UDC 629.735.015.4:629.735.45(045)
DOI: 10.18372/2306-1472.69.11050

Wang Bo[1]
Volodymyr Kharchenko[2]
Alexandr Nakhaba[3]

MATHEMATICAL MODEL OF AUTOMATIC FLIGHT OF POLIKOPTER UAV NAU PKF "AURORA"

[1,2]Ningbo University of Technology
201, Fenghua Road, 315211, Ningbo, China
[2,3]National Aviation University
Kosmonavta Komarova Avenue 1, 03680, Kyiv, Ukraine
E-mails: [1]vanbo@ nau.edu.ua; [2]kharch@nau.edu.ua; [3]nakhaba91@ukr.net

Abstract

Purpose: *Development of mathematical and experimental models of polikopter UAV NAU PKF "Aurora" of oktakopter scheme for experimental flights in manual, semi-automatic and unmanned mode.* ***Methods:*** *14/03/2016 - 21/03/2016 held a serie of experiental flights (10 flights) of 10 rats on altitude 700 meters on polikopter (oktakopter) NAU PKF "Aurora" in germetic kabin with the study of his somatic, nevrological status after the flight. Flights also carried out with experimental animals on board for such a safety assessment.* ***Results:*** *The obtained logs of 'black box' of the autopilot indicate very small (almost invisible) fluctuations in pitch, roll and yaw during the flight, minor variations on altitude during almost stationary hovering of polikopter at different altitudes, and fully adequate to movements and maneuvers of aircraft vibrations and parameters of these sensors.* ***Discussion:*** *In the course of these studies demonstrated experimentally the possibility of completely safe flight of the mammals (rats) on polikopter vehicle, even in the open cockpit. With appropriate refinement possible in the future to raise the issue of the development and construction of passenger polikopter flyers for totally safe air transportation of people [6,7,8]. In terms of adverse mechanical effects on the human body (acceleration overload fluctuations, vibrations) polikopter transport is safer and less harmful to the passengers than road transport, which is particularly important in the delivery of patient of neurosurgical, politravmatological, cardiologycal and critical care profile at critical condition in intensive care units and operating hospitals and medical centers.*

Keywords: oktakopter; passenger polikopter; polikopter; polikopter flyer; UAV.

1. Introduction

The number of cars over the past 10 years has almost increased, and the road infrastructure is almost unchanged, which led to a sharp increase in traffic jams. This in turn has significantly worsened road links and complicate the work of the municipal emergency services (police, emergency medical service and others.) [1]. This, in turn, does not allow the timely delivery of emergency patients directly at the operating health centers of third level to provide them with timely a specialty medical care, which increases the level of disability, mortality and leads to significant economic losses [6].

2. Analysis of the latest research and publications

To solve the problem of urban and long-distance communications in Ukraine solely through the repair and modernization of the road infrastructure is very difficult. A good solution to this problem could be the use of helicopter aviation [2]. But, unfortunately, today's large cities of Ukraine are not designed for use by police and medical helicopters, since they do not have a sufficient number of helipads for takeoffs and landings. [3] In addition, the helicopter has a very large size and very unsafe open propellers, which are almost impossible to hide under the protective grilles. [4] Unfortunately most of the helicopters are not able to carry out perfectly smooth vertical takeoff and landing, "jewelry" precise maneuvering at different heights (especially at low altitudes) and carry absolutely still hang at different heights. [5]

3. Research tasks

To solve the problems of indicated vehicle needs with more independent support points, (Propellers VTOL), equipped with autopilot and adequate automatic flight stabilization system. Thus, for a more complete solution to this problem it is necessary to use the aerial multirotor vehicle or polikopter.

4. The solution of the problem.

To resolve this issue built an UAV NAU PKF "Aurora" [5] capacity of 5 kg, equipped with modern autopilot and the automatic flight stabilization system.

Mathematically, the flight of the vehicle is described as follows [4]:

5. "Aircraft-Satellite-Ground Station" Channel

To resolve this issue built an UAV NAU PKF "Aurora" [5] capacity of 5 kg, equipped with modern autopilot and the automatic flight stabilization system.

