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## **RESEARCH ON THE ADVANTAGES OF USING UNMANNED AERIAL VEHICLES EQUIPPED WITH SMALL ARMS AT THE TACTICAL LEVEL**

*A comparative analysis of the capabilities, characteristics, advantages and disadvantages of using unmanned aerial vehicles of the tactical level was carried out. It was determined that shooting unmanned aerial vehicles can be used at both the operational and tactical levels and in almost all aspects have an advantage in terms of combat capabilities over other types of assault unmanned aerial vehicles. Among them: a wider range of effective action, the possibility of using protected control methods, the minimum probability of detection, the low probability of hitting the device with small arms, the possibility of multiple use.*

*On the basis of the conducted analysis, directions for further research on the development, construction of unmanned aerial vehicles are indicated.*

**Keywords:** *unmanned aerial vehicles, small arms, small unmanned aerial vehicles.*

**Statement of the problem.** One of the important means of conducting combat operations in the russian-ukrainian war is the use of unmanned aviation systems (UAS). Their integration into modern military operations of various levels radically changes the nature of hostilities, expanding the combat, reconnaissance, assault, logistics and other capabilities of military formations. At the tactical level, in addition to reconnaissance and other actions, units of unmanned aerial vehicles (UAVs) take an active part in the conduct of combat, mainly by dropping ammunition on enemy positions and defeating equipment and manpower by self-detonation. Such actions, along with positive points, have certain disadvantages. Among them is the low probability of injure ammunition hitting the during the target drop, the high risk of insurging to the pilots themselves [when equipping the UAV with a drop (UAVRS)], the guaranteed loss of the attack aircraft, etc.

However, an increase in the efficiency of the use of UAS can be achieved by using small arms with unmanned systems in the tactical link. Such experience already exists for unmanned ground and surface systems. Recently, these means have been quite effectively used by small arms during the performance of special combat missions. At the same time, the use of small arms by unmanned aerial vehicles has hardly been researched, and the available prototypes do not give adequate results of use. Therefore, among the promising areas of

development of UAS, an important place is occupied by equipping unmanned aerial vehicles with small arms as a way to increase the degree of damage to the enemy at the tactical level. This line of research is relevant.

### **Analysis of recent research and publications.**

The issue of the use of unmanned aerial vehicles in military affairs was raised in many scientific and journalistic sources. Thus, in studies [1, 2, 3], an analysis of the main types of UAVs and their methods of application in forensics for military purposes and directly in military conflicts was carried out. Article [4] addresses the integration of UAS with various types of weapons and control systems, which makes it possible to increase the overall effectiveness of military operations. Proceedings [5–8] state the prospects for the development of UAS in the military sphere. Publication [9] presents the classification of kamikaze drones, features and tactics of their use. Article [10] states the features of the use of attack UAVs in the conditions of modern combat operations. The method of using an aircraft-type drone with a shotgun from Besomar and its methods of use in the fight against other unmanned aerial vehicles is given in [11]. The results of an experiment to shoot down enemy Mavic copters using FPV shotgun drones are highlighted in the work [12]. The source [13] mentions the use of FPV drones with a Kalashnikov assault rifle.

However, despite the large number of scientific publications on the proposed topic, little attention

is paid to ways of using UAS equipped with small arms at the tactical level. There is no information about the requirements and restrictions on small arms and unmanned systems themselves regarding the possibility of installing small arms on them. In addition, all the mentioned samples [12, 13] are prototypes and were used only as experimental, while their effectiveness is doubtful today. Therefore, the issue of analyzing modern small arms systems and assessing their tactical and technical characteristics, limitations and risks regarding the possibility of use from unmanned aerial vehicles requires further research.

**The purpose of the article** is to substantiate the need to use unmanned aerial vehicles equipped with small arms, based on the analysis of the capabilities, characteristics, advantages and disadvantages of using tactical-level unmanned aerial vehicles.

