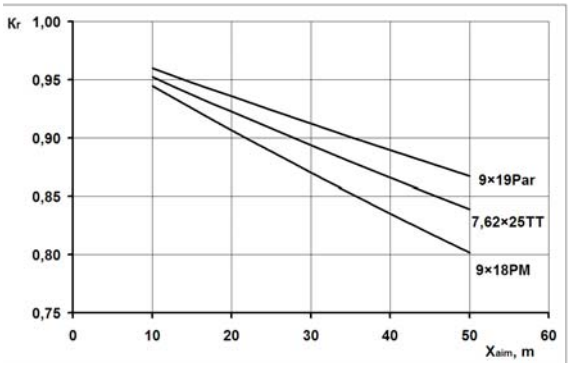

Fig. 2. Dependences of necessary conditional restoration coefficient value on aiming distance for gun projectiles

Projectile conditional restoration coefficient mainly determined by projectile material property [7]. Thus, at first site, ricochet energy reduction for existing cartridges could be done by means of choosing projectile material with proper K_r value. But projectile material change leads to probable projectile mass changing (due to materials' density difference), and correspondingly to projectile ballistic coefficient changing. For one's part, it causes necessary E_{km} value changing and makes the earlier accepted K_r value to become incorrect. So ricochet energy reduction is not trivial task. To meet this problem appropriate solving procedure is designed (fig. 3).

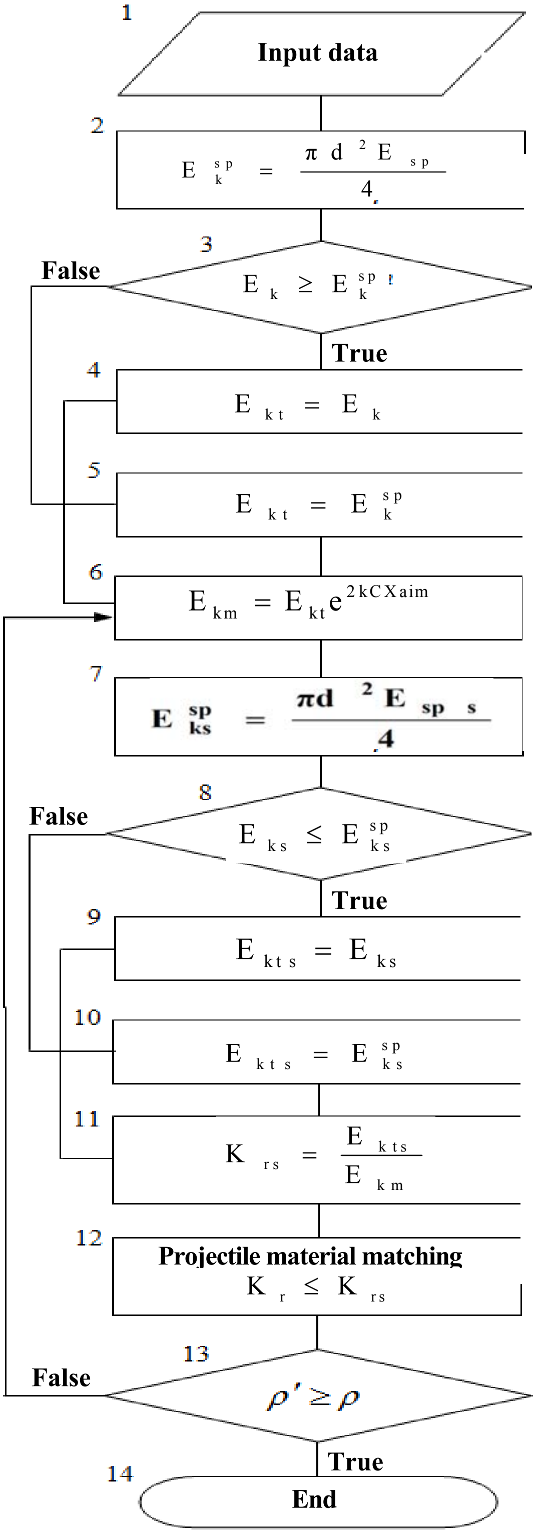

Fig. 3. Algorithmic diagram of the procedure

Procedure input data (fig. 3, unit 1) are the aim of weapon use is target hitting; limitation is projectile ricochet safety; target distance, $X_t = X_{aim}$; projectile caliber, d; projectile material average density, ρ; projectile ballistic coefficient, C; necessary to hit target projectile specific energy $E_{sp} \geq 0{,}5$ J/mm^2; necessary to hit target projectile kinetic energy $E_k \geq 30$ J; safe ricocheting projectile specific energy $E_{sp\,s} < 0{,}5$ J/mm^2; safe ricocheting projectile kinetic energy $E_{k\,s} < 29$ J; fire mission effectiveness criterion – irrelevant persons injuring maximal probability $W_{ip\,max} = 0$.

Unit 2 (fig. 3). Projectile kinetic energy corresponding to projectile specific energy enough target to be hit E_k^{sp} is defined.

Unit 3 (fig. 3). Projectile kinetic energy value enough target to be hit and are compared.

Units 4 and 5 (fig. 3). Necessary projectile kinetic energy at the moment of target hitting E_{kt} is defined.

Unit 6 (fig. 3). Necessary muzzle projectile kinetic energy E_{km} is calculated.

Unit 7 (fig. 3). Projectile kinetic energy providing safe specific energy for irrelevant person is defined.

Unit 8 (fig. 3). Safe projectile kinetic energy E_{ks} value and projectile kinetic energy value providing safe specific energy E_{ks}^{sp} level are compared.

