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TRAJECTORY OPTIMIZATION FOR SOLAR SAIL IN CISLUNAR NAVIGATION CONSTELLATION WITH MINIMAL LIGHTNESS NUMBER CONTROL

Abstract

The increasing lunar space exploration activities give rise to higher demands for navigation constellation system in cislunar space. Apart from the traditional satellites and libration point satellites constellation, recently solar sail is proposed as an emerging type of spacecraft which can take place of satellites to construct navigation constellation due to its adjustable sunlight pressure and no consume of fuel.

In such cislunar navigation system, artificial lagrange points (ALP) of the Sun-Earth and solar sail circular restricted three-body problem are solved to arrange solar sail constellation dispersedly. Subjected to sunlight pressure and lunar gravity, few or even no closed periodic orbits of solar sail can be generated near the ALP, so to increase the orbits number for higher navigation accuracy, some control which changes sail's lightness number and attitude is implemented to stabilize sails' orbits. However, since the deployment and folding process of solar sail membrane is complicated, the change of sail's lightness number consumes lots of energy, besides, for the limitation of industrial manufacture, the range of lightness number is quite small which just allows of variation from 0.47 to 0.55. Based on this fact, this paper selects the displaced orbits of solar sail over ALP as optimization object to design an optimal orbit with minimum control, during which the lightness number has the least change.

Therefore, the following steps are taken to solve above problem. Firstly, establish the sun-earth barycentric synodic frame to develop the dynamics equation and determine the regions of artificial equilibrium solutions. Then, select the constellation arrangement according to the relationship between the constellation position and navigation accuracy evaluated by factors such as GDOP. Next, with the application of overall-plan theory, we develop the orbital optimal equations of sail with the constraint of lightness number and analyze the stability of such orbit under the disturbed case. Finally, navigation and position are simulated for spacecraft's cislunar orbits to evaluate the navigation performance.

Compared to other cislunar navigation systems, the solar sail navigation constellation with the optimal trajectory design has two important innovations: one is the solar sail three-body problem breaks the restriction on the number of five classical lagrange equilibrium solutions to generate large amounts of ALP, which greatly increases the selectable range of solar sail constellation; the other is instead of eliminating or compensating the lunar gravity, this paper takes lunar gravity as the power for the motion of solar sail to reduce control energy.