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IMPULSIVE STATION-KEEPING OF FROZEN ORBITS AROUND PLANETARY MOONS USING MANIFOLDS OF AVERAGED DYNAMICS

Abstract

Natural moons of the giant planets in the solar system have attracted increasing attention. Previous research has indicated that some planetary moons may harbor liquid ocean beneath the ice shell. These moons are referred to as icy moons and have become important targets for exploration. Several missions have been developed, including the launched Jupiter Icy Moons Explorer (JUICE) led by ESA and the near-future Europa Clipper led by NASA.

High-inclination frozen orbits are desirable choices for science orbits about planetary moons. Frozen orbits are able to maintain nearly constant mean elements or have minimized natural drifting, which are advantageous for prolonged observation and low station-keeping consumption. Due to the strong third-body perturbation from the planet, high-inclination frozen orbits are usually dynamically unstable. Therefore, to support the long-term observation, it is necessary to investigate station-keeping strategies for the frozen orbits. To our best knowledge, there is currently a lack of research in this aspect.

This paper proposes an impulsive station-keeping strategy for unstable frozen orbits around planetary moons. In the doubly averaged phase space, a "trigger sphere" is set near the frozen orbits to detect deviation events and activate station-keepings. Through impulsive maneuvers, orbital elements on the trigger sphere will be adjusted to the stable manifolds of the frozen orbit so as to mitigate the risk of continuing orbital deviations. Two approaches are considered to generate station-keeping maneuvers. Both approaches are two-impulse. The first approach adjusts the mean argument of periapsis while keeping the other mean elements invariant. The second approach adjusts the mean eccentricity and mean inclination without changing the other mean elements. The two approaches lead to different changes in the phase space and will reset the orbits at different points on the stable manifolds of the frozen orbits.

With high-inclination frozen orbits around Europa as examples, numerical experiments are carried out to validate the proposed station-keeping strategy. Comparisons are made between the two approaches of generating maneuvers in terms of the V cost, time consumption, and required control frequency. Numerical results can prove the efficacy of the strategy. The strategy proposed in this paper can be applied to the station-keeping of unstable frozen orbits about different planetary moons, which could offer support in future exploration missions.