UDC 629. 735.05: 621.38 (045)
DOI: 10.18372/1990-5548.55.12748

[1]A. P. Kozlov
[2]R. L. Pantyeyev

EMERGENCY ACCESSION OPERATIONAL VIDEO CONTROL SYSTEM

[1,2]Aviation Computer-Integrated Complexes Department, Educational&Scientific Institute of Information-Diagnostics Systems, National Aviation University, Kyiv, Ukraine
E-mails: [1]ap_kozlov@ukr.net, [2]romanpanteevmail@gmail.com

Abstract*—A brief overview of the gathering information existing means about the emergencies is given. The system with the artillery launch of aerospace video surveillance equipment is considered, and the structure and functioning of the emergency zone suborbital video surveillance system are defined. It was shown the necessity of the remote control devices set development for reducing the video surveillance unit. The aerostat-parachute system with remote control by the operator on the radio channel is proposed. The structure and parameters of the automatic control system for the descent vehicle movement is analyzed. The implementation evaluation of the technical solution, parameters calculations of the aerostat-parachute system were made. Using software (Project 1), It was the optimal weight calculated by the given aerostat-parachute system parameters that was displayed on the speed versus time graph.*

Index Terms—Natural disaster; emergency incident; video surveillance system; artillery launch; aerostat-parachute system; descent parameters.

I. INTRODUCTION

Natural disasters (earthquake, flood), industrial accidents and catastrophes, the environmental consequences of anthropogenic impact on the biosphere (oil spills, forest fires), the use of different types of weapons in armed conflicts create situations that are dangerous for life and population health.

Fig. 1. Suborbital video surveillance system

By receiving information about the event, the Ministry of Emergency Situations (MES) chooses protection measures and means, depending on the type, nature and occurrence of the emergency incident. An operational group is formed that performs search and rescue operations: aerial reconnaissance of the terrain, landing of rescuers in the area of emergency, evacuation of victims from areas of emergency, as well as the rescue operations conduct related to the elimination of the consequences of an emergency event.

II. PROBLEM STATEMENT

At present, for the prompt collection of information in the event of an emergency situation, the main role is played by aviation equipped with modern means of video surveillance. Suborbital video surveillance systems are also being developed, which use rocket launchers. However, the creation of the missile installations complex that provides operational control of emergency situations on the territory of Ukraine requires considerable financial costs and time of its implementation.

Taking into account that artillery equipment, which is in the arsenal of the Ukrainian army, is used quite a bit, and aging is gradually being written off, it is advisable to use this technique for other purposes. In particular, for the artillery start-up of a video camera for monitoring the emergency zone. The Aerospace Society (ASS) of Ukraine proposed a suborbital video surveillance system with artillery launch (Fig.1).

The principle of the suborbital video surveillance system is as follows. The launching of the video surveillance system unit is carried out by the gun launching of the projectile, inside of which a small-sized missile with an instrument container and a parachute system is placed in place of the combat charge. The initial parameters of the projectile's movement (direction and angle of inclination) are determined by the coordinates of the given observation zone. The projectile leads a small rocket with equipment to a height of 10–12 km. Then the small rocket is detached and launched. The initial parameters of its motion are determined by the parameters of the movement of the artillery shell at the time of separation of the small rocket. The missile has a hypersonic ramjet engine, or solid fuel, developed on the basis of new technologies. The vertical component of the flight speed of a rocket gradually decreases and at an altitude of 70–90 km it reaches $V_{\text{vert}} = 0$. The container with the payload is separated from the rocket and goes into the free fall mode. To reduce the speed of descent, the parachute opens. Controlling the parameters of the camcorder's descent is performed by the operator of the command post remotely via the radio channel.

The first experimental artillery launches (on the Crimea territory) showed that at the height of the camera compartment the parachute is not opened due to the very low density of the atmosphere. The construction was supplemented by a rubber chamber shaped like a torus. When the chamber is filled with compressed air, the torch stretches the parachute fabric, providing braking during descent. The results of the system tests were negative. The parachute's tissue was severely damaged or even burned when it entered the denser layers of the atmosphere due to heating at high speed. Graphite fabric was used. Its use allowed achieving some positive results. However, the system requires modernization and refinement.

