ABSTRACT
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Title of Paper

Wrinkles in a Membrane with a Small Thin Film with Different Stiffness under Tension Load: Experiments and Simulations

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Abstract

Solar sails generally require flat thin membranes, but wrinkles actually occur in membranes and cause some problems. For example, in actual operation of the Japanese spinning solar sail spacecraft IKAROS[1] after its sail deployment, the windmill effect was observed. The phenomenon is that the spin rate changes when sunlight collides with the wrinkled and deformed membrane. Because of the windmill effect, its propellant was wasted to maintain the spin rate. This is equal to shorten the mission life of the spinning solar sails. Satou et al. suggested that the propagation of wrinkles throughout the membrane was considered to be induced by curving thin-film solar cells[2]. They also concluded that higher out-of-plane stiffness of the IKAROS membrane than expected can be caused by the increased bending stiffness due to the curving solar cells. Therefore, it is important to design and manage wrinkles in sails, and thin-film solar cells on membranes can have a significant influence on wrinkling and deformation of membrane structures.

In this paper, we measure and simulate wrinkles in a part of an idealized solar power sail membrane with and without a small thin film with different stiffness from the membrane under tension load for prediction of wrinkles in a JAXA's next large spinning solar power sail using thin-film solar cells. This work contributes to understand the effects of a small thin film on wrinkles in a thin membrane. For the ground measurement experiment, apparatus to subject a membrane to a state of tensile is designed and constructed, in order to measure wrinkles using a three-dimensional digital image correlation method with two digital cameras. Geometrically nonlinear finite element analysis is conducted in order to consider a finite element model which is able to simulate wrinkles in membranes with the small thin film simply and effectively. The finite element models of the membrane are based on shell elements. The numerical simulations (Fig.1) are carried out with the general purpose finite element code ABAQUS.

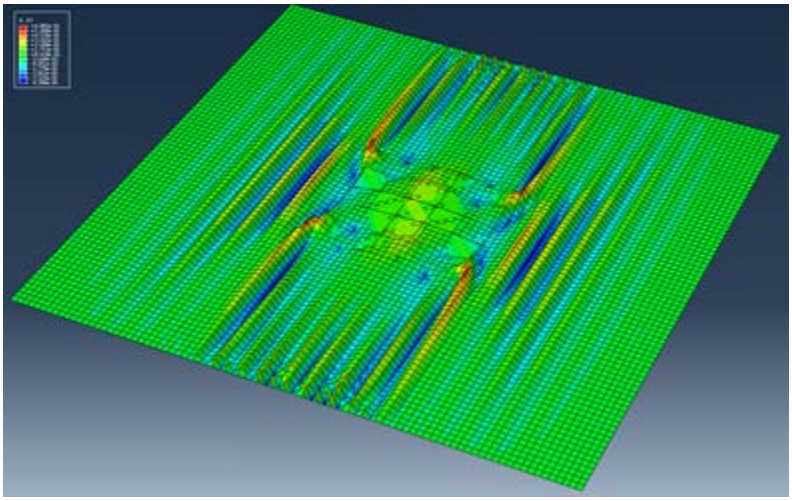

Fig.1 An example of FEM analysis of a membrane with a small thin film with different stiffness

Reference

[1] Osamu Mori; Ryu Funase; et. Al, IKAROS Extended Operation for Advanced Solar Power Sail Mission, Trans. JSASS, Aerospace Technology Japan, 12, ists29, pp.Tk_19-Tk_24, 2014.

[2] Yasutaka Satou; Osamu Mori; Nobukatsu Okuizumi; Yoji Shirasawa; Hiroshi Furuya; Hiraku Sakamoto, Deformation Properties of Solar Sail IKAROS Membrane with Nonlinear Finite Element Analyses, AIAA SciTech2015, Kissimmee, Florida, Jan. 5-9, 2015.