ATTITUDE MODELING OF BIASED-MOMENTUM 3-AXIS STABILIZED SPACECRAFT HAYABUSA2 IN SUN-TRACKING MOTION

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ABSTRACT

The goal of this paper is to apply sun-tracking motion to biased-momentum and 3-axis stabilized spacecraft, Hayabusa2. In this paper, dynamical model of Hayabusa2 in sun-tracking motion is established and it is represented in 9 parameters. Numerical simulation using such model is compared with flight data.

In interplanetary missions, solar radiation pressure (SRP) is a major disturbance to a spacecraft. Some missions, however, utilize this SRP disturbance to stabilize the spacecraft attitude. Two typical examples are; the emergency operation of Hayabusa and the attitude control demonstration of IKAROS.

In these missions, it is confirmed that angular momentum vector of a spacecraft can track the sun direction automatically with properly settings; this motion is called sun-tracking motion. Working only one reaction wheel along the axis that needs to be pointing in the sun direction, the spacecraft will roughly point towards this direction. By actively using SRP, this improved attitude control system is realized and efficiently increases redundancy and saves spacecraft fuel consumption. In contrast with the fact that the past missions used this technique exclusively to spin-stabilized spacecraft, this paper attempts to extend this sun-tracking technique to a biased-momentum 3-axis stabilized spacecraft, Hayabsua2.

SRP torque working on Hayabusa2 is approximately described by 9 parameters and analytical attitude model is established by using them. Attitude motion is mainly depending on 6 parameters and inner angular momentum is mainly decided by the other 3 parameters. Analytical attitude motion is combination phenomenon of precession, torque-induced main attitude motion, and nutation, torque-free circular motion around the angular momentum vector. Interestingly, the equilibrium direction of precession is not exactly the sun direction and the history of precession draws elliptic circle. The equilibrium direction has certain offset from the sun direction and the offset direction is also depending on rotational angle around body-Z axis. The radius of elliptic circle also changes convergently or divergently depending on attitude conditions. These new phenomenon is unique to 3-axis stabilized spacecraft and not observed in spinning spacecraft.

Using a FEM-based detailed spacecraft surface optical property model, 9 parameters are obtained. This FEM model takes into account the complex shape of spacecraft, optical constants of each component, and the effect of shadowing. It also becomes possible to estimate attitude motion by using such parameters. In the numerical simulation it is used the Euler angle expression to represent the attitude and a 4^{th} order Runge-Kutta method to integrate the equation of motion. The simulations are developed in C++ language.

Numerical simulation results which use 9 parameters obtained from FEM model are compared with the real spacecraft behavior for specific time. The results well agree with the flight data, so the analytical result of sun-tracking motion is proven and this newly derived model is sufficiently effective for future orbiting phase of Hayabusa2.

Attitude motion of a biased-momentum 3-axis stabilized spacecraft is established analytically in this study and it is proven in comparison with flight data. This analytical model is not restricted to Hayabusa2 but is applicable for various 3-axis stabilized spacecraft. This control method mechanism is also simple and does not need any new algorithm, so sun-tracking motion can be applied to various interplanetary missions in future.