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GEOMETRICAL MODEL OF INSTALLATION REQUIRED FOR STARTING ANTI-AIRPLANE-FREE AIRCRAFT TYPE

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A geometric mobile model of the missile launcher is designed to launch drones of the aircraft type using a passenger car as a counterweight.

Keywords: drone, trebushet, Lagrangian, Lagrange equation of the second kind, geometric model.

Formulation of the problem. In our time, unmanned aerial vehicles of the type (hereinafter - unmanned aerial vehicles) have been widespread, intended for monitoring of objects of agriculture and forestry. To launch such aircraft in the field, it is advisable to use catapult type devices [1].

From the literature known [2, 3] the installation AVTO-01 Launcher, which schematically repeats the typewriter of the type requires and allows the launch of airborne drones weighing up to 10 kg. In contrast, this car is a car on which the headset AVTO-01 Launcher is mounted on a roof with a special frame (Fig. 1). In addition, such a launch system is compactly folded and can be transported on a passenger car on public roads.

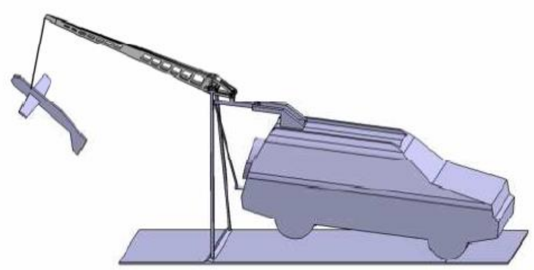


Fig. 1. Install AVTO-01 Launcher (borrowed from [3])

To deploy the plant to the working condition of the operator, it is necessary to install on the ground two metal supports, secure a lever on the needle and use an electric winch to lift the rear of the vehicle - that is, to create a counterweight at the short end of the lever. AVTO-01 Launcher allows you to "disperse" an unmanned aerial vehicle weighing 10 kg to a speed of 12 m / s at an altitude of 8 m, after which it continues the flight on its own engine. Essential here is that the launch is due to the potential energy of the vehicle. The advantages of the AVTO-01 Launcher include the lack of catapult components of rubber, pneumatics and electronics, characteristic of other launch technologies. In order to adjust the installation parameters, it will be expedient to develop a geometric model of the catalytic system.

Analysis of recent research and publications. To ensure the effective dynamics of the machine requires the need to calculate the parameters of its elements. It is expedient to do this within the framework of Lagrange's mechanics [4, 5], which takes into account the kinetic and potential energy of the system. As a result of the solution of the compound Lagrange equation of the second kind you can obtain the desired trajectory of moving the drone on the slide, which will provide reliable beginnings of the valuable product.

For the analysis of dynamics, it is advisable to have phase trajectories of generalized coordinates, which is not sufficiently fully investigated in known works [6,7]. In works [2,3], calculations of the AVTO-01 Launcher setup dynamics are presented, which is expedient to supplement the solution of the compiled Lagrange equation of the second kind. In [8], the Lagrange equation of the second kind was compiled and solved to determine the trajectory of moving the load on the slings depending on the design parameters required. This article is based on the results of work [8].

Formulating the goals of the article. To develop a geometric model of type-type screwdriver requires, designed for launching an unmanned aerial vehicle type using a car, when the car itself will serve as a counterweight in this design.

Main part. In fig. 2 shows the scheme of the machine requires, which consists of a lever length $L_1 + L_2$, to which hinged two levers with lengths attached L_3 (denotes the shoulder) and L_4 (mounting the car as a counterweight). To the levers in the nodal points are fixed loads with masses m_1 (car) and m_2 (pilotless). Mass m_1 you need to choose a few orders of magnitude larger than the mass m_2. When the first load under gravity falls to the bottom, the second load is given an acceleration, which causes the throwing effect.

