Orbit-Attitude Coupled Dynamics of Solar Sail Spacecraft around Small Bodies

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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 significantly perturbed primarily due to the irregular shape of the small body and solar radiation pressure. In such a strongly perturbed environment, the coupling effect of the orbital and attitude motion has a significant effect that cannot be neglected. In addition, when the exposed surface of a spacecraft is deformed, the effect of solar radiation pressure completely differs from that of a spacecraft that has an ideal flat surface. In particular, this deformation effect is dominant for a solar sail spacecraft having a huge and flexible membrane.

However, natural orbit-attitude coupled dynamics of solar sail spacecraft around small bodies that are stationary in both the orbital and attitude motions have yet to be observed. The present study therefore investigates the natural coupled motion of solar sail spacecraft that involves both a Sun-synchronous orbit (Fig. 1) and a Sun-tracking attitude motion (Fig. 2). This orbit-attitude coupled motion enables a spacecraft to maintain its orbital geometry and attitude state with respect to the Sun without requiring active control. Thus, the proposed method can reduce the use of orbit and attitude control systems, which reduces the weight of a spacecraft and prolongs the life time of the mission.

The present study investigates the theory behind achieving Sun-synchronous orbits with Sun-tracking attitude motion for a solar sail spacecraft. In addition, several simulations are performed, which assume a Jovian Trojan asteroid exploration mission with solar sail spacecraft (which is scheduled to be launched by JAXA in the early 2020s). It is thereby demonstrated that this novel orbit-attitude coupled motion is feasible for real missions.

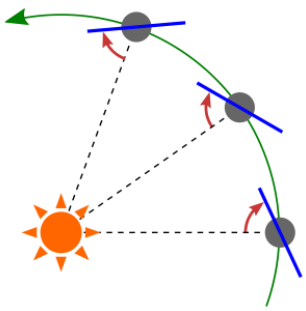

Fig. 1. Sun-synchronous orbit

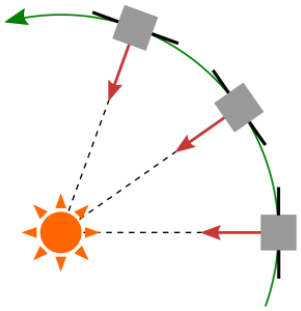

Fig. 2. Sun-tracking attitude motion