SRF CONICAL HALF-WAVE RESONATOR TUNING DEVELOPMENTS*

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Abstract

A conical Half-Wave Resonator is considered as an option for a first accelerating cavity for beta=v/c=0.11 with the resonance frequency 162.5 MHz for a high-intensity proton accelerator complex proposed at Fermi National Accelerator Laboratory (Project X).

We present results of different options of the cavity mechanical tuning. The "standard" tuning method of beam port deformations is an effective tuning method still requiring a relatively high tuning pressure. The side tuning is considered as a novel option for the resonance frequency adjustment featuring lower tuning force and an option of the structure design for the resonator frequency shift self compensation.

INTRODUCTION

The main purpose of this work is to perform the conceptual design of the conical Half-Wave Resonator (cHWR) in complex with its liquid helium vessel securing the minimal sensitivity of the resonant frequency to fluctuations in helium pressure and to ensure that the slow tuner providing the target tuning range of about 50 kHz/mm. The standard method of HWR tuning is the beam port deformations. A pneumatically actuated mechanical slow tuner compresses the cavity along the beam axis changing an accelerating gap width and hence the cavity capacitance. This results in highest tune sensitivity since the highest electrical field is located at accelerating gaps. On the other hand accelerating gaps is the biggest source of the microphonics caused by an external pressure applied at the beam ports. To minimize them one should provide the special stiffening measures to increase the rigidity of accelerating gap regions. This contradicts with the tuning procedure that requires a certain flexibility to ensure the deformations.

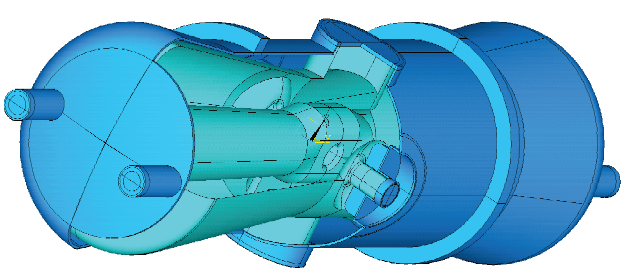

Figure 1: Simulation model of cylindrical cHWR with helium vessel.

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The side-tuning cavity frequency adjustment can be developed as an alternative to the beam port deformations featuring lower tuning force and an option of the structure design for the resonator frequency shift self compensation.

CAVITY BEAM PORT TUNING

Calculations of the cavity frequency shifts caused by external wall pressure and tuning force were provided with coupled analyses using ANSYS codes. The simulation model of cylindrical HWR is shown on Fig. 1. The helium vessel model was fixed by means of special rings simulating the structure supports in the cryomodule. IFMIF beam port structure design has been used to increase accelerating gap regions rigidity. Fig. 2 presents calculation results for df/dp for different constraint conditions of coupler ports with beam port stiffness variation. The high mechanical stability is essentially inherent to Half-Wave cylindrical Resonators. The total effect of external pressure application on all cavity and liquid helium vessel walls results in nearly complete compensation of the frequency shifts caused by cavity and vessel wall deformations (df/dp is close to zero). The dependence of df/dp on resonator wall thickness is about 0.9 Hz/mbar/mm.

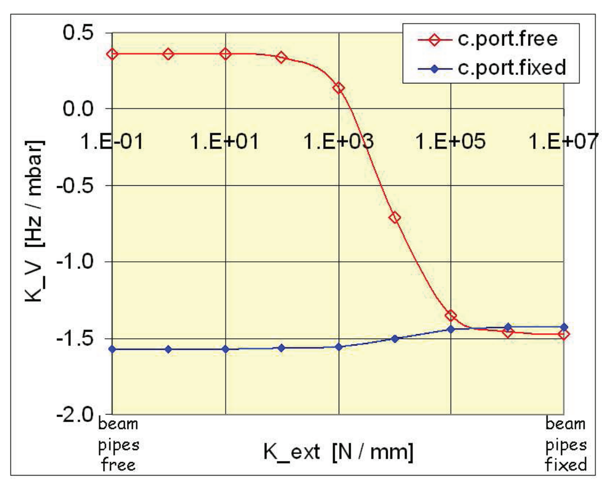

Figure 2: cHWR with helium vessel under external pressure.

The “standard” tuning procedure with beam port deformations results in tune sensitivity up to 130 kHz/mm (Table 1).

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Table 1: Conical HWR Tuning Simulation Results

	frequency shift	tuning force	max stress v. Mises
	kHz / mm	N / mm	MPa / mm
beam port tuning cHWR-180	-130.2	10713	313
side tuning cHWR-180	-79.9	862	329

CAVITY SIDE TUNING

Preliminary investigations of Half-Wave Resonator side tuning have been published in [1-4]. The conceptual design of the liquid helium vessel is investigated also to reach the lowest possible resonance frequency shift from the external pressure on cavity walls.

Two cavities with different diameters 180 mm (cHWR-180) and 250 mm (cHWR-250) of the cavity central part were investigated to understand the behaviour of the proposed helium vessel design for the resonator frequency shift self-compensations (Fig. 3).

