Analiza konstrukcionih karakteristika automatskih pušaka domaće proizvodnje u cilju opremanja jedinica Vojske Srbije

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Apstrakt: Veličina slike rasturanja pogodaka i njena udaljenost od cilja opredeljuju stepen tačnosti i preciznosti automatske puške. Puške su bile, i još uvek su osnovno oružje pešadije, a po svojim dimenzijama i načinu rukovanja ubrajaju se u kategoriju individualnog oružja. Vrlo uspešno se upotrebljavaju za gađanje na daljinama do 400 m, odlični strelci mogu uspešno da gađaju i na daljinama do 600 m. Automatska puška je namenjena za uništavanje neprijateljske žive sile i vatrenih sredstava neprijatelja. U radu su prikazane taktičko-tehničke i borbene karakteristike automatskih pušaka domaće proizvodnje i to AP M70 AB2 7,62 mm, PA M21 5,56 mm, PAM M17 6,5 mm. Izvršena je uporedna analiza konstrukcionih karakteristika navedenih automatskih pušaka i njihove municije upotrebom softvera Expert choice i primenom AHP metode. Na osnovu dobijenih rezultata donet je zaključak o najefikasnijoj automatskoj pušci, a u cilju uvođenja u operativnu upotrebu i opremanja jedinica Vojske Srbije. Na osnovu rezultata istraživanja došlo se do zaključka da najbolje konstrukcione karakteristike poseduje puška automatska modularna M17 u kalibru 6,5 mm.

Ključne reči: analiza, konstrukcione karakteristike, automatska puška, AHP metoda

Analysis of the construction characteristics of automatic domestic production rifles for the purpose of equipping units of the Serbian Army

Abstract: The size of the scattering image and its distance from the target determine the degree of accuracy and precision of the automatic rifle. The rifles were and still are the primary weapon of the infantry, and according to their dimensions and manner of handling, they belong to the category of individual weapons. They are very successfully used for shooting at distances up to 400 m, excellent shooters can successfully shoot at distances up to 600 m. The automatic rifle is intended to destroy the enemy's live force and the enemy's firepower. The paper presents the tactical-technical and combat characteristics of automatic domestic guns, AP M70 AB2 7,62 mm, PA M21 5.56 mm, PAM M17 6.5 mm. A comparative analysis of the construction characteristics of the previously mentioned automatic rifles and their ammunition was completed by using the Expert choice application and the AHP method. On the basis of the obtained results, the conclusion about the most effective automatic rifle was made, with the aim of introducing into operational use and equipping units of the Serbian Army. Based on the results and research, it came to the conclusion that the 6.5 mm automatic modular rifle M17 is equipped with best design characteristics.

Key words: analysis, construction characteristics, automatic rifle, AHP method

1. Introduction

The concept for the development of an automatic rifle began in 1910 with the rifle of the famous gunsmith Fedorov, which had a firing regulator and detachable frame. This rifle enters armaments in Russia in 1916. The next invention important for the development of AR was for Germans who in the 1930s began the development of ammunition with medium gunpowder filling that would be lighter than the standard 7.92 mm bullet and thus the weapon more accurate and easier to use in automatic mode. (Jakovljevic,

1995) The most famous weapons in this caliber were the MP43 and the StG.44. The same rifle inspired the famous Mikhail Kalashnikov to design the most famous and popular AK-47 rifle of today.

Most automatic weapon systems are powered by bullet firing energy, whether based on pipe twitch, bolt twitch, or gunpowder gases lending, but there are also externally driven types, such as Gatling system weapons, which can be mechanical, electrical or hydraulic. This type of automatic weapon is usually of a larger caliber and is used in fighter aircraft and ships.

Automatic weapons are characterized by high-velocity burst firing at up to several thousand bullets per minute and loading with a high-capacity magazine. Today's ARs are mostly in 5.56 mm NATO, 7.62 mm or 5.45 mm caliber with the most common magazine capacity of 30 rounds. The effective range is usually up to 600 m.

Modern rifles in the armaments of the armies of the world are equipped with a firing regulator, which provides in addition to bursts and single firing. For the sake of economy and increase in efficiency, modern automatic rifles have a limiter for firing 2-3 bullets in the burst. All modern automatic rifles have sufficient kinetic energy to destroy unprotected people at distances of more than 1000 m so the overall assessment of the quality of rifles depends on many other factors, such as the design characteristics, caliber, rifle length, AR mass, initial bullet speed, effective range, firing rate, magazine capacity, bullet weight, AR reliability.

Modern automatic rifles are increasingly equipped with optical sights, laser target markers, laser rangefinders and ballistic computers. Automatic rifles become modular-type weapons that are equipped with additional systems and devices depending on the task-mission for which they are used.