Mathematically, the flight of the vehicle is described as follows [4]:

$$\begin{cases} x = Ax+B_u u + B_f f \\ y = C_y x + D_{yu} u + D_{yf} f \\ z = C_z x+ D_{zu} u + D_{zw} f , \end{cases}$$

where x ϵ R^{11x1} - the state vector; u ϵ R^{4x1} - the control vector; y ϵ R^{11x1} - the output vector, to generate feedback; f ϵ R^{3x1} — vector of atmospheric excitations that act on an aircraft in horizontal and vertical planes (three-axis); z ϵ R^{3xl} - vector of the output variables to assess the quality of the system; A ϵ R^{11x11}, B_u ϵ R^{11x4}, B_f ϵ R^{11x3}, C_y ϵ R^{11x11}, D_{yu} ϵ R^{11X4}, D_{yw} Є R^{11x3}, C_z ϵ R^{3X11}, D_{ZU} ϵ R^{3x4}, D_{zf} ϵ R^{3x3} - matrix, which describe the model of the aircraft in the space of states.

State vector of polikopter comprises the following components [4]:

$$x = [V_x,\ V_y,\ \omega_x,\ \omega_z,\ \gamma,\ \delta,\ V_z,\ \omega_y,\ r_{3,3}]^T \quad [4]$$

where V_x, V_y, V_z - longitudinal, lateral and vertical linear velocities; δ, γ - angles of pitch and roll; ω_x, ω_z, ω_y – angular velocity of the pitch, roll and yaw; r 3,3 - the change of state feedback gyroscope.

Mathematical model of the automatic control of the polikopter UAV NAU PKF "Aurora":

$$Ex = Ax + Bu;$$

$$y = Cx,$$

where x - state vector; u - control vector; y - the vector of surveillance; A, B - matrix status and control; C - a matrix of observations, measurements for determining the output data to develop a control algorithm.

Model of longitudinal motion of polikopter is described as follows:

$$x = [V, \alpha, \zeta, \omega_z, H]^T;\ u = [\delta_{tr}, \delta_{h}]^T,$$

where V - air velocity (m / s); α - angle of attack (degrees); H – altitude of flight (m). When the longitudinal movement is controlled by increasing the speed of rotation of two rear electric motors of polikopter (oktakopter), which leads polikopter tilt forward so that the rear of polikopter rises, and the front part lowered.

Vector of external excitation for longitudinal movement of polikopter described as follows:

$$f_{ed} = [V_{dist}, \alpha_{dist}, \omega_{zdist}]^T,$$

where $\omega_{z\ exc}$ – turbulent incremental of angular pitch velocity.

Turbulence angle of attack $\alpha_{exc} = V_{exc} / V$.

Status and control vector for lateral movement of polikopter described as follows:

$$x = [\beta, \gamma, \omega_x, \omega_y, \psi]^T;\ u = [\delta_{el}, \delta_{rud}]^T,$$

where β - slip angle (degrees); γ - the roll angle (degrees); ω_x - the angular velocity of the roll (deg /s); ω_y - rate of change in yaw (degree); ψ – yaw angle (degrees). When the lateral movement of polikopter controlled by an increase in speed of the two left or right oktakopter motors, resulting in a tilt of the oktakopter platform right or left (as appropriate).

Vector of external excitation for lateral movement of polikopter described as follows:

$f_б = [\beta_{dist}, \omega_{x\ dist}, \omega_{y\ dist}]^T$, where the turbulent slip angle is described as follows – $\beta_g = -V_z/V$, where V_z- the lateral component of the true airspeed.

The transfer functions of the longitudinal motion of the polikopter UAV described as follows [9]:

$$\begin{cases} s^2\theta(s) + a_1 s\vartheta(s) + a_2\alpha(s) = -a_3\delta_h(s) + a_4 M_{z\ dist}(s); \\ -s\alpha(s) + a_5\alpha(s) + s\vartheta(s) = a_6 F_{y\ dist}(s), \end{cases}$$

where s=d/dt.

The transfer function of pitch movement under the control action is described as follows [8]:

$$W_\vartheta^{\delta h}(s) = \frac{\vartheta(s)}{\delta_h(s)} = \frac{a_3(s-a_5)}{s\left[s^2 + (a_1 - a_5)s + (a_2 - a_1 a_5)\right]}$$

In standard form, according to the theory of automatic control a transfer function of the movement on the pitch under the control action is as follows:

$$W_\vartheta^{\delta h}(s) = \frac{K_h^{\ \delta_h}\ (T_{h1}s+1)}{s(T_h^{\ 2}s^2 + 2\xi_h T_h s + 1)}.$$

