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OPTIMAL ELLIPTIC ORBITAL RENDEZVOUS WITH CONTINUOUS RADIAL THRUST ON THE CHASER

Abstract

Low-thrust technique is an important approach to accomplish orbital transfer and rendezvous missions. There exist many methods for the minimum-fuel or minimum-time low-thrust orbital transfer and rendezvous. In most previous literatures for the optimal rendezvous problem, the thrust vector is aligned with the target's Local-Vertical Local-Horizontal (LVLH) frame. Moreover, as a special low-thrust case, the continuous radial thrust has also been widely studied. However, the current researches of the radial thrust mainly focus on the orbital characteristics and the spacecraft escape condition. The orbital rendezvous problem with the radial thrust has not been studied. Since the thrust is imposed on the chaser, thus the thrust vector should be aligned with the chaser's LVLH frame, and the thrust is only in the radial direction. This paper studies the optimal control problem for the fixed-time elliptic orbital rendezvous using continuous radial thrust on the chaser.

By using relative direction cosine matrix, the relative motion equations in the target's LVLH frame can be obtained with the thrust vector in the chaser's LVLH frame. Because the direction cosine matrix is related to the system state variables, the resulting relative motion equations are nonlinear, and then the classical Riccati method is not suitable to solve this optimal control problem. A new technique based on the Hamilton-Jacobi theory and the generating function is proposed. Firstly, the nonlinear optimal rendezvous problem is transformed into a two point boundary value problem (TPBVP) by utilizing the Pontryagin's principle. Secondly, according to the theory of the Hamiltonian dynamics, the problem focuses on solving the generating function by using the canonical transformation and the Hamilton-Jacobi theory. Then, by assuming a proper form for the generating function, we can derivate the differential equations and the initial condition which the generating function should satisfy. Finally, we can get the initial values of the adjoints by integrating the generating function, and then the solution of the optimal control problem is obtained.

This method does not need an initial estimate of the adjoint variables, and the generating functions are only dependent on the transfer time and the state equation of the system. For different boundary conditions, we need not recalculate the generating function, and the initial values of the adjoints can be obtained through the matrix operations. The numerical simulation result shows that this method can be effectively used for the optimal rendezvous problem on elliptic orbits using continuous radial thrust.