UDC 623.44

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"MAN-MACHINE" SYSTEM CHARACTERISTICS INFLUENCE ON THE EFFECTIVENESS OF FIRE MISSIONS CARRIED OUT BY SECURITY FORCES PERSONELL

The article is devoted to the study of the weapons' technical characteristics influence on shooter's functional parameters. This influence can affect fire mission effectiveness. It is especially important for security forces whose fire mission specificities can demand fire to be more accurate or more rapid than in case with armed forces. The article defines the varieties of weapons' technical characteristics and shooter functional parameters, as well as correlation between them that can significantly influence fire mission effectiveness. Defining this correlation can help to advance security forces' armament through creating (updating) weapons' technical requirements. The general way to obtain weapons' technical requirements (specifications) is represented.

Keywords: *small arms, fire mission effectiveness, shooter functional parameters, security forces.*

Introduction

Despite the quick development of new types of weapons and military techniques, role of small arms is still important in modern conflict. For example, according to [1], in 2003 up to 90 % of casualties were killed by small arms. As small arms are the main means of security forces to neutralize lawbreakers, researching in the field of small arms effectiveness is particularly significant nowadays.

It is important to provide high weapon application effectiveness. It means maximum probability of fire mission realization while minimum time and ammunition consumption. The effectiveness of fire mission realization is estimated by the following indicators [2]: target hitting probability W; average expected time of fire mission realization T, s; average expected ammunition consumption for fire mission to be realized N, units.

The first and the second of these indicators are more important for security forces according to specificities and conditions of their activity. They indicate reliability and rapidity of fire mission realization [3].

In the field of engineering special attention is paid to the study of the impact of particular weapon technical characteristics on fire effectiveness. The improvement of small arms is based on the studies of this impact. Thus, for example, to advance fire accuracy it is improved weapon technique grouping pattern, to advance weapon pointing it is increased optic's zoom [4–5], to increase firing rate it is enlarged magazine capacity.

At the same time, such modernizations lead to other weapons' characteristics change, such as: mass, detail or overall dimensions, center of mass position, moments of various forces, light-gathering strength of optics etc.

All of those parameters can affect not only weapon mechanism, but also shooters. Thus, weapon mass enlarging increases shooters' weariness when they overcome long distances or obstacles, shifting mass center from pivot (back plate of butt or back surface of pistol's hilt) leads to increasing hand muscle tension, enlarging of triggering force or free running in order to improve weapon usage safety [6] causes unnecessary movements and tremor when firing, decreasing light-gathering strength of optics leads to target visibility losses etc.

Unfortunately, the influence of these characteristics on a shooter is not always considered when creating weapon performance technical requirements. Adoption of weapon samples with irrational parameters indirectly confirms this statement. Let's consider, for example, mass parameters of such weapon samples.

Being adopted by National Guard of Ukraine (NGU) 9 mm submachine-gun Fort-224 mass is 3.8 kg. It is 1,7 times more than the average mass (2,28 kg) of similar combat submachine-guns with similar characteristics, and 2.4 times more than the mass of the lightest submachine-gun adopted by security forces (Steir TMP – 1,6 kg). Sniper rifle Fort-301 mass is 7,4 kg which is 1.6 times more than the mass of similar combat properties such as Drahunov's sniper rifle (4,5 kg).

Magnification of optical sight Zeiss hansoldt ZF 6-24×56, adopted by NGU and compounded with rifle Fort-301, is 6…24. It's too big in view of aiming distance of Fort-301 (1000 m). It is completely enough to have optical sight 1P21 (in original 1П21) with magnification values of 3…9. Besides, the Zeiss hansoldt mass is 1.17 kg that is 1.5 times more than the mass of 1P21.

Zeiss hansoldt ZF 6-24×56 minimal magnification is 6 ×, that is too much for short firing distance (average security force's firing distance is from 45 m to 100 m [7]) due to essential observation angle shortcut (from 3.5° of Zeiss hansoldt to 6° of 1P21).

Thus, weapon technical characteristics can affect fire mission results not only in direct way but by influencing shooter functional parameters (characteristics of a shooter that have an influence on fire mission results) too. It can be concluded that small arms application should be regarded as a man-machine system that depends both on weapons' technical characteristics and on shooter functional parameters as well as on interrelation between them.

The article's goal is to prove the necessity to consider shooter functional parameters affected by weapon technical characteristics while defining the fire mission effectiveness.

Basic section

Target affecting probability depends on probability of hitting element (HE) to hit target [2]:

$$W = 1 - \left(1 - \frac{P}{K}\right)^{n}, \qquad (1)$$

where P – probability of HE to hit target;

n – quantity of shoots, units.;

K – quantity of target hits necessary for the target to be disabled, units.

