UDC 528.2

SIMULATION OF THE CRUISE MISSILE THRUST VECTOR USING MATLAB

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Intoduction

When organizing a meeting of an airplane with a task, a number of problems have to be decided, which are reduced to receiving information about the movement of the task and the airplane, transmitting information to control points and data processing it, forming control commands, guidance and pointing the airplane, etc. The guidance system can be considered as an automatic control system for the movement of the airplane relative to a certain calculated trajectory determined by the guidance method. At the same time, the guidance method is understood as a given law of attitude of the missile to the task, which, depending on the coordinates and parameters of the task movement, determines the required movement of the missile, ensuring that the missile hits the task.

Possible reasons for the incorrect of the thrust vector may be the location of two nonlinear multidimensional links in the instruction loop or difficulties related with the use of a polar control scheme. In this relation, it is recommended to continue the study of this problem for the Cartesian control scheme of the propulsion system to receive an algorithm for the thrust vector using the method of predictive models.

Currently, research in the space sector is developing quickly in Kazakhstan. The relevance of research in the area of design and effective use of spacecraft and launch vehicles is high. While the design of spacecraft is related with the difficult assembly and testing of again built spacecraft, the design of launch vehicles is related with the operation of the Baikonur Cosmodrome. In such studies, it is important to use modern technologies, especially innovations in the area of automation of mathematical models. One of them is the MATLAB Simulink package. The creation of a piloted rocket model with its application is important not only for the space industry, but also for the military. The MATLAB Simulink package provide you to create a visual, high-precision and compact model of guided missile movement. The relevance of the topic is certain by this.

The aim of this work is to build a model of the cruise missile thrust vector using the MATLAB Simulink package.

Research question is: What recommendations are formed on the application of the motion model?

The following tasks have been set:

- to study the characteristic of the thrust vector of cruise missiles;
- to analyze the existing methods of guidance of rockets and spacecraft;
- to create a motion model of a winged rocket using the MATLAB Simulink package;
- to perform calculations using the developed model and study the reliability of the model;
- to formulate of recommendations for the use of this model.

In this article, we have consider the pointing systems of atmospheric-type airplane and perform simulation modeling of classical pointing methods (direct guidance method, chase method, proportional guidance method). The proportional guidance method is at the moment the standard and most effective and used method of targeting homing missiles for aiming both non-maneuvering objective and maneuvering ones and in addition, all methods have their own difficulties of realization.

The object of the research is the simulation of the thrust vector in the Matlab/Simulink package.

The airplane motion control system is a group of devices and software program located on board the rocket, designed to control the movement and position of the rocket at all stages of its operation in order to ensure the required effectiveness of the task application. It is important to note the difference between navigation and guidance: navigation is the determination of the position of the center of mass of the airplane relative to some inertial coordinate system without taking into account the location of the task, and guidance is the calculation of the method of achieving the objective. With the growing need for the tactical and technical characteristics of modern missiles and the development of the theory of control, there is a significant complication of the tasks solved by the control system. It is necessary to ensure the accuracy of guidance, the required type of trajectory, the optimality of the static and dynamic characteristics of the reaction of the rocket to the control signal, as well as to perform the suppression of external influences.

Since ancient times, people has dreamed of the possibility of flying, and flying machines are exactly what this desire and the scientific and technical vector of human development have led him to. When organizing a meeting of an airplane with a task, a number of tasks have to be solved, which are reduced to obtaining information about the movement of the task and the airplane, transmitting information to control points and processing it, forming control commands, pointing and homing the airplane, etc. The guidance system can be considered as an automatic control system for the movement of the airplane relative to a certain calculated trajectory determined by the guidance method.

Bykov consider that the variable thrust vector nozzles give the machine exceptional maneuverability, and above all allow it to deflect the nose from the direction of flight for long periods of time. This ability could not be reproduced on Western airplane for many years. The thrust vector deviates by 15° in the vertical plane. This allows you to freely change the direction of flight on both the vertical and horizontal axes.

The thrust vector of cruise missiles is provided by turning the entire nozzle or part of it.

The SU-35 is a Russian jet super-maneuverable multi-purpose fighter of the fourth generation. It is equipped with two two-circuit turbojet engines "AL-41F1S" with an afterburner and a thrust vector controlled in one plane. In order to increase the number of angles of deflection of the engine thrust and create a pseudo-angle, the axes of rotation of the deflected nozzles are tilted - the nozzles are deflected down-inwards and up-outwards.

