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TRANSITION PROCESSES MODELING IN A PARTIALLY INVARIANT STABILIZATION SYSTEM

Introduction. The publication suggests how to significantly improving the spacecraft center of mass movement stabilization accuracy in the active phases of trajectory correction during interplanetary and transfer flights, which in some cases provides for high navigation accuracy, when rigid trajectory control method is used. It is the simplest to implement method allowing avoiding more complex control methods. Improvement of control accuracy increases chances for successful implementation of the flight program. However, a significant reduction in the correcting impulse lateral error leads to reduction in fuel required for corrections, and thus increases the payload [1-3].

Problem Statement. The publication addresses spacecraft that use high-thrust propulsion system for correcting impulses and control at active phases. Since the time of the active phase T, which is determined by specified velocity impulse is not known and quite limited during correction maneuvers [4, 5] and in view of the fact that a guaranteed approach evaluating accuracy is always used to solve a guidance task in practice, in this publication, we shall understand the maximum dynamic error of the transition process $\dot{y}_{\max}\left(\dot{z}_{\max}\right)$ with normal (lateral) drift velocity of the spacecraft as the accuracy of spacecraft center of mass movement stabilization in transverse directions [2, 3]. Consequently, our purpose is to significantly increasing stabilization accuracy of the spacecraft center of mass tangential velocities (reduction of the maximum dynamic error in the drift velocity of the spacecraft in the transition process). This shall be due by synthesis of highly accurate stabilization algorithms in the rigid trajectory control system on the trajectory correction phases outside the atmosphere when using high-thrust engines. The spacecraft center of mass movement stabilization system in the normal (lateral) plane applied in the trajectory correction phases shall be the subject of research. Either a high-thrust sustainer of propulsion system provided with deviating or linearly moving combustion chamber shall be using in the correction phase to control motions of the spacecraft [4, 5].

Process Modeling. The characteristics of the test spacecraft shall be the values of the dynamic coefficients:

$$C_{\vartheta\delta} = 13.2\frac{1}{s^2}; C_{y\vartheta} = C_{\vartheta\delta} = 0.23\frac{m}{s^2 \cdot grad}.$$

The following values are taking to simulate performance of the servo control:

$$T_c = 0.01s;\ K_c = 1\frac{\mu A}{V};\ I_0 = 3\mu A;\ I_N = 40\mu A;\ K_{OD} = 0.5\frac{grad}{s\mu A}.$$

The following values of the above characteristics were selecting for modeling:

$$K_{AVS} = 1\frac{V \cdot s}{grad};\ T_F = 0.01s;\ T_1 = 0.01s;$$

$$k_{\dot{\vartheta}} = 14s; k_{\ddot{\vartheta}} = 6s; k_{\dot{y}} = 40\frac{V \cdot s}{m}; k_{\ddot{y}} = 80\frac{V \cdot s^2}{m}.$$

The signal error $\xi_{\dot{\vartheta}}$ is considered Gaussian uncorrelated random value, with a zero mathematical expectation and mean square deviation (MSD) $\sigma_{\xi_{\dot{\vartheta}}} = 0.01\frac{grad}{s}$. The modeling was doing by numerical integration of the equations [6] with application of Runge-Kutt 4th order method, with a controlled step size. Random values $\xi, \xi_{\dot{\vartheta}}$ were modeling with application of Gaussian pseudo-random number sensors (Fig. 1).

