Transportation Analysis of the Fermilab High-Beta 650 MHz Cryomodule*

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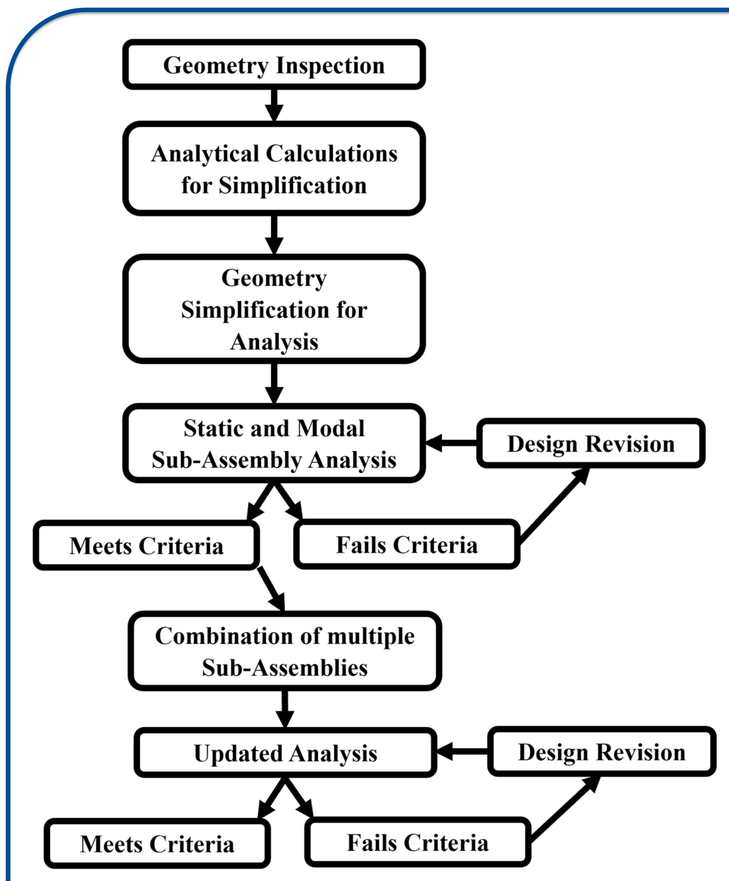
Introduction

The prototype High-Beta 650 MHz Cryomodule (pHB650 CM) will be transported via road/air methods from Fermilab to the U.K. roundtrip to validate the design for future transports. A frame designed by STFC UKRI will serve to mitigate shock and vibration. Per FNAL requirements, the pHB650 CM must withstand 5 G axial, 3 G vertical, and 1.5 G transverse shocks with all stresses below their yield limits. Additionally, all critical components should have resonant frequencies above 20 Hz to mitigate the likelihood of fatigue failure. Structural and modal analysis was performed to verify the pHB650 CM design, starting with individual components which were then combined to create the full CM.

Methods

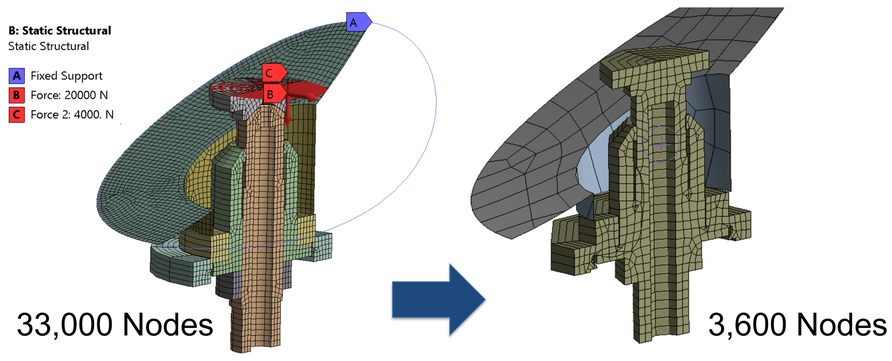


Methods Flowchart

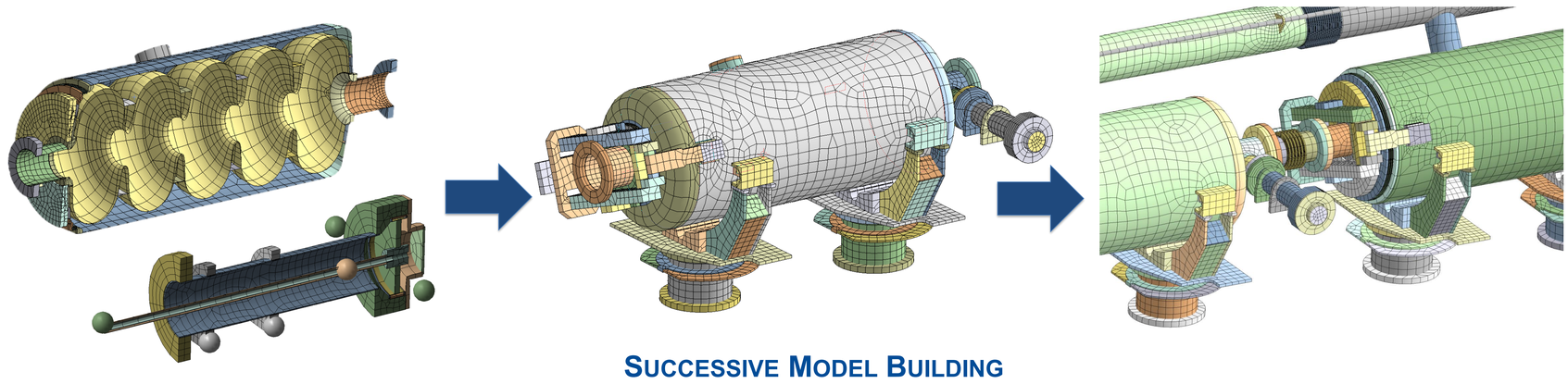
Models Analyzed:

