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ANALYSIS OF APPLICATION OF THE UAVs FOR MILITARY TASKS

Aim. The purpose of this work is to analyse and study the possibilities of using unmanned aerial vehicles (UAVs) for military purposes. **Methodology.** One of the important tasks of using UAVs is topographic aerosurveying for processing large-scale plans, which, as confirmed by the experience of military actions, are a necessity to work with them by appropriate composition. But this process is rather complicated, since many requirements for carrying out the aerosurveying must be observed such as adhering to the height of surveying for the scaling of aerial images, and to the stabilization of the aircraft to reduce angles of inclination and speed for receiving longitudinal overlap. All these factors lead to rapid detection of an object and its destruction. Therefore, the authors have made an analysis of modern type of UAVs that are used for aerosurveying of military objects. Also it presented a detailed classification of military UAVs, established a list of tasks that they can perform, and made appropriate conclusions. Requirements for the establishment of military UAVs have been developed. The research of the developed UAV Arrow has been carried out in order to confirm the possibility of its application in aerial surveying purposes. **Results.** To determine the aerodynamics performed by both the Arrow aircraft and the Trimble UX5 UAV aircraft in aerating of the same plot. A comparative analysis of the values of the angles of yaw, roll, and pitch of UAV Arrow and Trimble UX5 for each route is made. **Scientific novelty and practical significance.** UAV currently perform different tasks in many industries of the economy and defence of countries. The main advantage of using UAVs in military affairs is that they can perform their tasks in automatic or semi-automatic modes with minimal human participation in the control process. Taking into account the military conflict in the east of Uraine, this issue becomes particularly relevant, since the determining of peculiarities of using of UAVs for military purposes will allow: to reduce losses among both the military and the civilian populations which are often attacked; to conduct invisible reconnaissance of ground objects and enemy targets in enemy occupied territory; to determine targets for attack; to make a point artillery or air strike on enemy targets and subsequently to control the results of the attack; to conduct radio-electron struggle; to detect and to neutralize enemy's UAVs.

Key words: aerial surveying, pitch, roll, unmanned aerial vehicle, yaw.

Introduction

In the modern world, leaders in the field of military aircraft manufacturing are Israel, the USA, Canada and Russia. At the same time, fighting in the East of Ukraine promoted the development of enterprises which produce UAVs for military purposes. Today, for Ukraine, the most urgent task is to study and analyse possibilities of using UAVs by leading world countries in local wars and armed conflicts. In case of absence of its own military experience in the use of UAVs, only a study of foreign knowledge will allow us to formulate without error the concept of the development and use of unmanned aviation in Ukraine. As noted, this issue becomes particularly relevant, since defining the properties of UAVs for military purposes will allow: to reduce losses both among the military and civilian populations which are often attacked; to conduct invisible reconnaissance of ground objects and enemy targets in enemy territory; to determine targets for attacks. We will conduct a brief analysis of literary sources relevant to this topic.

In the article [Mynochkin et al., 2017], the application of unmanned aerial vehicles as retransmitters of tactical mobile radio networks is analysed. The classification of unmanned aerial vehicles is carried out and a list of tasks performed by UAVs in the civilian and military spheres is

established. The structure of the mobile component and the role of tactical mobile radio networks with the use of UAVs in them is considered. Also, the authors submitted the list of Ukrainian enterprises which work in the field of production of military aircraft and technical characteristics of the UAVs.

We believe, the classification presented by the authors is not complete, since only the tasks performed by UAVs in the civil and military spheres of activity are given.

In the article [Tsimbalistova, 2015], classification of UAVs by structural features, by possibilities of solving of tasks, by take-off weight, by flight time, by flight height, and by functional purposes is proposed, but this classification as well as in the article [Mynochkin et al., 2017] is common to military and civilian UAVs.

In work [Grebenikov et al., 2009], range of tasks that can be solved by unmanned aviation and its advantages in comparison with manned aircraft are defined. Requirements for the establishment of UAVs are formulated. Technical characteristics of two projects of UAVs are presented. Namely UAV «Inspector», which is intended for the certification and implementation of remote control of the technical state of main pipelines and UAV “Pchelka”, designed to perform remote monitoring of various objects and areas in the near zone,. But the testing and the research of developed UAVs are not given, so it is not clear whether it is actually possible to apply these UAVs by their destination.

