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ARTIFICIAL FROZEN ORBITS AROUND MERCURY

Abstract

Elements of orbits around Mercury are influenced by the strong elliptic three-body perturbation, especially for orbits at high eccentricity, the periapsis altitude changes dramatically. Frozen orbits whose mean eccentricity and argument of perigee remain constants are obviously a good choice, but the forming conditions are too harsh to meet practical needs. This situation brings big challenges to the topographic mapping or other Mercury missions.

To deal with the problem, a continuous control method that combines analytical theory and parameter optimization is proposed to form an artificial frozen orbit. The artificial frozen orbits around Mercury are investigated on the basis of double averaged Hamiltonian, of which the second and third zonal harmonics and elliptic three-body perturbation are considered. In this paper, coefficients of perturbations which satisfy the conditions of frozen orbits are involved as control parameters, and the relevant artificial perturbations are compensated by the control strategy. So probes around Mercury can be kept on frozen orbit under the influence of continuous control force. Then we derive the constraint equations for each case of frozen orbits, and complex method that is efficient in constrained optimization is used to search for the energy optimized artificial frozen orbits. The choosing of optimal parameters, the objective function setting and the issue of fuel consumption are also discussed in the study.

Three groups of high inclination orbit examples with large ranges of semi-major axis and eccentricity are given. The result shows that this kind of control method can effectively maintain the eccentricity and argument of perigee frozen, so the mean periapsis altitude and periapsis latitude can be kept unchanged. Evolution curves of optimal control parameters are given for each group of examples. Through the variation of these curves, it can be seen that the fuel consumption is relatively low for the high inclination orbits at small semi-major axis or high eccentricity, and the control force of a large number of artificial frozen orbits is in the output range of low-thrust engine. The continuous control method of artificial frozen orbits proposed in this paper can also be further applied for explorations of other celestial bodies.