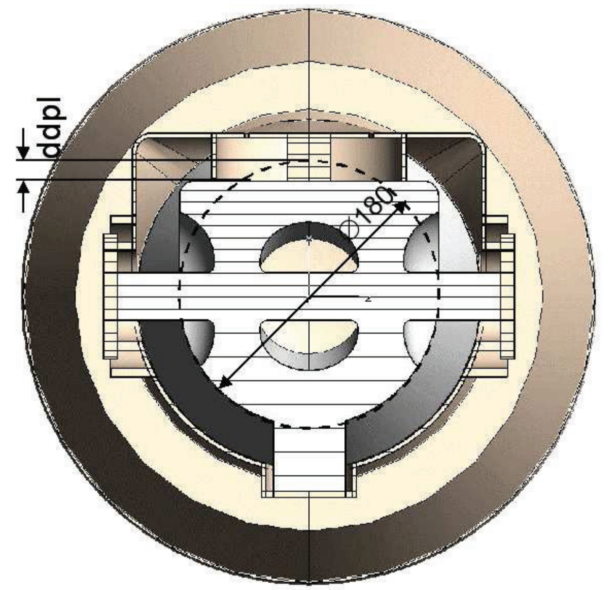

Figure 3: cHWR simulation model.

To use effectively the outer conductor walls for cavity tuning deformations, the central part of cHWR is made asymmetric with a planar surface on one side. This planar surface is used for deformations. The distance to the cavity central electrode (tuning gap) defines the position of the tuning planar surface to achieve the required project tune sensitivity. The parameter "ddpl" (Fig. 3) was varied to change the tuning gap. For cHWR-180 ddpl=10 mm is sufficient to reach the resonator tuning sensitivity of about 80 kHz/mm (Table 1). This position of the tuning plate doesn't change the optimised cavity RF parameters like the peak electric and magnetic fields on the cavity surface relative to the accelerating electrical field on the cavity axis (B_{pk}/E_{acc} and E_{pk}/E_{acc}). The tuning plate working position of cHWR-250 with 250 mm central diameter should be ddpl=35 mm to reach the target tune sensitivity of 50 kHz/mm (Fig. 4). This results in substantial E_{pk}/E_{acc} enhancement (Fig. 5).

Because of the strong dependence of the ratio E_{pk}/E_{acc} on the tuning surface position of cHWR-250, the final choice for cavity prototype was made in favour of cHWR-180 design.

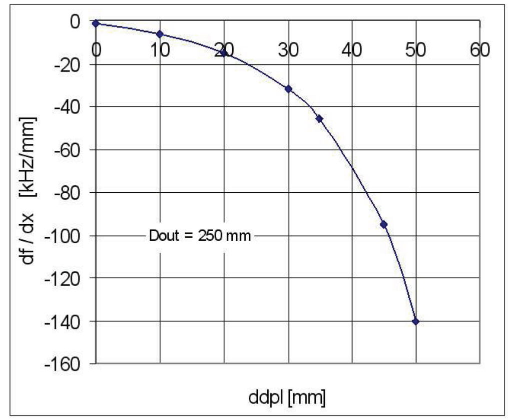

Figure 4: cHWR-250 with helium vessel tuning sensitivity.

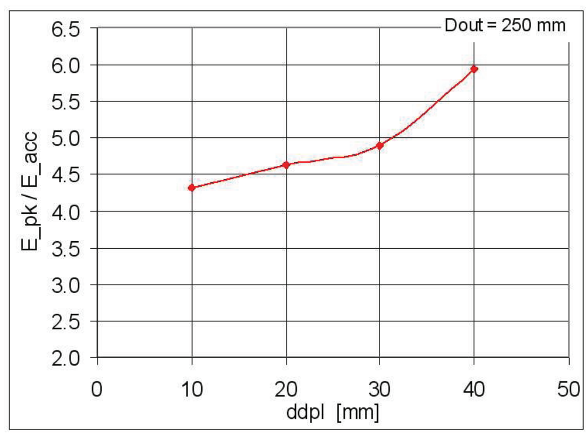

Figure 5: cHWR-250 surface peak electrical field.

To enable the possibility of most effective df/dp adjustment the installation of a bellow combined with an additional tuner ring was investigated (Fig. 3). The bellow is simulated as a slot in the vessel tuning plate. The tuner ring is installed around the bellow (tuner ring radius is bigger than bellow radius) connecting cavity and helium vessel tuning plates. The tuner ring installation provides compensation of the cavity tuning wall external pressure deformation. The best compensation conditions define an optimum value of the tuner ring radius.

Different vibrations in the cavity are additional source of microphonics in cHWR. The strongest resonator detuning is driven by resonant pendulum motion of the central electrode. In our cHWR the central electrode is designed with large cross section to increase the lowest mode frequencies. The provided analyses resulted in 171 and 192 Hz for two lowest pendulum mode frequencies.

