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THE ALGORITHM FOR CALCULATINGTHE CHARACTERISTICS OFTHE TAKE-OFFFROM THE SPRINGBOARD UAV

Abstract.The article presents the technique calculation of kinematical parameters the unmanned aerial vehicle (UAV) at take-off with springboard. The influence on these parameters some characteristics of the unmanned aerial vehicle is analyzed

Keywords: unmanned aerial vehicle, control takeoff from a springboard, parameter optimization springboard

The rapid development of unmanned aircraft recently significantly expanded the list of volumes and solved problems. One of the measures for the empowerment use of unmanned aerial vehicles (UAVs) in a lack of the necessary platform for its take-off may be the use of special springboards.

Their use is justified for ships with decks which will run UAV in mountainous and forested areas where they are based, etc.

In addition, by creating a springboard for the initial vertical velocity allows takeoff UAV with greater payload mass.

In the particular case by increasing the supply of fuel on board the UAV can increase its range and duration of the flight or by installing additional equipment - to expand the list of solved tasks.

Special springboards for takeoff manned aircraft have been used successfully since the early eighties of the last century, primarily for the needs of military aviation ship basing [1 ... 5].Their use could reduce the safe speed of lift-off, reduce the length of run, increase the payload on board, etc.

Obviously, it is advisable to use the advantages of a springboard for unmanned aircraft based on its specific characteristics that require the development of special methods and techniques of calculating the characteristics of takeoff from the springboard for specific UAV.

The article presents the technique calculation of kinematical parameters the unmanned aerial vehicle (UAV) at take-off with springboard.

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The springboard is usually a small sloping area, which is a continuation of a section horizontal runway (Fig. 1). The inclined section can be flat or curvilinear.

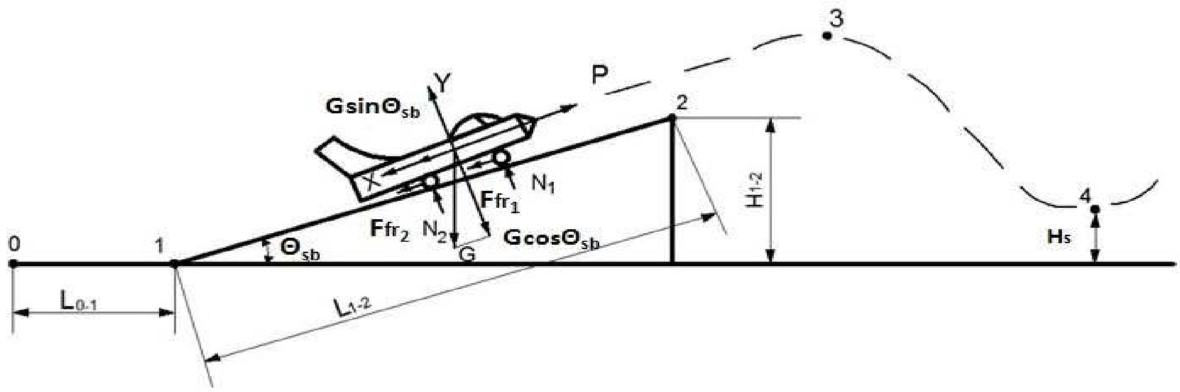

Fig. 1. Scheme take-off from the springboard

The take-off from the springboard has two important peculiarities, which distinguishes it from a conventional take-off at moment of lift-off:

First, the lift force of UAV is considerably below the weight owing to small velocity;

Second, the UAV at moment of lift-off has a certain initial angle θ, which is equal to angle of springboard at end-point 2 (fig.1).

After lift-off the UAV moves along a trajectory, which is close to ballistic curve, at the beginning with height increasing (point 3) and then comes down up to safe value with increasing of velocity. The take-off must be organized thus, that with a decrease in a height, in point 4, the UAV possessed an enough reserve of height and velocity, which can provide a safety prolongation of flight. The safety prolongation of flight will be depend on like parameters of UAV (the value V2, thrust-to-weight ratio of UAV μ, maximal coefficient of lift force), so and characteristics of springboard (its length and angle of slope). These characteristics must be given for each concrete UAV.

At the same the characteristics of existing springboards will set certain requirements for different types of UAV with their dimensions and weight, aircraft performance and operational characteristics. Changing the speed during the run-up describes the known equation[I]:

$$j_x = \frac{dV}{dt} = g(n_{xa} - \sin \Theta)$$

where $n_{xa} = \frac{P_x - X_a - F_{fr}}{G}$.

So, at process of running start an angle of attack is constant, and the difference of friction force (Ffr) and drag force (Xa) is approximately constant.

If vector of thrust is not rotated at process of running start, then a longitudinal overload (nxa) can consider constant.

From mechanics it's known, that for uniformly accelerated motion a length of traversed path (L_{0-1}) is connected with end speed (in point 1) with help next dependence:

$$L_{0-1} = \frac{V_1^2}{2j_{mid}}, \tag{2}$$

where

$$j_{mid} = gn_x = g(\mu_x - f_{rf}) \tag{3}$$

$\mu_x = \frac{P_x}{G}$ - an average thrust-to-weight ratio of UAV;

j_{mid} - average acceleration in direction of motion;

$f_{rf} = 0.5(f + \frac{1}{k_1})$ -Reduced factor of friction.

