Universität Stuttgart
Fakultät für Bau- und Umweltingenieurwissenschaften

Xiaomeng Fu

Ponding of membrane structures

Motivation

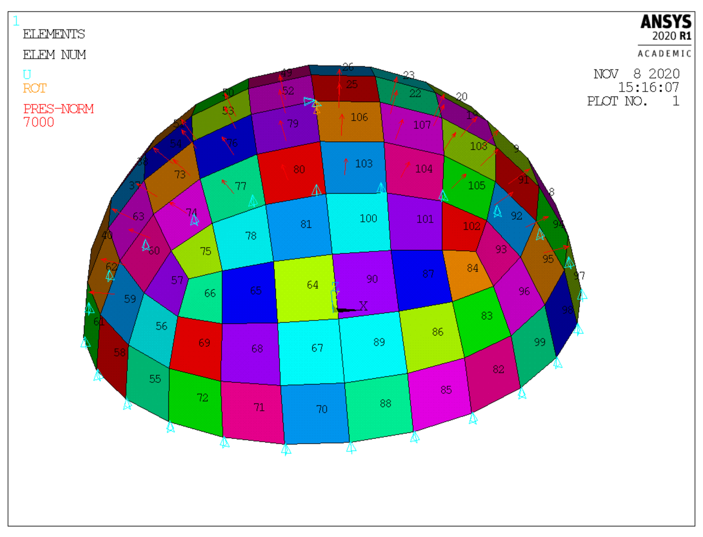
Membrane structures are flexible materials with a large ratio of surface size to thickness. The ponding causes deformation of the membrane structure. With late rainfall or snowfall, the fluid on the membrane structure continues to increase. There are two possible results: either the membrane structure finally reaches an equilibrium state or the membrane structure is destroyed before it reaches the equilibrium state. This thesis is based on this phenomenon. An attempt is made to establish a suitable model to simulate and analyze this phenomenon. Step by step, from a simple balloon model to a complex ponding model. The purpose of this thesis is to investigate the phenomenon of ponding in membrane structures. It analyzes the main factors influencing the water ponding on membrane structures to reach an equilibrium position, as well as the role of the load stiffness matrix.

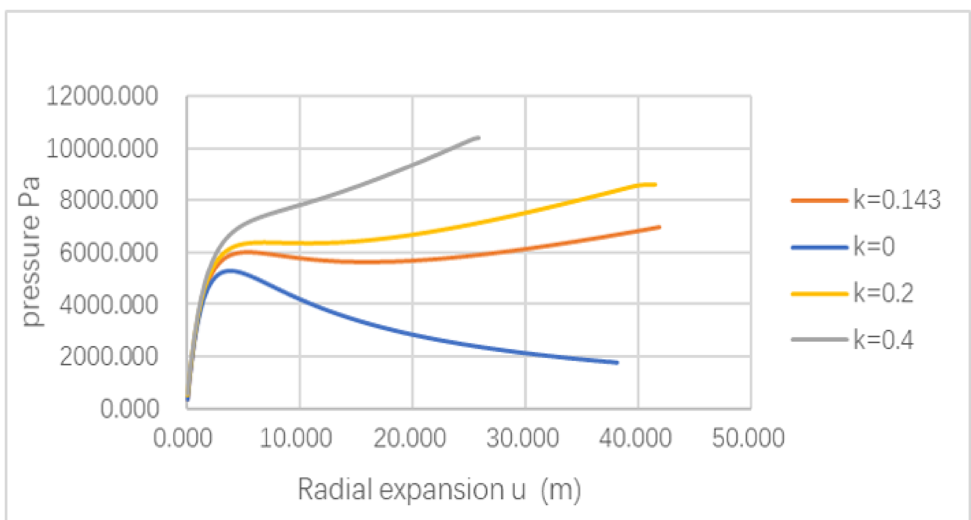
Related Theories and Analysis Methods

- **Path Following**
- $\boldsymbol{R}(\boldsymbol{z}) = \begin{bmatrix} \boldsymbol{G}(\boldsymbol{z}) \\ \boldsymbol{f}(\boldsymbol{z}) \end{bmatrix} = \boldsymbol{0}$

- **Load Stiffness**
- $\boldsymbol{K}_{\mathrm{T}}(\boldsymbol{D},\lambda) = \boldsymbol{K}_G(\boldsymbol{D}) + \boldsymbol{K}_U(\boldsymbol{D}) + \boldsymbol{K}_E(\boldsymbol{D}) - \boldsymbol{K}_L(\boldsymbol{D},\lambda)$
- $\boldsymbol{K}_L = \frac{\partial \boldsymbol{F}_{ext}}{\partial \boldsymbol{D}}$

“Balloon”-Model





The main parameter that affected the critical point was the hardening parameter k. According to the results of the analysis, parameter k determines whether critical points occur in the curve.

