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COUPLED ATTITUDE-ORBIT DYNAMIC MODELING OF HIGH AREA-TO-MASS SPACECRAFT AND SIGNIFICANCE ANALYSIS OF PERTURBATION FACTORS

Abstract

The past few years have seen a rapid development on the engineering and space experiment of high area-to-mass ratio spacecraft, such as ChipSats, solar sail. Compared to the traditional satellites, the effect of the terrestrial perturbations on spacecraft with high area-to-mass ratio is more significant. It is possible to utilize the perturbation actively to propel the spacecraft through available design of structure and actuation system of them. In order to achieve the high ratio of area-to-mass (up to 10m2/kg), configuration with thin plate or membrane and materials with small density are chosen. Since there is no need to design the propulsion system which requires propellant for this kind of spacecraft, the mass of it can be further reduced, and so is the launch cost. Recent researches on high area-to-mass ratio spacecraft focus on the effect of perturbation on the orbital evolution of such uncontrolled objects as ChipSats or space debris. However, the attitude and orbit motion of the high area-to-mass ratio object is strong coupling, and it would make more sense when considering perturbation adjusted by the controlled actuation system of spacecraft, by which more potential applications could be explored. Hence, it makes the study practically significant to establish the coupled attitude-orbit dynamic model for high area-to-mass spacecraft under the multi-force system, consisting of gravity, solar pressure, atmosphere drag, geomagnetic force and J2 perturbation. The work represented in this paper can be divided into three aspects. First, a design technique of active actuation system utilizing solar pressure and geomagnetic force with the help of novel material and micro-electro-mechanical system (MEMS) technology is proposed. Second, the coupling motion between the attitude and orbit is characterized through analyzing the influence of the individual perturbation on the satellites, which would contribute to the modeling of the coupled motion. Third, the dynamic model is used to quantify the effect of each perturbation on the coupled motion of spacecraft, and six orbit parameters and three attitude parameters are used to describe range of significance for each perturbation. The work in this paper will lay a solid foundation for the further design of optimal control.