This factor takes into account a resistance for UAV motion owing to runway (through factor of friction f) and ram air (through lift-drag ratio in end of horizontal section K1). After horizontal section it's - an itself springboard. Its surface may be flat (fig. 1) or curvilinear (fig. 2).

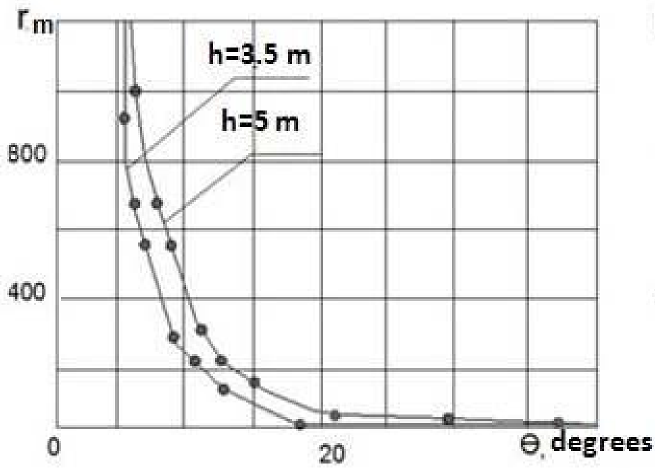

Fig.2. Dependences a radius from the end angle of springboard

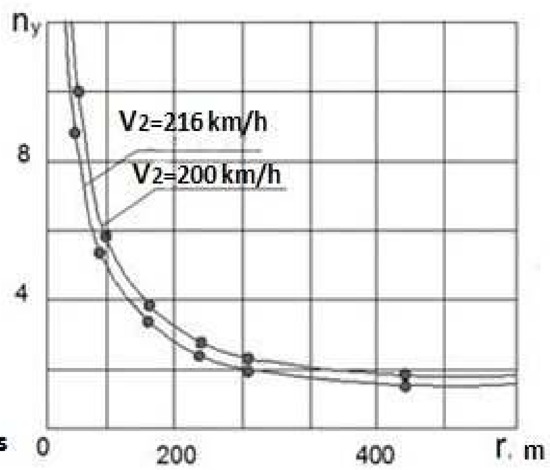

Fig. 3. Dependence the value overload n_y from radius r

Thus a height (H_{1-2})of springboard must be restricted because of its mass parameters, of constructive and other conditions, for placing it on the concrete object. The motions on flat and curvilinear springboards have their peculiarities. The length L_{1-2} and the height H_{1-2} of flat springboard are connected through obvious dependence:

$$L_{1-2} = \frac{H_{1-2}}{\sin\Theta_{sb}} \quad (4)$$

At motion on springboard on UAV acts a constant force $G \cdot \sin\Theta_{sb}$ which decreases the acceleration by value $\Delta j_{пп} = -g\sin\Theta_{sb}$, In this case common acceleration is equal $j_x = j_{mid} - g\sin\Theta_{sb}$. So, the value $g\sin\Theta_{sb}$ is constant, general motion remains uniformly accelerated and changing of the velocity can write as:

$$V_2^2 - V_1^2 = 2j_x L_{1-2} = 2j_{mid} L_{1-2} - 2gL_{1-2}\sin\Theta_{sb} = 2j_{mid} L_{1-2} - 2gH_{sb}. \quad (5)$$

Second summand determines a value of a speed loss because of a slope angle springboard. From formulas (1-4) follows, that a value of UAV acceleration, in process of running start, is basically determined by a thrust-to-weight ratio and slope angle springboard.The more UAV has acceleration, the shorter path for take-off (fig.3).

If the springboard with curvilinear surface (fig. 2), then angle will change from 0 to Θ_{sb}. The decelerating force $G\sin\Theta$ will increase gradually from 0, at the entrance to the springboard, to the value $G\sin\Theta_{sb}$ in the end.

Since the force $G \cdot \sin\Theta$ has an influence on kinetic energy at climb, therefore a loss velocity from action this force don't depend on a form of springboard, and is determined only its height (see (5)).

Let us suppose that the curvilinear segment of springboard presents a cylindrical surface with constant radius and its height is restricted up the value H_{sb} owing to constructional considerations (see fig. 4). So, we can calculate

$AB = r \cdot \cos\Theta_{sb}$, $B1 = r$, $H_{sb} = r - r\cos\Theta_{sb}$. Further we can determine a connection between radius (r), of height (H_{sb}) and an end angle of springboard:

$$r = \frac{H_{sb}}{1 - \cos\Theta_{sb}}. \tag{6}$$

According to 6 the bigger value of angel Θ_{sb}, the less radius ofspringboard must be (at certain height).

Dependences a radius from the end angle of springboard for values H_{sb}=3.5 m and H_{sb}=5 m are shown in fig.2.