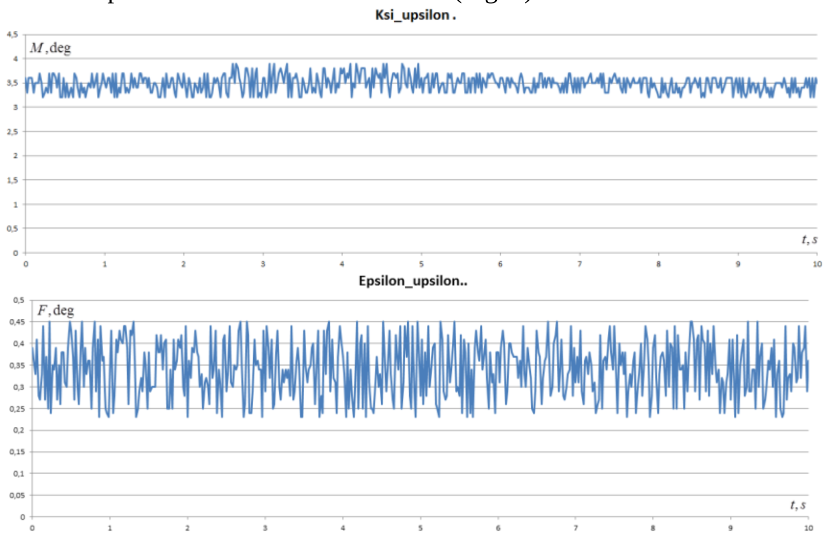

Fig. 1. Random modification realizations of the disturbing moment M and destabilizing force F in mathematical modeling $\left(m^H F = 0.35^0; m^H M = 3.5^0\right)$

Discussion. In order to do a comparative analysis of the stabilization accuracy in the invariant and in standard stabilization systems, similar mathematical modeling have done for the standard system as well. A block diagram for a model of the standard stabilization system used in the simulation shown at Fig. 2.

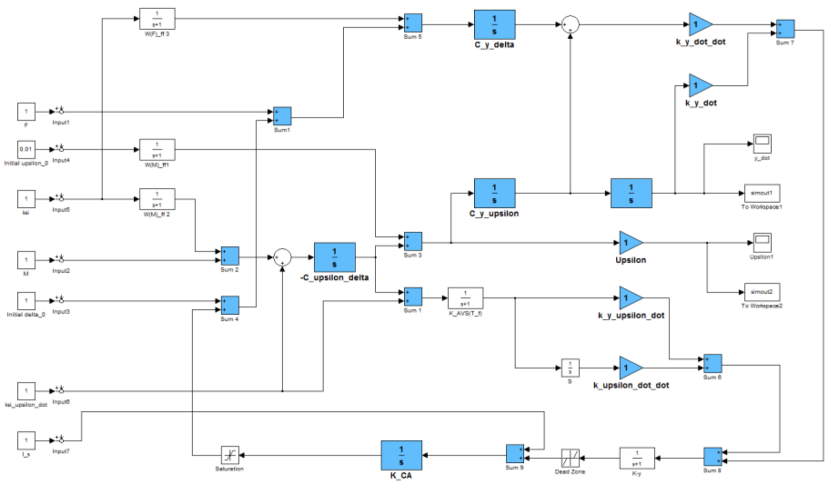

Fig. 2. Block diagram of a partially invariant center of mass stabilization system used in the mathematical modeling

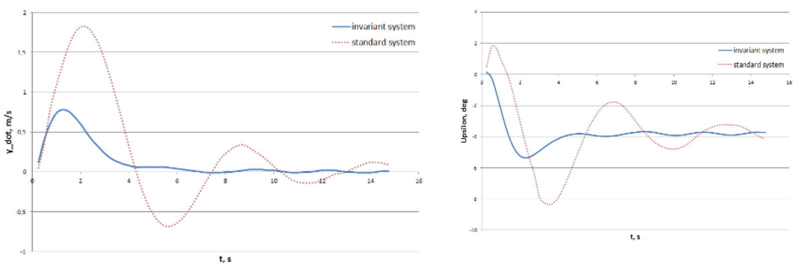

Fig. 3. Spacecraft drift velocity and X-axis transition processes in the normal plane in the invariant and standard stabilization systems

$$\left(m_F^H = 0.3\deg; m_M^H = 3.5\deg \right)$$

Transition process diagrams for the invariant and standard stabilization systems are showing in Fig. 3 and correspond to maximum value case

m_F^H, m_M^H. As the mathematical modeling shows, application of the invariant algorithm in this case improves the accuracy of center of mass roll stabilization twice or three times [6].

Conclusion. Transition processes in the invariant stabilization system have significantly less attenuation time than in the standard system. Random disturbances caused by fluctuating of propulsion system operating conditions during normal operation, as well as random MSD measurement errors have no significant impact on the stabilization accuracy.

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