The transfer function of pitch movement under the disturbance is described as follows [10]:

$$W_\vartheta^{Mz\ dist}(s) = -\frac{\vartheta(s)}{M_{z\ dist}(s)} = \frac{a_4(s-a_5)}{s\left[s_2 + (a_1 - a_5)s + (a_2 - a_1 a_5)\right]}.$$

In standard form, according to the theory of automatic control of the transfer function of pitch movement under the control action is as follows [8]:

$$W_\vartheta^{M\,z\ dist}(s) = \frac{K_H^{\ M\,z\ dist}(T_{h1}s+1)}{s(T_H^{\ 2}s^2 + 2\xi_b T_h s + 1)}.$$

In this transmission ratio manipulated variable pitch angle is described as follows [10]:

$$K_h^{\ \delta_в} = -\frac{a_3 a_5}{a_2 - a_1 a_5},$$

transfer ratio of disturbance pitch angle is described as follows [9]:

$$K_B^{\ M\,z\ dist} = -\frac{a_4 a_5}{a_2 - a_1 a_5},$$

time constant characterizing a maneuverability of polikopter on the pitch angle is described as follows [10]:

$$T_{h1} = \frac{1}{a_5},$$

the time constant is equal to the period of their own (undamped) vibrations of polikopter pitch is described as follows [8]:

$$T_h = \frac{1}{\sqrt{a_2 - a_1 a_5}},$$

the relative coefficient of damping of the natural oscillations of polikopter at pitch is described as follows [8]:

$$\xi_h = \frac{a_1 - a_5}{2\sqrt{a_2 - a_1 a_5}}.$$

The transfer functions of motion of polikopter UAV at roll described as follows [10]:

$$W_\gamma^{\delta el}(s) = \frac{\gamma(s)}{\delta_{el}(s)} = \frac{K_{el}}{(T_{el}s+1)s};$$

$$W_\gamma^{M\,x dist}(s) = \frac{\gamma(s)}{M_{x dist}(s)} = \frac{c_3 K_{el}}{(T_{el}s+1)s},$$

where $K_{el}=c_2/c_1$ – transmission correction coefficient, a $T_{el} = 1/c_1$ – time constant of moving of polikopter at roll.

Yaw transfer functions of polikopter are described as follows [8]:

$$\left.\begin{aligned} W_\psi^{\delta rud}(s) &= -\frac{\psi(s)}{\delta_{rud}(s)} = \frac{K_{rud}^{\ \delta_{rud}}(T_{rud1}s+1)}{(T_{rud}^2 s^2 + 2\xi_{rud}T_{rud}s+1)s} \\ W_\psi^{M\,y dist}(s) &= \frac{K_{rud}^{\ M y dist}(T_{rud1}s+1)}{(T_{rud}^2 s^2 + 2\xi_{rud}T_{rud}s+1)s} \end{aligned}\right\},$$

At the same time a ratio of the transmission of control influence of the angle of direction is described as follows:

$$K_{rud}^{\delta_{rud}} = \frac{b_3 b_5}{b_2 - b_1 b_5}$$

transmission ratio of the disturbing force to the angle direction is described as follows [9]:

$$K_{rud}^{M_{ydist}} = -\frac{b_4 b_5}{b_2 - b_1 b_5},$$

the time constant characterizing the maneuverability of polikopter at corner of yaw described as follows [10]:

$$T_{rud1} = \frac{1}{b_5},$$

the time constant is equal to the period of own non dempfed fluctuations of polikopter on the yaw axis is described as follows [8]:

$$T_{rud} = \frac{1}{\sqrt{b_2 - b_1 b_5}},$$

the relative coefficient of damping of the natural oscillations of polikopter on the yaw axis is described as follows [9]:

$$\xi_{rud} = \frac{b_1 - b_5}{2\sqrt{b_2 - b_1 b_5}}.$$

A series of test flights, including experimental animals on board to a height of 800 meters on the polikopter (oktakopter) NAU PKF "Aurora" in a sealed and an open cabin with a record of logs of “black box” of the autopilot, with audio and video recording of flight, with a further determination of physical, neurological status, and behavioral reactions of animals after such a flight. Results of aircraft technical testing and biomedical research of the experimental group of animals were compared with similar results of flyght in the control group of animals that were in the same cabin with working propellers, but without a flight. Statistical analysis of the results for validation studies.