Sub-Assemblies
- Coupler, Tuner, Cavities, Supports
- Two-Phase Pipe, Cryogenic Piping
- Thermal and Magnetic Shields
- Strongback, Vacuum Vessel

Assemblies
- String Segment, Full String
- Vessel + Strongback
- Full HB650 CM



Model Optimization

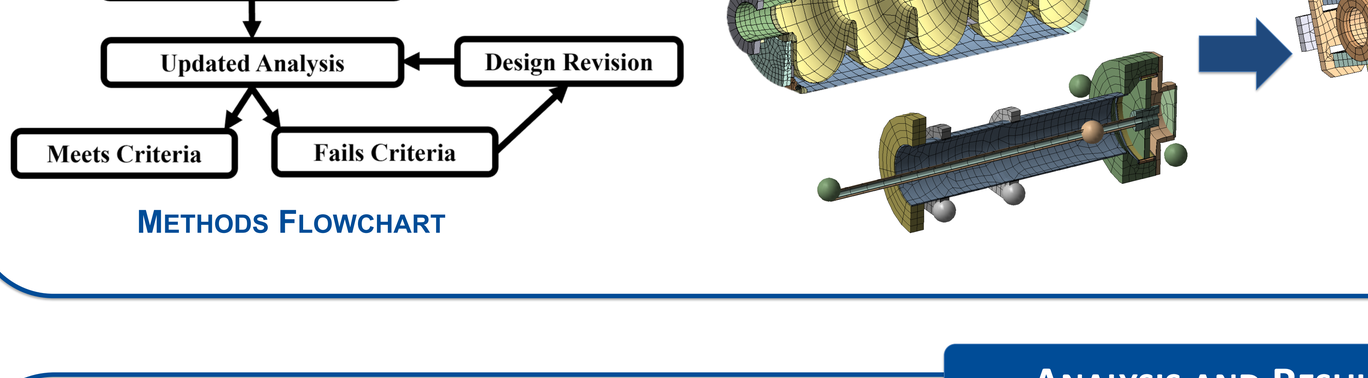


Successive Model Building

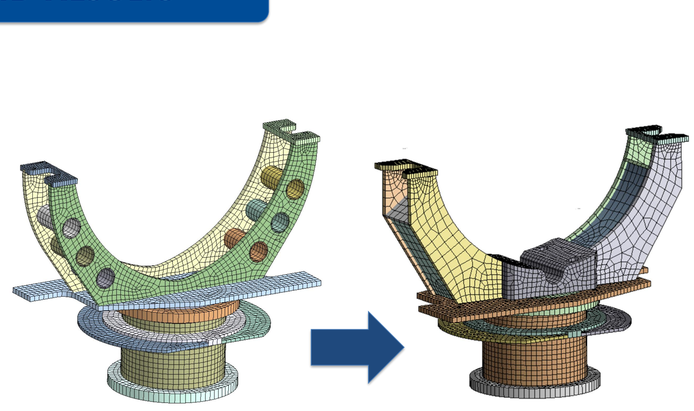
Analysis and Results

Summary of Results

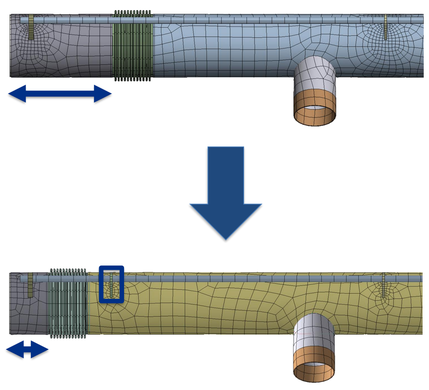
- Sub-assembly results found most design improvements, but some complex behavior was not seen until larger assemblies
- All components have acceptable stresses and resonant modes
- Highest stresses seen at vessel transport mounts during 5 G
- The first mode sees the string move transversely at 18 Hz, which was acceptable due to high stiffness and low deflection
- Bellows fatigue life acceptable based on maximum deflections and analytical calculations
- The complete model used only 601K nodes due to mesh optimization and model simplification



Complete pHB650 Mesh

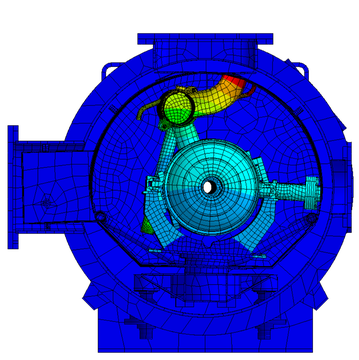


Cavity Support

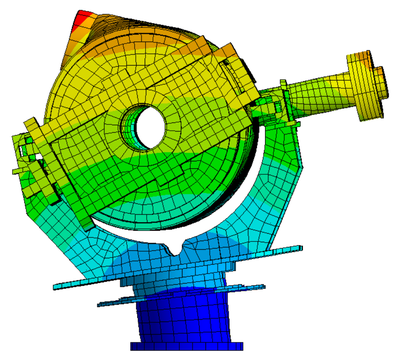


Two-Phase Pipe End

Sample of Design Improvements



18 Hz Transverse Mode



22 Hz as Sub-Assembly

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