Unit 9 and 10 (fig. 3). Providing irrelevant persons safety projectile kinetic energy at the moment of target hitting E_{kts} is defined.

Unit 11 (fig. 3). Conditional restoration coefficient value providing safe ricochet projectile kinetic energy level K_{rs} is calculated.

Unit 12 (fig. 3). Projectile material having K_r value not exceeded K_{rs} is selected.

Unit 13 (fig. 3). Selected material density ρ′and projectile average density ρ are compared.

Projectile ballistic coefficient grows when ρ′<ρ. It leads to muzzle projectile kinetic energy’s increasing and decreases admissible value of K_{rs} correspondingly. In such case inequality in unit 12 can fail and muzzle projectile kinetic energy value and relevant values must be recalculated (transfer to unit 6).

While $\rho' \geq \rho$ is true, projectile after ricocheting will have safe energy level for irrelevant persons.

When it is impossible to match a material providing appropriate conditional restoration coefficient value, projectile design should be corrected. As it is well known, body rigidity also depends on its design features. Constructive elements' weakening leads to increasing of body rigidity and to possibility to accumulate energy by means of elastic deformation. Besides, it increases energy consumption for plastic deformation that promotes increasing of conditional restoration coefficient value.

It should be noted that a projectile fragmentation inside human's body is admissible because of impossibility to identify small fragments by X-ray equipment. Therefore it appears not to be acceptable application of expansive projectiles like those filled with small shot having increased ricochet properties.

Thus, it needs to find the ways that would allow weakening of projectile body without provoking its fragmentation. There are some of them:

making of a hollow space inside a projectile between core and shell;

weakening of a projectile core by perforating or making of hollow spaces inside it;

weakening of a projectile core by fragmentation;

weakening of a projectile core by making of stress concentrators.

Influence of a projectile's body weakening on a projectile's energy after ricochet could be one of the further researches of this theme.

Conclusions

1. One of the ways of providing safety for irrelative persons when security force's personnel apply their firearms is reducing of projectile's velocity after ricochet.
2. It is determined that projectile's material density influences on ricochet velocity.
3. The procedure to provide safe after ricochet parameters of a projectile by projectile's material matching is designed.

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МЕТОДИКА ЗНИЖЕННЯ ЕНЕРГЕТИЧНИХ ХАРАКТЕРИСТИК ПОРАЖАЮЧОГО ЕЛЕМЕНТУ ПІСЛЯ ВІДБИТТЯ ВІД ПЕРЕШКОДИ

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Удосконалення зброї сил безпеки на сьогодні є актуальною проблемою оскільки антитерористична та правоохоронна діяльність стають важливими складовими вирішення сучасних конфліктів. В той же час, майже у всьому світі поліція та інші безпекові служби ще досі використовують звичайну бойову зброю у правоохоронній, антитерористичній діяльності та при виконанні інших силових завдань всередині держави. Як показує відповідний аналіз, питання розробки спеціальної зброї для сил безпеки, на відміну від бойової зброї, досі залишаються недостатньо розвинутими. Одним з проблемних питань застосування вогнепальної зброї силами безпеки є можливість ураження сторонніх осіб, представників дружніх сил та самого стрільця у результаті рикошету поражаючого елементу від твердих поверхонь. У статті розглянуто можливість підвищення безпечності застосування вогнепальної зброї в умовах ризику рикошету за рахунок зниження швидкості руху поражаючого елементу після його відбиття від поверхні перешкоди до прийнятного рівня, зокрема за рахунок змінювання механічних властивостей матеріалу поражаючого елементу. Встановлено, що наряду з міцністю матеріалу, з якого виготовлений поражаючий елемент, важливим чинником, який впливає на розв’язання завдання забезпечення безпеки застосування стрілецької зброї з урахуванням рикошету є також його щільність. Це обумовлено впливом щільності матеріалу поражаючого елементу на балістичний коефіцієнт, отже на динаміку падіння його швидкості на траєкторії польоту. Розроблено методику забезпечення безпечності поражаючого елементу після відбиття від перешкоди на основі вибору його матеріалу. Використано відомі залежності та методи зовнішньої та термінальної балістики. Результати можуть бути використані для модернізації існуючих або при розробленні нових боєприпасів для стрілецької зброї сил безпеки. Напрямком подальшого дослідження є вивчення впливу характеру ослаблення елементів конструкції поражаючого елементу на його енергетичні характеристики після відбиття від перешкоди.

Ключові слова: *стрілецька зброя, сили безпеки, безпечність застосування зброї, рикошет, умовний коефіцієнт відновлення.*

МЕТОДИКА СНИЖЕНИЯ ЭНЕРГЕТИЧЕСКИХ ХАРАКТЕРИСТИК ПОРАЖАЮЩЕГО ЭЛЕМЕНТА ПОСЛЕ ОТРАЖЕНИЯ ОТ ПРЕПЯТСТВИЯ

А.И. Биленко, А.А. Кириченко, Д.В. Павлов

Одним из проблемных вопросов применения огнестрельного оружия силами безопасности является возможность поражения посторонних лиц в результате рикошета. Установлено, что важными факторами, влияющими на решение задачи обеспечения безопасности применения стрелкового оружия с учетом рикошета являются прочность материала, из которого изготовлен поражающий элемент и его плотность. Разработана методика обеспечения безопасности поражающего элемента после отражения от препятствия на основе выбора его материала. Использованы известные зависимости и методы внешней и терминальной баллистики. Направлением дальнейшего исследования является изучение влияния характера ослабления элементов конструкции поражающего элемента на его энергетические характеристики после отражения от препятствия.

Ключевые слова: *стрелковое оружие, силы безопасности, безопасность применения оружия, рикошет, условный коэффициент восстановления.*