In the article [Belous, 2016], it is said that since 2015 Ukraine began to catch up with leaders in the field of development of military aircraft – the USA and Israel. Particular merit for this belongs to the cooperative productive efforts of the educational, scientific, and manufacturing industries, which, in a short time, provided an opportunity to monitor the situation in the Anti-Terrorist Operation Zone from the air. For example, the authors show the UAV “Spectator”, which is developed by students of National Technical University of Ukraine “Igor Sikorsky Kyiv Polytechnic Institute” and introduced into production by the State Concern “Ukroboronprom”. But the authors do not give the technical characteristics of this UAV and do not provide information about other UAVs created for military purposes. Also, the authors developed a generalized classification of unmanned aerial vehicles.

In the publication [Timochko, 2007; Meyer-Fujara J., 2018; Watts A., 2012; Clothier, 2011], approaches to the classification of unmanned aerial vehicles are considered, the main terms are defined, modern achievements and directions of development are shown. The author pays particular attention to foreign models of UAVs, and information about the development of national models is not given.

In publications [Nalyvayko et al., 2009; Stetsenko et al., 2004; Shulzhko, 2013] a lot of attention is paid to UAVs as a means of struggle with air defence complexes and as a means of damage to other ground targets, but in fact there is no information about the UAVs as a means of modern military exploration, or that they can be used for the subsequent creation of large-scale maps and plans that are very necessary in military actions.

In the publication [Glotov et al., 2017], the main advantages of the use of UAVs for military purposes are defined: relatively small weight and low visibility in all ranges of radio wavelengths for the enemy's air defence complexes; possibility of application in the radioactive, chemical, and bacteriological pollution of air and terrestrial; when conducting air reconnaissance from the UAV, there is no threat of attack to the crew by means of enemy’s air defences; UAVs can be located at a distance of 1-15 km from interested transmitters, which allow them to intercept signals that are not readily available for interception by radio-intelligence (RTR) satellites from geostationary orbits (about 36 thousand km). Also, the authors proposed a general classification of UAVs by technical and organizational features, but did not separate UAVs of military tasks.

Aim

The purpose of this work is to analyze and study the possibilities of using unmanned aerial vehicles (UAVs) for military purposes

Methodology

From the presented analysis of literary sources, the authors proposed a division into several directions, by which the construction of UAVs can be carried out.

The first direction is characterized as follows:

1. The construction of UAVs maximizes simplicity (there are no stabilizers and aerial devices for the camera, and no GPS receiver for determining the linear elements of external orientation).

2. The dimensions and weight of the UAVs are maximally reduced, and hence the payload decreases.

3. The stabilization occurs due to increased flight speed.

4. The prevention of tearing during aerosurveying is achieved by increasing the overlapping of images

in both longitudinal and transverse overlaps (up to 90 %).

5. Image processing in the process of creating orthophotomaps is carried out in automatic mode using advanced modern software.

In the second direction, we note the following:

1. The presence of powerful digital surveying systems, which are capable of automatically taking into account the yaw angle in flight, and the installation of geodetic GPS receivers that determine with an appropriate accuracy elements of external orientation.

2. The navigation equipment (camera), which allows piloting an airplane both manually and in automatic modes.

3. The aircraft stabilizer that reduces pitch and roll angles, and thus the possibility of speed reduction.

4. Keeping parameters during the process of aerosurveying (straightness of routes, predetermined longitudinal (60–80 %) and transverse (30–40 %) overlaps.

5. There is no need for field work for plan-high referencing of points in order to perform photo-triangulation.

Based on the above, it should be noted that the priority in our opinion is the second direction, since it enables to ensure the implementation of a qualitative aerosurveying process in order to further the processing of large-scale ortho-photos and topographical plans.

Further analysis of literary sources led the authors to solve the problem of more a detailed classification of UAVs, because it is extremely important, since it simplifies and eases the substantiation of the choice of specific UAVs for their application in the interests of national security of the country. Therefore, the following classification of military UAVs is proposed, which is presented in Fig. 1. On the basis of this, national and foreign UAVs are selected, the technical characteristics of which are used for the purpose of aerosurveying of military objects. See Figure 1 and Table 1.

