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POWERED SWING-BY USING TETHER CUTTING

Abstract

The swing-by maneuver is known as a method to change the velocity of a spacecraft by using the gravity force of the celestial body. The powered swing-by has been proposed and researched to enhance the velocity change during the swing-by maneuver, e.g. Prado (1996). The research reports that applying an impulse maneuver at periapsis maximizes the additional effect to the swing-by. However, such impulsive force requires additional propellant. On the other hand, Williams et al. (2003) researched to use a tether cutting maneuver for a planetary capture technique. This current paper studies another way of the powered swing-by using tether cutting, which does not require additional propellant consumption.

A Tethered-satellite is composed of a mother satellite, a subsatellite and a tether connecting two satellites. In a swing-by trajectory, a gravity gradient force varies according to the position of the tethered-satellite, and consequently its attitude motion is induced; the tethered-satellite starts to liberate and rotate. Cutting the tether during the tethered-satellites' rotation can add the rotational energy into the orbital energy.

In this research, since the gravity gradient effect on orbital motion is small, the orbit can be considered a hyperbolic orbit. Assuming that the tether length is constant, Eq.(1) describes the equation of the attitude motion of a tethered-satellite within the SOI (sphere of influence) of the secondary body.

$$\theta'' = \frac{1}{1 + e \cos \alpha} \left\{ 2e(\theta' + 1) \sin \alpha - \frac{3}{2} \sin 2\theta \right\} \quad (1)$$

where e is an orbit eccentricity, α is a true anomaly, θ is an attitude angle and l is tether length. The prime means the derivative with α .

The mother satellite and subsatellite can obtain not only the velocity change but the position change by the tether cutting; they are denoted as $\Delta \mathbf{v}$ and $\Delta \mathbf{r}$, and described in Eqs. (2) and (3), respectively.

$$\Delta \mathbf{v} = -l_1(\dot{\alpha} + \dot{\theta}) \begin{bmatrix} -\sin(\alpha + \theta) \\ \cos(\alpha + \theta) \end{bmatrix} \quad (2)$$

$$\Delta \mathbf{r} = -l_1 \begin{bmatrix} \cos(\alpha + \theta) \\ \sin(\alpha + \theta) \end{bmatrix} \quad (3)$$

where l_1 is a distance between the center of gravity of the tethered-satellite and the mother satellite. Since α and θ are functions of time, $\Delta \mathbf{v}$ and $\Delta \mathbf{r}$ are also functions of time. This means that changing the tether cutting point can maximize the velocity change in this proposed powered swing-by maneuver. Furthermore, the optimum cutting point depends on the attitude and angular velocity when the tethered satellite enters the SOI. We propose a systematic design procedure to obtain the desired velocity change by optimizing the cutting point, the initial attitude and the initial angular velocity of the tethered satellites.