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DESIGNING CISLUNAR CO-ORBITAL TRANSFER NETWORKS IN THE EARTH-MOON SYSTEM

Abstract

The co-orbital motions have three classical types: tadpole, quasi-satellite, and horseshoe orbits. These orbits exhibit favorable stability and special configuration covering five Lagrange points. Hence, cislunar co-orbital orbits can offer unique value in space situational awareness and navigation missions in the Earth-Moon system. Furthermore, a transfer network connecting the three kinds of cislunar co-orbital orbits could provide logistical support for the spacecraft located on co-orbital orbits, such as the deployment and refueling missions. Since some resonant orbits with a specific resonant ratio can shuttle back and forth among different co-orbital orbits in the Earth-Moon rotating system, in this paper, we propose an innovative approach based on resonant orbits to designing co-orbital transfer networks.

For the cislunar resonant orbit with a period ratio $k : k_p$ between the spacecraft and the Moon, we investigate how $k : k_p$ influences the spatial configuration and the cycle of the transfer network. A preliminary study reveals that the spatial configuration of prograde resonant orbits is determined by the parameter k, while the cycle of the co-orbital transfer network is determined by the parameter kp. Furthermore, we derive the relationship between the resonance ratio $k : k_p$ and the fuel consumption of the co-orbital transfer network to insert co-orbital orbits. Generally speaking, if the resonance ratio $k : k_p$ is closer to the value of $1 : 1$, the fuel consumption required is smaller. According to the above analysis, the overall performance of cislunar resonant orbits for co-orbital transfer networks is obtained and evaluated. Then, taking the quick traversal and fuel-saving requirement into consideration, the Pareto optimal solution is picked from the above solutions.

Finally, we study the transfer design from the low Earth orbit to co-orbital transfer networks. Two design methods based on the patched-conic approach and stable manifolds of cislunar resonant orbits are proposed, respectively. Those transfer orbits are further extended to the ephemeris model through multiple shooting methods. The results of this research can be applied to the space situational awareness and navigation system in the Earth-Moon system.