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ANALYSIS OF FACTORS AFFECTING VARYING MAXIMUM RANGE ABILITY FOR UNMANNED AERIAL VEHICLE

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Abstract. *We consider the importance of rejecting the controls for a particular unmanned aircraft in a hospital flight. It is shown how the balancing properties unmanned aircraft affect the flight range.*

Keywords: aeronautical range, alignment, balancing aircraft, glide, range, Unmanned Aerial Vehicle.

1. Introduction

Maximum range with a limited amount of fuel depends on minimizing its costs during the flight. This minimization requires a consideration of performance characteristics of unmanned aircraft and meteorological conditions flight. By performance characteristics include features layout, balancing the aircraft and its individual characteristics. By meteorological flight conditions are different wind direction, rain, and temperatures.

2. Purpose

The aim of this work is to analyze the factors and factors that may affect the flight range drone.

The work is to determine the dependence of the balancing of deviations from the vertical stabilizers $\bar{y}_p$ distance between the center of mass and the focus plane.

For large values of $\bar{y}_p$, additional deviations stabilizer, the need to compensate for the time from the forces of drag can be significant. This in turn will lead to additional consumption.

3. Analysis of the literature

After analyzing the literature, which considered this question, there are some highlights.

One of the most successful solutions to this issue was Louis Charles Breguet, who formulated one of the fundamental laws of aviation science. Formula range by Breguet shows: the distance can fly the plane determined by three factors – performance engine, airframe aerodynamic quality and the relative weight of fuel (i.e. the ratio of weight to take on board fuel to the total takeoff weight of the device). Consider his approach to increase the range and flight endurance aircraft by reducing fuel consumption during flight.

Maximum range will also be achieved with the maximum value of aerodynamic perfection aircraft – an amount equal to the product of the aerodynamic qualities aircraft on his speed, of course, if other conditions are equal.

With increasing speed, aerodynamic quality will initially rise and then begin to subside. Maximum VK will match the optimal value of speed. If we take the maximum value VK_{max} = 100%, we can show how the relative importance $\overline{VK} = (VK)/VK_{max}100\%$ of the speed of flight. In practice, you want to select a range of values of the speed at which you can provide value VK = 99%, in line with the deterioration of aerodynamic efficiency by no more than one percent. This will be the most beneficial range of flight speeds that correspond to maximum range.

Also increase the range and duration of flight by using fuel economy by determining the optimal balancing deviation controls for selecting economic regimes of flight. The solution to this problem is actively engaged Stanislav Y. Skrypnichenko (1988).

When analyzing the flight mode to use balancing polarization aircraft. This raises the problem of determining the optimal deviation of control or high lift that will provide the lowest drag. This problem can be solved on the basis of the principle of superposition, i.e., determining the optimal deviation of control or high lift can be performed without regardless of the equations of motion of a point from the condition lowest coefficient of drag and equilibrium points at each value of the coefficient of lift. The result is optimal balancing polar.

So to determine the optimal values of deflection angles of control are considered polarization plane or horizontal tail. Based on the conditions that each coefficient of lift aircraft was such flaps deflection angle at which the minimum value of the coefficient of drag C_x.

Obviously, for the most economical flight should provide by means of optimum tuning control aerodynamic configuration of the lowest coefficient of drag aircraft considering its balancing. This condition is met, firstly, the optimal location of the mass is usually the most rear of the permissible, and, second, the minimum value of the coefficient of drag horizontal tail, which is achieved at the optimal position wheel height.

Methods variations can properly investigate a series of non-stationary dynamics problems flying. Knowledge of analytical solutions allows simply examine the impact of changes in the main parameters of the aircraft and engine, as well as changes in external conditions on the flight characteristics of the aircraft.

Varied, or free, will feature the variation of the mass of the aircraft or in the performance of Tsiolkovsky hypotheses about the constancy of the relative velocity of particles that are discarded. Quite a large number of surveyed nonlinear mechanics optimization methods available functions are entitled to the following, purely empirical assertion: if a system of nonlinear equations of mechanics does not contain free functions, the following functions should enter one or the other technique, including physical features of the problem. Of course, new features, usually increases the order of the system, but the possibility of a closed system using optimality conditions gives a good way to obtain analytical solutions

4. Analyze of problem

When considering the trajectory problems of flight dynamics is usually assumed that all the forces acting on the aircraft, attached to its center of mass. This allows us to calculate the main parameters of the flight, but not to determine all flight conditions that should be achieved for a given flight condition.

To do this, one must also consider the torques M_x, M_y, M_z, acting on the aircraft during the flight, and the resulting impact of the rotating movement of the plane (Fig. 1).

