

A vector-form hybrid particle-element method for modeling and nonlinear shell analysis of thin membranes exhibiting wrinkling

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Main Goal

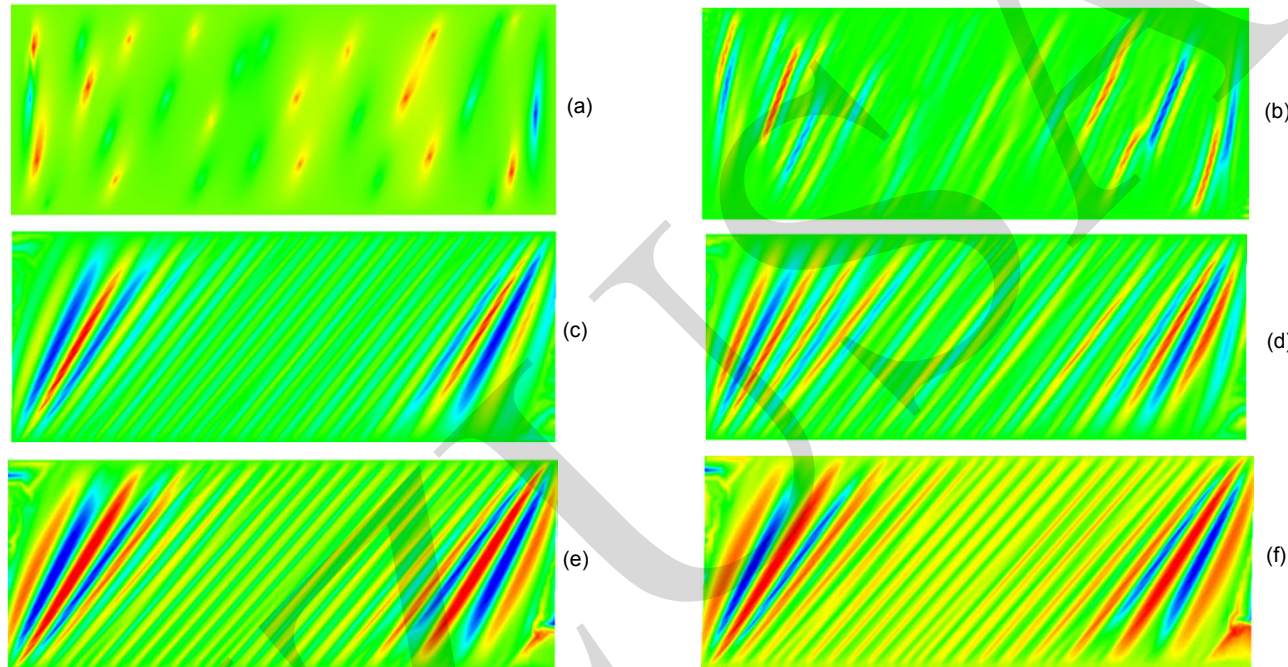
- Propose a recently-developed numerical method-VHPEM for investigating the wrinkling phenomena of flat thin membranes.
- Improve the wrinkling simulation technology based on the bifurcation buckling theory of shells.
- Acquire the deformed geometry of the wrinkled membranes in detail for the structures with high precision requirement of shapes.

Main Approach and Strategies

- Construct a 3-node triangular shell element with the non-zero bending stiffness taken into account on the basis of an appropriate kinematical description of the particles in 3D thin membranes involving large rigid body motion.
- A pseudo bifurcation analysis incorporated into the VHPEM is performed to initiate the out-of-plane wrinkling deformation for the perfect flat membranes are only subjected to in-plane loading.
- To overcome the numerical difficulties associated with wrinkles, a pseudo-dynamic scheme using the explicit time integration is introduced

Computation Models and Results

■ Rectangular thin-film membrane subject to in-plane shear loading

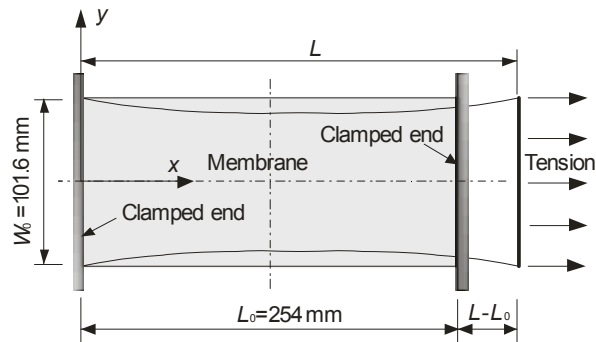


Contour maps of out-of-plane deformation w (mm) for the development of wrinkles under the desired shear displacements δ_x (mm)