The development of automatic rifles in our country begins in the late 1960s, a rifle modeled on the AK-47, automatic rifle M70 in 7.62 mm caliber production of Zastava from Kragujevac. Said rifle is manufactured in several different variants.

2. Factors of comparative analysis

Comparative analysis of automatic rifles was performed on the basis of structural characteristics such as: caliber, weapon mass, weapon dimensions, initial bullet speed, bullet mass, magazine capacity, mean turning and theoretical firing rate. The aforementioned characteristics of AR have a direct impact on the efficiency of weapons.

Weapon mass is an important combat feature of automatic rifles, because the requirements and modern concept of warfare tends to decrease the weapon mass as low as possible. The mass of the weapon directly affects the mobility and the ability to transfer fire. In order to provide as low mass as possible, new types of materials (usually polymers) are used, which provide the same characteristics as metals, but with a much lower mass.

Caliber represents the distance between two opposing fields. Automatic rifles most commonly use reduced ammunition 7.62 x 39 mm, 5.56 x 45 mm (NATO), 5.45 x 39 mm caliber. The caliber determines the weapon's effect on the target. In smaller calibers, the stopping power is smaller, the initial bullet velocity is higher, the smaller jerk and the thin bullet metal jacket, and as a consequence, gunshot wounds occur, while in automatic rifles larger calibers, the stopping power is higher and the initial velocity is lower, so the kinetic energy on target is higher and it results in bullet fragmentation in the human body and severe wounding of the living force. (Tancic and associates 2009) Automatic rifles are primarily intended for small and medium-range combat up to 500 m, and it is therefore desirable that the ammunition used has greater penetration power so that it can penetrate both level 3A and level 4 ballistic protection at distances of 500 meters or more. Caliber is one of the most significant characteristic of automatic rifles. In this paper were analyzed automatic rifles of 7.62 mm, 5.56 mm and 6.5 mm caliber.

Automatic rifle length means the length from the beginning of the muzzle to the shoulder support on the stock. The automatic rifle length has the greatest influence when handling and carrying weapons, and therefore the automatic rifle length is a very important feature. If the automatic rifle is longer it reduces its mobility and is more demanding for handling in a small space, so it tends to make the length of the automatic rifle shorter to increase the mobility and handling indoors, but long enough not to reduce the

precision that is immediate dependent on the length of the pipe. Most modern automatic rifles have a folding or telescopic-type stock, which significantly reduces their length.

The initial bullet velocity represents the grain velocity at the moment of leaving the muzzle. Higher initial velocity directly affects the firepower of the weapon, thereby increasing the kinetic energy of the bullet, and thus the effect on the target. Smaller caliber rifles achieve a higher initial bullet velocity than larger caliber rifles, which is directly conditioned by the weight of the bullet.

Magazine capacity is another basic parameter that directly affects the firepower of a weapon. Increasing the magazine capacity increases the mass and dimensions of the weapon, but also increases the practical firing rate. Automatic rifles require high firing rates, and smaller capacity magazines empty relatively quickly and require frequent replacement. The small capacity of the magazine and its frequent replacement directly affect the safety and security of the shooter in performing combat operations. For this reason, automatic rifles need more magazine capacity, to reduce the frequency of magazine replacement in combat. The standard AR magazine capacity is 30 rounds.

The mass of the bullet has a direct effect on the initial velocity of the bullet, and therefore on its penetration as well as the kinetic energy of the projectile. The mass of the bullet is inversely proportional to the initial velocity, the larger the mass of the bullet decreases the initial velocity. Higher bullet velocity directly affects the projectile's penetration.

The type of basic sight used on a particular AR significantly affects the accuracy and precision of shooting, which is one of the most significant features of automatic rifles. Depending on the type of sight, the magnitude of the direct shooting errors also depends.

Firing rate is a design feature that has a direct impact on combat operations, as it represents the number of rounds fired per unit of time and has an effect on the firepower of the weapon.

Probable deflection (Pd) is a measure of the dispersal of hits whose magnitude is chosen such that half of the hits are equally likely to be smaller and the other half of the hits larger than the absolute value. (Kokelj and Randjelovic, 2018) Probable deflection is one of the most significant features that characterize the accuracy and precision of AR shooting (Radovanovic and associates 2016, Randjelovic and associates 2019a).