6. Results and discussion

These logs of flight of “black box” of the autopilot indicate very small (almost invisible) fluctuations in pitch, roll and yaw during the flight, minor variations on altitude during almost stationary hovering of polikopter at different altitudes, and fully adequate to the movements and maneuvers of aircraft vibrations of performances of these sensors. Analysis of video from an entrenched to the polikopter camera also shows the smooth and almost "jewelry" precision maneuvering of polikopter at different heights, which indicates almost entirely solving the technical problem.

Log files of the “black box” of the autopilot analyzed in program Mathlab, and in the programs of flight simulation XPlane and FlightGear. We analyzed in detail video with three onboard cameras, namely 1 - with the navigation IP-cameras, which is directed downwards and that removes what is on the ground, that is, over what flies polikopter (it is necessary to orient the operator when controlling the aircraft) 2 - with sides IP-camera, which is directed downwards cockpit of the aircraft (which is necessary to observe the behavior of the top of the animal), and 3 - with side IP- camera which is located on the front of the cab and which is directed in the horizontal direction on the rear wall cabin (which is necessary to observe the behavior of the animal in the horizontal direction).

Here are the printed pages of "black box" of the autopilot of unmanned aircraft NAU PKF "Aurora", which shows changes to some of the most important parameters of automatic flight (6 of 200) that a frequency of 10 Hz simultaneously recorded during the experimental flight of polikopter. The left 4/5 of the graph displays automatically phase of flight, right 1/5 of the chart - the manual flight control. It is evident that during manual control - amplitude of the pitch, roll and yaw is the most than during the automatic flight due to shortcomings human pilot in comparison with electronic autopilot.

These experiments were carried out mainly for the study of the possibility of safe transport of patients with emergency conditions in the medical centers of the third level of the organization of Health especially in serious and critical condition, as well as to assess the risk of emergency depressurization of the cabin at a height of 800 meters, which can occur in a variety of abnormal and emergency situations. Such tests are important to provide the necessary human flight security measures and other living creatures on the futures better and more kinds of lifting of polikopter transport.

