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EUCLID MODIFIED SRF CONICAL HALF-WAVE RESONATOR DESIGN*

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Abstract

The new low-beta conical Half-Wave Resonator (cHWR) is suggested for CW proton accelerators of new generation with relatively low beam loading, where frequency detune caused by microphonics and helium pressure fluctuations is essential. This particular design, considered in the paper, has operation frequency of 162.5 MHz, β=v/c=0.11, and is suitable for the first section of the PIP-II superconducting accelerator which is under development at Fermilab.

The main idea of the cHWR design is to provide a self-compensation cavity design together with its helium vessel to minimize the resonant frequency dependence on external loads. A unique cavity side-tuning option is also under development.

Niowave, Inc. proposed a series of cavity and helium vessel modifications to simplify their manufacturing. The whole set of numerical simulations has been generated to verify that the main parameters of the initial structure design were not affected by the proposed modifications.

Here we present the main results of the cavity and helium vessel modified design.

INTRODUCTION

The very first investigations of the conical Half-Wave Resonator were made in the frame of the COSY Linac project [1]. The recent cavity developments [2] aimed 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.

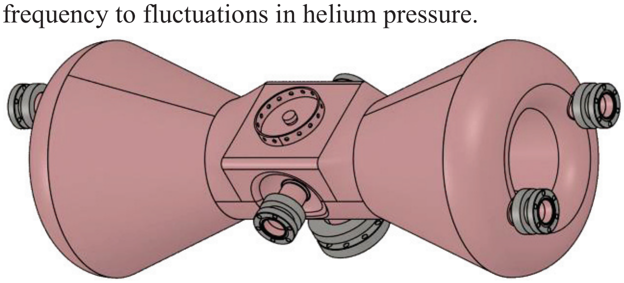

Figure 1: cHWR modified design.

The side-tuning cavity frequency adjustment was developed as an alternative to the beam port deformations featuring lower tuning force ensuring sufficient tuning sensitivity of 50 kHz/mm and an option of the structure design for the resonator frequency shift self compensation. 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 (Fig. 1).

CAVITY DESIGN MODIFICATIONS

The high mechanical stability is essentially inherent to Half-Wave cylindrical Resonators. The provided cavity-helium vessel design [2] confirmed that 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 1.9 Hz/mbar/mm.

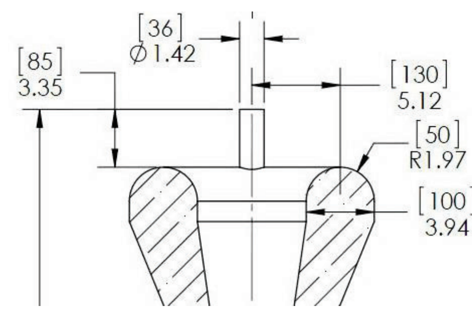

Figure 2: cHWR proposed dome geometry.

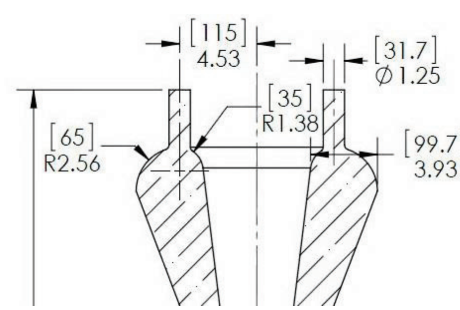

Figure 3: cHWR modified dome geometry.

Niowave, Inc. proposed a series of cavity and helium vessel modifications to simplify their manufacturing. The main changes of cHWR geometry are related to the cavity's dome region. The shape of the dome end cup was changed from the symmetrical shape with small torus radius R50 into asymmetric with R35 and R65 (Figs. 2-3). Since in this project we are not aiming to get an accurate frequency value the cavity conical shape of the outer and inner conductors directly join the end cup without intermediate cylindrical part.

The distance between vacuum ports was reduced from 260 mm to 230 mm. Diameters of vacuum ports and

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apertures of the beam pipes have been changed from ID=33 mm to ID=36 mm. The beam pipe of the inner central electrode was kept ID=33 mm.

The proposed geometry modifications resulted in the change of the cavity RF parameters (Table 1). Vacuum ports were included in the simulation model. This usually results in the shift of B_{pk} from the inner conductor to the vacuum port joint with end cup and in the larger B_{pk}/E_{acc} value. The cavity cone part length was adjusted to fit the required frequency that has been changed by proposed modifications.

