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MATERIALS AND STRUCTURES SYMPOSIUM (C2)
Space Structures II - Development and Verification (Deployable and Dimensionally Stable Structures) (2)

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MODIFIED MULTI-PARTICLE MODEL OF SPACE MEMBRANE STRUCTURES CONSIDERING MECHANICAL CHARACTERISTIC OF CREASES

Abstract

Most of space membrane structures have creases on their membranes. The first solar power sail "IKAROS" launched by Japan Aerospace Exploration Agency (JAXA) in 2010 deployed its folded membrane centrifugally by spinning itself. IKAROS has a cylindrical main body at the center and four trapezoidal membranes called petal around the main body. The petals were folded up into concertinas and wrapped round the main body before the deployment. JAXA is currently developing the next-generation solar power sail which has the same structure as IKAROS and a wider membrane than IKAROS.

The creases on space membrane structures significantly affect the behavior of its membrane. The creases make the bending or compressive stiffness of the membrane larger. IKAROS could not deploy its petals at the same time because the deployment of a specific petal lagged behind that of the other petals significantly. This deployment behavior is called the asymmetric deployment and was observed by some deployment experiments in a vacuum chamber. The asymmetric deployment might affect success and failure of a mission because the asymmetric deployment confuses the attitude of a spacecraft. The creases are considered a cause of the asymmetric deployment but the factor of the asymmetric deployment has not been clarified yet. Furthermore, previous simulation models do not consider the mechanical characteristic of the creases sufficiently and they have not recreated the asymmetric deployment.

Therefore, this work proposes an analysis model of space membrane structures considering mechanical characteristic of creases. This analysis model is modeled by multi-particle method because it is difficult to simulate the dynamic behavior of the membrane by using finite element models due to computational convergent and cost. In the proposed model, the strength of the creases and the bending or compressive stiffness resulting from the creases are simulated by many rotational springs and compressive springs. The spring constants or natural angles are determined by two static experiments under gravity. The proposed model also considers the local buckling on the creases.

The deployment experiments in a vacuum chamber were simulated by the proposed model. The simulations successfully recreate the asymmetric deployment and the proposed model is validated. Furthermore, the simulations clarified that the local buckling on the creases affects the behavior of the membrane and the asymmetric deployment. The proposed model and the knowledge obtained by these simulations contribute many missions using space membrane structures like solar sail missions.