Vacuum Airship Design With Finite Element Analysis

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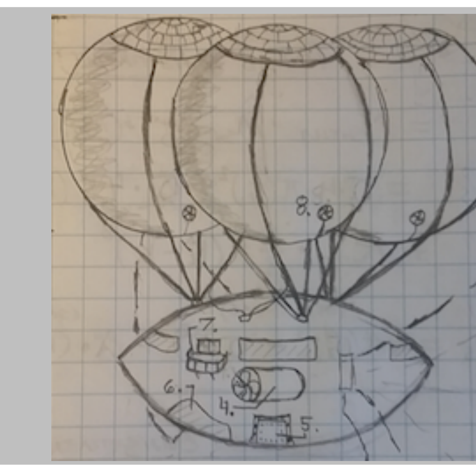


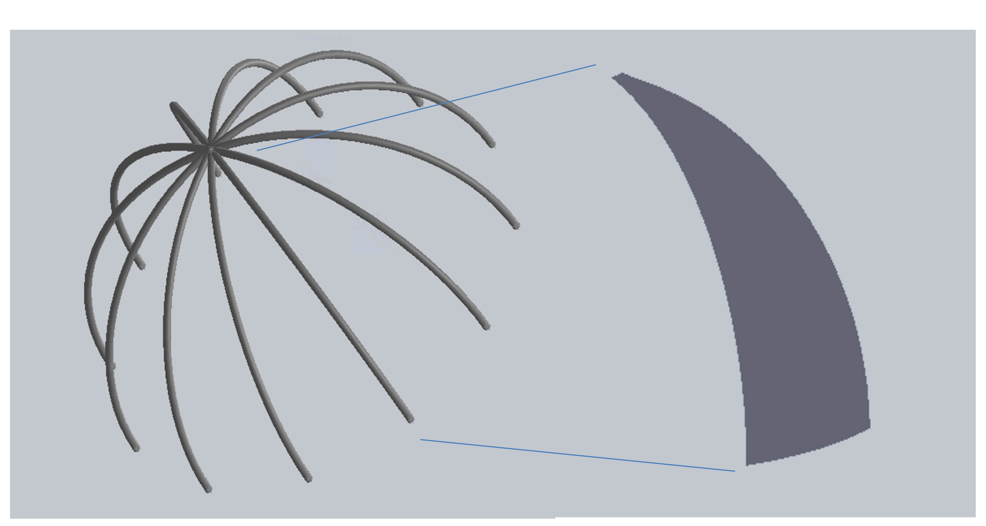
Introduction

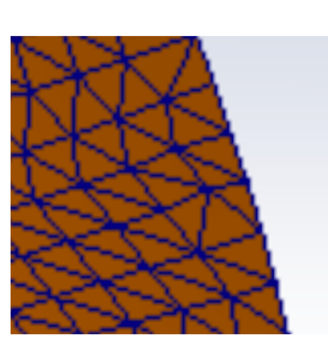
Modern Airships float by enclosing helium or hydrogen, but what if we could enclose a vacuum instead? Such a craft would need an airtight membrane with a strong support structure. We examine one design using both SolidWorks (SW) Simulation Finite Element Analysis and principles of structural statics.

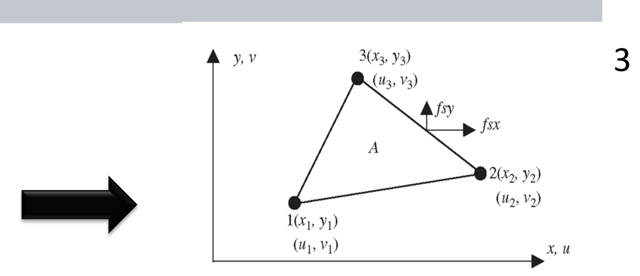
Research Objective

The goal of this project is the design and fabrication of a Vacuum Airship. Present research seeks to answer the following question; is the highest mechanical stress exerted by atmospheric pressure smaller than the tensile strength of existing aramid fiber textiles?

