Paper ID: 34096
oral
student

ASTRODYNAMICS SYMPOSIUM (C1)
Attitude Dynamics (2) (9)

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ORBIT-ATTITUDE COUPLED MOTION AROUND SMALL BODIES: SUN-SYNCHRONOUS ORBITS WITH SUN-TRACKING ATTITUDE MOTION

Abstract

Rendezvous missions to small bodies, such as asteroids and comets, have been of interest in recent years. The motion of a spacecraft in the proximity of a small body is strongly perturbed mainly because of the irregular shape of the small body and the solar radiation pressure (SRP). In order to understand this unique environment, orbital dynamics and attitude dynamics around small bodies have been analyzed in many previous studies. In those analyses, the orbital motion and the attitude motion of a spacecraft were analyzed separately, and dynamic interaction between these motions has not been revealed. Moreover, the past research on attitude dynamics focused on the attitude of a spacecraft with respect to a small body, although the attitude with respect to the Sun is often the information of interest for solar power generation and thermal design. This research, therefore, investigates natural motion in orbit-attitude coupled system which involves both a Sun-synchronous orbit and Sun-tracking attitude motion. Sun-synchronous orbits, which are also called as frozen orbits, are periodic orbits in the Sun-centered rotating frame. On the other hand, Sun-tracking attitude motion is the motion that a spacecraft keeps tracking the Sun with small oscillation. This orbit-attitude motion enables spacecraft to maintain its orbital geometry and attitude with respect to the Sun, ideally with no active control. Thus, the proposed method can reduce the usage of orbit and attitude control system, such as thrusters and reaction wheels, which results in reducing the weight and prolonging the mission life time of a spacecraft. This paper consists of two parts. First, the orbital motion and the attitude motion are analyzed independently, which are modeled as Lagrange planetary equations and linearized Euler equations, respectively. As a result, analytical solutions of Sun-synchronous orbits and Sun-tracking attitude motion are successfully obtained. Next, orbital motion and attitude motion are propagated simultaneously by numerical integration based on orbit-attitude coupled equations of motion. It is then demonstrated that the analytical solutions can be valid approximation of the numerical solution. This research clarifies that Sun-synchronous orbits with Sun-tracking attitude motion are feasible for small-body missions and exhibit unique dynamic characteristics.