III. Problem Solution

Review and analysis of existing spacecraft descent systems showed the inapplicability of the devices considered to solve the task. It is necessary to develop a set of remote control devices for the parameters of reducing the video surveillance unit: descent speed, movement direction, convenient angular position. The use of an aerostat for reducing the descent rate is considered. This makes it possible to reduce the descent rate and to avoid overheating of the equipment when entering the denser layers of the atmosphere. Aerostat will also increase the time of video surveillance, which is especially important for obtaining quality information about emergency situations. When entering the denser atmosphere, the balloon stops, the rate of decline is zero. It is necessary to reduce the volume of the balloon. It is proposed to develop an aerostat-parachute system.

An important parameter of the applicability of the system is the time and area of observation. To assess the scale of an event, the intensity of events, the probability of evaluation requires a certain time interval. The time interval and observation area is determined by the initial observation height and the descent rate. To increase the observation time interval, it is necessary to change the descent parameters. The most important parameter in this case is the movement speed of the video camera in the period from the opening of the parachute to its entry into the denser layers of the atmosphere. To solve this problem, it is proposed to use an aerostat-parachute system (APS).

Taking into account the experience accumulated by the science of balloons [1], which were actively used to study the properties of the atmosphere, an aerostat design is proposed for controlling the rate of reduction of a container with a payload. In accordance with the laws of Archimedes, it is known that a buoyancy force acting numerically equal to the weight of the liquid (gas) in the volume displaced by the body acts on the body immersed in the liquid (gas) [2]. Proceeding from this, a balloon filled with a gas that is lighter than air will have some lifting power and thereby reduce the rate of fall of the payload. After analyzing the properties of light gases, helium was chosen (its density is 0.1785). The density of hydrogen is half the size, however, this application is unsafe. The use of an aerostat is particularly important in the high layers of the atmosphere where the air density is very small and the parachute system is practically ineffective.

When the balloon enters the denser layers, the velocity of the fall substantially decreases until it hangs. Further reduction can be achieved by dropping helium. Thus, the construction of the APS has the form shown in Fig. 2.

Proceeding from the above, it is proposed to create a system representing a combination of a balloon and a parachute. When the rocket reaches its maximum height, an accelerometer sensor is triggered, which fixes the state of weightlessness, and helium from the cylinders that are attached to the container begins to fill the torus, and then fills the balloon. The free fall of the balloon will be slowed by the actions of the Archimedes force. As the balloon enters the denser layers, its fall speed decreases to zero.

To ensure the set value of the descent rate, it is necessary to develop an automatic control system (ACS) for the descent rate and perform calculations of the parameters of its operation. Reduction of the balloon in the denser layers of the atmosphere is proposed to be carried out by dumping helium, gradually converting the balloon into a parachute system. Adjusting the speed of descent will increase the time interval for surveying the observed area. The control is carried out by the operator of the Ministry of Emergency Measures remotely by radio.

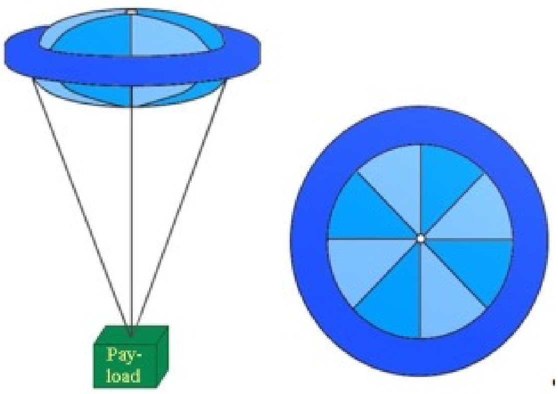

Fig. 2. Balloon-parachute system design

The aerostat-parachute system landing should be safe for the camcorder. The soft landing system is proposed, which consists of the weights on a cable that is attached to a spring with two contacts along the edges. Also in the basis of the container is mounted a small powder charge. When weight touches the earth's surface, the spring is compressed, one of the contacts closes, the signal is fed to the powder charge, the brake powder device is triggered. The shock wave reduces the speed of the fall and softens the touch with the earth's surface. This provides the device with an effective landing with no damage to the structure, which makes it possible to use it repeatedly.

To conduct research on the parameters of the soft landing automatic control system, it is necessary to perform calculations with the mathematical modeling help. Let's consider:

$$F_B = V\rho g, \qquad F_B = m_B g,$$

$$m_B = V\rho, \qquad P = mg,$$

where V is the volume of air; ρ is the air density; m is the descent vehicle weight; m_B is the payload weight; v is the body free fall speed.

