Asteroid De-spin and Deflection Strategy Using a Solar-sail Spacecraft with Reflectivity Control Devices

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ABSTRACT

In order to prevent a catastrophic asteroid collision with the earth, past research has proposed various asteroid deflection strategies, including nuclear/kinetic impactor, spacecraft propulsion, mass driver, and laser ablation. One of the complications in such a mission stems from the spinning motion of an asteroid. Since asteroids have irregular shapes and their own unique spin axis directions, the spinning motion of an asteroid prevents a precise and effective deflection operation. For this reason, de-spinning of a target asteroid provides benefits for asteroid impact avoidance. Asteroid de-spin can be achieved by applying the asteroid deflection methods described above to reduce the angular momentum of an asteroid. Another possible approach for asteroid de-spin is to control the spin rate of an asteroid by capturing them with a net or a tether. Although these de-spin strategies have been analyzed in past studies, these methods might require enormous resources to compensate for the large angular momentum of an asteroid. In addition, the performance of de-spinning an asteroid is significantly dependent on the shape and property of the asteroid.

To solve these problems, this paper proposes a novel asteroid de-spin strategy using a solar-sail spacecraft with reflectivity control devices (RCDs) on its membrane. The basic strategy is to attach a solar sail to an asteroid and generate solar radiation pressure (SRP) torque induced by the difference in the reflectivity of the RCDs, as shown in Fig.1 (left). The RCDs are powered by solar cells mounted on the membrane, and thus, the proposed de-spin mechanism does not require any fuel or
mechanical devices, leading to a low-cost and reliable operation. Moreover, because this method leverages the SRP force acting on a sail membrane, it is less dependent on the shape and surface property of an asteroid. Both the solar sail deployment technology and the attitude control maneuver via RCDs have been demonstrated in past space missions, and therefore, the proposed strategy is promising for real missions.

As a consequence of the asteroid de-spin, the attitude of the asteroid is under control of the attached solar sail. This capability can ensure effective asteroid deflection/disruption operations proposed in past studies. Besides, the trajectory of the asteroid can also be deflected owing to the SRP acceleration constantly acting on the membrane, as shown in Fig. 1 (right). The asteroid deflection using a solar sail enables a safe and fuel-free operation. It is also advantageous in that the motion of an asteroid is easy to predict because this method is less dependent on the shape of an asteroid and does not involve an impact event. Moreover, the deflection performance of the proposed method can be enhanced by controlling the Yarkovsky effect.

This paper constructs the dynamical model of the proposed asteroid de-spin and deflection mechanism using a solar sail with RCDs. Based on this model, the performance of this novel method is analyzed with analytical and numerical simulations. It is then demonstrated that the proposed strategy would be useful for collision avoidance operation of potentially hazardous asteroids.

Fig. 1. Asteroid de-spin (left) and asteroid deflection (right) using a solar sail

Comments:

We would prefer to make an oral presentation.