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COMPLETE SEPARATION OF THE VERTICAL AND HORIZONTAL INDEPENDENT COMPONENTS OF THE FLIGHT IN POLICOPTER UAV NAU PKF "AURORA" AND MATHEMATICAL MODEL OF THIS FLIGHT.

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Abstract

Purpose: *This article presents a mathematical model and the experimental results of automatic flights of the policopter UAV NAU PKF "Aurora" of oktacopter scheme with additional elektroimpeler engines of horizontal thrust.* ***Methods:*** *UAV NAU PKF "Aurora" is developed for experimental flights in manual, semi-automatic and unmanned modes. The uniqueness and scientific novelty of data of flight testes is in a complete separation and isolation of vertical and horizontal components of the flight, which enables a fundamentally new way of moving of vehicle in the aerial space. This approach gives a ability to obtain all advantages and to eliminate disadvantages of helicopter and airplane in fundamentally new aircraft by structure and by function – namely in the policopter flyer with additional independent engines of the lateral thrust.* ***Results:*** *Obtained a new experimental data that allowed to better understand the nature of the physical forces, providing the flight of the policopter.* ***Discussion:*** *Revised a physical basis of the airscrew (propeller), namely on the example of flight of the policopter proved that most of the thrust of the propeller provided by the mechanical impulse (kinetic energy $E_к=mv^2/2$) by the impulse, that a airscrew receives at his collisions with air molecules,but not by the gradient of air pressure below and above the airscrew. Is put forward a hypothesis of gravitational nature of the flight and introduced the notion of "functional antigravity", that a force completely identical in function and opposite on the direction of the force of gravity (gravity force). Deduced a mathematical formula of "functionally antigravitational" transport, namely:$G \cdot M \cdot m/R^2 = m_f \cdot v^2/2$ – for the flights of the aircraft with a mass m over universal astronomical body with a mass M, and $m \cdot g = m_f \cdot v^2/2$ – for the flights of the aircraft with mass m over a planet Earth.*

Keywords: oktacopter; passenger policopter; policopter; policopter flyer; UAV.

1. Introduction

The number of cars for the past 10 years has almost doubled, and the road infrastructure is almost unchanged, which led to a sharp increase in traffic jams. This in turn worsened the automobile traffic and difficult work of municipal emergency services (police, emergency medical service, etc.). [1]. This, in turn, allows time to bring patients with urgent conditions directly in the operating medical centers of third level of Health Organization to provide them with timely specialized medical care, which increases the level of disability, mortality and leads to significant economic losses [2].

2. Analysis of the latest research and publications

Solve the problem of urban and intercity connections in Ukraine only by repairing and upgrading of road infrastructure is extremely difficult. A good solution of this problem could be the use of aviation vehicles [3]. Airplanes allow quickly and economically deliver passengers and cargo over long distances, but they have several significant shortcomings that prevent their use in densely populated megalopolis conditions – namely 1. complete and indissoluble dependence of vertical component thtough a horizontal flight, ie during creation of the necessary capacious wing forces only if certain (high enough for megalopolis) horizontal airspeed and 2. complete dependence on the airfield support (from a rather long runways). Helicopter allow an independent vertical component from the horizontal flight, but they can get independent of the vertical component horizontal flight, which limits their horizontal velocity at 350-500 km/hour. Also, unfortunately modern big cities of Ukraine is not suitable for the use of police and medical helicopters, because they do not have enough helipads for takeoff and landing. [1] In addition, the helicopter have too large dimensions and extremely dangerous open propellers, which are almost impossible to hide under the guard [2]. Most helicopters are not able to perform perfectly smooth vertical takeoff and landing, "jew" precise maneuvering at different heights (especially at low altitudes) and produce absolutely stationary hovering at different heights [1].

3. Research tasks

Develop a mathematical model and experimental model of theaircraft with a fully independent and separated horizontal from vertical component of the flight, with a large number of independent points of support, ie (airscrew of vertical takeoff), with lateral engines of horizontal traction equipped with autopilot and fairly effective system of automatic stabilization of the flight. So to better resolve this problem, it is necessary to use a multirotor aircraft or a policopter.