Methods







$$\Phi(x,y) = [N_i][\Phi_i]$$

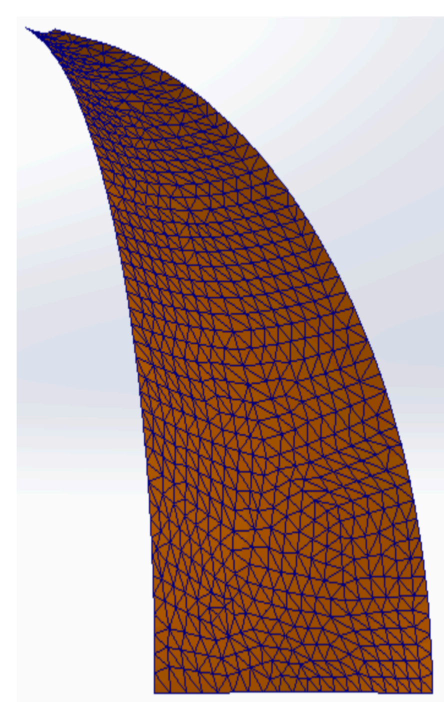
To analyze stress within non-uniform geometry, we have selected the **Finite Element Method.** This method splits a model into many simple pieces which are then used to generate a **system of equations** which is solved to obtain an approximation of the internal stress. **SolidWorks Simulation** software was used to carry out the FEM studies.