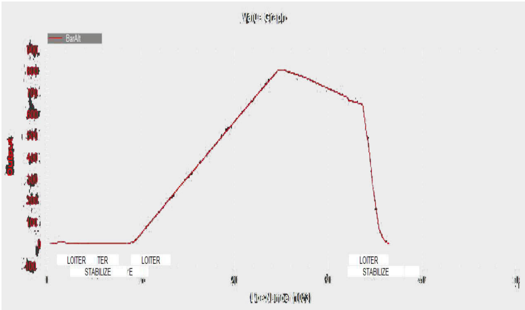

Fig. 1. Chart of changes in barometric height

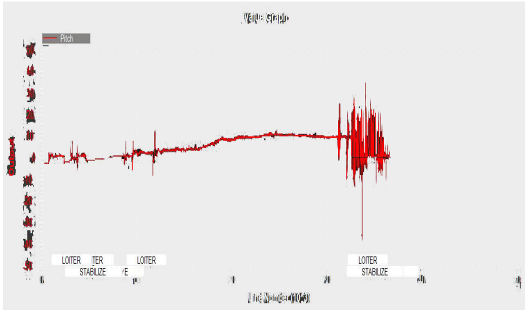

Fig. 2. Chart of axis pitch oscillations

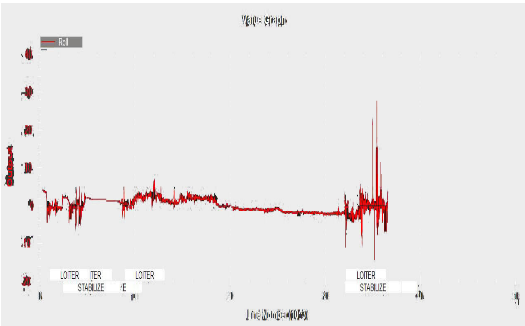

Fig. 3. Chart of axis roll oscillations

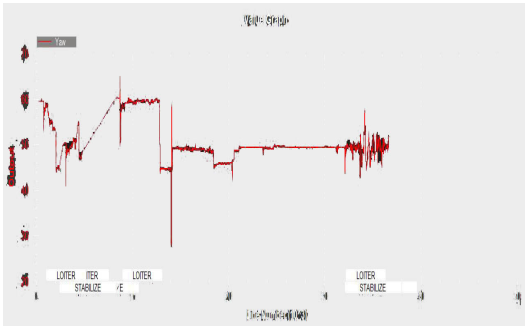

Fig. 4. Chart of yaw axis oscillations

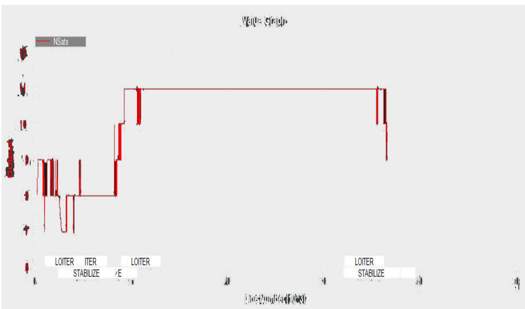

Fig. 5. Chart of change of the number of GPS - satellites

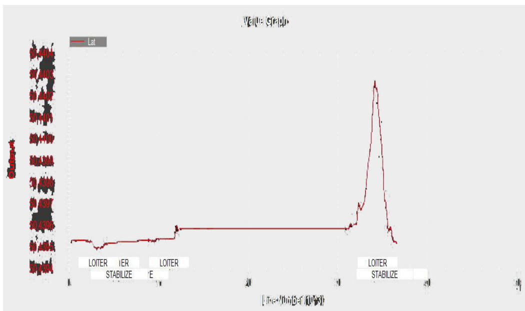

Fig.6. Chart of deviation in latitude

The findings suggest that very low levels of accelerations, vibrations (on pitch, roll, yaw) and vibration compared with road transport, which can be extremely in demand for transportation of patients to medical centers of the third level of health care in serious and critical condition (eg patients with severe craniocerebral trauma, spinal trauma and other acute pathologies). This flight does not exceed the permissible levels of vibration and acceleration for this challenging category of passengers.

7. Conclusions

In the course of these studies demonstrated experimentally the possibility of completely safe flight of mammals (rats) on polikopter vehicle, even in the open cockpit. It also proves that the depressurization of the passenger cabin of polikopter at an altitude of 800 meters does not represent a serious threat to life and health of the crew. When comparing the results in the experimental and control groups of animals experimentally proved that the flight of the living beings on polikopter in the open cockpit to a height of 800 meters is almost does not cause adverse effects in somatic, neurological and behavioral status of animals, found only a slight increase of stress level (at 5-10%). With appropriate refinement possible in the future to raise the issue of the development and construction of passenger polikopter flyers for totally safe air transportation of people [6-13]. In terms of adverse mechanical effects on the human body (acceleration overload fluctuations, vibrations) polikopter transport is ten times safer and less harmful to the passengers than road transport, which is particularly important in the delivery of patient of neurosurgical, politravmatological, cardiological and critical care profile in cruiserweight and critical condition in intensive care units and operating hospitals and medical centers.

References

[1] Kharchenko V.P., Cybul'ov P.M. (2013) *Vykorystannja polikopternyh tehnologij dlja buduvannja innovacijnoi' ekonomiky v Ukrai'ni ta shljahy i'h kommercializacii'* [Using of polikopter technology to build innovative economy in Ukraine and ways to kommertsialization]. – Conference on Intellectual Property, 2012. K.: KNTEU.– 109 p.

[2] Volodko AM. (1984) *Osnovy letnoj jekspluatacii vertoletov* [Fundamentals of flight operation of helicopters]. Aerodynamics M.: Transport,. – 256 p.

[3] Lebedev V.V., Krylov V.V. (2000) *Neotlozhnaja nejrohirurgija* [Emergency neurosurgery]. – M.: Medicine .- 568 p.

[4] Johnson, W. (1983) *Teorija vertoleta: v 2 knigah* [The theory of the helicopter: 2 books.] Moscow: Mir. - Bk. 1 - 503 p.

[5] Volodko A. M. (1988) *Fundamentals of Aerodynamics and helicopter flight dynamics.* M. : Transport. – 342 p.

[6] Bogdanov Yu. C., Mikheev R. A. Skulkov DD (1990) *Konstrukcija vertoletov* [The design of helicopters]. – M. : Mechanical engineering. – 272 With.

[7] Krasovsky A.A. Vavilov J. A (1986) *Sistemy avtomaticheskogo upravlenija letatel'nyh apparatov* [Automatic control systems of aircraft]. – M. : VVIA them. prof. NOT. Zhukovsky. – 462 s.

[8] Kharchenko V.P., Chepizhenko V. I., Tunick A.A., Pavlova S.V. (2012) *Avionika bezpilotnih lital'nih aparativ* [Avionics of drones]. K. : OOO "Abris-print". – 464 p.