**Summary of the main material.** Modern unmanned systems are designed to solve a wide range of tasks in the military sphere, namely: conducting surveillance and reconnaissance; the task of strikes on ground (surface) targets; setting radio-electronic interference; adjusting artillery fire, etc. In other words, UAVs, if possible, replace or ensure the action of other forces and means, which makes their use more accurate and effective. Such replacement or assistance is already available in almost all spheres of military affairs. Today, at different levels of military administration, reconnaissance, assault, reconnaissance-strike, transport and other UAVs of various types and kinds are widely used for military operations, but still an important issue remains the possibility and completeness of their use at the tactical level. This assumes the presence of certain requirements and restrictions regarding the safety of use, range

and height of use, all-weather, high maneuverability, immunity, maximum loss to the enemy, stealth, maximum take-off weight, etc.

It is noted in the works [4, 5, 9, 10] that in modern armed conflicts, existing types of kamikaze [drumming ammunition (DA)] and UAV aircraft are effectively used at the tactical level. The advantages of such methods of using UAVs are: range, the possibility of adjusting actions in real time, inconspicuousness (minimum effective dispersion surface, small overall dimensions, height of action, high flight speed), relatively high reliability and accuracy of defeating enemy forces and means, etc.

The main disadvantages of their use are the influence of various types of interference on the aircraft. In addition, for a DA with a relatively high probability of hitting the enemy, the loss of the UAV itself is a mandatory condition for the performance of a fire mission. For UAVs – there is a low probability of damage, a relatively long time for the fire mission, the need to hover over the target, a high probability of detonation of the discharge charges, the need to return to the base for reloading after the mission. All this leads to the search for alternative solutions to ways of using UAVs in battle. This study considers an alternative method, which consists in the use of small arms for fire damage to enemy forces and means directly from an unmanned aerial vehicle. Let's introduce for such devices the term rifle unmanned aerial vehicles (Gun-armed drones) – shock-type unmanned aerial vehicles that use small arms fire to hit objects.

Table 1 shows a comparative analysis of indicators and characteristics of UAVs, DAs and UAVs.

Table 1 – Comparative analysis of indicators and characteristics of unmanned aerial vehicles

Indicator	UAV	DA	Gun-armed drones
Range of action	Small, medium, large	Small, medium, large	Direct proximity to the operator, small, medium
Application level	In the interests of the platoon/company	In the interests of the platoon/company/battalion	In the interests of the group, department, platoon, company
Management method	Radio command, telepiloted, optical (laser)	Radio command, telepiloted, autonomous (self-controlled), optical (laser)	Radio command, telepiloted, optical (laser), autonomous (self-controlled), wired
Visibility. The possibility of suddenness of actions	High. Almost absent	Average. Yes (due to the use of high maneuverability and speed)	Minimal. Yes (due to remote application)

End Table 1

Indicator	UAV	DA	Gun-armed drones
Task time	Depends on the operator's skills and UAV characteristics	Depends on the skills of the operator and characteristics of UAVs	Depends on the time of readiness of the weapon and aiming devices, characteristics of UAV
Method and methods of action to defeat the enemy	Remotely (passive reset, slow reset, dive reset). In some cases, DA	Direct contact with the target	Remotely. Shooting from a certain distance and height in different ways (from a jump, hover or on the move)
Purpose for use	Live power, lightly armored and unarmored equipment	Live power, armored, lightly armored and unarmored equipment, UAVs and aircraft of various types	Live power, armored, lightly armored and unarmored equipment, UAVs and aircraft of various types
The possibility of remote influence on the target	Yes (from one provision only)	No	Yes (from various provisions)
Probability of hitting the target	Low (depends on operator skills)	Medium (depends on operator skills)	High (depends on the characteristics of the weapon and UAV)
Probability of hitting the target	Low (depends on the type of ammunition, immunity, presence of anti-drone nets on the target, operator skills)	Average (depends on the type of ammunition, the presence of anti-cumulative nets on the target, operator skills, immunity)	High (depends on the characteristics of weapons, types of ammunition, capabilities of the guidance system and characteristics of the UAV)
The possibility of a target to counteract the damage	Yes. Anti-drone grids, anti-cumulative grids, armor protection of equipment	Yes. Anti-drone grids, anti-cumulative grids, armor protection of equipment	Yes. Armor protection of equipment
Uav survivability	Low	Low	High
UAV types, on which it can be applied	Shock, reconnaissance and strike, transport	Shock, reconnaissance and strike, DA, interceptors	Reconnaissance, strike, reconnaissance and strike, DA, interceptors, transport
The type of UAV that is used	Aircraft type, rotary type	Aircraft type, rotary type, DA	Aircraft type, rotary type

