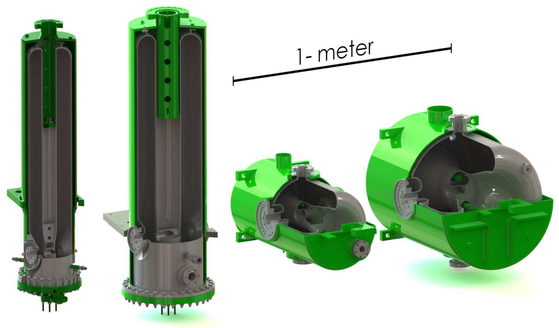
Multiphysics and Pressure Code Analysis for Quarter Wave β=0.085 and Half Wave β=0.29 Resonators

S. Miller#, M. Johnson, A Facco, Y. Xu, J. Binkowski

Facility for Rare Isotope Beams (FRIB), Michigan State University, East Lansing, MI 48824 USA

Abstract

The driver linac design for the Facility for Rare Isotope Beams (*FRIB*) at Michigan State University (*MSU*) makes use of four optimized superconducting radio frequency (*RF*) resonators to accelerate exotic ions to 200 MeV/μ. The RF resonators were optimized using computer simulations for all expected physical encounters and corresponding electrical resonant frequency changes. Principal guidance from the ASME boiler and pressure vessel code (BPVC) were applied.

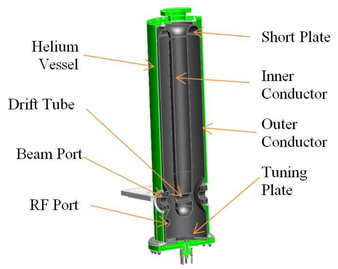


Requirements

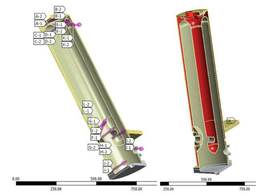
- Satisfies Elastic Stress Analysis Method at 2.0 ATM for 300K
- Capable of sustaining tuning stresses generated at maximum tuning range and pressure
- Pressure sensitivity between +/-4 Hz/torr
- LFD >-4 Hz/(MV-m)^2

Integrated Analysis Approach

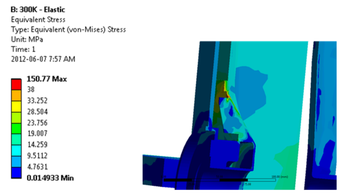
- Validate design using equivalence of the ASME Section VIII, Division 2
- Verify resonator tuning sensitivity, tuning range, and tuning force
- Determine resonators helium pressure sensitivity
- Compute Lorentz Force Detuning



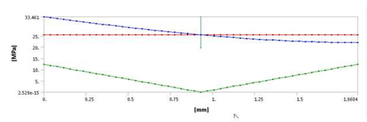
Material	Temp (K)	Elastic Modulus (GPa)	Yield Strength (MPa)
Niobium RRR250	295	103.0	38
Niobium RRR250	4	104.0	372
Niobium-45 Titanium	295	62.1	475
Niobium-45 Titanium	4	68.2	680
Grade 2 Titanium	295	106.9	275
Grade 2 Titanium	4	118.8	560



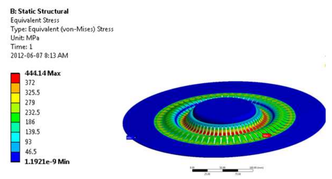
Stress Lines and Pressure Added to Resonator



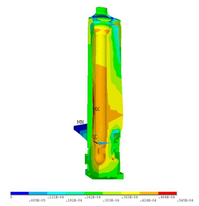
High Stress Regions Examined



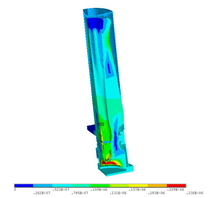
Evaluate High Stress Region against Elastic Stress Analysis Method



Evaluate Tuning Capability

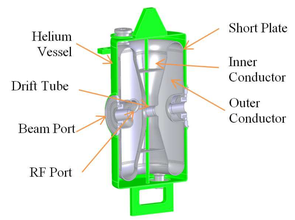


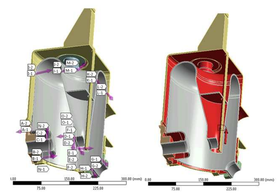
Determine Pressure Sensitivity



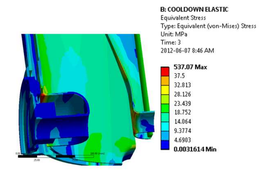
Compute Lorentz Force Detuning

Property	β=0.085	β=0.29
Pressure Capability 300K (ATM)	2.2	2.2
Pressure Capability 2K (ATM)	15	20
Tuning Sensitivity (kHz/mm)	3.2	216.5
Pressure Sensitivity (Hz/torr) Fixed Tuner	N/A	0.55
Pressure Sensitivity (Hz/torr) Free Tuner	-1.4	1.42
LFD (Hz/(MV/m)^2 Fixed Tuner	N/A	-2.71
LFD (Hz/(MV/m)^2 Free Tuner	-0.7	-3.72

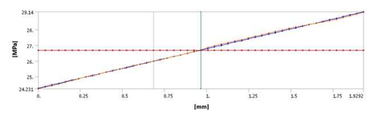




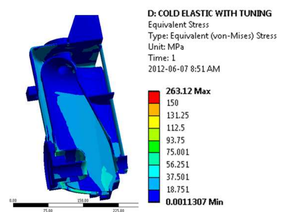
Stress Lines and Pressure Added to Resonator



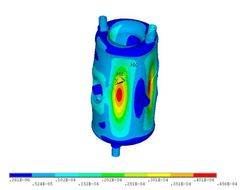
High Stress Regions Examined



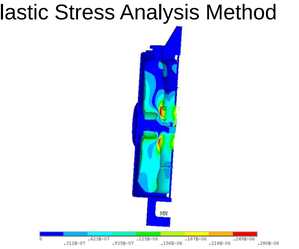
Evaluate High Stress Region against Elastic Stress Analysis Method



Evaluate Tuning Capability



Determine Pressure Sensitivity



Compute Lorentz Force Detuning

References

[1] J.Wei et al., "The FRIB Project – Accelerator Challenges and Progress", these proceedings.
[2] E. Zaplatin et al., "Structural Analyses of MSU Quarter-Wave Resonators". SRF 2009: Berlin, Germany.
[3] ANSYS, Inc., Cannonsburg, Pennsylvania, USA.
[4] T.J. Peterson et al., "Pure Niobium as a Pressure Vessel Material," Fermi National Accelerator Laboratory, Batavia, IL, USA.
[5] ASME Boiler and Pressure Vessel Code, 2010 edition.
[6] ATI Wah Chang, Technical Data for Niobium-Titanium, 2011.

Conclusion

The integrated mechanical analysis of the β=0.29 and β=0.085 resonator types at FRIB is complete. The β=0.29 half wave resonator has completed the analysis and has been shown to exceed the mechanical requirements. This resonator type has already undergone the request for quote process and two development resonators are expected by the end of 2012. The β=0.085 resonator has also completed its integrated mechanical analysis and exceeds the mechanical requirements. This resonator has also completed a request for quote process and two development resonators of this type are expected by the end of 2012.

FRIB Facility for Rare Isotope Beams
U.S. Department of Energy Office of Science
Michigan State University

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