Kiseleva argued that the homing process is implemented under the influence of a large number of random factors, the miss should be considered as a random variable. The complete characteristic of a random variable is, as we know, the density function of probability distributions. However, for practical purposes of designing homing systems, as a rule, they are limited to two points of the span distribution density function: the mathematical expectation and the variance.

The natural purpose of planning homing systems is to reduce the expectation and difference of the range.

A study conducted on guidance algorithms showed that the task of guiding cruise missiles is to organize and implement the launch and guidance of one or more missiles at one or more tasks with an precision that provide the operation of combat equipment and the destruction of tasks with a probability not lower than the set one.

An early study conducted by the review of modern types of space arms and priority developments of the world powers confirmed the need for appropriate improvement of the means of aerospace protection. This problem is becoming more and more relevant, as the dynamics of the militarization of outer space only increases every year. In the course of consideration of this problem, the questions related to the homing of airplane in space, the methods of organization of propulsion systems, and the linearization of multidimensional control objects were studied.

Among the design and technological features of modern jet engines, it is necessary to distinguish the control of the thrust vector and the technology of manufacturing high-quality turbine blades of compressors. To further improve the tactical and technical characteristics of jet engines, it is necessary to apply fundamentally new technologies and designs focused on the practical application of the latest achievements in the field of research in nuclear physics, plasma physics, thermonuclear fusion, nanomaterials and nanotechnology.

Methodology

The technical implementation of the approach of airplane in space is largely determined by the possibility of creating a motion control system that ensures the implementation of this operation. The development of guidance methods for approaching airplane and the creation of equipment that implements these methods is an indispensable condition for the successful solution of the task.

At the long-range guidance stage, the ground command and measurement system determines the movement of the airplane and the targets, predicts their movement and calculates the active maneuvers necessary to bring the airplane into the range of the on-board equipment for measuring the relative motion parameters. At the stage of long-range guidance, you can also use information from the onboard radar station. As a rule, this is done to duplicate the calculations of the ground complex in order to achieve the necessary reliability of the meeting operation.

The calculated the coefficients of the transfer functions of the aircraft using the following formulas:

$a_\delta = \frac{K_2}{I_y}$ - numerator coefficient;

$\omega^2 = \frac{K_3 + K_4\tau}{\tau I_y}$ - the square of the natural frequency of the airplane oscillations.

$\tau = \frac{mv}{K_1 + P}$ - airplane time constant,

$S = \pi d^2/4$ - the area of the midship of the airplane.

Substituting the initial data into the given formulas, that obtained the numerical values of the coefficients of the transfer function of the airplane.

Table 1.

S, m^2	V, м/c	$K_1 \times 10^5$	$K_2 \times 10^5$	$K_3 \times 10^5$	I_y kg·m^2	τ, c	a_d	ω^2	2dωS
0.0415	1473	1.7714	1.3102	1.3102	316.87	1.9115	41.467	449.387	4.657

Table 1 shows a block diagram of the AP - cruise missile.

The autopilot model in question has flexible feedback via a high-speed gyroscope. The power drive is shown by a sequential connection of a linear inertia-free link with a transmission coefficient k and a non-linear link-a limiter of the maximum angle of deviation of the rudder. The power drive is designed to deflect the op-amp rudders in proportion to the control voltage U_y. The control voltage U_y is the result of the summation of the command U_k and the stabilizing voltage. On the steering wheel axis there is a sensor that converts the angle of deviation into a voltage that is opposite in sign to the control one. Due to the negative feedback, the steering wheel is fixed at an angle of δ. The output of the power drive is the angle of deflection of the handlebars δ.

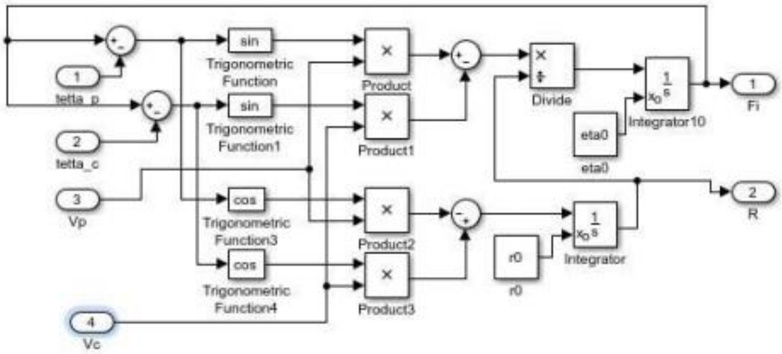

Figure 1. Block diagram of the AP - cruise missile

Direct guidance method.

The functional diagram of the direct guidance method is shown in figure 2.