Aerostat-parachute system descent speed:

$$v_{\text{APS}} = at.$$

According to the Newton's second law $F = ma$, so $a = F/m$.

If $F = P - F_B = mg - m_B g = g(m - m_B)$, then $a = \frac{g(m-m_B)}{m}$.

In case without balloon, i.e. $m_B = 0$, then $a = g$ – free fall.

When the mass of the APS becomes equal to m, i.e. $m = m_B = 0$; $a = \frac{g(m-m_B)}{m} = 0$ – then the drop will cease (suspended state or zero buoyancy).

$$\rho = \alpha\left(1 - \frac{\beta h}{\gamma}\right)^{\delta}. \qquad (1)$$

where α = 1.2255, β = 6.5, γ = 288, δ = 4.255.

$$h = H_0 - \frac{at^2}{2},\ H_0 \text{ – beginning of descent.}$$

From here

$$\begin{pmatrix} a = \dfrac{2(H_0 - h)}{t^2} \\ a = g\left(1 - \dfrac{m_B}{m}\right) = g\left(1 - \dfrac{V\alpha\left(1-\frac{\beta h}{\gamma}\right)^{\delta}}{m}\right) \end{pmatrix},$$

$$\frac{2(H_0 - h)}{t^2} = g\left(1 - \frac{V\alpha\left(1-\frac{\beta h}{\gamma}\right)^{\delta}}{m}\right),$$

the equation obtained from here

$$t = \sqrt{\frac{2(H_0 - h)}{g\left(1 - \frac{V\alpha\left(1-\frac{\beta h}{\gamma}\right)^{\delta}}{m}\right)}}. \qquad (2)$$

Data for modeling:

H_0 – 85 km, h – 85….5 km, Δh – 5 km;

$V = \frac{4}{3}\pi R^3$; R – 1 m, m – 5 kg.

Calculation algorithm:

1) Substitute in formula (2) h = 85, 80, 75, …, 5 km (17 points) calculate t (descent time).

2) Substitute in formula (1) h = 85, 80, 75, …, 5 km, get m_B.

3) Calculate $a = \frac{g(m-m_B)}{m}$.

4) Calculate $v_{\text{APS}} = at$.

5) Plot the descent rate reduction.

Using software, the changes in the speed of descent of the balloon-parachute system (APS) can be seen, starting the descent from 85 km to 0, displaying this on the graph – speed versus time.

Input parameters:

1) fall height allows to set the altitude in km to calculate the descent rate of the balloon-parachute system at a certain altitude, which will be interesting;

2) radius – input field for the torus radius;

3) mass – input field for the payload.

Output parameters:

1) H – descent height;

2) – descent time;

3) a – APS acceleration;

4) v – APS descent speed;

5) v_{ff} – APS free fall speed.

Displaying results:

1) time units – seconds, minutes, hours;

2) distance units – meters, kilometers.

3) time and distance units allow us to more effectively consider the balloon-parachute system descent rate on the graph.

IV. Results

During the research and analysis of the descent of the balloon-and-parachute system with the software, it is seen how the speed (v) of the device descent varies from an altitude of 85 km with a descent step of 5 km.

By the input parameters changing: radius - 6 m, object mass – 5 kg, it will be seen the change in the APS descent speed, so speed will decrease in Fig. 3.

