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Attitude Dynamics (1) (1)

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ATTITUDE DYNAMICS OF SMALL SATELLITES IN CIRCULAR NEAR-EQUATORIAL LEO/VLEO

Abstract

One of the most promising and popular applications of small satellites is Earth observation from low and very low Earth orbits (LEO/VLEO). The simplest way to control the satellite's angular orientation in these orbits, where the influence of the atmosphere is significant, is to use passive aerodynamic stabilization, since it does not require any power supply. In addition to the aerodynamic torque, one must also consider the gravitational and magnetic torques, the latter substantially depending on the orbital inclination. For near-equatorial orbits, characterized by small inclination, the magnetic torque can be approximately represented as a sum of two components: a small one and a large one. The small component depends on the true anomaly and thus is not conservative, while the large component is conservative and depends only on the satellite's attitude. Since the other two environmental torques are also conservative, one can define an unperturbed motion as the satellite's attitude motion under the action if the conservative torques and treat the small non-conservative component of the magnetic torque as a perturbation.

The aim of the study is to investigate the perturbed attitude motion of arbitrarily spinning axisymmetric satellites in the circular near-equatorial LEO/VLEO under the action of aerodynamic, gravitational, and magnetic torques. In order to achieve this, the equations of motion in the dimensionless form were derived, the unperturbed dynamic potential was introduced, several different groups of equilibrium positions of the satellite's longitudinal axis were found, the bifurcation analysis of these positions was performed, and a case study dealing with a deployable LEO/VLEO satellite was considered.

The proposed separation of the equations of motion into the unperturbed and perturbation parts allowed determining several regimes of angular oscillations, corresponding to the shape of the dynamic potential surface, which depends on several dimensionless system parameters introduced. The bifurcation analysis revealed the influence of these parameters on the unperturbed system. The numerical simulations, performed for a deployable LEO/VLEO satellite, showed that the magnetic perturbations may cause the chaotic attitude motion, manifested in the transition between the potential wells. These results reveal the need for active attitude control to prevent chaotic motion in the case of unexpected spin motion.