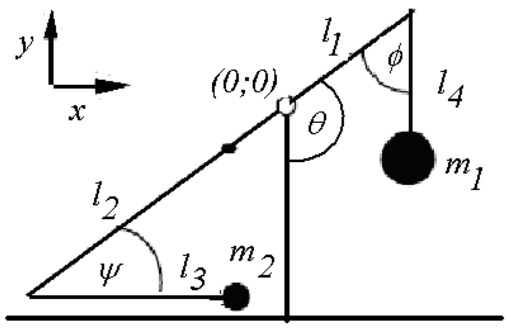


Fig. 2. The scheme requires

When compiling a mathematical model of a machine, it is necessary to take into account such an idealization: the unspecified elements of the system are not weighty, the support in the nodes are absent, the elements of the system are not deformed, the parameters and the initial values of the angles are given in conditional units.

As generalized coordinates, we will select corners $\theta(t)$, $\varphi(t)$ and $\psi(t)$, depicted in fig. 2. To describe the dynamics requires using the expressions for the kinetic T and potential U energies [4, 5]:

$$
\begin{aligned}
T := &-m_2\, l_3^{\,2}\, \theta'\, \psi' - m_2\, l_3\, l_2\, (\theta')^2 \cos(\psi) + m_1\, l_4^{\,2}\, \theta'\, \phi' + \frac{1}{2} (\theta')^2\, m_1\, l_1^{\,2} + \frac{1}{2} (\theta')^2\, m_2\, l_2^{\,2} \\
&- m_1\, l_4\, l_1\, \theta'\, \phi' \cos(\phi) - m_1\, l_4\, l_1\, (\theta')^2 \cos(\phi) + m_2\, l_3\, l_2\, \theta'\, \psi' \cos(\psi) + \frac{1}{2} m_2\, l_3^{\,2}\, (\theta')^2 \\
&+ \frac{1}{2} m_2\, l_3^{\,2}\, (\psi')^2 + \frac{1}{2} m_1\, l_4^{\,2}\, (\theta')^2 + \frac{1}{2} m_1\, l_4^{\,2}\, (\phi')^2 \;; \\
U := &-m_1\, g\, l_1 \cos(\theta) + m_2\, g\, l_2 \cos(\theta) + (-g \cos(\theta) \cos(\psi) - g \sin(\theta) \sin(\psi))\, m_2\, l_3 \\
&+ (\cos(\theta) \cos(\phi) - \sin(\theta) \sin(\phi))\, g\, m_1\, l_4 \;.
\end{aligned}
\tag{1}
$$

Here $\theta(t)$ – the function of the change in the angle of deviation from the vertical length of the lever $L_1 + L_2$, $\varphi(t)$ – the function of changing the angle between the levers in lengths L_4 i $L_1 + L_2$, $\psi(t)$ – the function of changing the angle between the levers in lengths L_3 i $L_1 + L_2$, g=9,81.

Using Lagrangian $L = T - U$ We obtain a system of differential Lagrange equations of the second kind:

