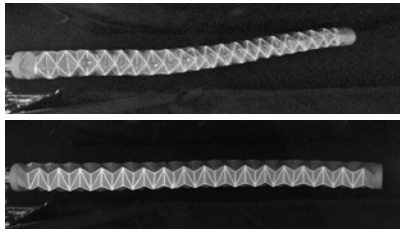
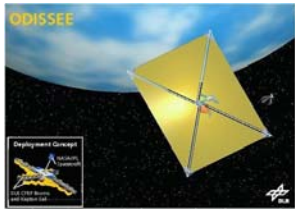


Inflatable Structures

Wrinkle Generation Study using Finite Element Analysis

I Background and Objective

Inflatable Structure Applications (solar sails, trusses, antennas)



Structure properties

- Small mass
- Small volume

General problems

- infinite degrees of freedom
- existence of unstable behavior

Goal: guarantee stable deployment

Guarantee final state



Need to understand structure behavior

Structure is a large and complicated membrane

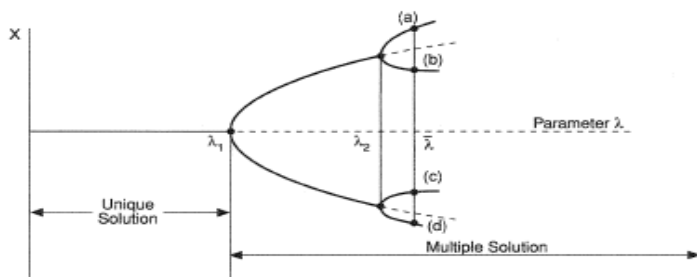


The inflatable structure and membrane structure share key behavior characteristics

II Approach

Bifurcation structure:

Path of connected equilibrium points from the starting state to the final state (structure behavior from start to finish)



Detail structure behavior

- Buckling results in wrinkle generation
- Bifurcation points generate different wrinkle patterns
- As the structure progresses new wrinkles are generated
- Structure ends with many possible configurations
- Some configurations are the same, some are different (unknown relations)

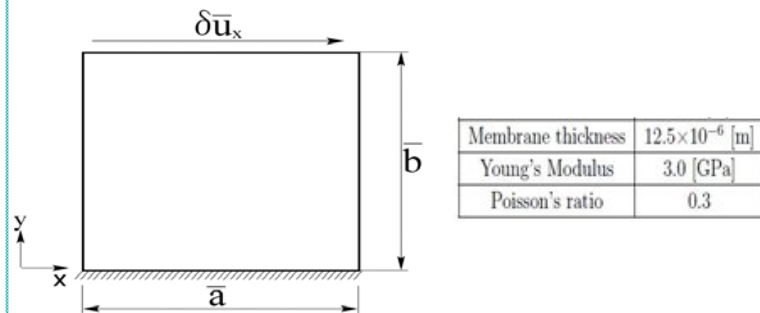
Controlling membrane behavior

- Influence of imperfections
 - removal of bifurcation points (imperfection pushes toward a specific path)
- Path stability and basin
 - dictates the direction in which initial conditions and disturbances take the system

Approaches

1. All paths result in the desired state
 - Modify structure so that all paths that do not lead to the desired state
2. Control path behavior
 - Introduce connections and constraints that limit the membrane and directly specify how it behaves
 - Introduce imperfections to eliminate bifurcations and reduce branching
3. Other approaches

III Finite Element Modeling



Geometry & Boundary condition

- Top and Bottom edges are clamped
- Case I a=0.1 [m], b=0.1 [m], Cyclic boundary at side edges
- Case II a=0.3 [m], b=0.1 [m], Free boundary at side edges

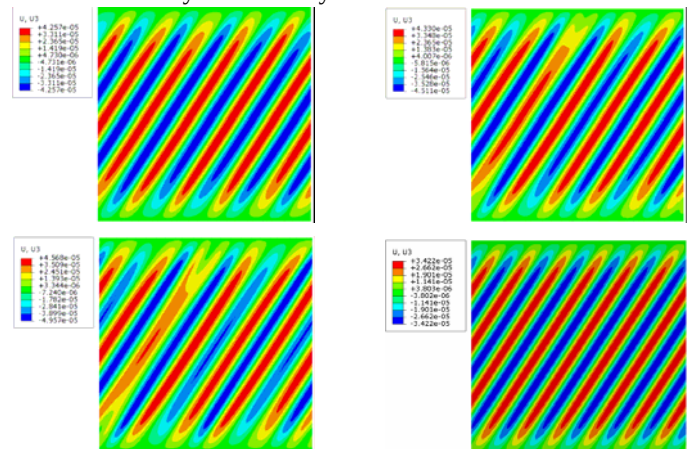
Analysis Procedure

1. Initial Stretch = 30 [μm] in y-direction
2. Increase shear displacement δu_x gradually

IV Numerical Result I

First wrinkle generation mechanism: buckling (bifurcation)

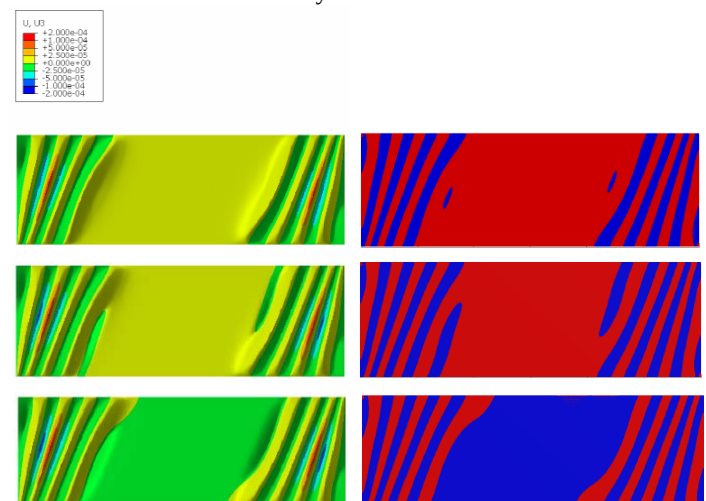
Condition: cyclic boundary membrane



(out-of-plane displacement; first three lead to a bifurcation, fourth is after a bifurcation)

Second wrinkle generation mechanism: buckling (without bifurcation)

Condition: Free boundary membrane



(left: out-of-plane displacement, right: curvature in x-direction)