[9] David Hynchul Shim. (2000) Control System Design for Rotorcraft-based Unmanned Aerial Vehicles using Time-domain System Identification *IEEE Int. Conference on Control Applications.* - P. 808-813.

[10] Tunik A.A. Parametric Robust Optimization of Digital Flight Control Systems / Tunik A.A., Abramovich E.A. // Proceedings of the National Aviation University. – 2003. – № 2. – pp. 31–37.

[11] Nakhaba A.A. SI «Institute of neurosurgery NAMS of Ukraine» (2013), *Gibridnij bagatocil'ovij aviacijnij transport.* [Hybrid multi-purpose transport aircraft.], State Register of Patents of Ukraine, Kiev, UA, Pat. № 79095.

[12] Nakhaba A.A. SI «Institute of neuro-surgery NAMS of Ukraine» (2014), *Sposib urgentnogo nadannja specializovanoi' medychnoi' dopomogy hvorym iz tjazhkoju cherepno-mozkovoju travmoju u pershi godyny z momentu oderzhannja travmy z vykorystannjam polikopternoi' aviacii'.* [Method of urgent specialized medical care to patients with severe traumatic brain injury in the first hour after an injury using polikopter aircraft.], State Register of Patents of Ukraine, Kiev, UA, Pat. № 88872.

[13] Nakhaba A.A. SI «Institute of neuro-surgery NAMS of Ukraine» (2014), Sposib urgentnogo nadannja specializovanoi' medychnoi' dopomogy hvorym iz uskladnenoju hrebetno-spyno-mozkovoju travmoju u pershi godyny z momentu oderzhannja travmy z vykorystannjam polikopternoi' aviacii'. [Method of urgent specialized medical care to patients with complicated vertebro-spinal injury in the first hour after an injury using polikopter aircraft.], State Register of Patents of Ukraine, Kiev, UA, Pat. № 88871.

Ванг Бо[1], В.П. Харченко[2], О.О.Нахаба[3]

Математична модель автоматичного польоту полікоптерного БПЛА НАУ ПКФ «Аврора»

[1,2]Технологічний університет Нінгбо, дорога Фенхуа, 201, Нінбо, Китай, 315211
[2,3]Національний авіаційний університет, просп. Космонавта Комарова, 1, Київ, Україна, 03680
E-mails: [1]vanbo@ nau.edu.ua; [2]kharch@nau.edu.ua; [3]nakhaba91@ukr.net

Мета: Розробка математичної та експериментальної моделі експериментального полікоптерного БПЛА НАУ ПКФ «Аврора» октакоптерной схеми для проведення експериментальних польотів в ручному, напівавтоматичному і автоматичному безпілотному режимах. **Методи дослідження:** З 14.03.2016 по 21.03.2016 проведена серія експериментального польотів (10 польотів) різніх 10 щурів на висоті 700 метрів на полікоптері (октакоптері) НАУ ПКФ «Аврора» у герметічній кабіні із подальшим визначенням соматичного та неврологічного статусу а також із визначенням поведінкових реакцій тварин після такого польоту. **Результати:** Отримані логи польотів «чорного ящика» автопілота свідчать про зовсім незначні (практично непомітні) коливання по тангажу, крену і рісканію під час польоту, незначні коливання по висоті під час майже нерухомого зависання полікоптера на різних висотах, і повністю адекватні рухам і маневрам літального апарату коливання показників цих датчиків. Аналіз відеозаписів з жорстко закріплених камер полікоптеру також свідчить про плавность і про практично «ювелірну» точність маневрування полікоптера на різних висотах, що свідчить про практично стовідсоткове вирішення поставленого технічного завдання. **Обговорення:** У ході даних досліджень експериментально доведена повністю безпечна можливість польоту живої істоти класу ссавців (щурів) на полікоптерному транспортному засобі, навіть у відкритій кабіні. При відповідному доопрацюванні можливо у майбутньому ставити питання про розробку і будівництво пасажирських полікоптерних флаєрів для повністю безпечної повітряного перевезення людей [6,7,8]. За рівнем шкідливих механічних впливів на організм людини (перевантаження прискорення, коливання, вібрації) полікоптерний транспорт в десятки разів безпечніший і менш шкідливий для пасажирів, ніж автомобільний транспорт, що має особливе значення при доставці пацієнтів нейрохірургічного, політравматологіческого, кардіологічного та реанімаційного профілю у тяжкому і вкрай важкому станах в операційні та реанімаційні відділення лікарень і медичних центрів.