Also, on the basis of the conducted analysis, the requirements for the creation of an optimal UAV for military applications were formulated: camera overview has to be 360 ° (panoramic); possibility of staying in the air > 2 hours; presence of an electric motor; radius min 50 km; encrypted video channel, control channel and telemetry; availability of GPS, Glonass; payload; presence of ZOOM function – 10x optical and 20x digital; presence of a thermal imager (recognition of a person at night with H > 300 m); ability to replace the camera; possibility of retransmission (800–1.2 GHz); resolution of digital camera with a min HD; frequency must be 800–1.2 GHz; presence of Wi-Fi; possibility of frequency adjustment in flight; inertial control system (minimum 3 turning points); ground control station from the antenna at a distance of 250–300 m (preferably Wi-Fi); protected touch monitor (water, sun, – 35 ° ... + 35 ° C); radioplate (fiberglass).

As you can see, the conditions are quite strict. Based on this, it was decided to develop the UAV, which would correspond to the second direction of development of UAVs with all requirements. Therefore, the scientists of Lviv Polytechnic National University and workers of the company “Abris design group” developed the UAV Arrow, which corresponds to the classical requirements of topographic surveying to create large-scale plans.

Briefly consider the characteristics of the proposed aircraft. The body of the aircraft is made of durable fiberglass and carbon fiber, resistant to external influences. To reduce the impact loads when landing it is equipped with a parachute system, as well as applied rubber dampers. The UAV is intended for operation in simple meteorological conditions in the range of temperatures –25 – +40 Celsius degrees. In the aircraft, a determination is made in the flight of the yaw and its automatic compensation by turning the aircraft to the angle of deviation from the route. The airplane is easy to handle for transportation in a compact transport case. The small working height and flight speed allow acquisition of high-quality photos with a resolution of 2 cm/pixel. To simplify and ease the preparation of the UAV Arrow before the start, there is a manual control panel that connects to the computer from which the project is launched. Digital camera Sony QX1 is used to take the photos of the earth’s surface. Determining of the location of the UAV in the case of an emergency landing occurs with the use of a GSM tracker. The technical characteristics of the UAV Arrow are given in table 2.