4. The solution of the problem

To solve this problem built a UAV NAU PKF "Aurora" [6] capacity of 5 kg, equipped by modern autopilot and system of automatic stabilization of the flight. Independent vertical component of the flight provided by the 8 engines of the high thrust and low speed, to ensure independent horizontal component of the flight – on both sides of the policopter established 2 elektroimpeler engines of the horizontal thrust (of low thrust and of high speed).

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} $\in$ 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 policopter comprises the following components [4]:

$x = [V_x, V_y, \omega_x, \omega_z, \gamma, \delta, V_z, \omega_y, r_{3,3}]^T$ [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 policopter 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 policopter 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 policopter (oktacopter), which leads policopter tilt forward so that the rear of policopter rises, and the front part lowered.

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

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

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 policopter 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 policopter controlled by an increase in speed of the two left or right oktacopter motors, resulting in a tilt of the oktacopter platform right or left (as appropriate).

Vector of external excitation for lateral movement of policopter 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 policopter 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:

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

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

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

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 policopter 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 policopter 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 policopter 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 policopter UAV at roll described as follows [10]:

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

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

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

Yaw transfer functions of policopter 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]:

$$K_{rud}^{M y dist} = -\frac{b_4 b_5}{b_2 - b_1 b_5},$$

the time constant characterizing the maneuverability of policopter 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 policopter 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 policopter 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 experimental flights in manual and automatic (unmanned) flight modes, as well as with biological objects (experimental animals) on board at a height of 1000 meters on the octacopter NAU PKF "Aurora" in a sealed and open cockpit with logging of the black box of the autopilot, with audio and video registration of flight, with further definition of somatic, neurological status, and behavioral reactions of animals after such flight. The results of flight-technical tests and biomedical studies of the experimental group of animals were compared with similar results from the control group of animals that were in the same cabin with propellers operating, but without flying. The statistical processing of the obtained results was carried out to confirm the reliability of the research data.

5. Results and discussion

Results and its discussion. The received logs of flights of the "black box" of the autopilot testify to slight fluctuations in pitch, roll and yaw during the flight, slight height fluctuations were detected during the almost stationary hovering of the polycopter at different heights, and fluctuations in the performance of these sensors were adequate to the movements and maneuvers of the aircraft. Analysis of video recordings from hard-coded polycaptor cameras also indicates smoothness and high accuracy of maneuvering of the polycopter at different altitudes, which in turn testifies to the fullest solution of the technical task. The black box files of the autopilot are analyzed in the Mathlab program, as well as in FlightGear and XPlane flight simulators. The video recordings from three on-board cameras are analyzed in detail, namely from the navigation IP-camera, directed downwards, which is necessary for the operator's orientation when controlling the aircraft, as well as from two on-board IP cameras directed down the cabin of the aircraft, which is necessary for monitoring Behavior of the animal from above and from the side.

Below are the data of the "black box" of the autopilot UAV UAV PKF "Aurora", which shows changes in the most important parameters of automatic polota, recorded synchronously with a frequency of 10 hertz during the experimental flight of the octacopter. On the left 5/6 graphs, the automatic flight phase is visible, the right 1/6 part of the charts reflects the manual flight control. In automatic flight, the amplitude of the oscillations in pitch, roll, and risk is significantly less than with manual control, which is due to the advantages of the electronic autopilot in comparison with the UAV operator.