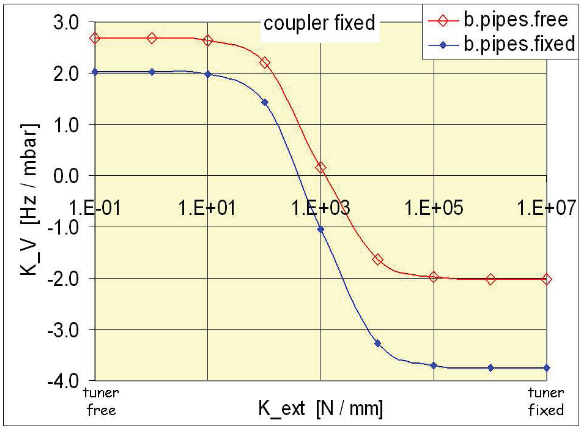

Figure 6: cHWR under external pressure with different beam port constraints and tuner stiffness variation (coupler port fixed).

The simulations of different schemes of helium vessel constraints were provided to predict the structure behaviour under external loads in the cryomodule. The helium vessel model was fixed by means of the external rings. The simulations were performed for two extreme conditions (fixed and free) of the beam ports and the coupler varying the tuner stiffness. The calculation results of df/dp for different constraint conditions of beam pipes and coupler port with tuner stiffness variations detect a weak dependence on the tuner stiffness – for two extreme cases of tuner constraints the frequency shift from helium external pressure is within +/- 3 Hz/mbar (Figs. 6-7). The dependence on the cavity wall thickness is about 0.9 Hz/mbar/mm.

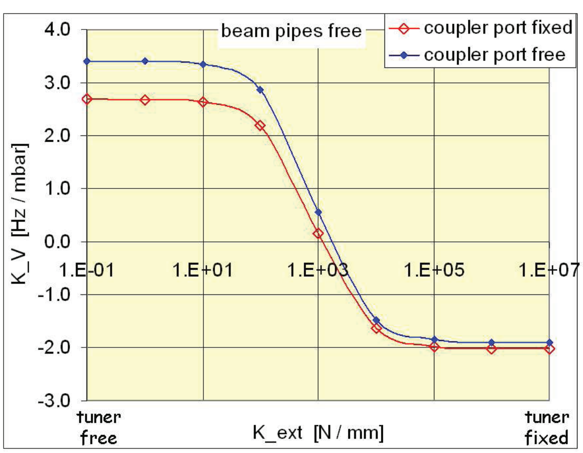

Figure 7: cHWR under external pressure with different coupler port constraints and tuner stiffness variation (beam pipes free).

The side tuning procedure results in tune sensitivity up to 80 kHz/mm with acceptable stresses 350 MPa/mm (Table 1). There is nearly no dependence on the resonator frequency slow tuning (Fig. 8).

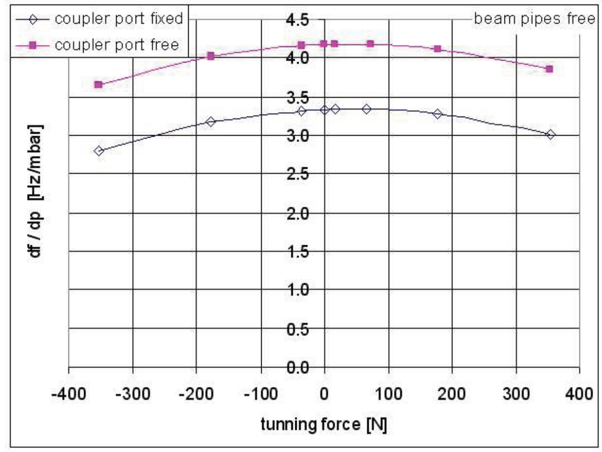

Figure 8: df/dp under course tuning.

CONCLUSIONS

The conceptual design of Half-Wave Resonator in the helium vessel with side tuning possibility is provided. The cavity helium vessel structure was designed to minimize microphonics caused by an external pressure within fabrication tolerances. The side option of the cavity tuner can be effectively implemented providing the target tune sensitivity and permits saving the space along the beam path and substantially reducing the required tuning force.

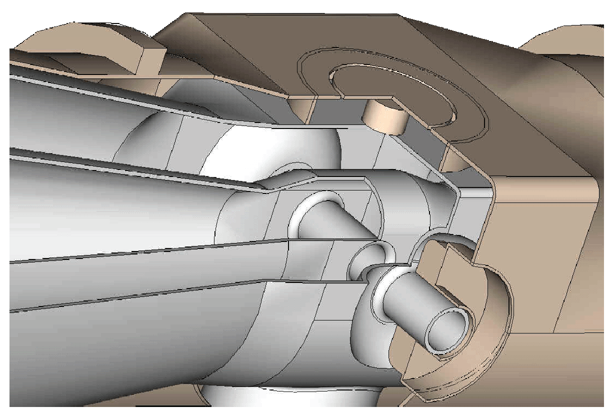

Figure 9: cHWR simulation model with bellow slot.

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