The values of the aerodynamic moments are calculated using formulas similar to formulas for aerodynamic forces (Lebedev, Chernobrovkin 1962):

$$M_x = m_x \frac{\rho v^2}{2} Sl; \quad (1)$$

$$M_y = m_y \frac{\rho v^2}{2} Sl; \quad (2)$$

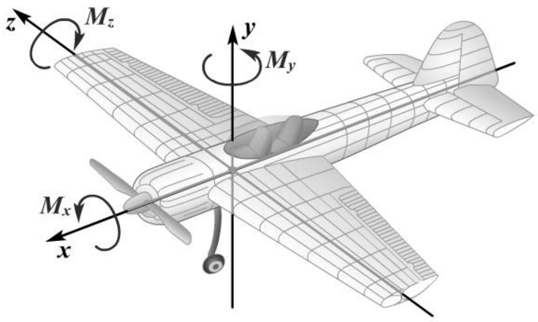

Fig.1. Moments of roll M_x, yaw and pitch M_y M_z

$$M_z = m_z \frac{\rho v^2}{2} Sl, \quad (3)$$

where m_x, m_y, m_z – moment coefficient roll, yaw and pitch, respectively;

ρ – density of the air;

v – velocity of the unperturbed flow;

S – wing area;

l – wingspan.

As the coefficients of lift and drag, the values depend on the geometric characteristics of the aircraft and its configuration and rudder deflection, and the angles of attack and slip and aerodynamic criteria of similarity. In addition, as can be seen from the quantities aerodynamic moments depend on the density of the air, the flight speed, area, and the characteristic geometric size of the wing.

Torque coefficient in contrast to the moments themselves are dimensionless and do not depend on the density of the air, the flight speed, area and geometry of the wing. Therefore, it is more convenient to use in the calculation of the torque coefficient, and the values of moments for them can always be determined by (1), (2) and (3).

In this paper, we consider the case of a symmetric flow around an aircraft which M_x and M_y = const. Then the aircraft will only point M_z.

The lift of the wing creates y_w nose down moment M_{zw}. Lifting capacity horizontal tail y_{ht} downward and creates pitching moment M_{zht}. In some cases, when the vector engine thrust is at a distance $\bar{y}_p$ above or below the center of mass, as we have time and M_{zp} generated by engine thrust. This point, depending on the thrust is above or below the center of mass can be negative or positive, respectively (Fig. 2).

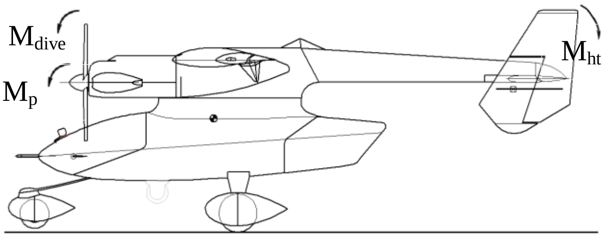

Fig. 2. Moment acting on the plane with a symmetric flow

This is one of the individual characteristics of each aircraft. Consider this question in more detail.

Dependence of the longitudinal moment propeller aircraft is given by (Skripnichenko 1981; 1988):

$$M_z = M_{zw} + M_{zht} + M_{zp} \tag{4}$$

Since usually considered not the pitching moment M_z, and its dimensionless coefficient m_z, then dividing the left and right side of (4) the product of dynamic pressure and wing area $\frac{\rho v^2}{2} Sb_a$, obtain a formula for the coefficient of pitching moment:

$$m_z = m_{zw} + m_{zht} + m_{zp}\,.$$

The coefficients of longitudinal moments and horizontal tail propeller thrust plane defined by the following formulas:

$$m_{zw} = m_{z0} - (\bar{x}_T - \bar{x}_F)C_y;$$

$$m_{zht} = m_{zht}{}^{\varphi}\varphi\,;$$

$$m_{zp} = -C_x \bar{y}_p + 0.05\frac{x_v i D^2}{Sb_a}C_y\,. \tag{5}$$

From (5) we can draw the first conclusions on the impact of the values of $\bar{y}_p$ on a flight, that is, the greater will be the value of $\bar{y}_p$ the greater will be the time and the engine thrust.

Examine this issue in more detail. Since the balanced flight $m_z = 0$, then:

$$m_z = m_{zw} + m_{zht} + m_{zp} = 0.$$

Hence we can write this equation:

$$m_{zht}{}^{\varphi}\varphi = m_{z0} - (\bar{x}_T - \bar{x}_F - 0.05\frac{x_v i D^2}{Sb_a})C_y - C_x \bar{y}_p. \tag{6}$$

And expressed the balancing angle of deflection of the stabilizer:

$$\varphi = \frac{m_{z0} - (\bar{x}_T - \bar{x}_F - 0.05\frac{x_v i D^2}{Sb_a})C_y - C_x \bar{y}_p}{m_{zht}{}^{\varphi}}. \tag{7}$$

From equations (5), (6) and (7) that the shoulder $\bar{y}_p$ significantly affect the balancing moments of tangage, as well as balancing the deviation regulators to establish a balanced flight (Fig. 3).