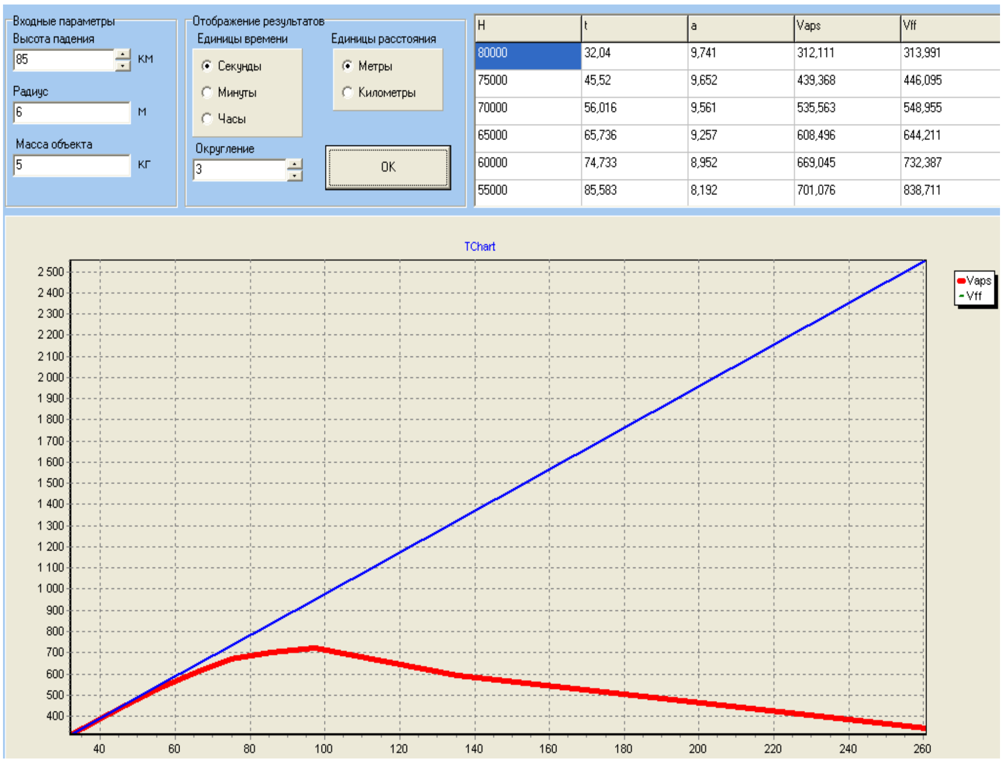

Fig. 3. Device descent speed by the input parameters: radius – 6 m, object weight – 5 kg

Proceeding from the studies of the APS decrerase rate, it can be seen that the proposed parameters: radius – 1 m, object mass – 5 kg will be optimal.

V. Conclusion

In the balloon-parachute system of video surveillance the following equipment is installed:

1. control unit for filling the torus and the balloon with helium: the filling is performed automatically by the signal of an accelerometer fixing the achievement of zero gravity;

2. control unit for slings to correct the horizontal component of the speed of motion of the video camera;

3. control unit for the angular position of the video camera;

4. control unit for the descent rate after reaching the minimum allowable descent rate;

5. control system for the descent vehicle soft landing.

Controlling the parameters of the camcorder's descent is performed by the operator of the Ministry of Emergency Measures remotely via radio. The camcorder's signal is transmitted to the operator's receiver via the radio transmitter of the container. Information from the camcorder is displayed.

To evaluate the implementation of the technical solution of the problem, calculations of the parameters of the APS motion were made. Selection of specific technical objects included in the system was carried out. Calculations of APS parameters with selected values showed the following: video camera descent speed from the height of 80 km gradually decreases and at an altitude of 9 km it is zero. Thus, the observation time can be significantly increased. Development and implementation of the system is real and expedient.

The implementation of the project in Ukraine will provide the opportunity to create a unique system for monitoring natural disasters, man-made disasters anywhere in the world.

REFERENCES

[1] R. Emden, *The fundamentals of aerobatic*. Moscow; Leningrad, 1936, 135 p.

[2] V. E. Kuzmichev, *Laws and formulas of physics. Directory*. Kiev, Naukova Dumka, 1989, 864 p.

Received October 18, 2017

Anatoliy Kozlov. Candidate of Science (Engineering). Assistant Professor.
Aviation Computer-Integrated Complexes Department, Education & Scientific Institute of Information-Diagnostics Systems, National Aviation University, Kyiv, Ukraine.
Education: Kyiv State University named after T.G. Shevchenko, Kyiv, Ukraine, (1965).
Research area: Capacitive Transducers with an Inhomogeneous Magnetic Field, Technological Measurements, Aviation Devices and Information Systems, Automation Systems Design.
Publications: more than 50 papers.
E-mail: ap_kozlov@ukr.net

Roman Pantyeyev. Candidate of Science (Engineering). Assistant Professor.
Aviation Computer-Integrated Complexes Department, Education & Scientific Institute of Information-Diagnostics Systems, National Aviation University, Kyiv, Ukraine.
Education: Donetsk National Technical University, Donetsk, Ukraine, (2001).
Research area: Information Systems, Control Systems Design, Identification of Complex Systems, Mathematical Modeling.
Publications: more than 20 papers.
E-mail: romanpanteevmail@gmail.com