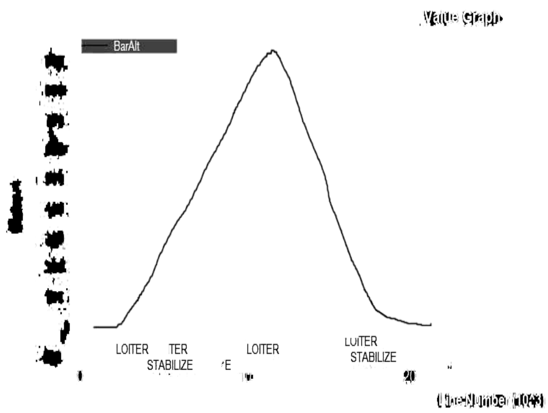

Fig. 1. Chart of changes in barometric height

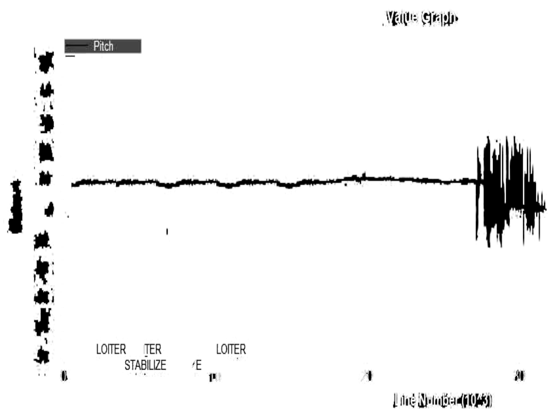

Fig.2. Chart of axis pitch oscillations

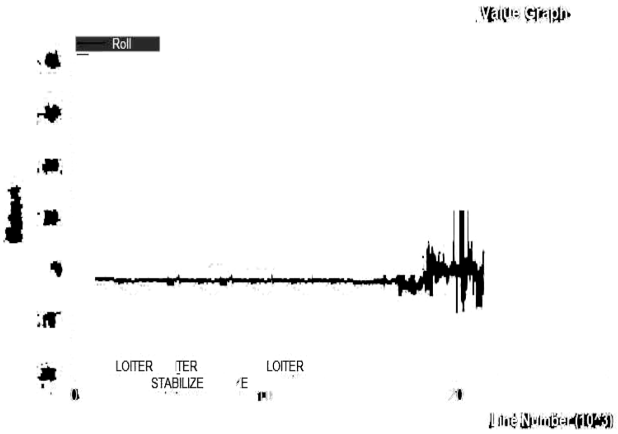

Fig. 3. Chart of axis roll oscillations.

