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On the triaxial electrodynamic attitude stabilization of a satellite in the orbital frame via control with distributed delay

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Abstract: The problem of triaxial attitude stabilization of a satellite in the orbital frame is considered. The problem is raised about the possibility of implementing such a system of electrodynamic attitude control by the type of a PID controller, in which the integral component of the control torque contains a distributed delay. A theorem on the asymptotic stability of the stabilized angular position of the satellite is proved. The theorem substantiates the possibility of constructing the indicated control system. The effectiveness of the designed attitude control with a distributed delay is confirmed by computer modelling.

Keywords: satellite, electrodynamic attitude control, PID controller, distributed delay, asymptotic stability

1. Introduction

A satellite with an arbitrary triaxial ellipsoid of inertia in a circular equatorial orbit is considered. The mode of direct equilibrium position in the orbital coordinate system is considered as the programmed mode of the satellite attitude motion. To stabilize the satellite in the programmed motion mode, an electrodynamic attitude control system is used, which generates the Lorentz and magnetic control torques [1]. These two control torques implement the restoring and damping components and also provide compensation [2] of the disturbing gravitational torque [3], that allow stabilizing the satellite in the programmed motion mode.

The novelty of the approach to solving the problem lies in the development of the concept of electrodynamic attitude control by using the restoring torque with a distributed delay [4]. The effectiveness of such type of a PID controller (see [5] and papers cited therein) is investigated.

2. Results and Discussion

A simple and easily verified sufficient conditions for the asymptotic stability of the programmed motion of the satellite has been obtained in a nonlinear formulation with the use of the approach developed in [4, 6] to constructing Lyapunov functions [7]. The obtained conditions impose restrictions on the coefficients at the restoring [1] and dissipative [1, 8] components of control torque and the value of delay. The suggested approach to electrodynamic attitude control design is compared with those considered in the previous publications. It was revealed that the distributed delay (integral term)

1) significantly improves the quality of control process and makes it smoother;
2) reduces the time of convergence to the program motion.

The first observation implies that the suggested modification of electrodynamic attitude control can be used to avoid undesirable satellite vibrations generated by attitude control system. For this reason, it is suitable for stabilization large-scale space structures. Especially in the cases where dangerous resonance oscillations may occur due to nonlinearity of structure [9]. The second observation implies that the introduction of distributed delay (integral term) makes the electrodynamic attitude control system much more effective compared with earlier known variants.

Thus, the development of the theory of electrodynamic attitude control is given for solving the practically important problem of triaxial attitude stabilization of a satellite in the orbital frame. Numerical modelling confirms the conclusion proved in the theorem.

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