3. Characteristic of automatic rifles

An automatic rifle is a type of firearm designed for firefighting against unprotected and ballistic vests protected by live force, and a rifle equipped with a trombone or grenade launcher can produce damage to objects and non-combat and lightly armored combat vehicles, it is also possible to illuminate and smoke the battlefield. The M70 AB2 automatic rifle (image 1) has the ability to fire a trombone (Federal Secretariat for National Defense, 1983), while the M21A automatic rifle has the ability to shoot with a grenade launcher (Stamenov, 2009). The M17 automatic modular rifle does not have the ability to fire a trombone and a grenade launcher. The M70 AB2 and M21A automatic rifles have mechanical sights, while the AMR M17 does not have a mechanical sight, it only has a reflex sight.

Figure 1. M70 AB2 automatic rifle

The M70 AB2 automatic rifle does not have the option of mounting accessories (optical, passive, reflex sights, laser target marker), and the M21 and M17 rifles have that capability. The AR M70 basic sight is mechanical, the AR M21 (image 2) basic sight is optical, and for AMR M17 the basic sight is reflex. The use of optical and reflex sights increases the accuracy and precision of shooting compared to a mechanical

sight, due to the lower possibility of creating error during aiming, which directly affects the efficiency of the rifle and the probability of hitting the target.

Figure 2. M21A automatic rifle

The automatic modular rifle M17 (image 3) is characterized by the fact that it has an interchangeable barrel and the possibility of using two calibers (6.5x39 and 7.62x39 mm.), which depending on the needs, doubly affects the efficiency of the rifle. Positive fact is the ability to use two different calibers and the rapid ability to replace barrels. The downside is the need to carry two ammunition kits as well as two types of magazines that need to be replaced due to the replacement of the barrel, which puts additional burden on the soldier. This paper analyzes the characteristics of AMR M17 in 6.5 mm caliber.

Figure 3. Automatic modular rifle M17

Table 1 shows the constructional, tactical, technical and combat characteristics of the automatic rifles manufactured at the Zastava Kragujevac factory, namely AR 7.62 mm M70, AR M21 5.56 mm M21 and AMR 6.5 mm M17.

Table 1. Characteristics of automatic rifles

characteristics of automatic rifles	M70 AB2 AR 7,62 mm	M21A AR 5,56 mm	M17 AMR 7,62/6,5 x 39 mm	
Caliber	7,62 x 39 mm	5,56 x 45 mm	7,62 x 39 mm	6,5 x 39 mm
automatic rifle length with folded stock	640 mm	750 mm	685 mm	
automatic rifle length with unfolded stock	950 mm	998 mm	850/935 mm	
firing rate	600 bullet/min	550-650 bullet/min	600 bullet/min	
magazine capacity	30	30	30	20
automatic rifle mass with empty magazine	3,7 kg	4,5 kg	3,5 kg	3,55 kg
mass with empty magazine	0,36 kg	0,35 kg	0,21 kg	0,16 kg
initial bullet velocity	720 m/s	914 m/s	840 m/s	760 m/s
bullet mass	17 g	12,1 g	16,1 g	17 g
bullet mass (grain)	8 g	4 g	7,1 g	8 g
basic sight	mechanical sight	optical sight	reflex sight	
ultimate bullet velocity at a distance 100 m	616	821	765	650
ultimate bullet velocity at a distance 300 m	435	647	628	475

4. Analysis of automatic rifles

Analytical hierarchical process (AHP) is one of the most well-known methods of scenario analysis and decision making by consistently evaluating hierarchies whose elements are goals, criteria, sub-criteria and alternatives. The method was modeled by Thomas L. Saaty (Tomas L. Saaty) in 1980 and is a tool to help decision makers solve complex problems. (Saaty 1980)

The analytical hierarchical process belongs to the class of soft optimization methods. It is basically a specific program for forming and analyzing decision hierarchies. (Nikolic and Borovic, 1996) The analytical hierarchical process method first enables the interactive creation of a problem hierarchy as preparation of decision scenarios and then evaluations in pairs of hierarchy parameters (goals, criteria and alternatives) in a top-down direction. In the end, a synthesis of all evaluations is realized and, by a strictly determined mathematical model, the weight coefficients of all elements of the hierarchy are determined. The sum of the weight coefficients of the elements at each hierarchy level is equal to 1 which gives the decision maker to rank all the elements in the horizontal and vertical directions.

The AHP method allows for an interactive analysis of the sensitivity of the valuation process to the final ranks of the hierarchy. In addition, during the evaluation of the hierarchy factors, until the end of the procedure and the synthesis of the results, the consistency of the reasoning of the decision makers is checked and the correctness of the obtained ranks of the alternatives and criteria, as well as their weight values (Randelović and associates 2019b).

Using the Expert choice software package and the AHP method, a comparison was made of the design characteristics of automatic rifles from domestic production, with the aim of finding the best alternative for equipping the units of the Serbian Armed Forces.

