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Author: Dr. Yuying Liang
China

Dr. Ming Xu
China
Prof. Shijie Xu
China

POLYGONAL-LIKE PERIODIC ORBIT AND ITS APPLICATION TO A CISLUNAR IN-ORBIT INFRUSTRACTURE

Abstract

Due to the development of space technology, human activities have been expanded into the cislunar space. With a growing amount of supplies transported, it is urgent to found a cislunar in-orbit infrustracture. This paper investigates a family of periodic orbits in the shape of polygon around Earth (called polygonal-like periodic orbit, abbr. PLPO) in circular restricted 3-body problem (abbr. CR3BP), and proposes a new conception of 'parking apron' to erect such cislunar infrustracture. Similarly, the free-return trajectory is essentially disposable cislunar infrastructure visiting Earth and Moon within one week. Besides, a reusable scheme (Casoliva 2008, Xu 2013) was addressed to allocate a spacecraft on certain cycler trajectories; however it requires unreasonably more than two weeks to revisit Earth and Moon regularly. To decrease the revisiting interval, this paper derives the periodicity conditions of PLPOs analytically, and studies the evolvement of PLPOs under lunar perturbation. Different from the traditional elements (a,e,ω,θ) in Keplerian model, the improved elements in syzygy frame are defined. Integrate the Lagrange Planetary Equation on the improved θ to eliminate it. The averaging method utilizes J2 term to design repeating orbits, while the lunar gravity is used in this paper to construct PLPOs. Subsequently, equations parameterized by the averaging a, e and ω are achieved to describe PLPO's periodicity. Considering that Hill's region degenerates as Jacobi integral decreases till the neck region appears around $LL1$ point, it is interesting to investigate the break of KAM tori containing PLPOs. Due to the periodicity, such break occurs only if the apogee locates inside the neck region geometrically. Belbruno (2001) used weak stability boundary associated to resonance motions to illustrate cislunar transfer conditions dynamically. However, Belbruno's results are concluded numerically. Therefore we investigate the relationship between Jacobi integral and the drift angle between successive apogees analytically. Then a Poincaré mapping is utilized to indicate what pair of (a, e) leads to cislunar transfers. So far the semi-analytical critical conditions of cislunar transfer are yielded (parameterized by averaging elements a, e and ω). From an engineering standpoint, PLPOs can act as 'parking apron' for a cislunar in-orbit infrastructure, where a space-station is allowed to stay under critical conditions. Once a tiny maneuver is implemented at the apogee on the far side of the Earth, the space-station is driven away from PLPO thus accomplishes a cislunar transfer. The fuel consumption of launch, station-keeping and maneuver is illustrated for this scheme.