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ORBITAL TRANSFER PERFORMANCE ANALYSIS FOR MOMENTUM EXCHANGE TETHER BASED SPACECRAFT SYSTEM

Abstract

Momentum exchange tether (MET) technology provides a feasible and effective way to enable orbit transfer with little or no propellant consumption. According to the Moon Mars Orbiting Spinning Tether Transport System proposed by Tethers Unlimited, Inc., such a MET based spacecraft system in general consists of a control station with ballast, a tether and a grapple mechanism. Considering the system initially keeps spinning and motions in an elliptical orbit while the target payload flies in a lower orbit, the spinning tether is oriented timely and vertically below the control station and swings backwards when the system reaches the perigee, then the grapple mechanism will rendezvous with and acquire the target payload. Half a rotation later, the tether can release and toss the payload into a higher energy orbit. The so-called momentum exchange process thus transfers some of the initial orbital energy and momentum of the transportation system to the target payload. Due to fuel efficiency and ease of use, the MET based orbit transfer technology has become a research focus in recent years.

The present paper focuses on the systematical analysis of the orbit transfer performance for the MET based spacecraft system. To do so, based on the Moon Mars Orbiting Spinning Tether Transport System Scheme, the rigorous mathematical derivation of the momentum exchange process is developed and therefore related mission parameters can be expressed in analytical forms. Especially, the analytical expression of the velocity increment of the payload, the vital index representing the orbit transfer performance, indicates that the value is mainly affected by the mass ratio and the initial relative orbital velocity at perigee. Next, for practical MET based orbit transfer missions with given conditions involving tether length, system mass and payload mass, a complete and systematical computation algorithm is proposed based on the derived equations to determine the required system parameters, including the ballast mass, the initial orbit parameters, the spinning velocity of the tether and the tether mass, to meet with the required GTO orbit transfer performance. The algorithm is of great importance to the determination of the system scheme in applications. Finally, given multiple system conditions, the proposed algorithm is utilized to assist the determination of various system schemes by which the orbit transfer performance of the MET based spacecraft is further investigated via comparisons. Meanwhile, the paper concludes the applicability analysis and mission proposals for the MET based orbit transfer spacecraft system.