Table 1: Conical HWR Parameters

		design	modified
frequency	MHz	162.5	162.5
$\beta = v/c$		0.11	0.11
R_aperture	mm	16.5	18
$\beta\lambda$	mm	202.94	202.94
R_cavity **)	mm	90	90
G	Ohm	40.78	36.36
R/Q	Ohm	118	119
E_{pk} / E_{acc} *)		5.02	5.1
B_{pk} / E_{acc} *)	mT/MV/m	6.64	7.1
B_{pk} / E_{pk}	mT/MV/m	1.32	1.39
tune	kHz/mm	-87	-87
*) $L_{eff} = N_{gaps} * \beta\lambda/2$, where N_{gaps}=2 – number of gaps			
**) Cavity radius in center			

The final modified geometry of the cavity with helium vessel with tuner bars and supporting rings is presented on Fig. 4. To enable the possibility of most effective df/dp adjustment a bellow combined with an additional tuner ring were installed. A slot in the helium vessel tuning plate is used to split the tuning and self-compensation functions.

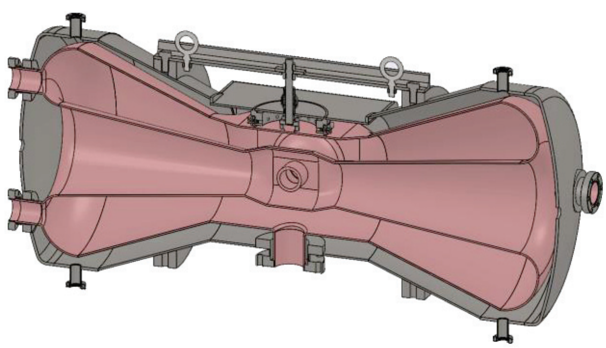

Figure 4: Final modified cHWR helium vessel design.

The tuner ring is installed around the bellow (tuner ring radius is bigger than bellow radius, Fig. 5) connecting cavity and helium vessel tuning plates and provides compensation of the cavity tuning wall external pressure deformation. The best compensation conditions define an optimum value of the tuner ring radius (Fig. 6).

HELIUM VESSEL PRESSURE TEST

The helium vessel leakage test was made evacuating the helium volume (Fig. 7) using a specially made hole in the helium vessel (HV) bottom part with a control of differential pressure and a displacement of the tuner stock. The symmetrical hole at the HV top dome will be used for liquid helium input and out gazing by the structure test in a vertical cryostat. The pressure gauge was installed directly at the vacuum pump.

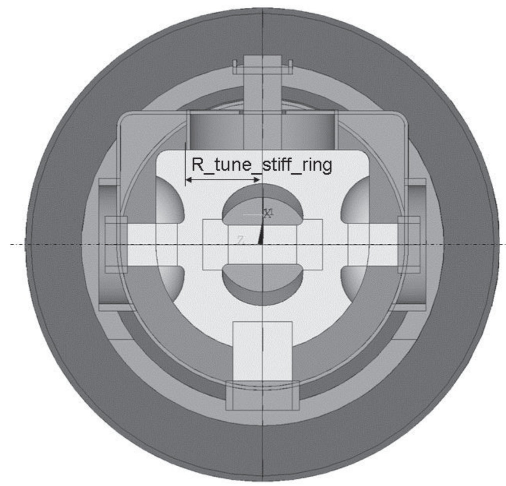

Figure 5: cHWR cross-section.

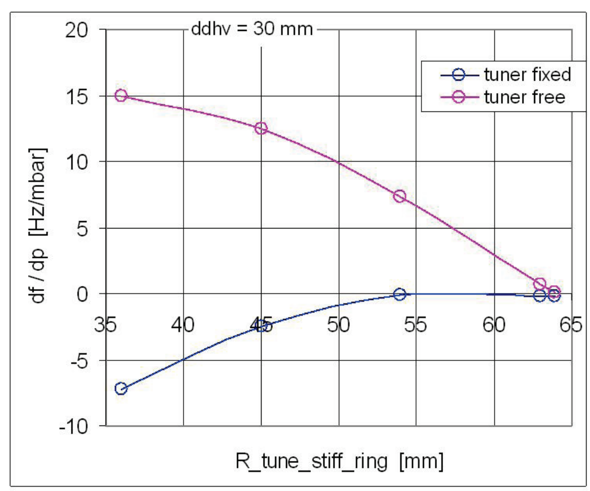

Figure 6: cHWR tuner ring position optimization.

