IAF ASTRODYNAMICS SYMPOSIUM (C1)
Interactive Presentations - IAF ASTRODYNAMICS SYMPOSIUM (IPB)

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LONG-TERM STATION KEEPING AROUND EARTH-MOON SYNODIC RESONANT HALO ORBITS USING SOLAR SAILS IN HIGH-FIDELITY DYNAMICS MODEL

Abstract

Libration point orbits in the Earth-moon system are of great interest because they are useful for many applications related to lunar exploration. Halo orbits are a typical example and they are generally unstable, thus station keeping control is required for a spacecraft to prevent orbital escape. Solar sails are a propulsion system which can take advantage of solar radiation pressure to produce thrust without consuming propellant. Although the magnitude of thrust is small, they are suitable for long-term missions such as station keeping around halo orbits because they can continuously apply delta-v to orbital control for an infinitely long time. Because the direction of the sun rotates in the Earth-moon rotating frame, halo orbits around Earth-moon libration points must be synodic resonant, where the ratio of the orbital periods to the synodic lunar period is rational. Orbit design and station keeping strategies have been studied by many researchers, and most of them used simple dynamics models such as Circular Restricted Three-Body Problem (CRTBP) and Bi-Circular Restricted Four-Body Problem (BCRFBP). The author previously examined the orbit design method in high-fidelity ephemeris model, but it was limited to short-term (less than half a year) orbits. In this study, we first show a long-term (e.g. more than a year) orbit design method in high-fidelity ephemeris model. This is challenging because the high-fidelity model is significantly different from CRTBP or BCRFBP, which do not consider the effect of eccentricity and inclination of the lunar orbit around the Earth. These factors considerably influence the orbital motion of solar sails and make it difficult to design long-term synodic resonant halo orbits, and no previous studies have accomplished it yet. To make it possible, we propose the sequential orbit design method, where relatively short-term orbits considering time-varying attitude of solar sails are sequentially designed such that they can smoothly connected to the previous one. Simulation results indicate that it can be applied to at least around two-year synodic resonant halo orbits. In addition, we propose the station-keeping strategy to stay near the reference orbits under the influence of navigation error and attitude control error. It is formulated using the state transition matrix and its Cauchy-Green tensor such that the unstable component associated to the position and velocity error with respect to the reference orbit is minimized. The simulation results show how the performance of the method changes according to the parameters (e.g. sail area-to-mass ratio, guidance frequency).