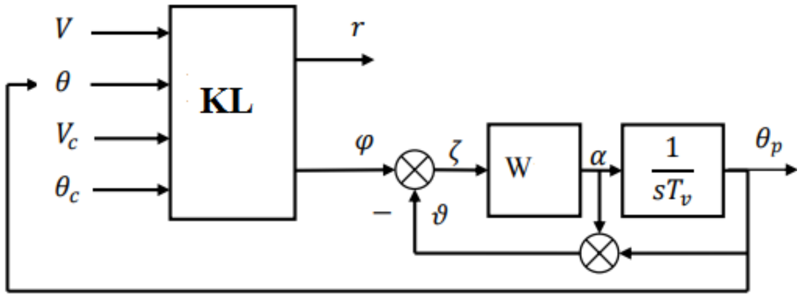

Figure 2. Functional diagram of the direct guidance method

The modeling schemes in Matlab/Simulink are shown in figures 3, 4.

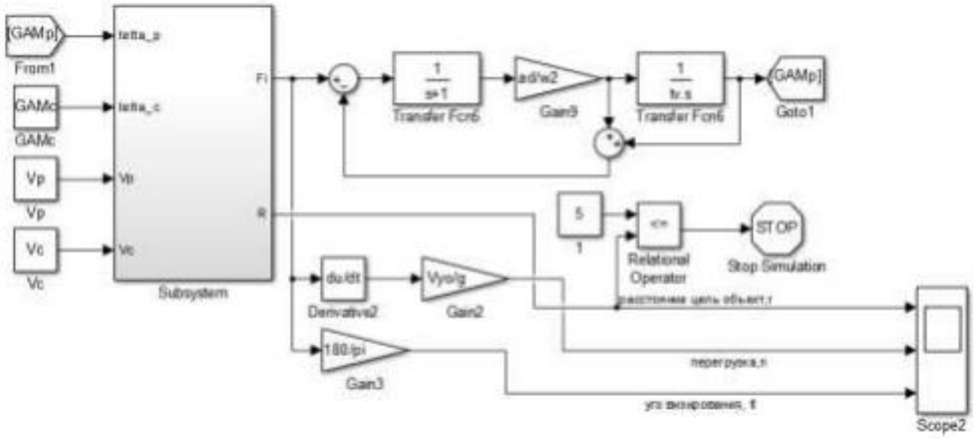

Figure 3. A scheme for calculating kinematic trajectories for the direct guidance method

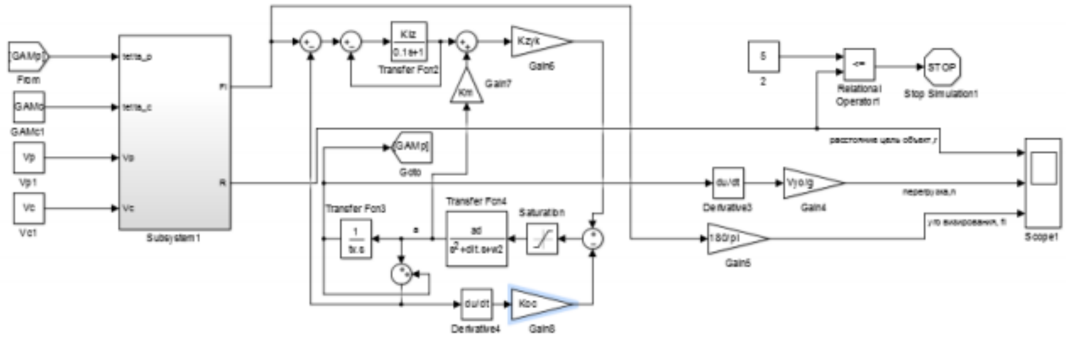

Figure 4. A scheme for calculating dynamic trajectories for the direct guidance method

The performed a simulation of the system with the following initial parameters and present graphs of trajectories, rocket overload *n*, changes in the angle of sight, and a graph of changes in the distance between the missile and the target *r*:
$r_0 = 10000$ m, target heading angle $\theta = 0$ deg, target speed $V_c = 0.5\ V_r$, target speed $V_c = 736$ m/ s, missile speed $V_p = 14730$ m/s.
Based on the simulation results, the kinematic and dynamic trajectories shown figure 5 are constructed.

