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SIMULATION OF THE EFFECT OF WIND ON THE ROCKET MOVEMENT IN THE PASSIVE PART OF THE TRAJECTORY

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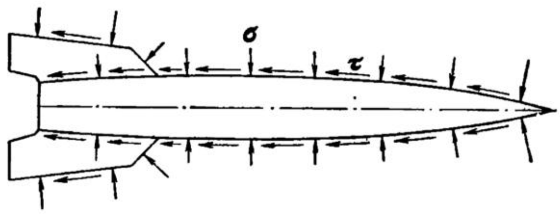
A lot of launches, scientific research and expeditions are conducted in the space industry. When designing all these launches, the main problem is to take into account all parameters and external and internal deviations.

The design of aircraft in general and the synthesis of their control systems are carried out taking into account the requirements for its dynamic characteristics, which include the stability of movement and the quality of transients and the impact of the missile on the control effect. A wide range of changes in flight conditions due to changes in the flight altitude and speed of the aircraft, characteristics of atmospheric turbulence, aerodynamic characteristics (aerodynamic lifting force and aerodynamic torque) determines the nonlinear and unstable mathematical model of the aircraft, which may lead to the inability to meet the requirements within the control system of an immutable structure with constant adjustments. It is known that in the flight process, the dynamic characteristics of the aircraft vary within a wide range, depending on the height and speed of flight, the traction of the engine unit, mechanical parameters and geometry of the design of aerodynamic surfaces. Possible failure of the executive bodies or damage to the load-bearing surfaces leads to unexpected changes in parameters. Maneuvering with large attack angles and controlling the engine vector, which is typical for many types of modern aircraft, leads to an increase in nonlinear aerodynamic effects, the effect of which can be described as a nonlinear change in the parameters of the control object due to variables of the state of the object.

Monitoring and forecasting the movement of artificial and natural space objects, studying the laws of their movement and designing their movement are necessarily associated with certain counting systems. This is a coordinate system and a time measurement system. Before moving on to the types of coordinate devices of the rocket's flight trajectory, it is necessary to note the principles of building systems. When drawing up a coordinate system, first mark its main plane and the direction of the axis of the negative on it and the location of the measuring head. Most often, the plane is considered to be the equator, ecliptic, plane that passes through the orbit of the aircraft or the Earth's surface at the starting point [1]. To calculate the trajectory of movement of a rocket, it is necessary to consider the movement of its center of mass and the movement of the rocket (as a solid body) relative to the center of mass. As we know, the center of mass is not a material point, but a geometric point. It describes the distribution of masses in the system [3]. The center of mass of the rocket moves like a material point, the mass of which is equal to the mass of the rocket, and it is affected by a force equal to the sum of external forces acting on the system, that is, on the rocket

The flight trajectory of a ballistic missile can be divided into three main parts: the active, passive part and movement in the Earth's atmosphere. In the first part, the flight is carried out under the influence of the engine's traction Force P, gravity G=mg, and aerodynamic forces. Aerodynamic forces include the lifting force Y and the resistance force Q. At the end of the active part of the trajectory, the rocket acquires a certain height of H1 and speed of v1. This speed is equal to the required speed for the next passive Part [7]. According to the dynamics, the difference between the active and passive parts is that the force of attraction is eliminated from the forces acting on the rocket [8]. The next passive part is perceived as the main part of the trajectory. It is also sometimes referred to as a ballistic zone. Because in this area, the rocket travels most of its way. In the passive part, the force acting on the rocket is the gravitational force. Aerodynamic forces are the result of the impact of the environment on the surface of the rocket during its movement. In general, each element of the rocket surface is affected by the normal force σ and the indirect force τ (fig.1).



1-figure. Effect of indirect and normal forces on the surface of the rocket

When calculating the movement of the rocket in the passive part of the trajectory, I will base on these conclusions:

1. The attraction of all celestial bodies, except the Earth, is not taken into account.
2. The Movement of the rocket is considered in the plane of a large circle. (Figure 2). The plane of a large circle refers to the plane passing through the center of the Earth [10].
3. The center of gravity of the Earth is located in the geometric center of the globe and the acceleration of gravity is chosen inversely proportional to the square of the distance from the center of gravity to the rocket.
4. In the passive part of the trajectory, the aerodynamic forces acting on the rocket are not taken into account.
5. The Polar coordinate system is used as an inertial counting system. Its pole is located in the center of the globe. And its initial direction is chosen as the direction to the perigee point.

