Paper ID: 33683
student

14th IAA SYMPOSIUM ON VISIONS AND STRATEGIES FOR THE FUTURE (D4)
Space Elevator and Tethers (3)

Author: Mr. Tsubasa Yamasaki
Kyushu University, Japan, tsubasa@aero.kyushu-u.ac.jp

Dr. Mai Bando
Kyushu University, Japan, mbando@aero.kyushu-u.ac.jp
Dr. Shinji Hokamoto
Kyushu University, Japan, hokamoto@aero.kyushu-u.ac.jp

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.

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

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.

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

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

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.