Shell Studies

Shell Section Models – Mesh Independence

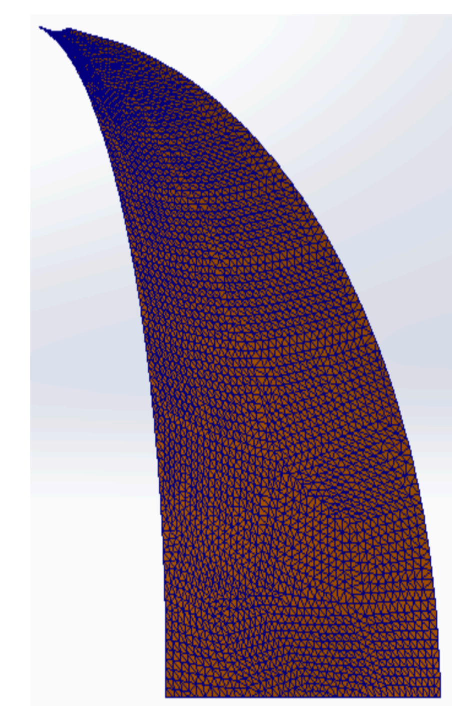
Normal Meshing Procedure

Standard Mesh



Peak Stress: **8.4×10^5 Pa**

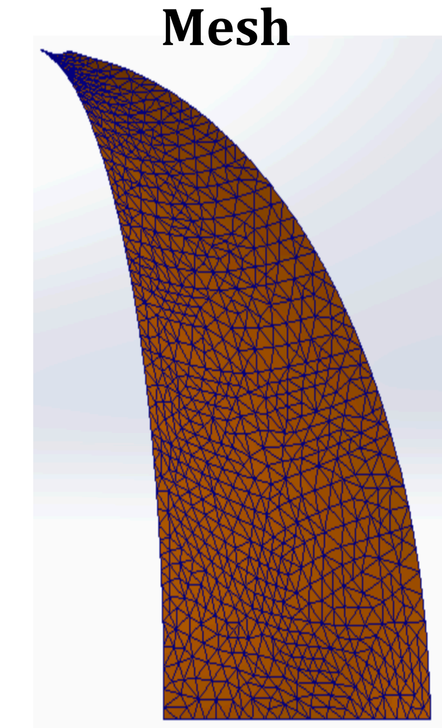
Fine Mesh



Peak Stress: **8.5×10^5 Pa**

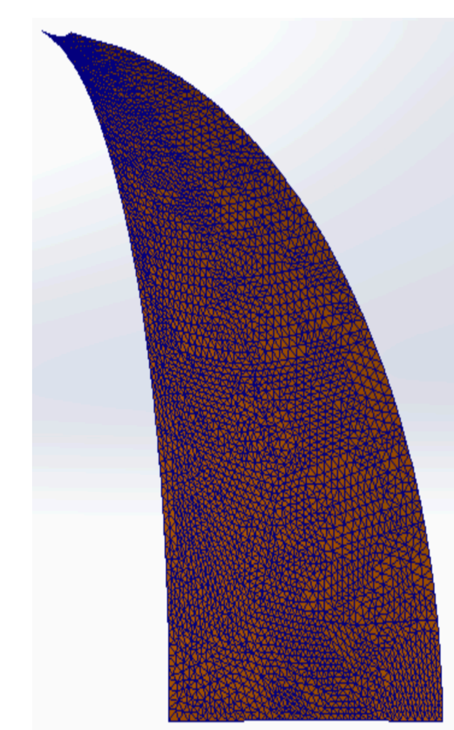
Curvature-Based Meshing Procedure

Standard Mesh



Peak Stress: **8.4×10^5 Pa**

Fine Mesh

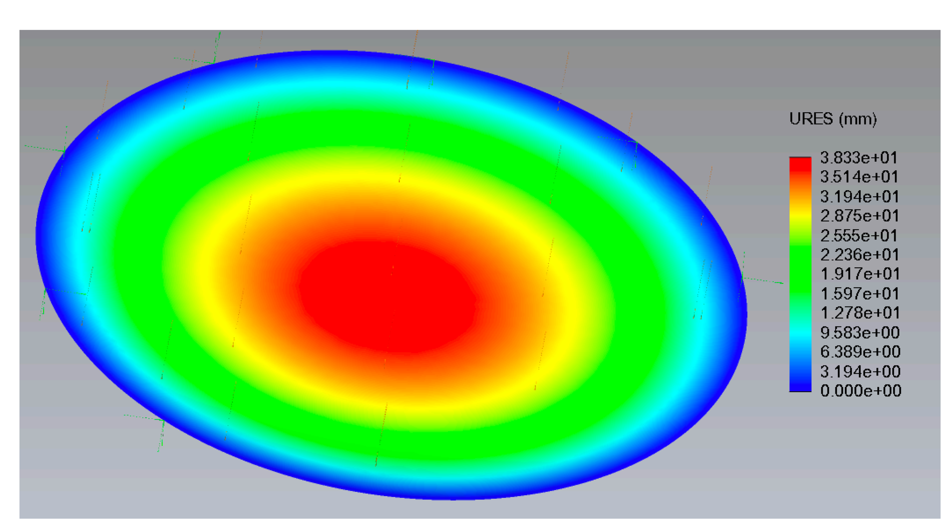


Peak Stress: **8.6×10^5 Pa**

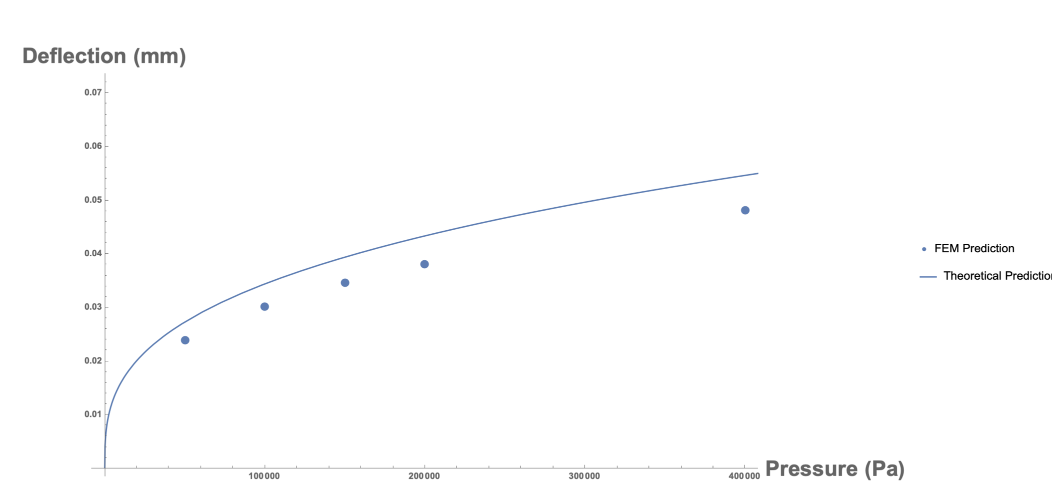
Shell-section models for one set of parameters for the Airship. Changing the mesh procedure or resolution has minimal effect on the results; the stress distribution patterns remain and peak stress changes by less than one order of magnitude.