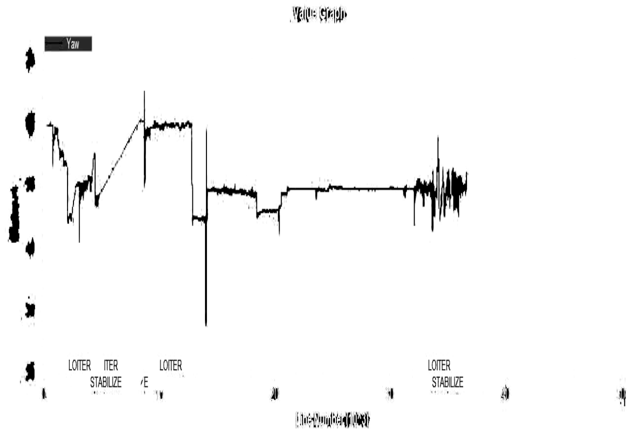

Fig. 4. Chart of yaw axis oscillations

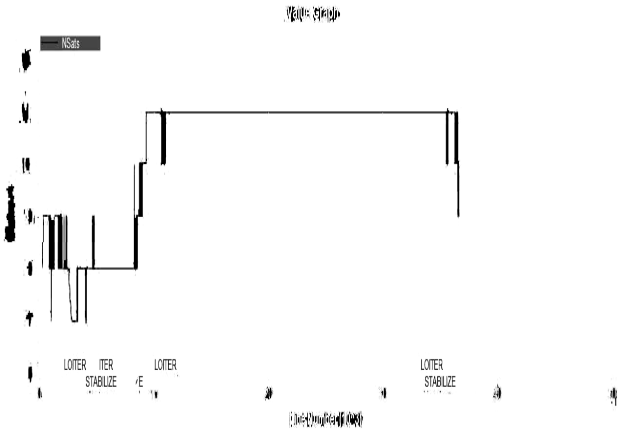

Fig. 5. Chart of change of the number of GPS – satellites

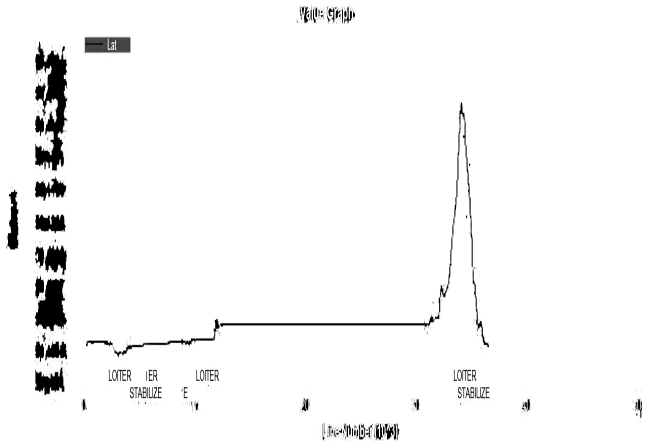

Fig.6. Chart of deviation in latitude

eriments were conducted as follows – first aircraft NAU PKF "Aurora" do vertical takeoff using eight vertically directed engines and hung in the air (ie, in a state completely compensated gravity of mass 5 kg, but the actual weight of 0 newtons = 5 kg x g (9,8 m / s / s) – 49 H of thrust of the motors of vertical takeoff). Then be enabled elektroimpeler engines of horizontal displacement (engines of low thrust, but of high speed), which gradually accelerated this weightless aircraft to a speed of 100 km/hour. So with this acceleration is not required to compensate the force of gravity, and it is only necessary to counteract the inertia of a weightless body of weight of 5 kg, which do not require significant energy consumption for the engine of horizontal acceleration, but only affects the value of the acceleration, ie the rate of acceleration of the aircraft to maximum speed (the smaller mass of the aircraft and more power of the engines of horizontal thrust – the more horizontal acceleration and faster aircraft will be accelerated to the maximum horizontal speed). After the flight a speed of elektroimpeler engines of horizontal thrust gradually decreased, the device gradually slowed down movement in the horizontal direction, moving 5–10 seconds under the influence of inertia. If necessary, immediate cessation of motion in the horizontal direction – after turning off the engine of horizontal thrust slightly increased speed of the front engines of vertical thrust, leading to tilt policopter back, after which the device still hung in the air at a certain height. Then the unit lines up for the pitch axis and then reduce smooth a speed of the engines of vertical thrust has smooth vertical landing in a given area, maneuvering with only by the engines of vertical thrust.