For security forces practice one hit is usually enough to disable or suppress target. Therefore, expression (1) can be simplified to:

$$W = 1 - (1 - P)^{n}. \qquad (2)$$

According to (1) and (2) there is a direct proportion between target affecting (disabling or suppressing) and target hitting [2]:

$$P = \left[\frac{1}{\sqrt{2\pi}\sigma_y}\int_{-\frac{Y}{2}}^{\frac{Y}{2}} e^{\frac{-(y-\bar{y})^2}{2\sigma_y^2}}dy\right] \times \left[\frac{1}{\sqrt{2\pi}\sigma_z}\int_{-\frac{Z}{2}}^{\frac{Z}{2}} e^{\frac{-(z-\bar{z})^2}{2\sigma_z^2}}dz\right], \qquad (3)$$

where σy –standard deviation (SD) of hitting points from dissipation axis in vertical direction, m;

σz – SD of hitting points from dissipation axis in lateral direction, m;

$\bar{y}$ – mathematical expectation of hitting points in vertical direction, m;

$\bar{z}$ – mathematical expectation of hitting points in lateral direction, m;

Y – target height, m;

Z – target width, m.

According to (3) minimizing of σy and σz, when $\bar{y}$ and $\bar{z}$ approach to 0, increases P and leads to enhancing of grouping pattern and fire accuracy correspondingly. In practice the approach of $\bar{y}$ and $\bar{z}$ to 0 is made by means of zeroing procedure. Values of σy and σz depend on certain factors we should further concentrate on.

One of these factors is technical grouping pattern σT. It is associated with weapon technical parameters. Security forces small arm's technical grouping pattern measured for single firing on 100 yards distance is σT = 0,002…0,005 meters for sniper rifle and σT = 0,02…0,03 meters for other [8].

The next factor which affects grouping pattern is aiming mistakes σA. Its values depend on both sight parameters and shooter's physical parameters such as movement coordination and eyesight sharpness. Thus, when firing in the prone position without hand rest values of σA can reach 0,013 meters, when firing in kneeling position it can reach 0,025 meters, when firing in short stops while moving it can reach 0,07 meters [9].

Movement coordination can also essentially affect grouping pattern.

The next factor is muscle tremor. It falls into static tremor (when aiming) and dynamic tremor (when triggering). Weapon's positioning declines if shooter has a bad movement coordination and tremor. It leads to target hit points declining from control point. By σC, σTS and σTD denote the SD partials corresponding to movement coordination, static and dynamic tremor.

Total SD value, considering partials mentioned above, can be obtained with (4):

$$\sigma = \sqrt{\sigma_T^2 + \sigma_A^2 + \sigma_C^2 + \sigma_{TS}^2 + \sigma_{TD}^2}. \qquad (4)$$

Suppose σT is constant not depending shooter functional parameters; then grouping pattern σ is function of σM, σC, σTS and σTD. These partials associated with shooter functional parameters can be affected, among other things, by weapon parameters.

Thus, fatigue affected by any kind of shooter activity (when he overcomes long distances or obstacles) can degrade movement accuracy [10] and sight sharpness [11], as well as increase static and dynamic tremor amplitude [12]. It leads to σC, σM, σTS, σTD growth. Muscle tension, which depends on weapon's mass and trigger strain, can affect movement accuracy and tremor amplitude [13].

Rapidity is considered to be important as well when security forces carry out their fire missions. It depends on a shooter's reaction speed which can be affected by fatigue and neuropsychological stress [14].

Shot noise impact on hearing and sight organs affects neuropsychological status of a shooter too. As a result, movement accuracy and rapidity, sight sharpness, reaction time, binaural hearing, attention and situation assessment ability decrease [14].

The analysis of security forces' typical missions allows us to define the most important parameters such as weapon mass, recoil energy, shot noise. For weapons held with one hand, used without rest, in cases of rapid fire direction changes, such characteristics as mass center position, triggering force and free running are of vital importance. Magnification and light-gathering strength of optical sight are important parameters of weapons with optics. Movement accuracy, static and dynamic tremor amplitude, sight sharpness, reaction time and binaural hearing should be highlighted among shooter functional parameters.

Interconnections of the abovementioned mission results' affecting parameters and fire mission's effectiveness indicators are demonstrated on fig. 1.