The cavity helium vessel was manufactured from a stainless steel. A special technology has been used to joint the cavity niobium port pipes with their stainless steel flanges using brazing via a copper layer. All cavity flanges except of the coupler port are identical with a copper ring used for a vacuum ceiling.

A helium vessel leakage test was provided with a vacuum in the helium volume (volume between cavity outer walls and helium vessel inner walls) and atmosphere in the cavity volume and outside the whole structure. These are the same conditions as in cavity operation in terms of the walls deformations but with the

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pressure directed in the opposite directions. This means that a helium vessel leakage test provides the same mechanical conditions to measure df/dp to prove the main project idea of the balanced cavity-HV structural design to minimize the resonant cavity frequency shift caused by external loads.

The tentative simulations of the helium vessel leakage test have been made for three structure options – a) without tuner fixing bar and without beam port stiffening rings, b) without tuner fixing bar and with beam port stiffening rings, c) with tuner fixing bar and beam port stiffening rings (Table 2).

Figure 7: Helium vessel leak check setup.

Table 2: HV Leakage Test Simulation Results

tuner shift	def_max	df / dp	str.v.Mises
mm	mm	Hz/mbar	MPa
no tuner bar	no bp ring		
0.00879	0.175	1.33	118
no tuner bar	bp ring		
0.00391	0.173	-0.035	116
tuner bar	bp ring		
0	0.171	-0.025	120

Working conditions of the cavity-helium vessel pressure applications with vacuum in the cavity volume and outside the whole structure result in practically the same results of deformations, stresses and frequency shift. It confirms that the cavity displacements are in the linear region in the range of simulations.

A working scheme of the cavity-HV stiffening supposes a firm tuner stock fixation and df/dp=0 within simulation accuracy. This defines the mechanical design goal for working conditions when atmosphere is in the helium volume and vacuum in the cavity volume and outside the whole structure (external volume in the test cryomodule). The simulations of the helium vessel leakage test with a tuner bar confirmed the cavity parameters under working conditions. The results are presented on Fig. 8 with approximation of df/dp=2 Hz/mbar at the same maximal tuner displacement of 0.0127 mm. Because of scope of the uncertainties in the final cavity parameters caused by different manufacturing factors the simulation model and real cavity geometries could differ that in its turn cause small differences between calculation and test results.

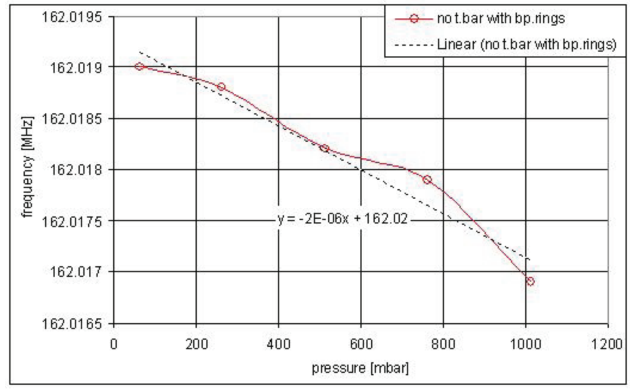

Figure 8: Frequency sensitivity to pressure measured during helium vessel leak check.

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

CONCLUSIONS

An engineering design of the conical Half-Wave Resonator in the helium vessel with side tuning possibility is completed. The modified cavity and helium vessel structure were designed to minimize microphonics caused by an external pressure. The side option of the cavity tuner was effectively implemented providing the self-compensated frequency shift design and target tune sensitivity and permits saving the space along the beam path and substantially reducing the required tuning force.

The provided helium vessel leakage test has proved the main project goal of the balanced self-compensation design.

The cavity with helium vessel has been fabricated at Niowave Inc. with supervision and quality control from Euclid Techlabs. After the bulk BCP and high pressure rinsing, the cavity with helium vessel will be tested at Niowave vertical test cryostat with measurements of quality factor Q_0, accelerating gradient and df/dP for the dressed cavity.

REFERENCES

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