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EVALUATION OF SHAPE AND SOLAR RADIATION TORQUE OF BOOM EXTENDABLE MEMBRANE STRUCTURE WITH DEVICES

Abstract

We are developing HELIOS, which is one of the components of Rapid Innovative Payload Demonstration Satellite – 3(RAISE-3). HELIOS is a 1m squared extendable membrane structure with solar cells, an interferometer, and a 5G antenna mounted on the membrane surface. Such a membrane structure with devices will lead to better functionality of the spacecraft, and various missions will be possible. Generally, an extendable membrane structure can be a boom type or a spin type. Spin type is easy to design and lightweight when the structure is bigger because this type uses centrifugal force to extend and maintain an extended state. On the other hand, boom type requires an extension mechanism, which makes it heavier than the spin type, so it isn't suitable for bigger structure. However, the type can be widely used for small and medium size structures because it is easy to constrain the position of the membrane and restrict the degree of freedom. HELIOS uses boom type.

The problem with devices being attached to the membrane surface is that the membrane shape is easy to change. In the solar sail demonstrator spacecraft IKAROS, launched by JAXA, the membrane surface was unexpectedly deformed by the attached device and the disturbance torque was generated. As a result, the demonstrator made an unexpected motion and required a substantial consumption of fuel to offset this torque. IKAROS was a spin type, but it is necessary to evaluate the shape change and solar pressure torque depending on the device even in the boom type.

In this study, we evaluate the shape and SRP torque of boom extendable membrane structures with devices attached to the membrane surface such as HELIOS. Two evaluation methods are used: prediction of membrane shape by finite element analysis and ground test. In the finite element analysis, we will investigate the shape of a square membrane with a side of 1m with devices in a zero-gravity environment using HELIOS as a theme. In addition, the SRP torque generated by deforming the membrane shape is calculated by numerical analysis. Additionally, ground test to reproduce membrane shape is performed with gravity compensation done by the buoyancy of the aqueous solution that matches the density of the membrane. The validity of the membrane shape deformation is shown by comparing the experimental results and the analytical results, and the shape and SRP torque of the boom extendable membrane structure with the devices are evaluated.