After analyzing the data of Table 1, it can be concluded that almost all types of tactical UAVs can be used from different ranges, as a rule, to the depth of tactical influence. Moreover, UAVs, as practice shows, are used from maximum ranges. This is primarily due to ensuring the safety of their service. However, it is this requirement that gives rise to other requirements. Among them is the need for a relatively long operating time, which causes the need to increase the take-off weight (increase the number of batteries). This increases the probability of detecting an aircraft and the possibility of exposure to various types of interference. As for the Gun-armed drones, there is

no need for direct approach to the target, and the maximum range of effective action on the target of the aircraft is calculated as the sum of the flight range and the effective firing range of small arms:

$$D_{efr\ max} = D_{fl} + D_{efr}, \quad (1)$$

where  $D_{efr\ max}$  is the maximum effective range of the UAV;

$D_{fl}$  is the flight range;

$D_{efr}$  is the effective firing range of installed small arms.

Taking into account the possible action of the Gun-armed drones in the interests of small combat groups with control directly from the battle

formations (position, line of attack), the range of their flight from the location of the operator can even be from several tens to several hundred meters (immediate proximity). This increases flight time without making changes to the design, makes it possible to make changes to the methods of controlling the UAV (to protect against interference), to use the take-off weight only in the interests of weapons and additional equipment, etc. In general, the effective flight range of such UAVs will depend on the flight range, the firing range of the established weapon model and the range to the target and will be determined depending on the task being performed:

$$D_{ef}(D_{fr}, D_{efr}, D_t) = \begin{cases} D_{efr}, & \text{whether } D_{efr} \geq D_t, \\ D_{fr} + D_{efr}, & \text{whether } D_{fr} < D_t \leq D_{fr} + D_{efr}. \end{cases} \quad (2)$$

The main methods of controlling UAVs and DAs are radio command, tele piloted, optical (laser), autonomous (self-controlled). Taking into account the possibility of application in the immediate vicinity of the operator for UAV, in addition to the specified control methods, a wired method can also be used, which, in addition to transmitting and receiving commands and reliable protection against radio-electronic interference, will provide electrical power to the device [3, 4, 7, 8].

Observability (visibility) of unmanned aerial vehicles is one of the main factors that affects their effectiveness. The inconspicuousness of the UAV is achieved in various ways: for radar detection by reducing the already rather low effective scattering surface – by using various types of interference; for sound detection – using low-noise engines; for visual detection – by changing the overall dimensions, using high maneuverability to reduce the time to detect the search object; by adjusting the object's contrast coefficient on different backgrounds; by reducing angular dimensions due to remote application. At the tactical level, taking into account the low altitudes of use of aircraft, their high maneuverability, speed and other indicators, the main unmasking features (UF) are

visual, acoustic, thermal. The UAVs are the most noticeable in terms of the indicated features, since in order for them to perform a fire task, there is a need to hover over the object of influence, aim, adjust the height and direction, which, accordingly, increases the time of the task and the time of its detection. Therefore, the suddenness of using such UAVs will be low. Regarding DAs, their UF s are the same as those of UAVs, but the time to detect such objects, if we take into account their high speed and maneuverability, is small. Therefore, they have a high suddenness of action. Shooting unmanned aerial vehicles, although they have the same ones as other UFs, still their ability to detect is minimal, taking into account the remote impact of weapons on the target. Therefore, the suddenness of using such UAVs will be quite high.