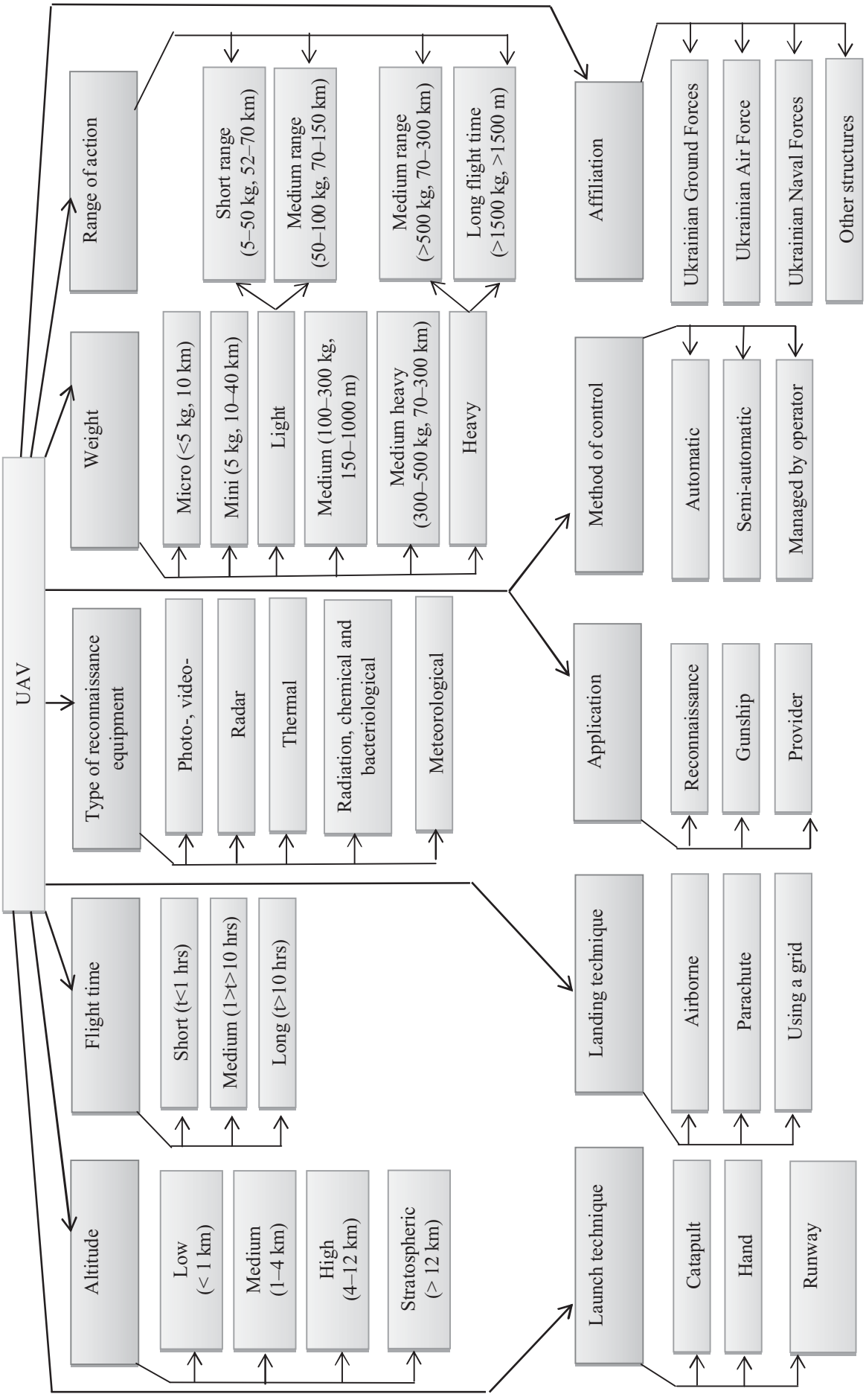

Fig. 1. Classification of military UAV

Table 1

Technical characteristics of national models of UAV

	Leleka-100	PD-1	Furija	Mara 2M	Fly Eye	KC-1	Spectator	Raven RQ-11
Purpose of UAV aerial surveying	patrolling	24 hour monitoring of the movement of the enemy	determining the coordinates of targets for artillery иadjustment (day-night)	video monitoring,	determining the coordinates of targets, to assist control of the battlefield and national borders	video monitoring, to assist control and monitor the movement of the enemy.	video monitoring, to assist control and monitor the movement of the enemy.	video monitoring, to assist control and monitor the movement of the enemy.
Is used by	Ukrainian Armed Forces (UAF)	UAF	UAF, National Guard of Ukraine (NGU)	UAF, NGU, State Border Guard Service of Ukraine (SBGS)	NGU, UAF	NGU	UAF, SBGS	NGU, UAF
Dimensions, mm	1980/1135	3200/2530	2050/900	1950/1140	3600/1900	2300/960	3000/1295	1400/900
Cruising flight speed, km/h	60–70	90	65	55	50	65	50	50
Max. flight speed, km/h	120	140	130	80	170	80	120	80
Maximum flight height, m	1500	2000	2500	3000	4000	3600	2000	4000
Flight time, h	2–2,5	5 and more	3	1–1,5	2–3	3–4	2	1–1,5
Max. take-off weight, kg	5± 0,5	23	5.5	2,3	11	5	5,5	1,9
Motor type	electric	internal combustion	electric	electric	electric	electric	electric	electric
Launch	hand-launched, with help of special means	runway	elastic or mechanical catapult	hand-launched	elastic or mechanical catapult	elastic or pneumatic catapult	hand-launched	hand-launched
Landing type	parachute, horizontal	airborne, automatic	parachute, airborne	airborne	parachute, airborne	parachute	parachute	airborne
Control mode	automatic, semi-automatic	automatic	manual, semi-automatic	–	2 operators	1–2 operators	–	–
Temperature range (^{0}C)	-20 to +40	-20 to +40	-20 to +40	-10 to +40	-20 to +50	-30 to +50	-20 to +40	-20 to +40
Maximum wind speed, m/s	20	20	15	14	12	12	15	15

Table 2

The technical characteristics of the UAV Arrow

Characteristics	Parameters
Takeoff weight, kg	4,8
Battery capacity, Ah	16
Minimum flight speed, km/h	50
Cruising flight speed, km/h	60-80
Maximum flight time, min	100
Maximum flight range, km	100
Maximum controlled distance from the base, km	15
Maximum flight altitude, m	5000
Minimum operational altitude, m	75
The maximum image resolution, sm/pix	2
Dimensions in transportation configuration, sm	120×25×25
Limiting wind speed, m/s	12

