20th IAA SYMPOSIUM ON SPACE DEBRIS (A6)
Post Mission Disposal and Space Debris Removal 2 - SEM (6)

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DYNAMICS ANALYSIS AND OPTIMAL STRATEGY OF PYRAMID DEORBIT SAIL

Abstract

For space debris mitigation, deorbit disposal of constellation satellites in Low Earth Orbit (LEO) at the end of their operational lifetime is considered as a necessary measure. In LEO region, the deorbit sail device provides an efficient way to accelerate the deorbit process by enlarging the windward area to increase the atmospheric drag and solar radiation pressure effects of the defunct satellites. By considering the two effects, the aim of this paper is to propose an optimal strategy for deorbit sail device in LEO deorbit missions.

The deorbit sail is modeled as a pyramid, and the coupled attitude and orbit dynamics of the system is studied. The geometry parameters of the pyramid deorbit sail, such as the number of support booms and the flare angle, as well as the position and mass properties of the spacecraft bus are not limited. In this paper, assume that the deorbit process of the deorbit sail system can be divided into atmospheric drag dominant region and solar pressure dominant region when either one dominates over the other (so the other one can be neglected). By simplifying the attitude dynamics model in the orbital plane, the stable bounds are found about the geometry of the sail, center-of-mass to center-of-pressure offset, mass properties of the spacecraft bus and the initial conditions in the two dominant regions.

Then, with the premise of stable attitude achieved by stable bounds above, two key parameters are proposed to evaluate the stability of the deorbit sail system for different environmental dominant regions. With the key parameters, the influence of geometries on the attitude stability is analyzed for pyramid deorbit sails, and further conclusions about the optimal configurations and initial attitudes are obtained from the analysis results, respectively. When both effects are considered, the optimal strategy is found by the two parameters through a global optimization approach.

Finally, numerical simulations with the attitude-orbit coupled dynamics model are conducted to verify the conclusions drawn from the key parameters, and the optimal strategy is obtained as well as simulated in deorbit missions to show the optimality with both effects considered.

The results from this work would offer theoretical guidance to the configuration design and attitude control of pyramid deorbit sail system in application.