Given that the force of gravity (gravity, the force of gravity) and mechanical impulse created by engine of vertical thrust (which counteracts the force of gravity) have the same mechanical nature in terms of the physics of these forces can be considered that a process of the weight-loss of the policopter and his vertical flight, as a result of so-called "functional anti-gravity" – that create a force, identical by physical nature and magnitude, but opposite on the direction of the vector to the gravity. A policopter and its predecessor helicopter can be considered by the antyhravitational transport (in the functional aspect) or transport on the functionally gravitational engines of the vertical thrust. I do this kind of antigravity limit by the concept of "functional" because not yet received absolute proof structural identity of these two forces (gravity and force of thrust of engines). Perhaps this identity exists, because in flight of the policopter unlike a flight of thehelicopter a screw diameter is ten times smaller, no aerodynamic plane (wing), and required ascensional force is achieved mainly by the greater speed of the rotors (from 7000 – to 40000 revolutions per minute), which eliminates the aerodynamic nature of the vertical flight of the policopter, because in such a small diameter of screws (8 screws to 12 inches each) aerodynamic forces (pressure gradient under the screw and over the screws) are too small, in order to raise the aircraft of weight 5 kg without aerodynamic surfaces (wings). The only force that can in this case provide a vertical takeoff – a mechanical impulse that occurs in a collision of the rotating at high speed (7,000 – 40,000 rpm) screw of vertical thrust with the molecules of still air and mathematically this force is a directly proportional to the mass of air from what happens collision of the screws and to the square of the speed at which this collision occurs, ie $mv^2/2$. A mechanical impulse has a gravitational nature, that is, when its occurrence, as with the force of gravity – changes the center of gravity of moving body (in our case – of rotating swiftly screws, the center of gravity which is mixed up in the vertical direction). That is in the rotating screws of vertical thrust appears an antigravitational strength (mechanical impulse acting against the force of gravity) is identical (structurally and functionally) to the gravity (gravity force) and the center of gravity of these screws shifts upward, which pulls the screw upward in the direction of its displaced center of gravity (in the direction of its movement). But unfortunately in the other parts of the policopter (in the cabin, in the metal frame) such change occurs. Accelerated up the air screw of vertical thrust only entail the frame and cabin of the policopter as another ordinary (non antigravitational) transport and the center of gravity of the body and cabin of the policopter unlike the screws shifted down (ie in the opposite of movement direction). Therefore, we call this transport partially antigravitational, ie antigravitational only by functional, but not by structural changes. Obviously, these same processes occur in all other propellers, fans, impeller, including the screws of horizontal thrust (eg propellers of conventional aircraft), which gives rise to hypotheses of gravitational (mechanical) nature of the work of any other aircraft screw, fan or impeller. That is the main physical force that moves the beloved air screw in vertical or horizontal direction – a mechanical impulse or kinetic energy $E_k = mv^2/2$, wich the air screw gets in collisions with air molecules in its rotation, but not a gradient of pressure of the air over and under the air screw. Pressure gradient over and under the air screw (aerodynamic component) also occurs during the operation of the air screw and depending on the geometry of the propeller can provide additional small portion of traction, but this component is secondary in nature and perform a non-root role in the screw, but only accompanies its main mechanical component $E_k = mv^2/2$. This secondary (aerodynamic) component can use as an additional ascensional power of policopter at low vertical speed of flight and especially in the mode of hovering of the policopter in the air, when added to its construction dome-shaped (parabolic) wing, that at the creating a profile of the classic "flying saucer." Then this secondary aerodynamic component at low speeds of vertical flight will create a so-called "Coandă effect" – an additional ascensional power by decreasing the air pressure above the parabolic wing "flying saucer" and increasing the air pressure under its parabolic wing, but we dont know how this "Coanda effect" will be effective in significantly increased speed of the vertical flight. Perhaps the solution to this issue will be a subject of further scientific research on the path of the creation of more advanced (more perfect) air transport.

Why is it so important that we get from this so-called "functional antigravity"? Full (structural and functional) antigravity with a displacement of center of gravity of the entire vehicle with passengers will in future almost immediately accelerate the vehicle to a top speed (from 0 to the speed of light) without inertial resistance, ie without any mechanical overload for passengers, because unlike other engines – firstly displacing the center of gravity of all the aircraft in the direction of his movement, and only then the displacement of the vehicle in the direction of his displaced center of gravity. That is, in this case, the direction of displacement of the center of gravity of the vehicle coincides with the direction of motion and such a vehicle does not counteract the inertia forces, but, on the contrary, co-operate to his flight.

In our case, complete structural and functional antigravity occurs only in a small area of the rotating screws of vertical thrust, while in another (larger) part of policopter such change occurs. But such antigravitational screws entail policopter up, counteracting on the function to the force of gravity, hovering a policopter in the air like a pendulum and ensuring him a vertical component of the flight completely independent of the horizontal component of the flight, which creates the conditions for smoother vertical takeoff and landing more accurate maneuvering at different heights, complete independence from the direction of the wind during the flight and landing, reduces the energy consumption for acceleration of the aircraft in a horizontal direction (because after the weight-loss of such vehicle, a sufficiently a small force of the engines of horizontal thrust for a sufficiently effective horizontal acceleration of the polycopter), and most importantly, this approach provides ten times safer flight and more comfortable driving of aircraft.