Results

The authors conducted a research of the created UAV in order to confirm the possibility of conducting of its application in aerial surveying purposes [Hlotov V., 2018]. To determine the operation of the aerostructure of the Arrow aircraft, an aerial survey was carried out from the Trimble UX5 UAV (which relates exclusively to the first direction of development of the UAV) of the same site. Comparative analysis of the angles of yaw, roll, and pitch of the Arrow and Trimble UX5 UAVs on each route was made. Graphs for three routes are presented on Fig. 2–4.

Graphs of the values of the yaw angles of UAV Arrow (Fig. 2) indicate that the maximum deviation from the course ranges from -5º to + 1º. Such results are explained by the fact that the yaw angle was automatically compensated by turning the aircraft for the angle of deviation from the course. At the same time, yaw angles of the Trimble UX5 UAVs range from -15 º to +5 º, which is beyond the tolerance limits.

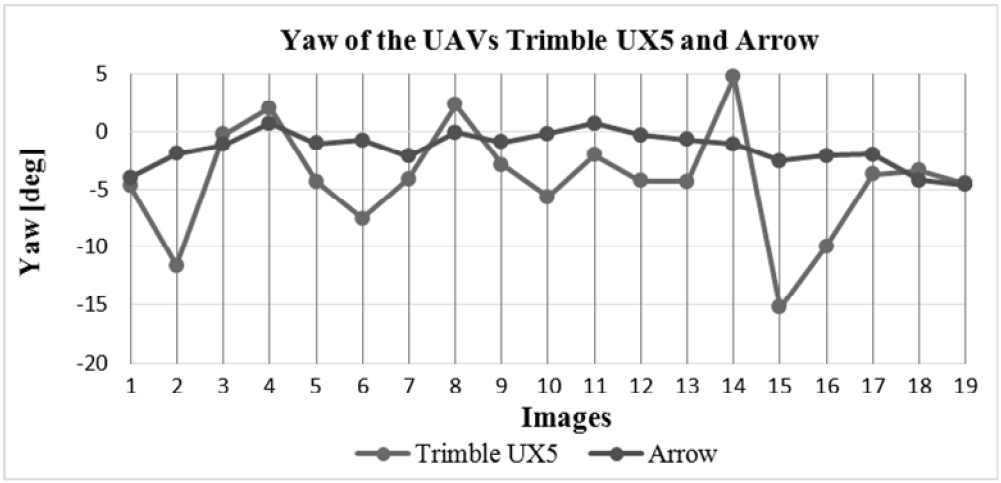

Fig. 2. Graphic yaw of the UAVs Trimble UX5 and Arrow

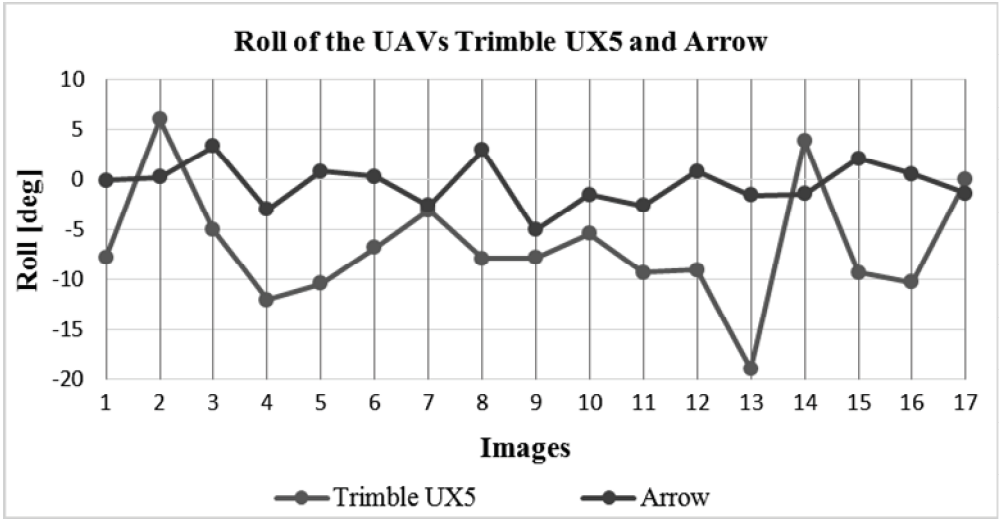

Fig. 3. Graphic roll of the UAVs Trimble UX5 and Arrow

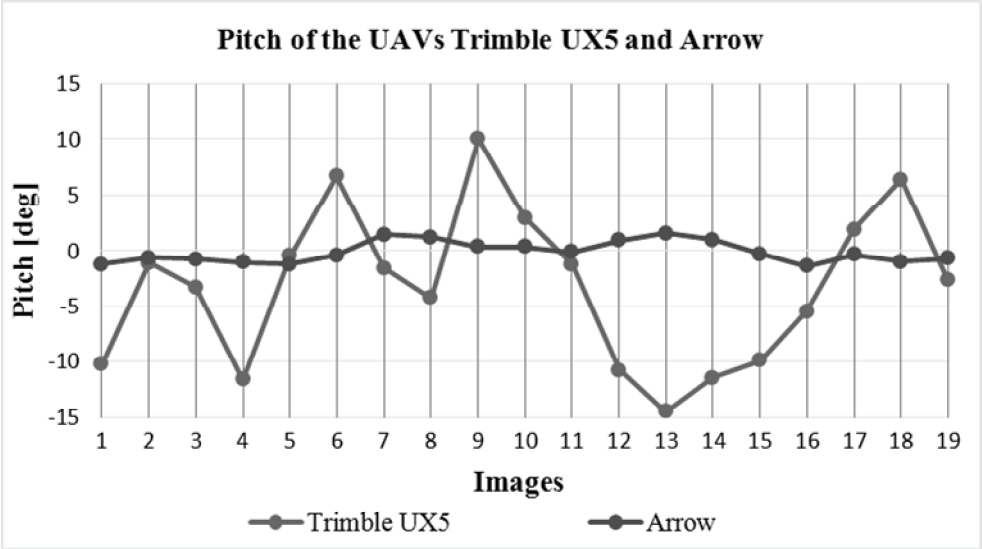

Fig. 4. Graphic pitch of the UAVs Trimble UX5 and Arrow

From the graphs of the roll angles of the UAV Arrow (Fig. 3), it can be seen that the angles range from -5º to +4º, which is explained by the stabilization of the structure. The roll angles of the Trimble UX-5 UAV range from -19º to +6º, which indicate that these elements are not acceptable, as it is known from the experience of image processing by the analytical method that these values should not exceed 10°–12°.

From the graphs of the values of the pitch angles of the UAV Arrow (Fig. 4), it can be seen that the angles range from -1º to +2º, which, as mentioned above, are due to the stabilization of the aircraft. The value of pitch angles of the Trimble UX-5 UAV range from -15º to +10º, which also exceed the tolerance.

