Optimization of Mechanical Properties of Superconducting Cavities for Project X LINAC

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Abstract

Project X is a proposed proton accelerator complex at Fermilab. The first part of Project X includes CW superconducting LINAC to accelerate a 1 mA average beam from 2.1 MeV to 3 GeV. The CW LINAC is based on five types of resonators operating at three frequencies: half-wave (1st type at 162.5MHz), spoke (2 types at 325 MHz), and elliptical (2 types at 650 MHz). The low beam current for CW operation of the Project X requires cavities to operate at a high loaded Q and thus, narrow bandwidth. Therefore, it requires optimal mechanical design of cavities to minimize the sensitivity to microphonics df/dP. The essential source of microphonics frequency (f) detuning is fluctuations of the helium pressure (P). One of the other possible sources of RF frequency instability is mechanical resonances. The cavity could be driven out of operating frequency by the mechanical deformations due to vibrations caused by external factors. In this paper we present the COMSOL Multiphysics® algorithms developed for evaluation of operating frequency shift due to both fluctuations in the helium pressure and mechanical resonances. We present and discuss the detailed results of simulations for 5-cell elliptical 650 MHz β=0.9 cavities. We also present the comparison the results of COMSOL simulations and measurements of ILC type cavities in Horizontal Test Stand at Fermilab.

An example of COMSOL simulations of frequency change due to fluctuations in Helium pressure in SRF cavity are presented below. A COMSOL model is shown at Fig. 1.
At the first step, the initial frequency of the cavity was calculated.
At the second step, a solid mechanical analysis was done. Boundary conditions used in mechanical calculations are:
- 1 bar pressure applied to all internal surfaces of the cavity and Helium Vessel
- fixed displacement of Vessel supports (7 on the Fig. 1)
- tuner stiffness is simulated by applying the spring constant between the conical flange and the bellows ring (3, 4 on the Fig. 1).

Moving mesh physics define the RF volume deformation induced by pressure.
A new run of RF module determines the frequency shift due to volume deformation.
The results of simulations are shown on the Fig. 2.

Conclusion: Modern cryogenic systems achieve rms pressure stabilities of ~0.2 mbar. This means, that even in worst case of infinite tuner stiffness, one can expect that the maximum frequency deviation due to pressure fluctuation will be <4Hz. This is acceptable.

Reference

[1] Gonin et al., "UPDATE OF THE MECHANICAL DESIGN OF THE 650 MHZ BETA=0.9 CAVITIES FOR PROJECT X", IPAC'13, Shanghai, China, WEPWO056.

Figures used in the abstract

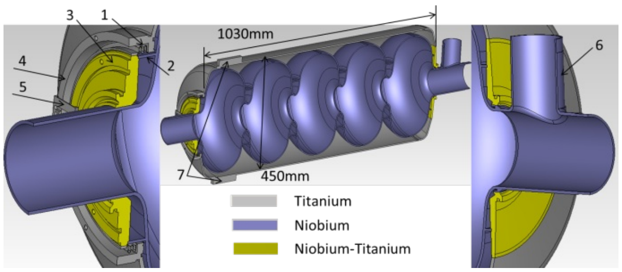

Figure 1: Figure 1: COMSOL model of mechanical assembly used in simulations. 1–bellows, 2 –stiffening ring between end half-cell, 3–conical flange, 4–bellows ring, 5–support brackets, 6 –power coupler, 7–Vessel supports. Left – tuner end group. Right – power coupler end group.

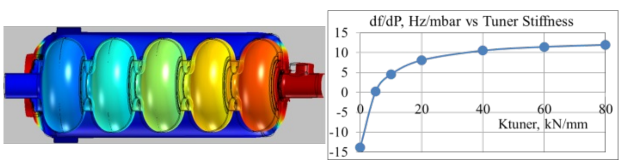

Figure 2: Figure 2: Total displacement for 1 bar internal pressure (Ktuner =20kN/mm) and df/dP vs. stiffness of the tuner