$$
\begin{aligned}
&-m_1\, g\, l_1 \sin(\theta) + m_2\, g\, l_2 \sin(\theta) - m_2\, g\, l_3 \sin(\theta) \cos(\psi) + m_2\, g\, l_3 \cos(\theta) \sin(\psi) \\
&\quad + m_1\, g\, l_4 \sin(\theta) \cos(\phi) + m_1\, g\, l_4 \cos(\theta) \sin(\phi) - \theta''\, m_1\, l_1^{\,2} + m_1\, l_4\, l_1\, \phi'' \cos(\phi) \\
&\quad - m_1\, l_4\, l_1\, (\phi')^2 \sin(\phi) + 2\, m_1\, l_4\, l_1\, \theta'' \cos(\phi) - 2\, m_1\, l_4\, l_1\, \theta' \sin(\phi)\, \phi' - \theta''\, m_2\, l_2^{\,2} \\
&\quad + 2\, m_2\, l_3\, l_2\, \theta'' \cos(\psi) - 2\, m_2\, l_3\, l_2\, \theta' \sin(\psi)\, \psi' - m_2\, l_3\, l_2\, \psi'' \cos(\psi) \\
&\quad + m_2\, l_3\, l_2\, (\psi')^2 \sin(\psi) - m_2\, l_3^{\,2}\, \theta'' + m_2\, l_3^{\,2}\, \psi'' - m_1\, l_4^{\,2}\, \phi'' - m_1\, l_4^{\,2}\, \theta'' = 0 \;; \\
&m_2\, l_3\, l_2\, (\theta')^2 \sin(\psi) - m_2\, g\, l_3 \cos(\theta) \sin(\psi) + m_2\, g\, l_3 \sin(\theta) \cos(\psi) - m_2\, l_3\, l_2\, \theta'' \cos(\psi) \\
&\quad + m_2\, l_3^{\,2}\, \theta'' - m_2\, l_3^{\,2}\, \psi'' = 0 \;; \\
&m_1\, l_4\, l_1\, (\theta')^2 \sin(\phi) + m_1\, g\, l_4 \cos(\theta) \sin(\phi) + m_1\, g\, l_4 \sin(\theta) \cos(\phi) + m_1\, l_4\, l_1\, \theta'' \cos(\phi) \\
&\quad - m_1\, l_4^{\,2}\, \theta'' - m_1\, l_4^{\,2}\, \phi'' = 0 \;.
\end{aligned}
\tag{2}
$$

We solve the system of equations (2) in the Maple environment numerically using the Runge-Kutti method with the following initial conditions: θ_0, φ_0, ψ_0 – initial values of angles of deviation of levers; θ'_0, φ'_0, ψ'_0 – initial velocity of change of angles of deviation.

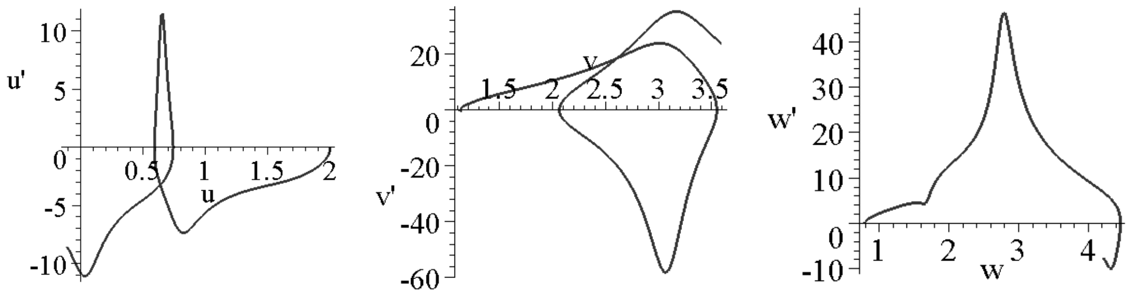
Using approximate solutions for functions $\theta(t)$, $\varphi(t)$ and $\psi(t)$ (designate them as $\Theta(t)$, $\Phi(t)$ and $\Psi(t)$), in the coordinate system xOy the trajectory of cargo movement must be built according to the formulas:

$$
\begin{aligned}
x(t) &= -l_2 \sin(\Theta(t)) + l_3 \sin(\Theta(t) - \Psi(t)); \\
y(t) &= l_2 \cos(\Theta(t)) - l_3 \cos(\Theta(t) - \Psi(t)).
\end{aligned}
\tag{3}
$$

That is for certain moments of time t using formulas (3) it is possible to determine the instantaneous coordinates of the center of the UAV in the vertical plane in the Cartesian coordinate system xOy.