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Scientific novelty and practical significance

UAV currently perform different tasks in many industries of economy and defence of countries. The main advantage of using UAVs in military affairs is that they can perform their tasks in automatic or semi-automatic modes with minimal human participation in the control process. Taking into account the military conflict in the east of the country, this issue becomes particularly relevant, since the determining of peculiarities of usingUAVs for military purposes will allow: to reduce losses both among the military and among the civilian populations, which are often attacked; to invisibly conduct reconnaissance of ground objects and enemy targets in enemy occupied territory; to determine targets for attack; to make a point artillery or air strikes on enemy targets and subsequently to affect the results of the attack; to detect and to neutralize the enemy's UAVs.

Conclusions

1. The analysis of literary sources, which highlights the use of UAVs for military purposes, was conducted.

2. The UAVs classification for use in the military area is developed.

3. Basic tasks and advantages of UAVs are defined.

4. Requirements for creation of military UAVs are developed.

5. The national aerosurveying UAV is developed and investigated.

6. Experimental and research work confirmed that the second method using the Arrow is promising in terms of requirements for the use of UAVs in military affairs.

7. In future, it is planned to develop modifications of the proposed UAV Arrow for the purpose of their use in military operations.6. Experimental and research work confirmed that the second direction is promising in terms of requirements for the use of UAV in military affairs.

7. In future, it is planned to develop modifications of the proposed UAV "Arrow" for the purpose of their use in combat operations.