Ключові слова: БПЛА; октакоптер; пасажирський полікоптер; полікоптер; полікоптерний флаєр.

Ванг Бо[1], В.П. Харченко[2], А.А. Нахаба[3]

Математическая модель автоматического полета поликоптерного БПЛА НАУ ПКФ «Аврора»

[1,2]Технологический университет Нингбо, дорога Фенхуа, 201, Нинбо, Китай, 315211
[2,3]Национальный авиационный университет, просп. Космонавта Комарова, 1, Киев, Украина, 03680

Цель: Разработка математической и экспериментальной модели экспериментального поликоптерного БПЛА НАУ ПКФ «Аврора» октакоптерной схемы для проведения экспериментальных полетов в ручном, полуавтоматическом и автоматическом беспилотном режимах. **Методы исследования:** З 14.03.2016 по 21.03.2016 проведена серія експериментальних польотів (10 польотів) різних 10 щурів на висоту 700 метрів на полікоптері (октакоптері) НАУ ПКФ «Аврора» у герметичній кабіні із подальшим визначенням соматичного та неврологічного статусу, а також із визначенням поведінкових реакцій тварин після такого польоту. Также проведены полеты с экспериментальными животными на борту для оценки безопасности таких полетов. **Результаты:** Полученные логи полетов «черного ящика» автопилота свидетельствуют о совсем незначительных (практически незаметных) колебаниях по тангажу, крену и рисканию во время полета, незначительные колебания по высоте во время почти неподвижного зависания поликоптера на разных высотах, и полностью адекватные движениям и маневрам летательного аппарата колебания показателей этих датчиков. Анализ видеозаписей с жестко закрепленных камер поликоптера также свидетельствует о плавности и о практически «ювелирной» точности маневрирования поликоптера на разных высотах, что свидетельствует о практически стопроцентном решении поставленной технической задачи.

Обсуждение: В ходе данных исследований экспериментально доказана полностью безопасная возможность полета живого существа классу млекопитающих (крыс) на поликоптерном транспортном средстве, даже в открытой кабине. При соответствующей доработке возможно в будущем ставить вопрос о разработке и строительстве пассажирских поликоптерных флаеров для полностью безопасной воздушной перевозки людей [6,7,8]. По уровню вредных механических воздействий на организм человека (перегрузки ускорения, колебания, вибрации) поликоптерный транспорт в десятки раз более безопасный и менее вредный для пассажиров, чем автомобильный транспорт, что имеет особое значение при доставке пациентов нейрохирургического, политравматологического, кардиологического и реанимационного профиля в тяжелом и крайне тяжелом состояниях в операционные и реанимационные отделения больниц и медицинских центров.

Ключевые слова: БПЛА; октакоптер; пасажирский поликоптер; поликоптер; поликоптерный флаер,

Wang Bo (1980). PhD. Professor.
College of Economics and Management of Ningbo University of Technology, China.
Research area: presided over a “high-end project” launched by Chinese Bureau of Foreign Experts; presided over and accomplished a longitudinal project launched by the provincial education department; presided over a 800-thousand Yuan horizontal project launched by Ningbo Traffic Detachment; took a major part in a project on international cooperation launched by Ministry of Science and Technology of China (2/6); took part in a municipal project on social sciences and quite a number of horizontal projects in Ningbo.
Publications: 40.
E-mail: vanbo@ nau.edu.ua

Kharchenko Volodymyr. Doctor of Engineering. Professor.
Vice-Rector on Scientific Work of the National Aviation University, Kyiv, Ukraine.
Editor-in-Chief of the scientific journal Proceedings of the National Aviation University.
Winner of the State Prize of Ukraine in Science and Technology, Honored Worker of Science and Technology of Ukraine.
Education: Kyiv Institute of Civil Aviation Engineers, Kyiv, Ukraine.
Research area: management of complex socio-technical systems, air navigation systems and automatic decision-making systems aimed at avoidance conflict situations, space information technology design, air navigation services in Ukraine provided by CNS/ATM systems.
Publications: 510.
E-mail: knarch@nau.edu.ua

Nakhaba Alexandr. (1980). Post-graduate Student.
National Aviation University, Kyiv, Ukraine.
Publications: 4.
E-mail: nakhaba91@ukr.net