Conclusions

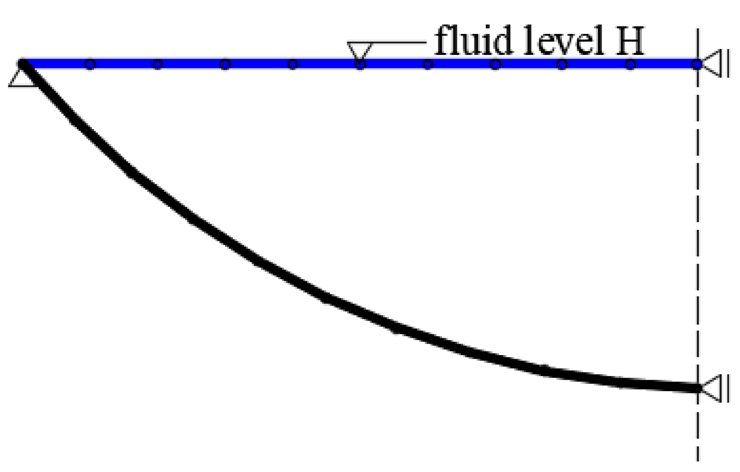
- The deformation of its equilibrium state is influenced by its own material properties and the length of the membrane side.
- load stiffness matrix can significantly reduce the computational effort in structural analysis by reducing the number of iterations.

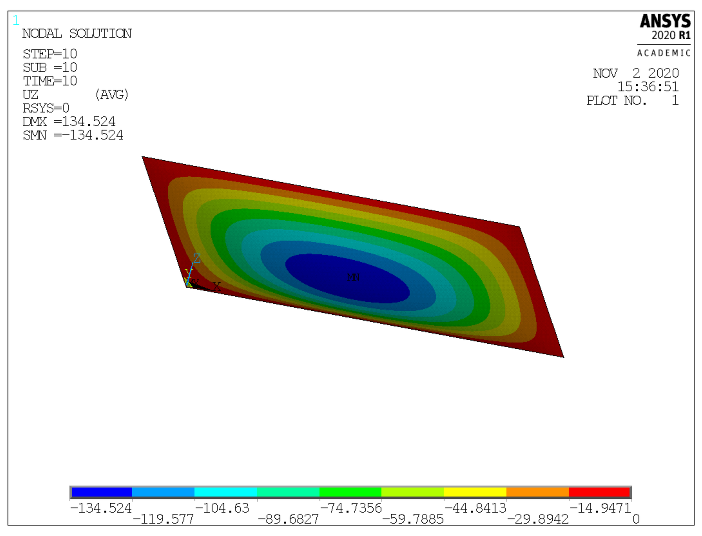
Supervision:
Rebecca Thierer, M.Sc.

https://www.ibb.uni-stuttgart.de

Ponding model

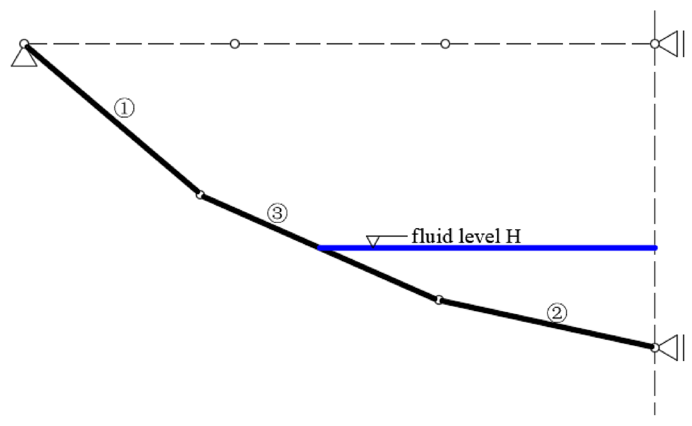
- **constant liquid surface**

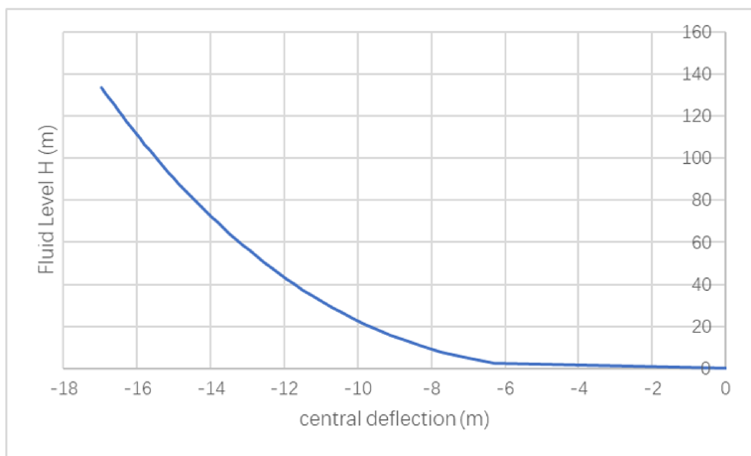




Midpoint deformation analysis of two different materials

- **variable liquid surface**





Equilibrium Path : Liquid Level-Deformation-Curve

Literature

- Zhou, Yang; Nordmark, Arne; Eriksson, Anders: Instability of thin circular membranes subjected to hydro-static loads. In: International Journal of Non-Linear Mechanics 76 (2015)
- Eriksson, Anders: Structural instability analyses based on generalised path-following. In: Computer methods in applied mechanics and engineering 156 (1998)

Baustatik und Baudynamik