As it follows from calculation, the most strongly the angles Θ_{sb} affect on a value at small angles Θ_{sb} .So, at increasing of angle Θ_{sb} from 7° to 20° the value r should decrease approximately from 600 to 90 (m), i.e. nearly sevenfold.

However, at decreasing r should grow the values of centripetal force and normal overload (n_y), which act on the UAV.

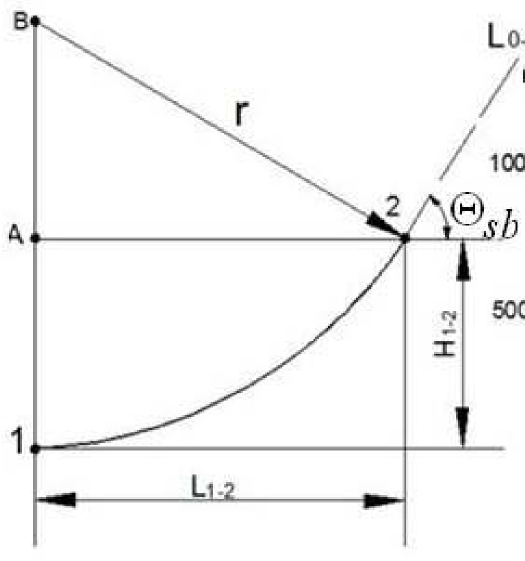

Fig. 4.Dependence the radius r from the end-angle of

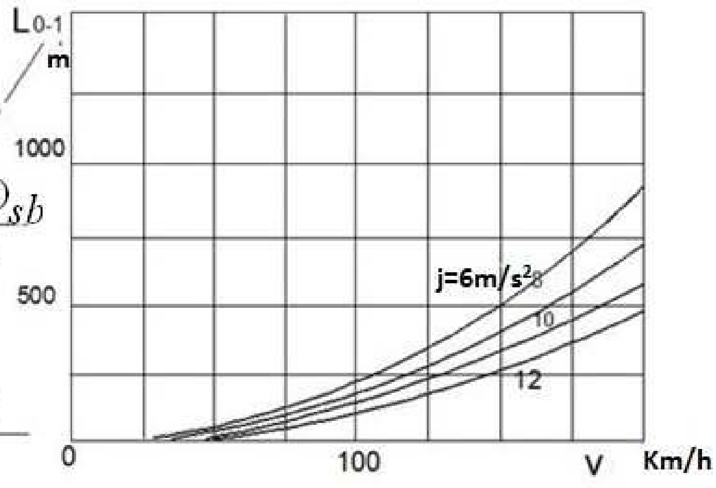

Fig. 5. Dependence the length of horizontal sector from a velocity

Since a velocities of UAV are small at process of running start, then an overload is created mainly of the normal reactions of springboard N=N1+N2, which act on chassis of UAV (fig. 1). As known, the

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curvilinear character of UAV motion is determined centrifugal $\frac{mV^2}{r}$ and centripetal forces $Y + P_y + N - G \cdot \cos\Theta$. From their equality it is possible to receive expression for radius of curvature[1]:

$$r = \frac{GV^2}{g(Y + P_y + N - G \cdot \cos\Theta)} = \frac{V^2}{n_y - \cos\Theta}, \qquad (7)$$

where $n_y = \frac{Y + P_y + N}{G}$.

Dependence a normal overload ny from radius curvature of springboard is shown in fig. 3. As it follows from calculation the normal overload begins increase intensive at decreasing a radius below 100 m. So, if the UAV will move up to curvilinear trajectory with radius 100 m, then overload will be $n_y = 4$.

If a value r is equal 50 m, then at same velocity (V2=200 km/h) on the UAV should act an overload $n_y = 7$.

Naturally, that a control of the UAV with such overload is difficult. From (7) follows that at constant r an increment of overload will increase approximately proportional square of velocity, i.e. maximal value of overload the UAV will test in end of springboard. Thereby,for decreasing of overload on the UAV, the springboard can do with variable radius: a small in the beginning and an increased r in end part. So, at moving along curvilinear trajectory, the angle velocity of turn trajectory will be determined a linear speed and a value r.

$$\frac{d\Theta}{dt} = \frac{V}{r}. \qquad (8)$$

The path, traversed along curvilinear section of springboard, can determine as length of arc 1-2 (fig. 4):

$$L_{1-2} = r \cdot \Theta = \Theta. \qquad (9)$$

Received formulas allowed to develop analgorithm for calculation of characteristics of UAV's take off from springboard. Based on the algorithm the methodology of calculation was developed.

It is possible to conduct the optimization of parameters at the springboard for different kinds of UAV's by using this method.

Taking into account constant changes of weather conditions of flights and requirements to flight task succeeding, which cause change of weight and dimension, operational and other features, this method must be implemented on the Decision Support System (DSC).

DSC use considering realspringboard's and UAV's characteristics, flight tasks requirements will enable to issue recommendations concerning payloadof UAVs and peculiarities of control of take-off with springboard

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