Estimation of Shape and Optical Parameters of Spinning Solar Sail Equipped with Reflectivity Control Devices

Akihiro Ishikawa[1*]
[1]*The University of Tokyo, Japan*
ishikawa@space.t.u-tokyo.ac.jp

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Solar sails, which are accelerated by solar radiation pressure (SRP), do not require any fuel for propulsion. In particular, spin-type solar sails are considered to have many advantages in terms of reducing structure's weight and increasing size of their membranes, but require much fuel consumption for changing their attitude because of large angular momentum of the spinning. As a solution for this disadvantage, Reflectivity Control Device (RCD), which can electrically generate torque, has been proposed. By controlling attitude of spinning solar sail via this RCD only, a complete fuel-free spacecraft system will be achieved. It has been revealed on orbit that the attitude motion of spinning solar sail highly depends on SRP effects caused by slight deformation and variation of the optical properties of the sail surface [1]. As an example, Fig. 1 shows that slight differences of deformation (expressed by ξ in Fig. 2) cause huge differences of attitude motion. Importantly, these parameters of shape and optical properties are not determined until sail deployment is completed on orbit. Therefore, the parameters must be estimated from flight data promptly and precisely in order to predict and control the attitude. However, little attention has been paid to the prompt and precise estimation of the parameters.

The present paper proposes a method of the shape and optical parameters estimation based on Generalized Spinning Sail Model (GSSM) [1] and Extended Generalized Spinning Sail Model (Extended GSSM) [2]. The GSSM expresses the SRP effects by only three parameters representing shape and optical properties and the Extended GSSM adds seven parameters to those of the GSSM in order to include the effect of torque generated by the RCD. The purpose of this study is to estimate these ten parameters promptly and precisely for predicting and controlling the attitude. By taking into account nutation motion of spin axis, which is neglected in the GSSM and the Extended GSSM, the proposal method can achieve the prompt and precise estimation.

In order to verify the proposal method, this study has also devoted effort to building high-fidelity simulator of attitude motion of spinning solar sail equipped with the RCD based on Generalized Sail Model (GSM) [3]. The GSM provides a precise SRP torque exerted on an arbitrary-shaped sail, whereas it needs twenty-seven parameters for calculating the SRP torque, so it is unsuitable for estimation from flight data. Therefore, this study uses the GSM only for building the attitude simulator which represents the actual attitude motion on orbit and provides data for the estimation of the GSSM and the Extended GSSM parameters.

This study will contribute to building precise guidance, navigation, and control systems of the spinning solar sails.

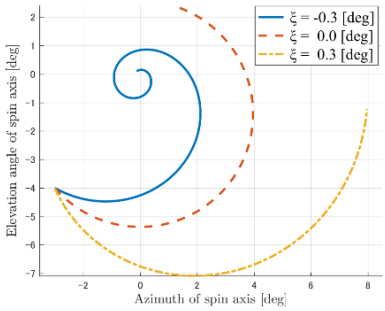

Fig. 1. Difference of attitude motion

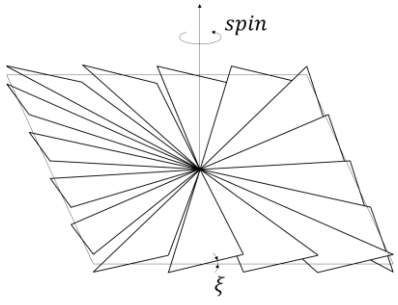

Fig. 2. Deformation model of spinning solar sail

References

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