References

Belous V. (2016) Classification of Unmanned Aerial Vehicles and its Importance for Forensic Practice, *Theory and Practice of Forensic Examination and Criminology*, 16, 47–57.

Clothier R. (2011) UAS Classification: Key to effective airworthiness and operational regulations. In Royal Aeronautical Society Unmanned Aircraft Systems Specialist Group, UAS Classification Workshop, 24th June 2011, London, UK.

Glotov V., Gunina A., Teleshchuk Y. (2017) Analysis of the possibilities of using unmanned aerial vehicles for military purposes. *Modern achievements in geodetic science and production*. Lviv. *1* (33). 139–146.

Grebenikov A., Zhuravsky A., Myalitsa A. and others (2009). Problems of Unmanned Aeronautical Complexes in Ukraine. *Open Information and Computer Integrated Technologies*. Kharkiv: NAKU. 42, 111–119.

Hlotov V., Hunina A., Kolesnichenko V., Prokhorchuk O., Yurkiv M. (2018) Development and Investigation of UAV for Aerial Surveying ISTCGCAP., No. 87, c. 48–57. https://doi.org/10.23939/istcgcap2018.01.048.

Meyer-Fujara J. Applications of military and non-military Unmanned Aircraft Systems (UAV), C. 43. http://www.academia.edu/11154604/Applications_of_military_and_nonmilitary_Unmanned_Aircraft_Systems_UAV_

Mynochkin A., Sova O., Marilov O., Trotsko O. (2017). Analysis of the use of unmanned aerial vehicles as retransmitters of tactical mobile radio networks. *Collection of scientific works of VITI*, 1, 61–70.

Nalyvayko Y., Skoryk A., Board, O. (2009). Features of the tactics of the actions of the NATO Air Force in the suppressed integrated air defense system. *Navigation and Communication Management Systems*, *2* (10), 124–128.

Shulezhko V. (2013) Basic directions of development and application of unmanned aerial vehicles, handbooks. K .: Ministry of Defense of Ukraine, 65 p.

Stetsenko O., Danik Yu., Pastushenko M. (2004). *Space systems of informational support of unmanned vehicles of different function*, handbook. Kyiv: Ministry of Defense of Ukraine.

Timochko O., Golubnichny D. (2007). *Classification of Unmanned Aerial Vehicles*, Ivan Kozhedub Kharkiv University of Air Force, Kharkiv.

Tsymbalistova, O. (2015). Development of the market of unmanned aerial vehicle services as the main direction of innovative progress of modern aviation. *Economic analysis:* Sb. sciences Works, Ternopil: Publishing and Printing Center of Ternopil National Economic University, 19, 1, 116–122.

Watts A., Ambrosia V., Hinkley E. (2012) Unmanned Aircraft Systems in Remote Sensing and Scientific Research: Classification and Considerations of Use Remote Sens., 4, p. 1671–1692. https://www.e-education.psu.edu/geog892/sites/www.e-education.psu.edu.geog892/files/images/lesson01/remotesensing-04-01671.pdf

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АНАЛІЗ ЗАСТОСУВАННЯ БПЛА ДЛЯ ВІЙСЬКОВИХ ЦІЛЕЙ

Мета. Метою роботи є аналіз та дослідження можливостей застосування безпілотних літальних апаратів (БПЛА) для військових цілей. **Методика.** Одним із важливих завдань використання БПЛА є топографічне аерознімання для опрацювання великомасштабних планів, що, як підтвердив досвід бойових дій, вже необхідні для роботи з ними відповідним складом. Але цей процес доволі складний, оскільки потрібно дотримуватись багатьох вимог для виконання знімання: забезпечити висоту знімання для масштабності аерознімків, стабілізацію літака, щоб зменшити кути нахилу та швидкість для утримання повздовжнього перекриття тощо. Всі ці чинники дають змогу швидко виявити об'єкт та знищити його. Тому автори проаналізували сучасні вітчизняні моделі БПЛА, які можуть застосовуватися і для аерознімання військових об'єктів, а також навели розгорнуту класифікацію БПЛА військового призначення та визначили перелік завдань, які вони виконують, зробивши відповідні висновки. Сформульовано вимоги до створення військових БПЛА. Проведено дослідження розробленого БПЛА Arrow, щоб підтвердити можливості його застосування в аерознімальних цілях. **Результати.** За допомогою аеропристрою літака "Arrow" та БПЛА "Trimble UX5" здійснено аерознімання тієї самої ділянки і виконано порівняльний аналіз значень кутів