Mathematically the flight of "functionally antigravitational" transport (transport with independent vertical component of the flight from the horizontal component of the flight) can be described as follows:

1. For the flights over universal astronomical body with a mass (M) of the aircraft of the mass (m):

$$G\frac{M \cdot m}{R_2} = \frac{m_I \cdot v^2}{2},$$

2. For the flights of the aircraft of mass (m) over the planet "Earth":

$$mg = \frac{m_I \cdot v^2}{2},$$

where G – the gravitational constant (6.67384(80) x $10^{-11} m^3 s^{-1} kg^{-1}$), M – weight of th universal astronomical bodie (stars, planets, planetary satellites, comets, asteroids, etc), R – universal range of astronomical body, m – weight of the aircraft (policopter), g – acceleration of gravity at the Earth's surface, m_I – the mass of the all molecules of the working body (gas, liquid, plasma, or others.) with which occurs a mechanical collision of all engines of vertical thrust of the aircraft, in this case, the working body is a air atmosphere, movers of the engines of vertical thrust is a propellers and engines of vertical thrust is a electric motors, but working body may be other, sources of working body can be others, engines may be others, and tngines of vertical thrust (of antigravitational action) may also be different (eg rocket engines, plasma engines, ion engines, photonic engines, quantum engines, etc.), v – total counter-speed of mechanical collision of movers of the engines of vertical thrust with the molecules of a working body (in this case, a speed of collision of the rotating air screw with the air molecules of the atmosphere).

Thus the air screw – mover (propeller) of the rotating electric motor – is the easiest source of the artificial gravity and is the simplest gravitational engine. But unfortunately, unlike a rocket, plasmic, ionic and quantum engines, this engine is a far from perfect and has many drawbacks – namely 1.working body of this engine (air) has a very low density compared to liquid and to plasma 2.working body of the engine circulates in the open, not in a closed circuit, so that the engine can operate only in the air space (atmosphere), and to work in a vacuum (outer space) is a necessary to ensure a circulation of working body in a closed circuit (that today unfortunately not solved by the modern aerospace science and technique), 3.the total speed of the collision of the mover of such engine with the molecules of the working body (stationary air) – is too low (unlike a plasmic, ionic, photonic and quantum engines) that does not allow to disperse a vehicle more than 1000 km/h, and does not allow to obtain a sufficiently high separating (specific) thrust per unit area and per engine volume, which in turn does not allow to significantly reduce the overall size and compactness of the vehicle. These deficiencies may become the basis for further research to create more perfect and more universal version of the gravitational engine, capable to operate in any environment (in the air, underwater, and in the space) and at significantly higher speeds.

A series of experimental flights, including those with the experimental animals on board to a height of 1000 meters on the policopter (oktacopter) NAU PKF "Aurora" at the sealed and open cockpit with a record of the logs of "black box" of the autopilot with audio and video recording of the flight, with further definition of physical, neurological status and behavioral reactions of the animals after a flight. Results of the flight-technical testing and of the biomedical research of the experimental group of animals compared with similar results of flights of the control group of animals. The statistical processing of results is carried out to confirm the reliability of the research data.

6. Results and discussion

The resulting logs of the flight on the "black box" of the autopilot show very little (almost invisible) fluctuations in pitch, roll and yaw during the flight, minor variations in height during the almost stationary hovering of the polycotter at various altitudes, and fully adequate to the movements and maneuvers of the aircraft, the oscillations of these indicators [6]. The analysis of videos from rigidly fixed cameras of the policopter also testifies to the smoothness and practically "jewelry" accuracy of maneuvering of the polycotter at different heights, which testifies to practically one hundred percent solution of the given technical task.