Let's calculate the model requires with parameters $m_1 = 2000$; $m_2 = 10$; $l_1 = 0{,}65$; $l_2 = 4{,}2$; $l_3 = 2{,}5$; $l_4 = 0{,}2$ and with the initial conditions $\theta_0 = 2$; $\theta'_0 = 0$; $\varphi_0 = \pi\text{-}2$; $\varphi'_0 = 0$; $\psi_0 = \pi/4$; $\psi'_0 = 0$ (for comparison with the results of work [2, 3]). Time limits for the integration of the system of equations (2) [$0 < t < 0{,}7$]. In fig. 3 shows the phase paths for the corners $\Theta(t)$, $\varphi(t)$ and $\psi(t)$. For technical reasons, the charts have changed the notation:$\Theta(t) \equiv u(t)$, $\varphi(t) \equiv v(t)$ and $\psi(t) \equiv w(t)$.

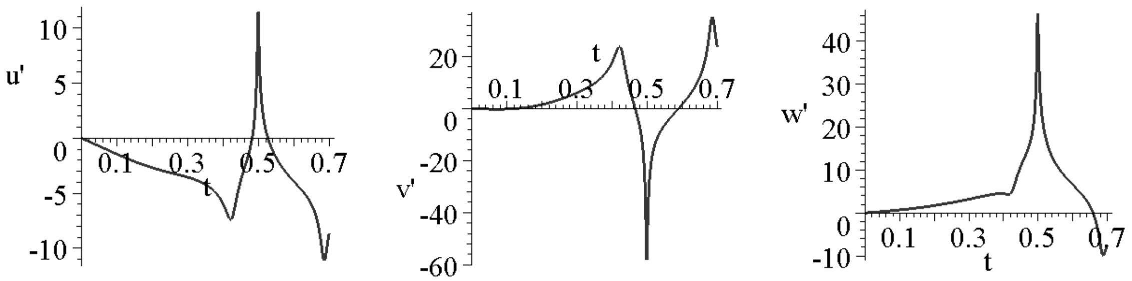
The analysis of phase trajectories allows us to find out that the maximum value of the rate of change of the angle $\psi(t)$ will be equal to $\psi = 2{,}9$. Then the extreme speed will reach and change the angle $\varphi(t)$.



a) b) c)

Fig. 3. The phase path for the parameter: a) $\Theta(t)$; b) $\varphi(t)$; c) $\psi(t)$

Determine the moment when the unmanned aerial will reach the maximum speed on the slings. To do this, we build a graph of the time dependence of the rate of change of the angle ψ. In fig. 4, *c* The corresponding graph is depicted, from which it is seen that the maximum rate of change of the angle ψ will occur at $t = 0{,}52$, which is the recommended time for the unmanned spacer separation.



a) b) c)

Fig. 4. Schedule of angular velocity changes in time:
a) $\Theta(t)$; b) $\varphi(t)$; c) $\psi(t)$

With the help of a composite program created an animated film scheme of action will require. In fig. 5, *a-c* The individual phases of the movement of its elements and the trajectory of the center of gravity of the unmanned vehicle are shown (Fig. 5, *d*).