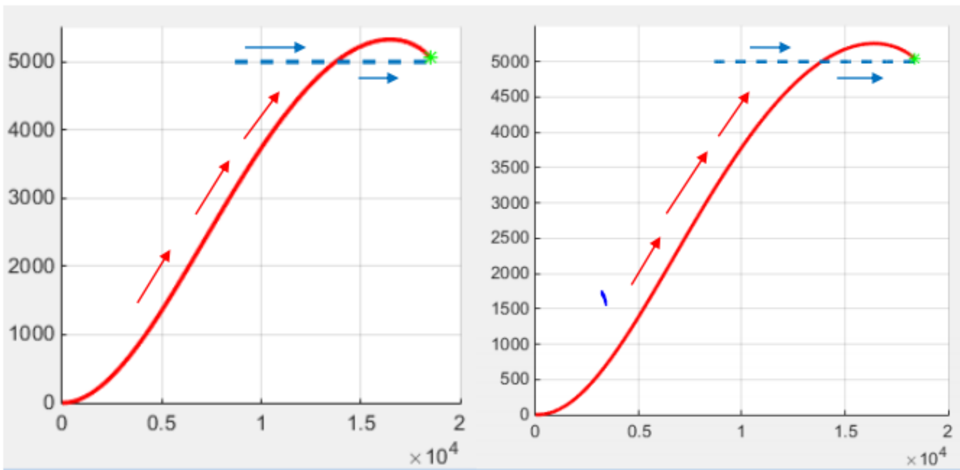

Figure 5. Simulation of the direct guidance method at θ = 0°

From the approximate analysis of the trajectory, it follows that the guidance trajectories with a constant and, in particular, zero bearing angle of the target require very large normal overloads for their implementation. As a result, the areas of possible attacks are very limited. The direct guidance method, characterized by the law $\zeta = 0$, is convenient to use in the case of low target speeds and airplane, provided that the initial range r_0 is sufficiently large.

The chase method.

Figure 6 shows a functional diagram of the chase method:

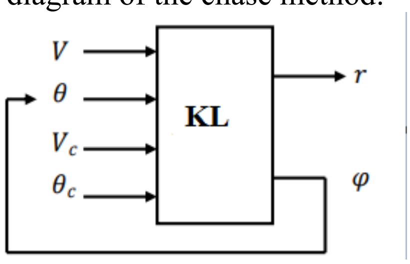

Figure 6. Functional diagram for kinematic problem statement

Figure 7 shows the scheme for calculating kinematic trajectories for the chase method.

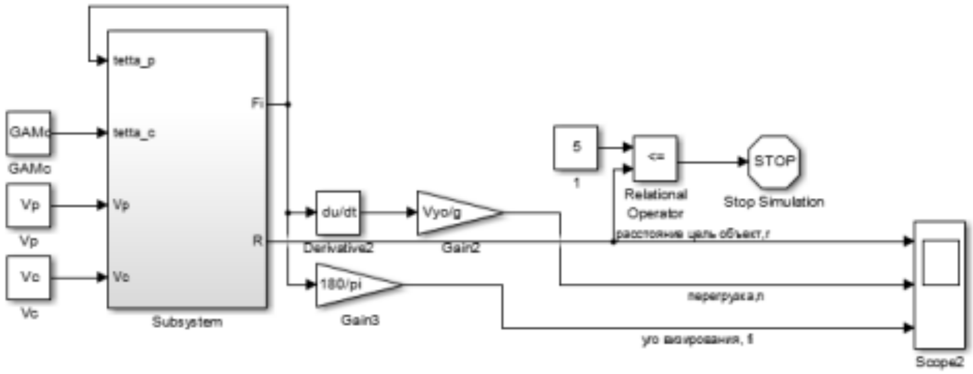

Figure 7. Scheme of calculation of kinematic trajectories for the chase method

It is worth noting that when modeling the speed of the rocket to the target speed have been taken with a ratio of 2 to 1 or less, because with a larger ratio, the angular velocity of the line of sight w_b tends to infinity, which is a consequence of the miss.

Results

In the course of the work, the main continuous methods of aiming anti-airplane guided missiles at aeroballistic targets were considered.

Based on the work done, we can conclude that each method has its own implementation difficulties.

The direct guidance method can only be successfully applied to point an airplane at a stationary target, for example, in guided bombs and projectile planes, or at a target whose speed is many times less than the speed of an airplane. In this case, it is necessary that the angle of attack a is minimal, i.e. that the direction of the longitudinal axis of the rocket coincides as accurately as possible with the direction of the velocity vector of the rocket.

When using the chase method, you should keep in mind two possible cases: the pursuit of a receding target and the pursuit of an approaching target. The trajectory of the airplane is strongly curved, especially when oncoming courses intersect.

For reliable target destruction, it is necessary to choose such guidance methods, the use of which does not require high loads on the missile, even under the most unfavorable shooting conditions.

Literature

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