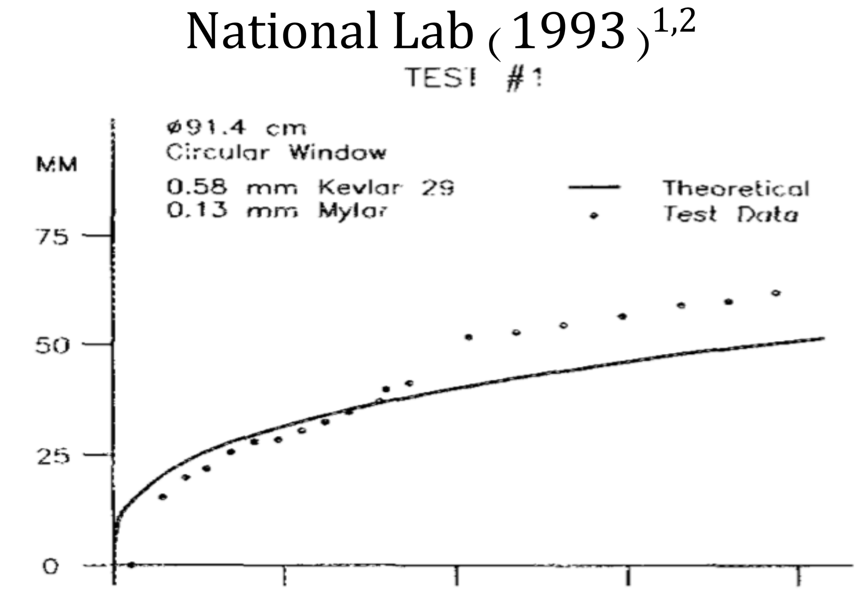
Deflection

Vacuum Window Deflection – Predictions VS. Test Data



LEFT: A Finite Element model of a Kevlar Vacuum Window deformed under pressure. LOWER LEFT: Theoretical prediction[1] and SW prediction for window displacement. LOWER RIGHT: Theoretical prediction and test data for window displacement, from Brookhaven National Lab (1993)[1,2]

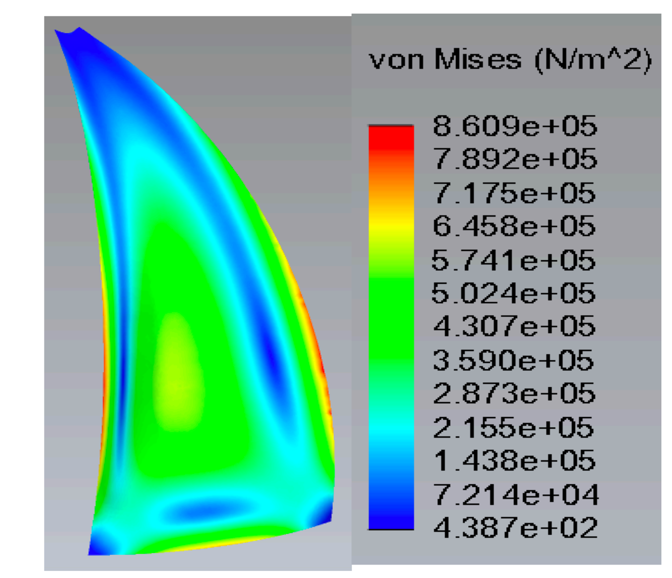




Conclusions

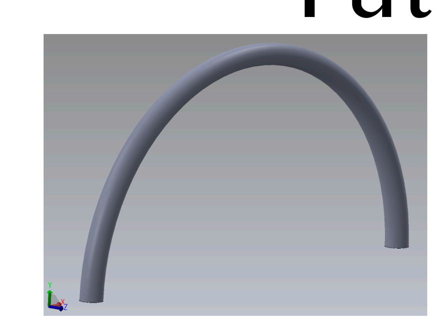
This report should be considered as a snapshot in the design process.

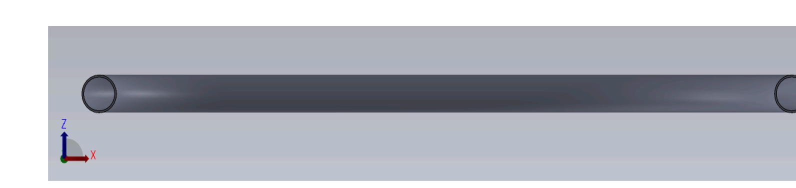
The results shown here suggest that our models are valid for at least order-of-magnitude calculations.



Peak stress for preliminary models is less than **1×10^6 Pa** even for very thin shells and aramid fibers have tensile strengths of more than **1×10^9 Pa.**

Future Research





Our next step is to model the inflatable support tubes which will support the shell.

References

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2. Timoshenko, S. P. (1964). *Theory of Plates and Shells (McGraw-Hill Classic Textbook Reissue Series)* (p. 568).
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Acknowledgments

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