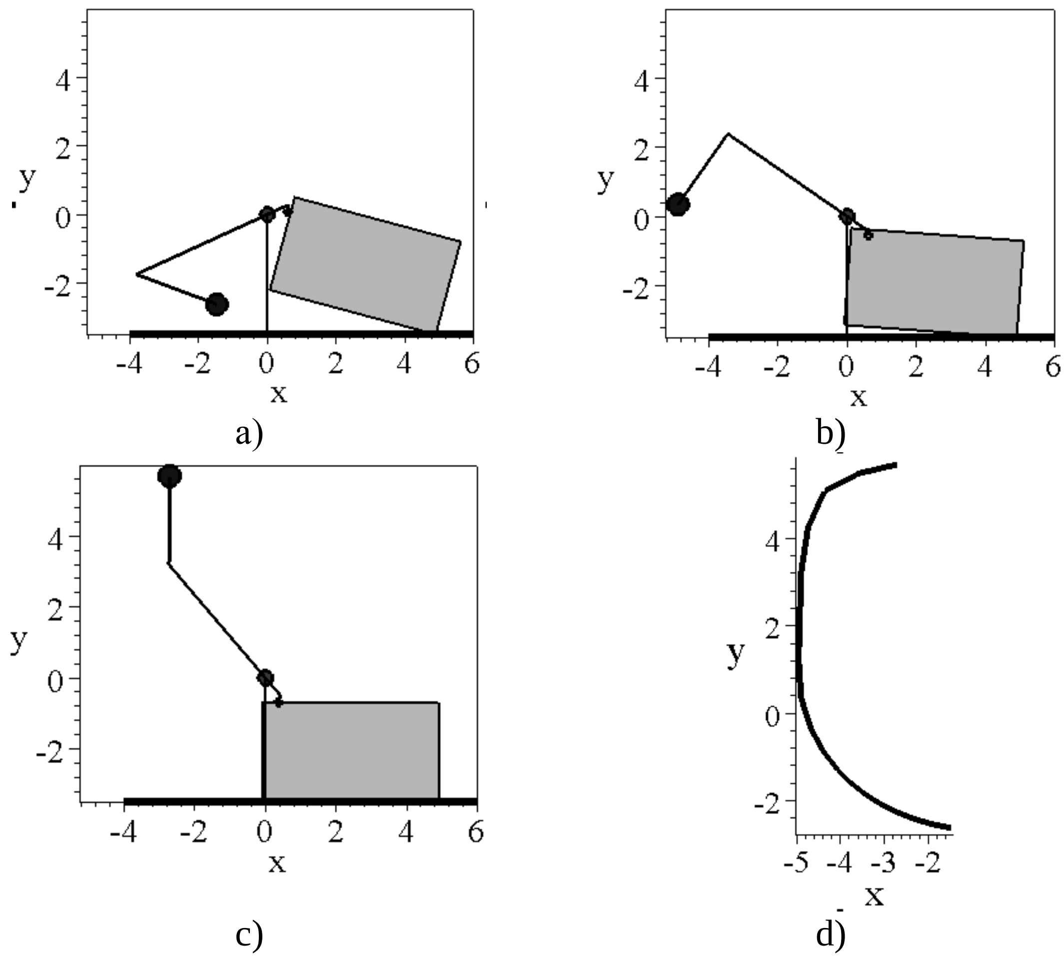


Fig. 5. Obtained images: a), b) current phases of throwing;
c) the phase at the time of the detachment of the UAV;
d) the trajectory of the center of gravity of the UAV

Висновок. The given method of determining the trajectory of dispersal of a drone on the slings of a milling machine will allow you to calculate the angle and speed of its departure. Further research is appropriate to connect with the search for options for rational parameters, depending on the type of drone and car.

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ГЕОМЕТРИЧЕСКАЯ МОДЕЛЬ УСТАНОВКИ ТРЕБУШЕТ ДЛЯ ЗАПУСКА БЕЗПИЛОТНИКОВ ТИПА САМОЛЕТА

Куценко Л.Н., Сухарькова Е.И.

Разработана геометрическая модель мобильной метательной установки требушет, предназначенной для запуска безпилотников типа самолета с использованием легкового автомобиля в качестве противовеса.

Ключевые слова: безпилотник, требушет, лагранжиан, уравнение Лагранжа второго рода, геометрическая модель.

ГЕОМЕТРИЧНА МОДЕЛЬ УСТАНОВКИ ТРЕБУШЕТ ДЛЯ ЗАПУСКУ БЕЗПІЛОТНИКІВ ТИПУ ЛІТАКА

Куценко Л.М., Сухарькова О.І.

Розроблено геометричну модель мобільної метальної установки требушет, призначеної для запуску безпілотників типу літака з використанням легкового автомобіля у якості противаги.

Ключові слова: безпілотник, требушет, лагранжіан, рівняння Лагранжа другого роду, геометрична модель.