The probability of detecting an object against a uniform background, as is known from publication [14], may be given by the following expression:

$$P_{detecting} = 1 - \exp\left(-\frac{J \cdot f^2 \cdot \alpha^3 \cdot \omega^{0.3} \cdot t_{detecting}}{(2\beta)^2}\right), \quad (3)$$

where  $\beta$  is the intelligence sector, deg.;

$J$  is the search factor (for the monocular method of monitoring is outlined by the range:  $C=12-36 \text{ degrees}^2 (\text{kd}/\text{m}^2)^{-0.3} (\text{arcminutes})^{-3} \text{c}^{-1}$  and reflects the person's training in intelligence;

$f$  is the coefficient that reflects the level of contrast between the search object and the background of the observed space and is in the range from 0.1 to 1;

$\alpha$  is the angle at which the object is observed, angular min; background brightness  $\omega$ , lm.

After performing the calculations, we see that the detection of a target of size  $0.3 \times 0.3 \text{ m}$  on a homogeneous background decreases with increasing object-background contrast ratio (Figure 1, *a*); also with increasing target search time with  $f = 0.4$ , the probability of its detection increases (Figure 1, *b*). In this regard, for visual search, in addition to the angular dimensions of the target, the object contrast ratio and the background, the time of the UAV task is also important.

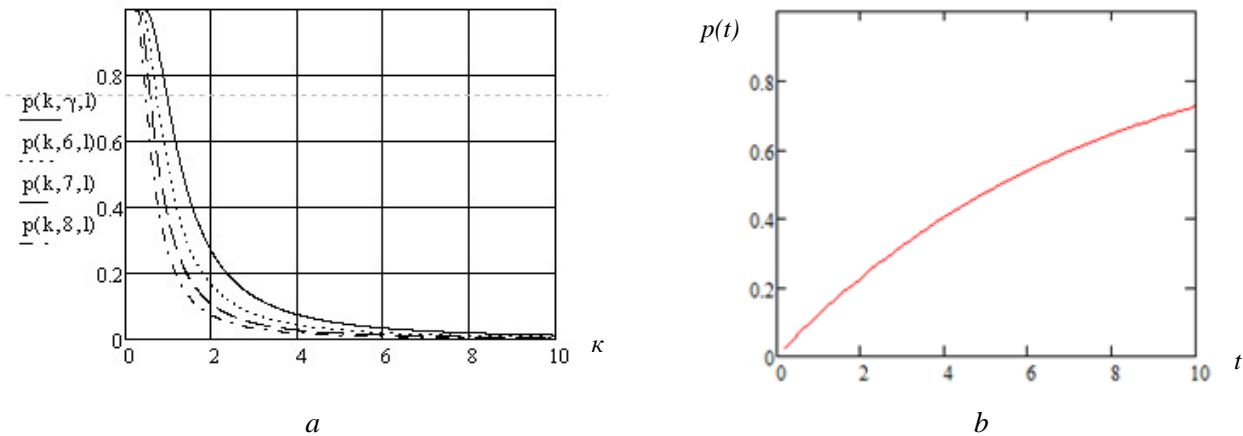


Figure 1 – Dependency graphs: *a* – probability of target detection size  $0.3 \times 0.3$  m from its contrast on a homogeneous background in a time of 4 s; *b* – probability of detecting a target of size  $0.3 \times 0.3$  m with  $f = 0.4$  from the search time

The main method of using UAVs is remote reset (bombing) from different heights above the affected object, and only in extreme cases it can be used as a DA. As a type of methods and techniques, the following can be distinguished: free (passive) reset (the ammunition moves to the target under the influence of the force of free fall); reset using diving; delayed reset (using a parachute).

For its part, a DA-type UAV needs direct contact with it to hit an object, that is, it is used as a "kamikaze" drone: one target – one drone. Both types of UAVs can be used against manpower and lightly armored and unarmored enemy vehicles, and DA can also be used against armored vehicles. In addition, they can be used both separately and by "swarm".