7. Conclusions

The mathematical and experimental models provide more accurate flight of the aircraft in the automatic and semi-automatic modes (compared to other types of aircrafts). Experimentally proved possible of the fully secure flight of mammals (rats) at the policopter aircraft, even in the open cockpit. Proved that the depressurization of the passenger cabin of policopter at the altitude of 1000 meters does not pose a serious threat to life and health of the crew. Flight in the automatic mode is a more accurate than in the manual control mode, which is associated with the deficiencies of the man-pilot in comparison with the electronic autopilot. With proper revision is a possible in the future to ask the questions about the design and construction of the passenger policopter flyers to fully secure air transportation of people [6,7,8]. At the level of harmful mechanical effects on the human body (overload of acceleration, fluctuation, vibration) a policopter transport is ten times safer and less harmful to passengers than road transport, which is particularly important at the delivery of patient of neurosurgical, politravmatological, cardiological and critical care profile in hard and extremely serious condition in intensive care units and operating hospitals and medical centers. During these experiments revised a nature of the action of air screw (propeller), and it proved that the main moving force of air screw (propeller) – is a mechanical impulse or kinetic energy $E_k = mv^2/2$), which the screw gets in collisions with air molecules in its rotation, but not a gradient of air pressure over and under the screw. That proved a mechanical (gravitational) nature of the moving (lifting) force of air screw (of the propeller). The concept of "functional antigravity" is introduced, ie the creation of a force similar in nature to the force of gravity (gravitation) and opposite to it in the direction of action (vector), which mainly do a weight-loss of the polycopter or helicopter during its vertical take-off, and which lies at the basis of the flight of any transport with a vertical take-off (helicopters, polycopters). The hypothesis of a gravitational nature of flight of the policopter and helicopter is put forward and derived a mathematical formula of the "functionally antigravitational" transport, namely: $G \cdot M \cdot m/R^2 = m_I \cdot v^2/2$ – for the flights of the aircraft with a mass m over universal astronomical body with a mass M, and $m \cdot g = m_I \cdot v^2/2$ – for the flights of the aircraft with mass m over a planet Earth.

References

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

[2] *Lebedev VV*, Krylov VV (2000) Neotlozhnaja nejrohirurgija [Emergency neurosurgery], M.: Medicine, 568 p.

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

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

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

[6] *Kharchenko VP,* Chepizhenko VI, Tunick AA, Pavlova SV (2012) Avionika bezpilotnih lital'nih aparativ [Avionics of drones]. K.: OOO "Abris-print", 464p.

[7] *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.

[8] *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.

[9] *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.

[10] *Nakhaba A.A.* SI «Institute of neurosurgery 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 policopternoi' aviacii'. [Method of urgent specialized medical care to patients with severe traumatic brain injury in the first hour after an injury using policopter aircraft.], State Register of Patents of Ukraine, Kiev, UA, Pat. № 88872.

[11] *Nakhaba A.A.* SI «Institute of neurosurgery 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 policopternoi' aviacii'. [Method of urgent specialized medical care to patients with complicated vertebro-spinal injury in the first hour after an injury using policopter aircraft.], State Register of Patents of Ukraine, Kiev, UA, Pat. № 88871.

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Повне відокремлення вертикальної і горизонтальної незалежних складових польоту у полікоптерному БПЛА НАУ ПКФ «Аврора» та математична модель такого польоту