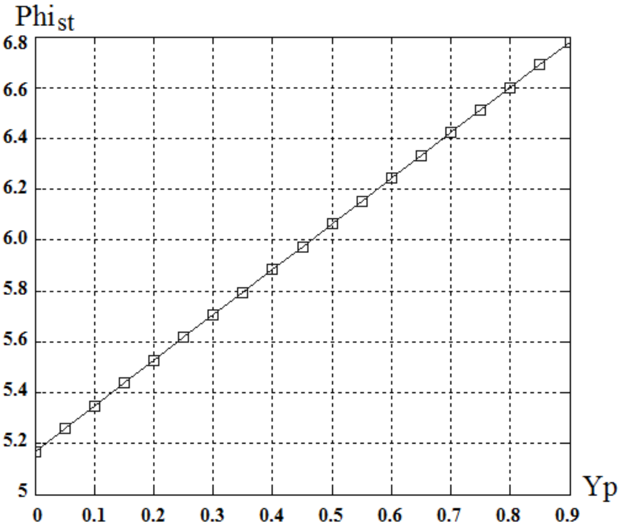

Fig. 3. The dependence of the deflection angle of the balancing of the stabilizer on the distance between the center of mass and thrust vector engine

In steady horizontal flight in most cases, the aircraft must balance not only by longitudinal balancing – elevator, stabilizer, but also lateral bodies. The reasons that necessitate balancing side, basically, is the individual characteristics of airframe, the uneven development of fuel console Quezon tanks, engine thrust asymmetry, etc. Also note that when balancing rejection of government resistance increases, and this leads to over-consumption.

The coefficient of lift balanced plane defined by the formula:

$$C_{y_{bal}} = C_y{}^{\alpha}(\alpha - \alpha_0) \pm \Delta C_{y_{ht}}.$$

Additional lift coefficient generated by horizontal tail surface, can be expressed as follows:

$$\Delta C_{y_{ht}} = C_y^{\varphi_{st}}\varphi_{st} + C_y^{\delta_e}\delta_e,$$

where φ_{st} – the angle of the stabilizer;

δ_e – balancing the angle of deflection of the elevator.

The value of the balancing deflection of the elevator can also be expressed from the expression for the aerodynamic pitching moment to balance the aircraft:

$$m_z = m_{z0} - (\bar{x}_T - \bar{x}_F) C_y{}^{\alpha} (\alpha - \alpha_0) + m_{zht} =$$
$$m_{z0} - (\bar{x}_T - \bar{x}_F) C_y{}^{\alpha} (\alpha - \alpha_0) + \qquad (8)$$
$$+ C_y^{\varphi_{st}} \varphi_{st} \bar{L}_{st} + C_y^{\delta_e} \delta_e \bar{L}_{\delta_e},$$

where $\bar{L}_{st}$ and $\bar{L}_{\delta_e}$ – relative shoulders of the application is the lift of the stabilizer and elevator:

$$\bar{L}_{st} = \frac{L_{st}}{b_a};$$

$$\bar{L}_{\delta_e} = \frac{L_{\delta_e}}{b_a}.$$

Equating equation (8) to zero (balanced flight) can be expressed (Udartsev et al. 1998):

$$\delta_e = -\frac{m_{z0} - (\bar{x}_T - \bar{x}_F) C_y{}^{\alpha} (\alpha - \alpha_0) + C_y^{\varphi_{st}} \varphi_{st} \bar{L}_{st}}{C_y^{\delta_e} \bar{L}_{\delta_e}}.$$

Hence balancing the value of the lift coefficient can be written:

$$C_{y_{bal}} = C_y{}^{\alpha} (\alpha - \alpha_0) = C_y^{\varphi_{st}} \varphi_{st} -$$
$$-\frac{m_{z0} - (\bar{x}_T - \bar{x}_F) C_y{}^{\alpha} (\alpha - \alpha_0) + C_y^{\varphi_{st}} \varphi_{st} \bar{L}_{st}}{\bar{L}_{\delta_e}}.$$

Additional balancing resistance is the sum of the profile and the induction of resistance, as well as additional resistance from government rejected:

$$C_{xbal} = \Delta C_{x\,i} + \Delta C_{x\,ht} + \Delta C_{x\,a} + \Delta C_{x\,vt}.$$

Additional balancing resistance from deflection of the elevator is:

$$\Delta C_{x\,i} = C_y^{\delta_e} \delta_e a_{bal} = \frac{m_{z0} - (\bar{x}_T - \bar{x}_F) C_y{}^{\alpha} \alpha_{bal}^2}{\bar{L}_{\delta_e}}.$$