Rifle unmanned aerial vehicles, unlike those mentioned above, are used remotely from any available direction and altitude, which increases the effectiveness of their actions against enemy manpower and equipment, in particular armored ones, depending on the type of weapons installed on them and the type of ammunition used. The anti-drone grid and anti-cumulative grid will not be effective against the small arms of such UAVs. However, in addition to the available methods of action, several inherent in these UAVs can be distinguished. Yes, they can be used as a means of covering a unit during assault operations, when clearing enemy objects, as a single means of fire and by the method of swarming influence from both one and several directions. At the same time, they can be used both as a means of supporting the actions of personnel and as an independent unit or unit in battle without their involvement. During fundamental actions when planning types of fire, they can be distinguished not only by directions,

but also by heights, which will increase the effectiveness of fire and reduce the probability of UAV damage by friendly fire. Techniques for using UAVs can be such as shooting from a jump, from hovering at a certain height and distance from the object of influence, from a move (both straight and from diving and cabration), etc.

Let's consider the probability of hitting a UAV target. Figure 2 is a graph of the probability of hitting a  $0.3 \times 0.3$  m target with a single 0.25 kg ammunition in moderate winds from the discharge height. As can be seen from the graph, the probabilities of hits are very small. To increase the probability of hitting the target, you need to reduce the drop height, minimize the impact of the wind, or use ammunition with planar damage. Dive reset is more accurate, but it requires better training of the operator's experience and skills and is hardly used.

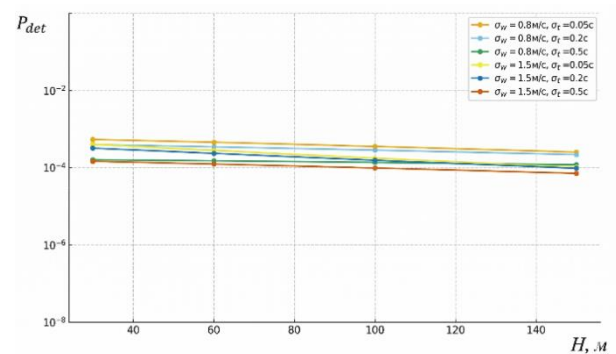


Figure 2 – Graph of the dependence and probability of hitting a target of  $0.3 \times 0.3$  m with one munition weighing 0.25 kg in moderate wind from the discharge height

Barrage ammunition requires high-quality training of the operator to hit the target and uses ammunition of various types and purposes to defeat it, which makes it possible to influence not only the manpower and automotive equipment of the enemy, but also his armored vehicles and aircraft. The probability of such a UAV hitting the target and hitting it is quite high. However, the presence of anti-drone nets and anti-cumulative grids reduces the probability of hitting and hitting the mentioned UAVs to a minimum.

The capabilities of the Gun-armed drones to hit and hit the target are slightly higher and will be equal to the probability of hitting small arms, taking into account certain errors. It depends on the characteristics of the weapon, methods of use, types of ammunition, the capabilities of the guidance system and the characteristics of the UAV.

The next issue is the survivability of the UAV. Indeed, UAVs have a relatively small probability of being hit by small arms due to their small linear (angular) dimensions, the ability to move (respectively, the need to calculate and determine a biased aiming point), errors when aiming weapons, the impossibility of conducting aimed fire, since there is no aiming point at such devices as such. Figure 3 provides a calculation of the probability of hitting a stationary conventional rectangular target with dimensions of 0.3×0.3 m and hitting it at different distances without taking into account the error of aiming the weapon at the target, which is due to the features of the aiming devices.

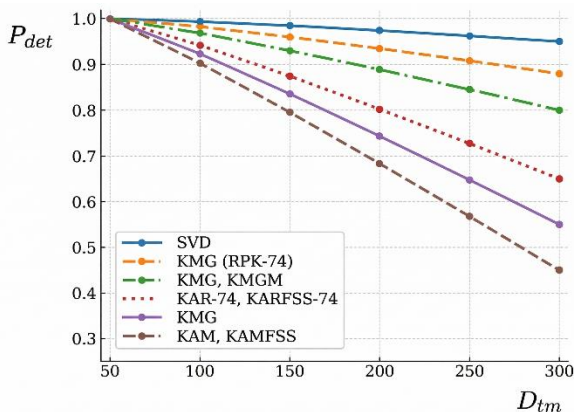


Figure 3 – Dependences of the probability of hitting a target of 0.3×0.3 m on the range to it without errors of aiming the weapon at the target, which are due to the features of the aiming devices