зносу, крену та тангажу БПЛА “Arrow” та “Trimble UX5” за кожним маршрутом для оцінювання роботи аеропристрою. **Наукова новизна та практичне значення**. Безпілотні літальні апарати (БПЛА) сьогодні виконують різні завдання у багатьох галузях економіки та оборони країн. Головною перевагою застосування БПЛА у військовій справі є те, що вони можуть працювати в автоматичному або напівавтоматичному режимах за мінімальної участі людини в процесі керування. Враховуючи військовий конфлікт на Сході України, це питання набуває особливої актуальності, оскільки визначення особливостей застосування БПЛА дасть змогу: зменшити втрати особового складу, а також серед цивільного населення, яке часто найбільше потрапляє під удар; вести непомітну розвідку наземних об’єктів та ворожих цілей на території противника; визначати цілі для ураження; наносити точкові артилерійські чи авіаційні удари по ворожих цілях і згодом вести контроль за результатами ураження; виявляти та знешкоджувати ворожі БПЛА.

Ключові слова: аерознімання, безпілотний літальний апарат, крен, кут зносу, тангаж.

Література

Білоус В. (2016). Classification of Unmanned Aerial Vehicles and its Importance for Forensic Practice, *Theory and Practice of Forensic Examination and Criminology.*, 16. 47–57.

Глотов В., Гуніна А., Телещук Ю. (2017). Analysis of the possibilities of using unmanned aerial vehicles for military purposes. *Modern achievements in geodetic science and production*. Lviv. 1 (33). 139–146.

Гребеников А., Журавский А. Мялица А. and others (2009). Problems of Unmanned Aeronautical Complexes in Ukraine. *Open Information and Computer Integrated Technologies*. Kharkiv: NAKU. 42, 111–119.

Міночкін А., Сова О., Марилів О., Троцько О. (2017). Analysis of the use of unmanned aerial vehicles as retransmitters of tactical mobile radio networks. *Collection of scientific works of VITI*, 1, 61–70.

Наливайко Ю., Скорик О. М. Доска. (2009). Features of the tactics of the actions of the NATO Air Force in the suppressed integrated air defense system. *Navigation and Communication Management Systems*, *2* (10), 124–128.

Стеценко О., Даник Ю., Пастушенко М.(2004). *Space systems of informational support of unmanned vehicles of different function*, handbook. Kyiv: Ministry of Defense of Ukraine.

Тимочко О., Голубничний Д. (2007). *Classification of Unmanned Aerial Vehicles*, Ivan Kozhedub Kharkiv University of Air Force, Kharkiv.

Цимбалістова О. (2015). Development of the market of unmanned aerial vehicle services as the main direction of innovative progress of modern aviation. *Economic analysis:* Sb. sciences Works, Ternopil: Publishing and Printing Center of Ternopil National Economic University, 19, 1, 116–122.

Шулежко В. (2013) Basic directions of development and application of unmanned aerial vehicles, handbooks. K : Ministry of Defense of Ukraine, 65 p.

Clothier R. (2011) UAS Classification: Key to effective airworthiness and operational regulations. In Royal Aeronautical Society Unmanned Aircraft Systems Specialist Group, UAS Classification Workshop, 24th June 2011, London, UK.

Hlotov V., Hunina A., Kolesnichenko V., Prokhorchuk O., Yurkiv M. (2018) Development and Investigation of UAV for Aerial Surveying ISTCGCAP., No. 87, p. 48–57. https://doi.org/10.23939/istcgcap2018. 01.048.

Meyer-Fujara J. Applications of military and non-military Unmanned Aircraft Systems (UAV), p. 43. http://www.academia.edu/11154604/Applications_of_military_and_nonmilitary_Unmanned_Aircraft_Systems_UAV_

Watts A., Ambrosia V., Hinkley E. (2012). Unmanned Aircraft Systems in Remote Sensing and Scientific Research: Classification and Considerations of Use Remote Sens., 4, p. 1671–1692. https://www.e-education.psu.edu/geog892/sites/www.e-education.psu.edu.geog892/files/images/lesson01/remotesensing-04-01671.pdf