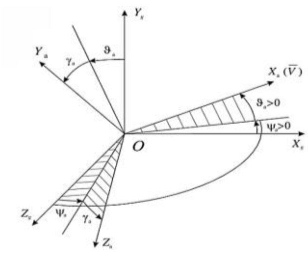
Based on these conclusions, the wind model on the passive part of the trajectory and the quantities and data necessary to determine its impact on the rocket are considered.

The trajectory of the aircraft in accordance with the standard atmosphere is calculated without the participation of wind. As we know, there are always air currents, that is, wind. Therefore, when studying the impact of wind on the aircraft, it should be taken into account. Introducing temperature changes, atomosphere density, and wind into ballistic calculations is a labor – intensive job. It is decided depending on the factors determined by the design and purpose of the rocket.

Wind is a very important meteorological factor for external ballistics. Its main characteristics are speed and direction. These parameters, in turn, are values that depend on the time and coordinates of the point under consideration. Based on the proven experimental data, this can be confirmed: the wind speed in the vertical direction is much less than the wind speed in the horizontal direction. Therefore, in ballistics, it takes without taking into account the wind directed directly. Gusts of wind can be the main cause of projectiles scattered from side to side. When conducting fire tests of shooting equipment, restrictions on wind speed are imposed. Allowed for unmanned missiles:

- Surface wind up to 10 m/s;
- Ballistic wind up to 20 m/s [11].
- Ballistic wind-calculated, conditionally accepted as a medium-constant wind. The effect of ballistic wind on a missile that is not guided along its trajectory causes deviations in distance and direction. This deviation is similar to the effect of wind, which varies in altitude. Ballistic wind is calculated by the measured wind distribution relative to the measurement time and altitude. It is taken into account when determining divergence and direction adjustments [12].

The angles connecting the normal and velocity coordinate systems are called Velocity angles, i.e. velocity tangent angles, velocity tilt angles, and velocity draw angles (fig.3).



3-figure. Angles connecting normal and velocity coordinate systems

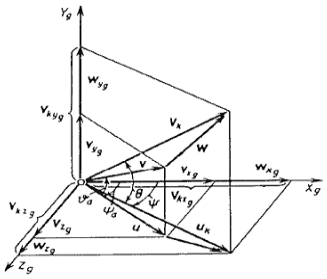
V_K we find the values of the projections of the Earth's velocity on the axis of the normal coordinate system:

$$V_{x_g} = V_k \cos\theta \cos\Psi;$$
$$V_{y_g} = V_k \sin\theta;$$
$$V_{z_g} = V_k \cos\theta \sin\Psi. \quad (2)$$

And if we consider problems on the plane, i.e. Ψ=0, then the horizon and vertical projections of velocity are defined in this way:

$$V_{x_g} = u = V_k \cos\theta;$$
$$V_{y_g} = w = V_k \sin\theta. \quad (3)$$

Figure 4 is used to obtain a system of equations for wind gusts.



4-figure. Scheme of mutual arrangement of wind and rocket velocity vectors

Looking at the figure, the speed of the rocket relative to the atmosphere in a constant wind is equal to:

$$V\cos\vartheta_a\cos\psi_a = V_K\cos\theta\cos\Psi - W_{x_g};$$
$$V\sin\vartheta_a = V_K\sin\theta - W_{y_g}; \quad (4)$$
$$-V\cos\vartheta_a\sin\psi_a = -V_K\cos\theta\sin\Psi - W_{z_g}$$

Now let's introduce the wind speed (5) into the equation

$$\ddot{x} = -E(\dot{x} - W_x);$$
$$\ddot{y} = -E\dot{y} - g; \quad (5)$$
$$\ddot{z} = -E(\dot{z} - W_z)$$

Then this system of equality is a system that describes the effect of wind on the movement of a rocket, the mass of which is constant. This system is built into a program, and the analysis of its main results will be done in the next chapter.