The graph shows that the probability of hitting a target at distances of 250 m approaches 0.5. If we take into account the guidance error due to the unsuitability of the sights of small arms for firing at air targets, which significantly affects the results of firing, we will see that even at a distance of 100 m, the probability of hitting the target decreases by 25–50%. Considering the fact that UAVs are able to act on targets remotely and do not need to approach the object of influence or directly contact it, the probability of shooting down such aircraft will be the lowest.

In addition, one of the main requirements for UAVs is the possibility of their repeated use. This is due to various aspects, primarily economic: the feasibility of use (the cost of the UAV should be much less than the cost of the affected object); long-term operation (reusability) reduces the cost of completing the task and the need for constant replenishment of the UAV fleet. The economic aspect can be expressed by some index  $R$ :

$$R = \frac{P_{pd\ i\ oi} \cdot S_{i\ cio}}{P_{pf\ i} \cdot \left(\frac{S_{uav} \cdot N_{uav}}{N_{npa}}\right)}, \quad (4)$$

where  $P_{pd\ i\ oi}$  is the probability of damage to the  $i$ th object of influence (target);

$S_{i\ cio}$  is the cost (value, importance) of the  $i$ th impact object (goals);

$P_{pf\ i}$  is the the probability of failure of the UAV during the 1st task;

$S_{uav}$  is the cost (value, importance) of UAVs;

$N_{npa}$  is the the number of possible applications of one UAV to perform the 1st task;

$N_{uav}$  is the number of UAVs.

Unmanned munition drop aerial vehicles can be used several times, but at the same time, the probability of survivability of  $P_{pf\ i}$  in them decreases during each subsequent use. Taking into account the specifics regarding the DA object, lesions can be used only once. Due to the presence of a certain amount of small arms ammunition, UAVs can be used on the target several times, and even if the ammunition runs out after reloading, they will have a greater probability of survivability  $P_{pf\ i}$  than other UAVs, given the possibility of remote impact.

Risk assessment during operation of UAVs equipped with grenades, – is an extremely important aspect of safety and application efficiency. Table 2 shows a structured analysis of risks during the operation of UAVs for various purposes. After analyzing the data in the table, it can be concluded that the least risks during operation are in the Gun-armed drones. Analysis of the possibilities of using small arms on UAVs indicates the possibility of its use on almost all types and types of unmanned aerial vehicles.

Table 2 – Risk factors during operation of UAVs for various purposes

Risk factors	Description	Probability of occurrence; consequences; level of risk		
		UAV	DA	Gun-armed drones
Mechanical	Damage to the hull or units of the UAV due to improper fastening of ammunition and weapons	Average; loss of apparatus; average		
Explosive	Involuntary detonation of ammunition during vibration, impact, overheating or short circuit	Medium; destruction of UAVs; injury to personnel	Medium; destruction of UAVs; injury to personnel	Very low
Electric	Locking electronics while controlling the UAV itself, the reset mechanism, descent, etc.	Medium; loss of control; accident		
Aerodynamic	Center of mass shift – instability in flight	High; loss of control; fall		
Human	Errors in preparing or loading a grenade (ammunition) or dropping (firing)	Medium; uncontrolled detonation or loss of the device, injury to the island; high	Medium, uncontrolled detonation or loss of the device, injury to the island; high	Low, uncontrolled shooting, injury to the island; low
Technical	Failure of the reset mechanism, attachment, descent or sensors	Medium; task failure, UAV fall; medium	Low; task failure, UAV fall; low	Low; task failure, UAV fall; low
REB	Interception of control or signal, detonation, firing during return	Low; loss of ammunition and UAV; high	Low; loss of ammunition and UAV; high	Low; loss of weapons and UAVs; high

The issue of implementing the possibility of installing weapons on UAVs has not yet been fully resolved and requires additional research, including: determining specific tasks for the implementation of the UAV, forming requirements for weapons systems, aiming, descent, glider and layout of the UAV according to a specific task, carrying out calculations and development prototypes, conducting tests and research operation.