А. П. Козлов, Р. Л. Пантєєв. Система оперативного моніторингу надзвичайних ситуацій

Наведено короткий огляд наявної інформації щодо збору інформації про надзвичайні ситуації. Розглянуто систему з артилерійським запуском аерокосмічного відеоспостереження, визначено структуру та функціонування суборбітальної системи відеоспостереження аварійної зони. Показано необхідність розробки пульта дистанційного керування для зменшення блоку відеоспостереження. Запропоновано аеростатно-парашутну систему з пультом оператора, що використовує радіоканал. Проаналізовано структуру та параметри системи автоматичного керування двигуном спуску. Надано оцінку технічному рішенню, розрахункам параметрів аеростатно-парашутної системи з використанням програмного забезпечення. Наведено приклад розрахунку оптимальної ваги, за даними параметрів аеростатно-парашутної системи, які показано на графіках швидкості та часу.

Ключові слова: стихійне лихо; аварійний інцидент; система відеоспостереження; артилерійський запуск; аеростатно-парашутна система; параметри спуску.

Козлов Анатолій Павлович. Кандидат технічних наук. Доцент.
Кафедра авіаційних комп’ютерно-інтегрованих комплексів, Навчально-науковий інститут інформаційно-діагностичних систем, Національний авіаційний університет, Київ, Україна.
Освіта: Київський державний університет ім. Т. Г. Шевченко, Київ, Україна, (1965).
Область досліджень: ємнісні перетворювачі з неоднорідним магнітним полем, технологічні вимірювання, авіаційні прилади та інформаційні системи, проектування систем автоматизації.
Публікації: більше 50 робіт.
E-mail: ap_kozlov@ukr.net

Пантєєв Роман Леонідович. Кандидат технічних наук. Доцент.
Кафедра авіаційних комп’ютерно-інтегрованих комплексів, Навчально-науковий інститут інформаційно-діагностичних систем, Національний авіаційний університет, Київ, Україна.
Освіта: Донецький національний технічний університет, Донецьк, Україна, (2001).
Область досліджень: інформаційні системи, проектування систем управління, ідентифікація складних систем, математичне моделювання.
Публікації: понад 20 робіт.
E-mail: romanpanteevmail@gmail.com

А. П. Козлов, Р. Л. Пантеев. Система оперативного мониторинга чрезвычайных ситуаций
Приведен краткий обзор имеющихся материалов по сбору информации о чрезвычайных ситуациях. Рассмотрена система с артиллерийским запуском аэрокосмического видеонаблюдения, определена структура и функционирование суборбитальной системы видеонаблюдения аварийной зоны. Показана необходимость разработки пульта дистанционного управления для уменьшения блока видеонаблюдения. Предложена аэростатно-парашютная система с пультом оператора, использующего радиоканал. Проанализирована структура и параметры системы автоматического управления двигателем спуска. Дана оценка техническому решению, расчетам параметров аэростатно-парашютной системы с использованием программного обеспечения. Приведен пример расчета оптимального веса, рассчитываемого на основе параметров аэростатно-парашютной системы, отображаемых на графике скорости и времени.
Ключевые слова: стихийное бедствие, аварийный инцидент, система видеонаблюдения, запуск артиллерии, аэростатно-парашютная система, параметры спуска.

Козлов Анатолий Павлович. Кандидат технических наук. Доцент.
Кафедра авиационных компьютерно-интегрированных комплексов, Учебно-научный институт информационно-диагностических систем, Национальный авиационный университет, Киев, Украина.
Образование: Киевский государственный университет им. Т. Шевченко, Киев, Украина, (1965).
Область исследований: емкостные преобразователи с неоднородным магнитным полем, технологические измерения, авиационные приборы и информационные системы, проектирование систем автоматизации.
Публикации: более 50 работ.
E-mail: ap_kozlov@ukr.net

Пантеев Роман Леонидович. Кандидат технических наук. Доцент.
Кафедра авиационных компьютерно-интегрированных комплексов, Учебно-научный институт информационно-диагностических систем, Национальный авиационный университет, Киев, Украина.
Образование: Донецкий национальный технический университет, Донецк, Украина, (2001).
Область исследований: информационные системы, проектирование систем управления, идентификация сложных систем, математическое моделирование.
Публикации: более 20 работ.
E-mail: romanpanteevmail@gmail.com