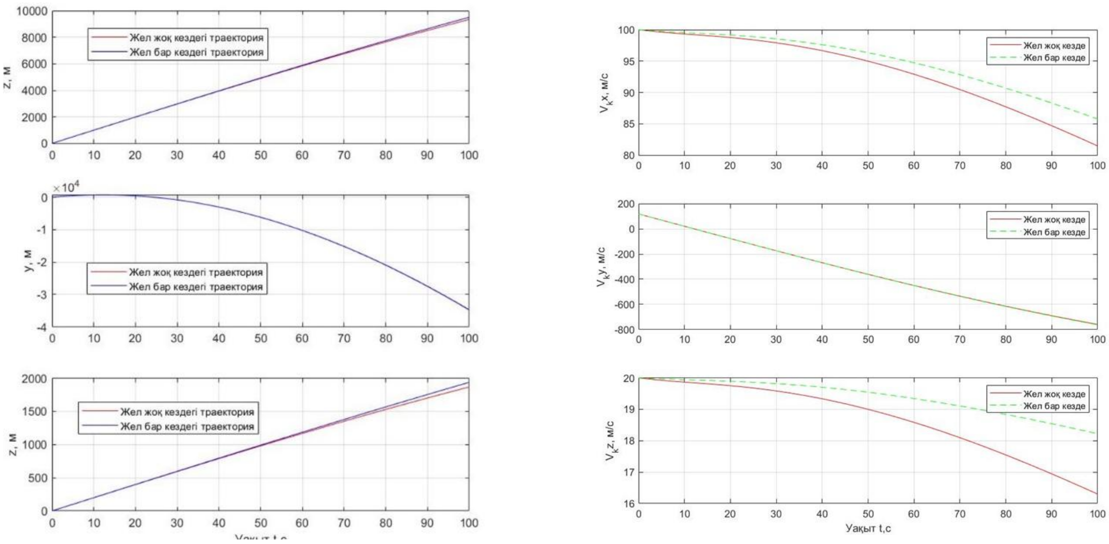
In the scenario itself, the first constant values or intervals required for us are obtained. As an example, I took a small, medium-sized, medium-sized aircraft. Its overall parameters:

Weight: m = 200 kg;

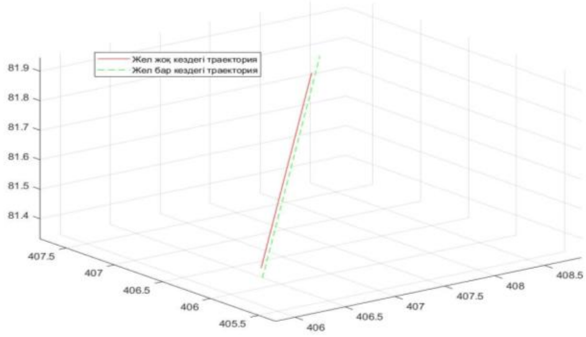
Cross-section diameter: d = 0.15 m;

In principle, the mass of the apparatus is constant in the passive part of the trajectory.

After the described program, the following results were revealed.



5-figure. Change in speed projections and trajectory projections over time in the presence of wind



6-figure. wind shear of the trajectory for 10 seconds (enlarged image)

That is, a program for solving a system of differential equations describing the movement of an aircraft, and a system of differential equations describing the effect of wind by introducing wind parameters into it by numerical method in the MATLAB software environment was written, and a spacecraft with a numerical calculation mass of 200 kg was taken as an example. But the prepared computer code can be used for any aircraft. It is only necessary to enter the technical parameters and dimensions of a particular aircraft.

We can come to this conclusion:

1. An increase in wind speed leads to fluctuations in the angle of attack
2. Regardless of the magnitude and direction of the wind, its influence on the speed and trajectory of the rocket is observed only in time.
3. From 10 seconds to 100 seconds, the trajectory shift increased by 160 times.

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