SHEARING-WRINKLING BEHAVIOR OF CREASED RECTANGULAR MEMBRANE

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1 Introduction

Membranes stretched in tension are found in a variety of large gossamer space structures in order to meet the requirements of future space exploration missions, including the JWST shield, solar sails, and space inflatable antenna reflectors. The surface of these membrane structures should be as wrinkle free, and crease free as possible, especially for the solar sails and the inflatable antenna reflectors [1].

The wrinkle is defined as an elastic response of a membrane due to the localized buckling in the compressed areas. It has been well studied by using the membrane method [2,3] and the thin shell method [4-6]. Large membrane structures must be folded for packaging or stowing before launching. These folding processes may create some permanent creases. The crease is defined as an inelastic deformation of the membrane characterized by a sharp cusp. The membrane creasing has not been well studied but the interest is growing[7,8].

In this paper, the wrinkling behavior of a rectangular creased membrane under shearing is analyzed by using the Direct Perturb-Force method[6] to deeply understand the wrinkle-crease interactions. The effects of the crease location on the wrinkling are also analyzed in the end.

2 Wrinkle-Crease Submission Method

The detailed flowchart of our method for wrinkle-crease interaction analysis is shown in Fig.1.

In our flowchart, there are 10 steps where the Direct Perturb-Force technique is the procedures from the STEP_4 to STEP_10 based on the MDC method[6]. Where, the residual stress from unfolding and the effective modulus of creased membrane are given by [7]

$$\sigma_{cy} = \frac{2EI}{R^2bh}\left(1-\cos\alpha_0\right) \qquad (1)$$

$$\frac{1}{E_{cef}} = \frac{1}{E} + \frac{\sqrt{2}-1}{\sqrt{6}}\frac{h}{L}\sqrt{\frac{E}{\sigma_t^3}} \qquad (2)$$

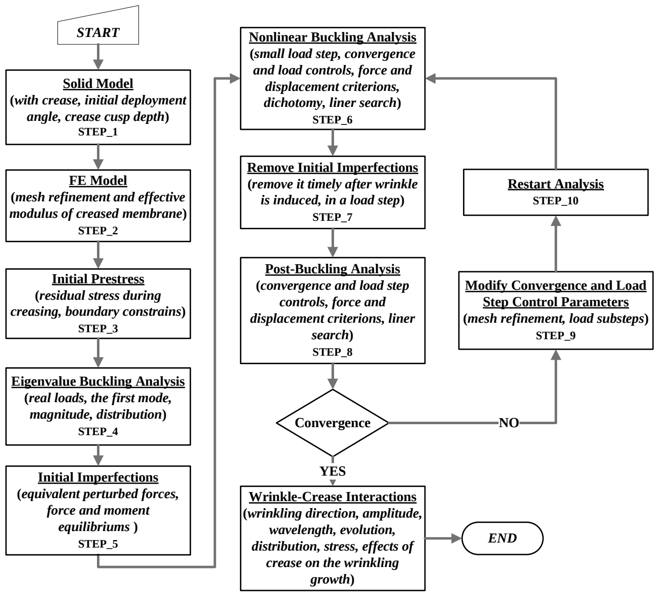

Fig.1 The flowchart of wrinkle-crease interaction analysis

3 Shearing-Wrinkling Simulations

A 0.1m×0.3m (b×L) rectangular Kapton-type HN® membrane with 2.5×10^{-5}m thick (h) is subject to shearing loads. The elastic modulus (E) is 2.5×10^{9}Pa and the Poisson's ratio (v) is 0.34. The yielding occurs at 69×10^{6}Pa, and the ultimate strength is 231×10^{6}Pa. The membrane is modeled by using 1400 ANSYS SHELL181 elements, in which 200 elements is used to model the creased region.

The residual stress from unfolding (σ_{cy}, Eq.1) is 7.63×10^{4}Pa which corresponds to a 45° crease angle (α_0) and a 1×10^{-3}m crease depth (R). The effective modulus of creased membrane (Eq.2) is 1.362×10^{9}Pa. The equivalent perturbed force is 5×10^{-5}N which is seeded in the FE model to induce the micro-level initial imperfection. The wrinkle-crease interaction analysis is performed under 0.001m imperative horizontal displacement in the end. The results are shown as follows.

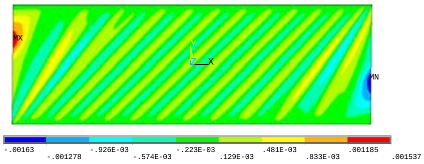

Fig.2 Wrinkling of rectangular membrane under shearing (no crease)

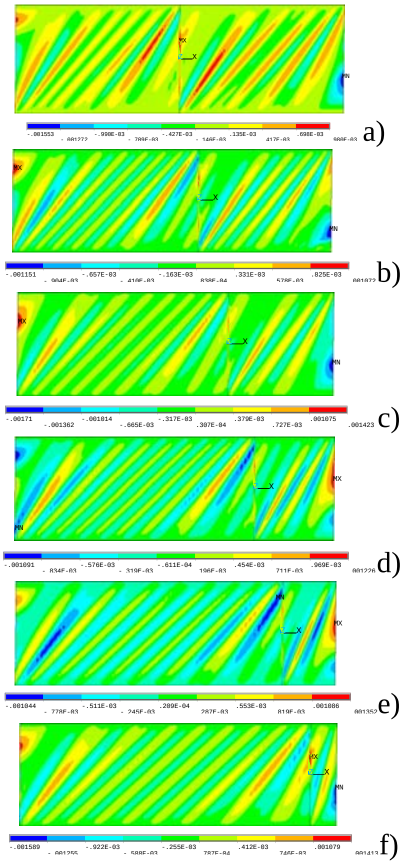

Fig.3 Wrinkle-crease interaction results under different crease locations a). 0mm; b) 25mm; c)50mm; d)75mm; e)100mm; f)125mm away from vertical midline

4 Conclusions

The crease may influence the stress transfer path in the membrane and further change the wrinkling direction, the wavelength, the amplitude and the wrinkling degree. With the crease location increases, the wrinkling angle, the wrinkling amplitude and the degree decrease except the wrinkling wavelength increase as the increasing crease location. In addition, the crease results in the unsymmetrical wrinkling shape. The crease-wrinkle interaction is more complicated than the wrinkling problem. We should avoid the concurrence of the wrinkle and the crease.

For the large space membrane structures with high precision requirement, it is necessary to accurately predict the crease-wrinkling interaction, so as to perform the effective structural design and the wrinkling control.

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