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LOW-ENERGY CISLUNAR AND TRANS-LUNAR TRANSFER TRAJECTORIES FROM THE VIEW OF LIBRATION POINTS

Abstract

Previous researches on lunar transfer in the context of restricted two body problem indicated that the hyperbolic velocity is required by the spacecraft to escape the Earth's gravity field; however, recent researches from the view of restricted circular three body problem (abbr. CR3BP) showed that it is not the necessary condition for lunar transfer. Compared with Hohmann transfer, another type of transfer trajectories with low fuel consumption and long transfer duration are achieved in the context of CR3BP, which is known as low-energy transfer trajectories. The occurrence conditions for low-energy trajectories are presented in this paper for the cislunar transfer transiting LL1 point and the trans-lunar transfer transiting LL2 point.

There exist cislunar and trans-lunar libration points near the Moon, which are referred as the LL1 and LL2 points respectively and can generate the different types of low-energy transfer trajectories from Earth to Moon. The time-dependent analytic model including the gravitational forces of Sun, Earth and Moon is employed to investigate the energy-minimal and practical transfer trajectories, which is referred as spatial bi-circular model (abbr. SBCM). Different from CR3BP, the equivalent gravitational equilibria are defined according to the geometry of instantaneous Hill's boundary due to the gravitational perturbation from Sun. The relationship between the altitudes of periapsis and eccentricities is achieved from the Poincaré mapping for all the lunar captured trajectories, which acts as an initial guess for the whole low-energy trajectories from Earth to Moon.

The minimal energy required by the capturing trajectory to the lunar surface is deduced in SBCM. It is presented that the asymptotical behaviors of invariant manifolds approaching to or from the libration points or Halo orbits are destroyed in the time-inpendent model. The energy-minimal and practical cislunar transfer trajectories are acquired by transiting LL1 point and LL1-Halo orbits respectively; however, the energy-minimal and practical trans-lunar transfer trajectories are obtained by transiting LL2 point and LL2-Halo orbits. For the trans-lunar case, the transfer windows for the trajectories escaped from Earth and captured by Moon are yielded by transiting LL2-Halo orbits, which can be used to generate the whole trajectories.

Furthermore, both of the two different transfer manners are applied to the low-thrust lunar transfer and the impulse-thrust insertion into distant retrograde orbits in the Earth and Moon system.