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A NEW DESCRIPTION OF PLANET-TO-PLANET TRANSFER IN ALTERNATING ROTATING COORDINATE WITH APPLICATIONS

Abstract

It recently attracts a growing interest to use the electric propulsion system in deep space exploration missions such as Japanese Hayabusa mission since fuel efficiency of this system is high due to its high Isp. The design of trajectories using electric propulsion system is, however, more difficult than using chemical propulsion system, because the electric propulsion system always runs and the impulse approximation of thrusts can not be applied. Recent studies show that the low-energy trajectory can be obtained when the trajectory passes through the troughs of Jacobi integrals in three-body problems. That is, this trajectory is descripted as a combination of two three-body problems of Sun-departure planet-spacecraft system and Sun-target planet-spacecraft system. These combined trajectories in three-body problems, however, are described in different coordinates so that this low-energy trajectory designing becomes complicated.

Then this paper proposes a new coordinate which include these two coordinates for a new method of designing trajectories. In this coordinate, these two Jacobi integrals can be drawn in one coordinate, and the combination of two three-body problems becomes much simple. This new coordinate is rotational coordinate whose angular velocity is defined as $\omega = \sqrt{\mu/r^3}$, where r is the magnitude of position vector of spacecraft. By this definition, the coordinate becomes Sun-departure planet fixed coordinate when spacecraft leaves the departure planet and becomes Sun-target planet fixed coordinate when spacecraft approaches the target planet. In this coordinate, therefore, the planning of low-energy trajectory is simplified to joining two troughs of Jacobi integrals with a line.

By using this coordinate, a new method of designing trajectories can be proposed. In this method, the shape of trajectories, such as straight line or cosine curve, is given artificially at first. Secondly, by substituting this shape function for the equation of motion, the time history of thrust is derived. The merit of this method is that it becomes possible to obtain trajectories by hand calculation, that is, it is unnecessary to use complicated numerical calculation such as DCNLP. The trajectories designed by this method are not optimized but are strong candidates in real flight when the shape functions are well defined.