The criteria (initial bullet velocity, effective range, AR mass, type of sight, caliber, mean probable 100 m deflection, bullet weight, rifle length, firing rate, magazine capacity) from which the effectiveness of automatic rifles were evaluated were derived from analysis of literature in the field of shooting theory and ballistics, results of conducted research and expertise and experience of members of the Ministry of Defense.

By directly entering the weighting coefficients of the criteria given by the decision maker, shown in image 4, with simultaneous graphical and numerical representation of the software obtained priorities (for the stated criteria), global criteria criteria were obtained (image 5).

Figure 4: Criteria weight coefficients

Figure 5: Problem Model - Criteria tree, criteria weighting values and alternatives priorities

Based on the obtained results, a dynamic sensitivity analysis was performed at the criterion level of the structural characteristics of automatic rifles as a function of the target (images 6 and 7). Figure 8 shows a diagram of the sensitivity of the design characteristics of automatic rifles, showing the choice of the most favorable alternative with respect to the given criteria, with a dynamic view for all the criteria individually and with the final solution of the problem.

Figure 6: Dynamic analysis of sensitivity of solution obtained by problem-level synthesis by criteria

Figure 7: Dynamic sensitivity analysis of the solution obtained by synthesis at the problem level depending on the criteria

Figure 8: Sensitivity diagram of the construction characteristics of automatic rifles

In addition to the analyzes presented, a head-to-head procedure was also implemented (images 9, 10 and 11) with the aim of comparing the effectiveness of automatic rifles with each other, in order to fully understand the ratio of the results.

Figure 9: Analysis of the construction characteristics of automatic rifles AR M70 and AMR M17

Figure 10: Analysis of the construction characteristics of automatic rifles AR M70 and AR M21

Figure 11: Analysis of the construction characteristics of automatic rifles AMR M17 and AR M21

Priorities of alternatives by each criteria were obtained based on the absolute values of the criteria by alternatives (Table 1). The result of synthesis of problems of structural characteristics of AP based on the research results are presented in the form of multi-criteria ranking list of alternatives (image 12).

Figure 12: Multi-criteria rank list of automatic rifle design features at target function level

Analyzes of the research results, as well as the conclusions, show the following:

- the efficiency of automatic rifles, depending on their structural characteristics, is influenced by: initial bullet velocity with 17.8%, effective range 14.8%, mass of automatic rifle with

- 7%, type of basic sight with 16.8%, caliber with 13.2%, mean probable 100 m deflection with 11.8 %, AR length 4%, theoretical firing rate 4.9% and magazine capacity 2%;
- the M17 automatic modular rifle stands out with 38.8%, followed by the AR M21 with 31.9%, while the worst results were recorded by the AR M70 with a total of 29.3%;
 - the AMR M17 has a 6.9% better construction performance than the AR M21, and 9.5% better construction performance than the AR M70, while the AR M21 has 2.6% more significant performance than the AR M70;
 - automatic modular rifle M17 6.5 mm rifle achieved the best results on analysis during the research.

5. Conclusion

For successful realization of the analysis, the Expert choice 2000 program was used in the work, the AHP method is also used, as one of the multi-criteria optimization methods, in solving the problem of selecting the model of automatic rifle with the best constructional characteristics, in order to equip the units of the Serbian Armed Forces.

In addition to defining problems, criteria and alternatives, the process of applying the method is described. By expert selection and evaluation of selected criteria and comparison of created models (alternatives) the model that represents the optimal solution for the given criteria has been chosen.

It can be concluded that in the particular problem, two criteria are particularly preferred, namely initial bullet velocity and effective range. The software solution has proven to be very practical and effective in finding the optimal solution, that is, analyzing different variants of the problem solving approach. In the context of decision support, using the Expert choice 2000 software package, it was concluded that the AMR M17 6.5 mm automatic rifle model possesses the best construction characteristics, which is 6.9% better than the AR M21A. The diagrams show the percentages of the representation of individual construction characteristics in each of the alternatives. The tool only suggests a possible solution, but the final decision is still made by the decision maker and he remains the elemental factor in the choice of the most effective model of automatic rifle.

Based on the conducted research, it is concluded that the M17 automatic modular rifle possesses the best construction characteristics and is the optimal choice for solving the problem of choosing the most efficient automatic rifle in domestic production.

For the purpose of the research, basic sights were used for each automatic rifle, for AR M70 it is a mechanical sight, for AR M21 it is an optical sight, while AMR M17 uses a reflex sight as a basic one. Continued research should be directed towards a comparative analysis of the results of shooting automatic rifles at different distances and in different conditions, in order to obtain a completely clear picture of the most effective automatic rifle, with the aim of equipping the units of the Serbian Armed Forces.

6. Literature

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