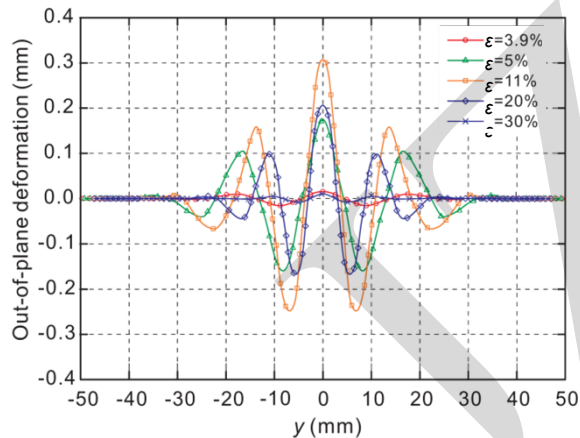
(a) $\delta_x=0.085$ and $\delta_y=0.025$, w (max./min.)=0.063/-0.085; (b) $\delta_x=0.095$ and $\delta_y=0.025$, w (max./min.)=0.078/-0.098; (c) $\delta_x=0.115$ and $\delta_y=0.025$, w (max./min.)=0.102/-0.113; (d) $\delta_x=0.15$ and $\delta_y=0.025$, w (max./min.)=0.374/-0.368; (e) $\delta_x=0.17$ and $\delta_y=0.025$, w (max./min.)=0.441/-0.436; (f) $\delta_x=3.0$ and $\delta_y=0.025$, w (max./min.)=1.190/-1.139

Three Representative Activities

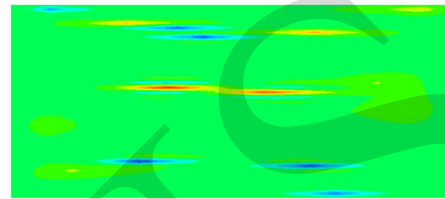
■ Rectangular thin-film membrane loaded in uniaxial tension



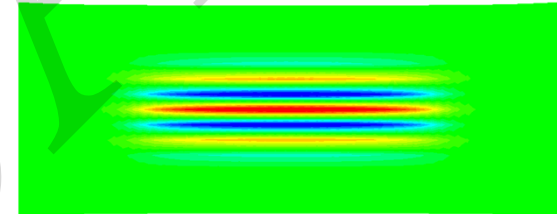
Problem setting of an end-clamped rectangular thin membrane loaded in uniaxial tension



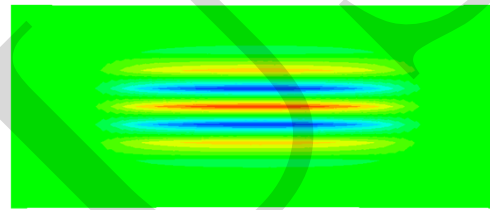
Profiles along the transverse mid-section of the membrane (at $x=127$ mm) at desired strain levels



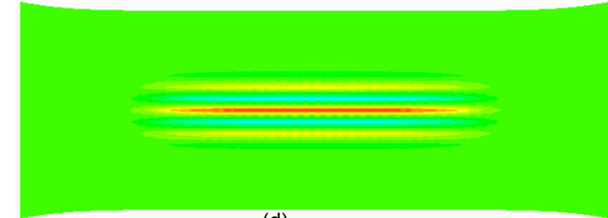
(a)



(c)



(b)



(d)

Contour maps of out-of-plane deformation for the evolution of wrinkles at desired strain levels

(a) $\varepsilon=1.5\%$, w (max./min.)=0.00725/-0.0044; (b) $\varepsilon=3.9\%$, w (max./min.)=0.0155/-0.0143; (c) $\varepsilon=11.0\%$, w (max./min.) =-0.3128/-0.2484; (d) $\varepsilon=30.0\%$, w (max./min.)=0.0105/ -0.0102