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

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EFFECT OF SHAPE IMBALANCE ON SPINNING MEMBRANE DEPLOYMENT FOR SOLAR SAIL

Abstract

The small solar power sail demonstrator IKAROS developed by JAXA was launched and deployed its large thin membrane successfully in 2010. Through the IKAROS operation, it was found that one of the most critical problems is a shape imbalance in the membrane deployment process. The shape imbalance means a shape change or deflection with regard to the symmetric reference shape. This paper especially considers effect of the membrane shape imbalance on the spinning deployment dynamics of various folding membrane types with high vacuum experiments and numerical simulations.

First, some evaluation factors about the shape imbalance are extracted by reference to the result of IKAROS and the previous on-ground experimental studies. As the types of membrane folding, rotationally skew fold, fan fold and square fold membrane models are selected.

Second, high vacuum experiments are conducted in order to evaluate the shape imbalance on the membrane deployment. For the experiment, each scale-down model corresponding to the three folding membrane types is made. From the experimental results it is observed that the rotationally skew fold membrane model and the fan fold one have the tendency to correct their shape imbalance during the deployment, and the square fold membrane model does not have such function. This is caused by the different timing at which the membrane between tip-masses is tensioned by the centrifugal force during the spinning deployment.

Next, numerical analyses with the multiple particle system model are conducted. With this analytical model, wrinkle effect is not considered because of the high calculation cost. However, compared with the experimental results, it is shown that the simple model is feasibly valid for the deployment dynamics. Then heterogeneous mass distribution of the membrane is also considered in the model in order to reveal the effect of the mass imbalance. As a result, the rotationally skew fold membrane has the lowest robustness of the mass imbalance of the three folding types. Furthermore, the time difference of the membrane releasing is considered in the model and the results show that the fan fold membrane has the lowest robustness of the time difference.

Finally, this paper concludes that the fan fold membrane is the best folding type in respect of the shape imbalance with consideration of the evaluation factors.