# DEVELOPMENT OF THE SUPERCONDUCTING HALF WAVE RESONATOR FOR INJECTOR II IN C-ADS *

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*Abstract*

The Development of the Half Wave Resonator (HWR010) is based on the China ADS. The HWR010 operates at 162.5 MHz and can provide more than 0.78 MV of accelerating voltage per cavity for proton with $\beta_{opt}$=0.10. We have designed the HWR010 in 2011. A copper model has been fabricated to test the HWR fabrication procedure. Five HWR010s have been fabricated in 2012. The HWR010s has finished the vertical testing and the Q0 is 4E8 at Epeak = 45 MeV/m, and one of the HWR010s has been vertical tested with helium vessel. The slow tuner and high power coupler for this HWR have been developed and tested.

## INTRODUCTION

Nuclear energy as a kind of clean energy will be widely used in Chinese energy program in the future. But one of the serious problems is how to handle radioactive waste produced by nuclear plants. The accelerator and nuclear scientists obtained a reasonable way to apply nuclear energy and dispose the nuclear wastes, this is an accelerator-driven system (ADS). IMP and IHEP are developing a high-intensity CW H- ion linac for China ADS (Accelerator Driven Sub-critical System). Two injectors are being constructed by IMP and IHEP to demonstrate the most critical R＆D issue related to the front-end of a CW high-power and proton linac. Injector I chose Superconducting spoke cavity to accelerate H- from 3.2 MeV to 10 MeV， which is being constructed by IHEP. Inject II chose Superconducting Half-wave Resonator to accelerate H- from 2.1 MeV to 10 MeV, which is being constructed by IMP. The main design parameters of Injector II are listed in Table1 [1]. HWR is a well built superconducting cavity international, there are many labs in the word have designed and constructed HWR cavities.

Table 1: The Basic Parameters of Injector II

| Parameters | Value |
|---|---|
| Particle type | Proton |
| Operation frequency(MHz) | 162.5 |
| Operation mode | CW |
| Input beam energy(MeV) | 0.035 |
| Output beam energy(MeV) | 10 |
| Beam current(mA) | 10 |

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In this paper, we present the electromagnetic design, Mechanical analysis, fabrication arts and test results of HWR010.

## ELECTROMAGNETIC DESIGN

The goal of the RF properties is to get a lower heat load and a higher accelerating gradient, which are determined by a higher R/Q0 (R is the shunt impedance and Q0 is the quality factor), a higher G factor, and lower peak surface fields (Bpk/Eacc and Epk/Eacc). There are four electron beams welding in the cavity high magnetic region when welding our HWR, and we can't grinding this region, so the performance limitation in the HWR is the thermal-magnetic quench, which leads us to put more care to minimize Bpk/Eacc. The cavity design was described in ref [2]. Parameters of the cavity geometry used in the RF optimization are shown in figure 1. The final geometry parameters and RF parameters are shown in table 2 and table 3.

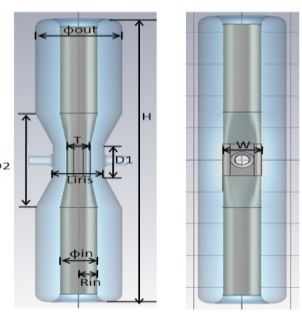


Figure 1: Parameters of the cavity geometry used in the RF optimization.

Table 2: Final Geometry Parameters of the IMP HWR010.

| Parameters | Value | Unit |
|---|---|---|
| Rbeam | 20 | mm |
| H | 900 | mm |
| Φout | 184 | mm |
| Φin | 80 | mm |
| Liris | 110 | mm |
| T | 45 | mm |
| W | 90 | mm |
| D1 | 100 | mm |
| D2 | 300 | mm |




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Table 3: Final RF Parameters of the IMP HWR010.

| Parameters | Value | Unit |
|---|---|---|
| Frequency | 162.5 | MHz |
| β opt | 0.10 | |
| Uacc | 0.78 | MV |
| Epeak | 25 | MV/m |
| Bpeak | 50 | mT |
| R/Q0 | 148 | Ω |
| G=Rs*Q0 | 28.5 | Ω |