### Conclusions

The creation of unmanned aerial vehicles is one of the promising directions for the development of tactical-level unmanned systems. They can be applied at the tactical level and in almost all aspects have an advantage in terms of combat capabilities over unmanned aerial vehicles with a drop system and "loitering munition".

The main advantages of the combat use of small unmanned aerial vehicles compared to other types of assault unmanned aerial vehicles are: greater range of effective action, the possibility of using protected control methods, minimal probability of

detection, low probability of hitting the vehicle with small arms, the possibility of multiple use.

In order to implement the possibility of installing weapons on unmanned aerial vehicles, it is necessary to conduct scientific research on the definition of specific tasks for the performance of unmanned aerial vehicles by riflemen, the formation of requirements for weapons systems, aiming, descent, glider and layout of Gun-armed drones according to a specific task, carrying out calculations and development prototypes, conducting tests and research operation.

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### **ДОСЛІДЖЕННЯ ПЕРЕВАГ ЗАСТОСУВАННЯ БЕЗПІЛОТНИХ ЛІТАЛЬНИХ АПАРАТІВ, ЯКІ ОСНАЩЕНІ СТРІЛЕЦЬКИМ ОЗБРОЄННЯМ НА ТАКТИЧНОМУ РІВНІ**

*Розглянуто одне з актуальних питань російсько-української війни – підвищення ефективності безпілотних авіаційних систем на тактичному рівні шляхом оснащення безпілотних літальних апаратів стрілецькою зброєю. Проаналізовано наявні підходи до бойового використання безпілотних літальних апаратів із системами доставки боєприпасів і боєприпасами-затримкою. Визначено їхні основні переваги та істотні недоліки, пов'язані з низькою ймовірністю влучання у ціль під час скидання боєприпасів, гарантованою втратою ударного апарата, значною залежністю від засобів радіоелектронної боротьби та наявністю ефективних засобів протидії з боку противника (антидронні та антикумулятивні сітки, броньований захист техніки). На цьому тлі було запропоновано концепцію малих безпілотних літальних апаратів – ударних безпілотних літальних апаратів, які вражають цілі вогнем стрілецької зброї з різних напрямків і висот без прямого контакту з ціллю.*

*У статті проведено порівняльний аналіз тактико-технічних характеристик безпілотних літальних апаратів, баражуючих боєприпасів та систем управління повітряними апаратами, розглянуто особливості їхнього застосування, виявлення ознак, живучість, можливі методи боротьби, проаналізовано чинники ризику під час експлуатації відповідних систем. Показано, що безпілотні літальні апарати можуть використовувати не тільки традиційні радіокеровані та дистанційно пілотовані системи, але й дротові схеми управління з одночасним електроживленням пристрою, що підвищує захист від радіоелектронної боротьби. Особливу увагу приділено питанню низької помітності та ймовірності виявлення безпілотних літальних апаратів на тактичному рівні, а також впливу розміру цілі, контрасту з фоном та часу пошуку на ймовірність виявлення. Розглянуто залежності ймовірності ураження малих цілей та знищення безпілотних літальних апаратів стрілецькою зброєю, що дає змогу обґрунтувати переваги дистанційного застосування вогню безпілотних літальних апаратів.*

*Запропоновано підхід до оцінювання економічної доцільності використання різних типів безпілотних літальних апаратів на основі інтегрованого індексу, що враховує вартість пристрою, його живучість, ймовірність влучання у ціль та цінність цілі. Висновлено, що безпілотні літальні апарати мають значний потенціал для використання на тактичному рівні, перевершуючи свої аналоги із системами скидання та боєприпасами-затримкою за низкою бойових показників, і потребують подальших досліджень щодо формування вимог до озброєння, систем наведення, компонування та випробування прототипів.*

**Ключові слова:** *безпілотні літальні апарати, стрілецька зброя, невеликі озброєні безпілотні літальні апарати.*

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