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Мета: Розробити математичну і експериментальну модель літального апарату із повністю незалежними і відокремленими одна від одної горизонтальної та вертикальної складовими польоту. **Методи дослідження:** З 06.06.2016 по 10.06.2016 проведена серія експериментальних польотів (20 польотів) 10 щурів на висоту 1000 метрів на полікоптері НАУ ПКФ «Аврора» у герметичній та відкритій кабіні. **Результати:** Отримані логи «чорної скриньки» автопілота свідчать про зовсім незначні коливання по тангажу, крену і рисканню під час польоту та незначні коливання по висоті під час майже нерухомого зависання полікоптеру на різних висотах. **Обговорення:** Розроблена математична і експериментальна модель забезпечують більш точний політ літального апарату у автоматичному та напівавтоматичному режимах. За рівнем шкідливих механічних впливів на організм людини (перевантаження прискорення, коливання, вібрації) полікоптерний транспорт в десятки разів безпечніший для пасажирів, ніж автомобільний транспорт, що має особливе значення при доставці пацієнтів нейрохірургічного, політравматологіческого, кардіологічного та реанімаційного профілю у тяжкому і вкрай тяжкому станах у операційні та реанімаційні відділення лікарень і медичних центрів. У ході даних експериментів переглянута природа дії повітряного гвинта, а саме доведено, що головна рухаюча сила повітряного гвинта – є механічний імпульс (кінетична енергія $E_к=mv^2/2$), що гвинт отримує при зіткненні із молекулами повітря при його обертанні, а не градієнт тисків повітря над і під гвинтом. Тобто доведена механічна (гравітаційна) природа рухаючої (підйомної) сили повітряного гвинта. Введено поняття «функціональної антигравітації», тобто створення сили подібної за природою силі ваги (силі гравітації) і протилежної їй за напрямом дії (вектором), що головним чином і обезважує полікоптер або гвинтокрил при його вертикальному зльоті і що лежить в основі польоту любого транспорту із вертикальним зльотом (гвинтокрилів, полікоптерів). Висунута гіпотеза гравітаційної природи польоту полікоптера та гвинтокрила і виведена математична формула «функціонально антигравітаційного» транспорту, а саме: $G \cdot M \cdot m/R^2 = m_l \cdot v^2/2$ – для польотів над універсальним астрономічним тілом із масою M літального апарату масою m, та $m \cdot g = m_l \cdot v^2/2$ – для польотів над планетою Земля літального апарату масою m.

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

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Полное разделение вертикальной и горизонтальной независимых составляющих полёта в поликоптерном БПЛА НАУ ПКФ «Аврора» и математическая модель такого полёта

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Цель: Разработать математическую и экспериментальную модель летательного аппарата с полностью независимыми и разделенными горизонтальной и вертикальной составляющими полёта. **Методы исследования:** С 06.06.2016 по 10.06.2016 проведена серия экспериментальных полётов (20 полётов) 10 крыс на высоту 1000 метров на поликоптере НАУ ПКФ «Аврора» в герметичной и открытой кабине. **Результаты:** Полученные логи «черного ящика» автопилота свидетельствуют о крайне незначительных колебаниях по тангажу, крену и рысканию во время полёта, о незначительных колебаниях по высоте при почти неподвижном зависании поликоптера на разных высотах. **Обсуждение:** Разработанная математическая и экспериментальная модель обеспечивают более точный полёт летательного аппарата в автоматическом и полуавтоматическом режимах. По уровню вредных механических воздействий на организм человека (перегрузка ускорение, колебания, вибрации) поликоптерный транспорт в десятки раз безопаснее 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. В ходе данных экспериментов пересмотрена природа действия воздушного винта, а именно доказано, что главная движущая сила воздушного винта – механический импульс (кинетическая энергия $E_к = mv^2/2$), который воздушный винт получает при столкновении с молекулами воздуха при его вращении, а не градиент давлений воздуха над и под винтом. То есть доказана механическая (гравитационная) природа движущей (подъемной) силы воздушного винта. Введено понятие «функциональной антигравитации», а именно создания силы подобной по природе силе тяжести (силе гравитации) но противоположной ей по направлению действия (по вектору), что главным образом и обезвешивает поликоптер или вертолёт при его вертикальном взлёте и лежит в основе полёта любого транспорта с вертикальным взлётом (вертолётов, поликоптеров). Выдвинута гипотеза гравитационной природы полёта поликоптера и вертолёта и выведена математическая формула «функционально антигравитационного» транспорта, а именно: $G \cdot M \cdot m/R^2 = m_l \cdot v^2/2$ – для полётов над универсальным астрономическим телом с массой M летательного аппарата массой m, и $m \cdot g = m_l \cdot v^2/2$ – для полётов над планетой Земля летательного аппарата массой m.

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

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