Additional balancing resistance deviation from the horizontal stabilizer can be calculated by the formula:

$$\Delta C_{x\,ht} = k_{ht} C_{y_{ht}}^{a}{}^{2} \frac{(a_{ht} + n_e \delta_e)^2}{\pi \lambda_{ht\,ef}}.$$

Additional balancing resistance of aileron and rudder vertical tail can be calculated according to the formulas:

$$\Delta C_{x\,a} = 0.5 \delta_a S_a (C_y^a)^2 (a_{bal} \frac{\delta_a S_a}{S_{u\,a}})^2 \frac{1}{\pi \lambda_{ht\,w}};$$

$$a_{bal} = \frac{C_y}{C_y^a} - a_0 + \Delta a_0.$$

Resistance from balancing flaps depends on the deviation of the flap limit switch from the zero position. The change in the angle of attack of zero lift at a deviation limit switch flap on the value of *h* is equal to:

$$\Delta a_0 = 0.55 \bar{h},$$

where

$$\bar{h} = \frac{h}{b_{flaps}};$$

$$\Delta C_{x\,vt} = k_{vt} (C_{z\,vt}^{\beta})^2 \frac{(a_{ht} + n_r \delta_r)^2}{\pi \lambda_{vt\,ef}};$$

$$C_{z\,vt}^{\beta} = -1.26(1 + 0.5\lambda_{vt})(1 + 0.27 M^2) \cos \chi_{vt}.$$

The value of effective elongation can be determined by the formula:

$$\lambda_{vt\,vt\,ef} = \lambda_{vt\,vt} \frac{K_{\chi}}{1 + \frac{S_i}{S_{vt\,vt}}},$$

where $K_{\chi} \approx 0.9$ – coefficient taking into account the rigid surface sweep;

S_i – area of the corresponding wheel.

Aerodynamic quality, taking into account the additional resistance decreases, and as a result, increases fuel consumption in horizontal flight, and this in turn leads to a decrease in the flight range of unmanned aircraft.

Calculating the value of balancing C_x and C_y can be estimated value of aerodynamic efficiency with the loss balanced by the formula:

$$K_{bal} = \frac{C_{y\,bal}}{C_{x\,bal}}.$$

To confirm the effect of the aerodynamic qualities, and in the investigation and balancing deflection on range, consider the following algorithm for calculating the range (Andreevsky, Derkach 1987).

So, calculate kilometer fuel consumption:

$$q_{km} = \frac{q_t}{V} = \frac{C_e P V}{V} = \frac{C_e m g}{K},$$

where q_{km} – kilometer fuel consumption – the amount of fuel consumed per engine plane kilometer;

q_t – hour fuel consumption – the amount of fuel consumed in a single engine aircraft flying hour;

V – speed of flight;

C_e – fuel consumption in kilograms per hour one kilowatt;

K – aerodynamic coefficient of quality.

Knowing kilometer fuel consumption, we can calculate the range of flight:

$$L = \int_{m_0}^{m_1} \frac{dm}{q_{km}} = \int_{m_0}^{m_1} \frac{dmK}{C_e mg}.$$

As $\frac{K}{C_e g} = \text{const}$, all the way flight, it can be taken out from under the integral, and then:

$$L = \frac{dmK}{C_e g} \ln \frac{m_0}{m_1}.$$

5. Conclusions

After analyzing this issue, we can conclude that the deviation balancing controls UAV direct impact on fuel consumption, and the greater will be the deviations, the smaller the distance can fly an aircraft.

The results are useful both in the design of the aircraft, and in optimization of flight and air navigation calculations

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В.П. Харченко[1], Є.С. Плахотнюк[2]. Аналіз факторів, що впливають на варіювання максимальної дальності польоту безпілотного літального апарата

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Показано, що балансування літального апарата призводить до збільшення лобового опору через відхилення органів керування, зміни кутів атаки та центрування літального апарата. Розглянуто вплив відхилення органів керування для конкретного безпілотного літального апарата в стаціонарних умовах польоту на дальність польоту.

Ключові слова: аеродинамічна якість, аеронавігаційна дальність, балансування літального апарата, безпілотний літальний апарат, дальність польоту, центровка.

В.П. Харченко[1], Е.С. Плахотнюк[2]. Анализ факторов, которые влияют на варьирование максимальной дальности полета беспилотного летательного аппарата

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Показано, что балансировка летательного аппарата приводит к увеличению лобового сопротивления за счет отклонения органов управления, изменения углов атаки и центровки летательного аппарата. Рассмотрено влияние отклонения органов управления для конкретного беспилотного летательного аппарата в стационарных условиях полета на дальность полета.

Ключевые слова: аэродинамическое качество, аэронавигационная дальность, балансировка летательного аппарата, беспилотный летательный аппарат, дальность полета, центровка.

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