Attitude Control of Hayabusa2 by Solar Radiation Pressure in One Wheel Control Mode

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ABSTRACT

The asteroid explorer Hayabusa2 was launched by Japan Aerospace Exploration Agency (JAXA) on December 3, 2014. The main mission of the probe is to sample pieces of asteroid, and bring it back to the Earth in order to do more advanced analysis on the ground. Hayabusa2 is planned to arrive at the target asteroid in 2018, and return to the Earth in 2020. After the initial checkout period for 4 months after launch, Hayabusa2 is now in “cruising phase” waiting for the Earth Swing-by planned in December 2015.

Hayabusa2 has 4 reaction wheels aligned to X, Y, Z and Z body-fixed axis for attitude control, meaning it has 2 reaction wheels aligned Z-axis. During the part of the cruising phase, one set of reaction wheels aligned X,Y,Z-axis are stopped and the remaining one Z-axis wheel is only used for attitude control, in order to save the operating life of reaction wheels for “mission phase” in proximity of the asteroid.

In the one wheel control mode, the angular momentum direction is slowly moved in the inertial space (generally called precession) due to the solar radiation torque. This attitude motion caused by the balance of the total angular momentum and solar radiation pressure is known to trace the Sun direction automatically with ellipsoidal and spiral motion around Sun direction. In Hayabusa and IKAROS mission, this attitude motion was actually observed in the flight operation, and we have accumulated the experience and knowledge of the attitude dynamics under the solar radiation pressure. Based on this knowledge in the past, the attitude dynamics model for Hayabusa2 mission had been developed before the launch [1].

According to the newly developed attitude dynamics model of Hayabusa2, the precession trajectory is the almost ellipsoid around the attitude equilibrium point, and this equilibrium point is determined mainly by the phase angle around Z-axis of the body with respect to the Sun direction. The geometry between the spacecraft’s center of mass and the center of the photon pressure dominantly affect this phenomenon. In Hayabusa2 case, both of the center of mass and the center of photon pressure shift from the geometric center of spacecraft to the other directions. The relative geometry of these two centers produces the bias of the solar radiation torque even in the case that the body Z-axis points to the Sun direction. As a result of the bias of the solar radiation torque, the equilibrium point is changed due to the phase angle around the body Z-axis illustrated in Fig. 1. This principle indicates that the precession trajectory can be controlled only by switching the equilibrium point direction by changing the phase angle.

In the actual operation of Hayabusa2, the spacecraft already experience the one wheel control mode. The attitude motion in this mode is almost corresponds to the expected motion based on the dynamics model developed before the launch. The precession trajectory is ellipsoid with small spiral around the equilibrium point, thus the attitude dynamics model is verified by the actual flight data. In the one wheel operation, the Sun-aspect angle is restricted within a certain limit angle in terms of the thermal condition of the spacecraft. Because the precession radius is determined by the initial attitude and the equilibrium point, the Sun-aspect

angle is about to exceed the limit angle due to the precession without change of the equilibrium point. Therefore, at this operation, we execute the attitude maneuver around Z-axis to change the equilibrium point in order to reduce the Sun-aspect angle, and succeeded. After that, we execute the maneuver around Z-axis again to change the equilibrium point to close point in order to make a small precession trajectory. Figure 2 shows the actual flight results in this operation. It is seen that the each trajectory of the precession is actually changed after 2 maneuvers around body Z-axis.

Here we emphasize that the fuel of the chemical thrusters are not used in series of this operation, because the attitude maneuver around the Z-axis is executed only by the reaction wheel. Even unloading for reaction wheel of Z-axis was not needed. By utilizing the solar radiation torque, we realize the fuel-free operation for few weeks with tracking Sun direction automatically.

This paper presents the concept and theorem of the attitude keeping and maneuvers by utilizing precession control under the solar radiation pressure, and introduce the other flight results of Hayabusa2 actual operation.

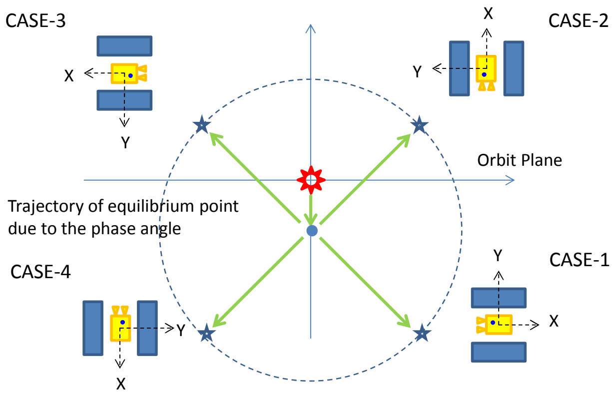

Fig.1. Concept of the change of the equilibrium point due to the difference of phase angle around body Z-axis

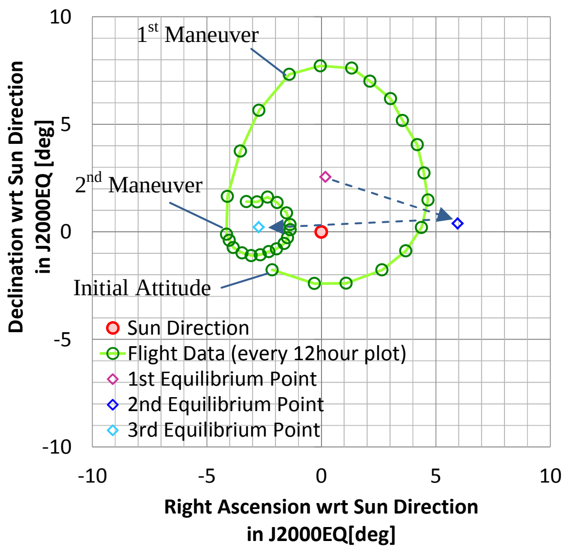

Fig.2. Flight results of the precession trajectory by switching the equilibrium point of the precession under the solar radiation torque

[1] *Kosuke Akatsuka, "Nonholonomic Behaviour of Biased-Momentum Asymmetric Spacecraft in Sun-Tracking Motion Using Solar Radiation Pressure," International Symposium on Space Technology and Science 2015, Kobe, Japan, July 4-10, 2015, Paper 2015-s-06-d.*