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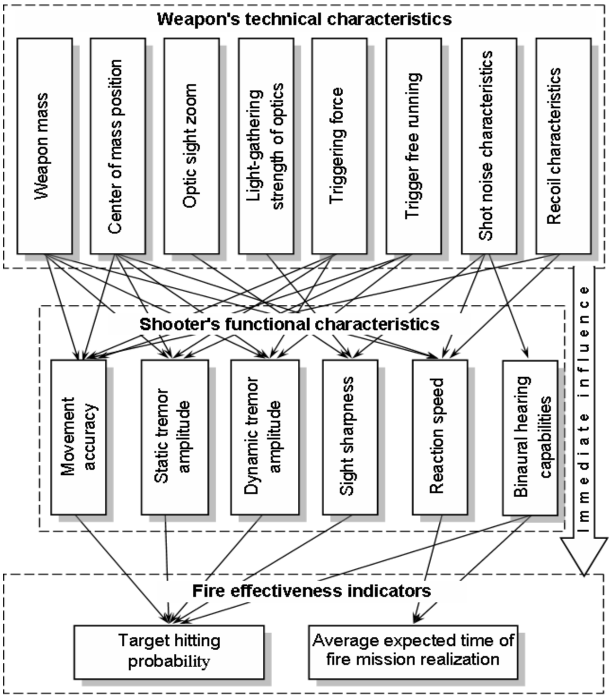

Fig. 1. Interconnections of weapons' technical characteristics, shooter functional parameters and fire mission effectiveness indicators

To define weapon's parameters impact on firing effectiveness through shooter functional parameters it is necessary to know how weapons' parameters affect shooter functional parameters.

There are some data in the scientific literature concerning how certain negative factors affect human functional parameters. But most of dependencies represented in the abovementioned sources are empirical and were taken from the experiments with people who are not security forces personnel. Therefore, this data needs to be verified and corrected.

If correct dependencies of shooter functional parameters on weapons' technical parameters are to be obtained, it would allow predicting the influence of weapons' technical parameters on fire mission effectiveness with consideration of human functional parameters. Obtaining an efficient integration of weapons' technical parameters and shooter functional parameters allows improving fire mission effectiveness.

Thus, fire mission effectiveness can be provided by solving the following tasks: obtaining dependencies of shooter functional parameters and weapos' technical parameters; advancing existing models of firing with small arms taking into account weapons' technical parameters and shooter functional parameters influence on fire mission results; developing a method to define weapons' technical requirements considering typical shooter functional parameters.

Conclusions

1. To define fire mission effectiveness it's appropriate to regard small arms as a man-machine system, taking into consideration both weapons' technical characteristics and on shooter functional parameters.

2. We created a list of weapons' technical characteristics and shooter functional parameters that considerably affect fire mission results and defined the correlations between them.

3. We created a set of tasks the solutions to which will allow achieving the necessary fire effectiveness by setting new weapon technical requirements considering shooter functional parameters.

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Надійшла до редколегії 1.11.2017
Схвалена до друку 7.12.2017

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ВПЛИВ ХАРАКТЕРИСТИК СИСТЕМИ «ЛЮДИНА–МАШИНА» НА ЕФЕКТИВНІСТЬ ВИКОНАННЯ ВОГНЕВИХ ЗАВДАНЬ ПРАЦІВНИКАМИ СИЛ БЕЗПЕКИ

О.І. Біленко, К.В. Першина, Д.В. Павлов

У статті обґрунтовано необхідність врахування впливу технічних характеристик зброї на функціональні характеристики стрільця під час визначення показників ефективності виконання вогневого завдання. Визначено перелік технічних характеристик зброї і функціональних характеристик стрільця, які мають сумісний та суттєвий вплив на результати виконання вогневих завдань, а також структура зв’язків між ними. Сформульовані завдання, розв’язання яких дозволить забезпечити задану ефективність стрільби шляхом формування вимог до технічних характеристик зброї з урахуванням функціональних характеристик стрільця.

Ключові слова: *стрілецька зброя, ефективність стрільби, технічні характеристики зброї, функціональні характеристики стрільця.*

ВЛИЯНИЕ ХАРАКТЕРИСТИК СИСТЕМЫ «ЧЕЛОВЕК – МАШИНА» НА ЭФФЕКТИВНОСТЬ ВЫПОЛНЕНИЯ ОГНЕВЫХ ЗАДАЧ РАБОТНИКАМИ СИЛ БЕЗОПАСНОСТИ

А.И. Биленко, К.В. Першина, Д.В. Павлов

В статье обосновано необходимость учета влияния технических характеристик оружия на функциональные характеристики стрелка при определении показателей эффективности выполнения огневой задачи. Определен перечень технических характеристик оружия и функциональных характеристик стрелка, которые имеют совместное и значительное влияние на результаты выполнения огневых задач, а также структура связей между ними. Сформулированы задачи, решение которых позволит обеспечить заданную эффективность стрельбы путем формирования требований к техническим характеристикам оружия с учетом функциональных характеристик стрелка.

Ключевые слова: *стрелковое оружие, эффективность стрельбы, технические характеристики оружия, функциональные характеристики стрелка.*