## MECHANICAL ANALYSIS

The HWR010 mechanical analysis was described in ref [3]. During mechanical analysis of HWR cavity, the variation of RF Eigen frequency was calculated and tested, including pressure sensitivity, Lorentz force detuning, tuning sensitivity and resonant vibration and etc. A sequential coupled field analysis RF-Structural-RF is used to predict the frequency shift due to cavity deformations under external pressure using codes ANSYS. AS the cavity stiffening environment is hard to determine, it is necessary to provide this research under two cavity beam port boundary conditions: fully fixed and completely free. Structure analyses result of HWR010 with beam pipes fixed is shown in figure 2. The simulation results of HWR010 pressure sensitivity under 1 Atm are shown in Table 4.

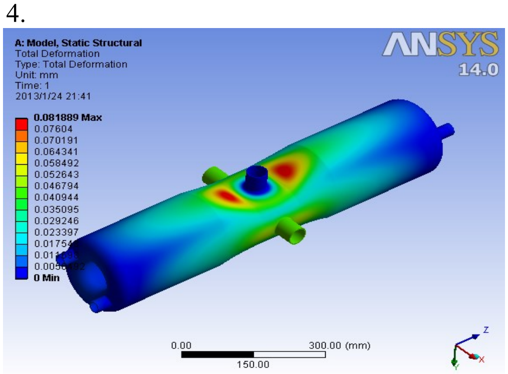


Figure 2: Structure analyses result of HWR010 with beam pipes fixed (cavity deformation).

Table 4: Pressure Sensitivity under 1 Atm.

| Boundary | fix | free | Unit |
|---|---|---|---|
| Displacement | 0.0695 | 0.252 | mm |
| Stress | 5.786 | 19.066 | ksi |
| △f | 17.892 | 110.773 | kHz |
| df/dp | 23.54 | 145.6 | Hz/torr |
| $K_L$ | 4.657 | - | $Hz/(MV/m)^2$ |

From the above result we can see that the main frequency shift is caused by the beam port displacements. Whatever the different boundary condition, the cavity is too soft so we need add some ribs on it for strength the cavity. The structure of the HWR010 ribs are shown in figure 3. The pressure sensitivity of HWR010 with ribs is about 5 Hz/mbar.

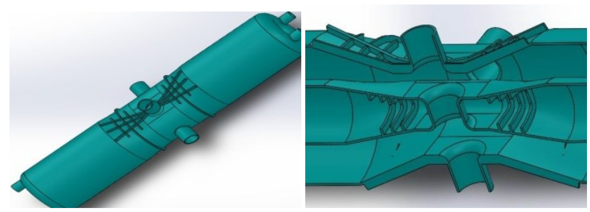

Figure 3: The structure of the HWR010 ribs.

## CAVITY FABRICATION

### *Copper Model*

A HWR copper model was built at IMP before fabricate the niobium cavity to test the HWR fabrication procedure. Figure 4 is the HWR copper model. The RF measurement and CST-MWS simulation result are shown in table 5. The frequency simulation result is a little smaller than the measurement result. The Q0 simulation result is about 20% higher than the RF measurement result.

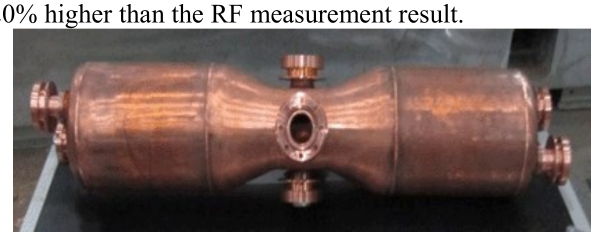

Figure 4: HWR copper model.

Table 5: Copper Model RF Measurement and CST-MWS Simulation Result.

| Parameters | Measurement | Simulation |
|---|---|---|
| Frequency | 162.6MHz | 162.18MHz |
| Q0 | 7040 | 8561 |

### *Niobium Cavity*

The HWR010 mainly consists of three parts, inner conductor, outer conductor and top/bottom covers. The inner conductor and outer conductor were fabricated from niobium sheets of 3 mm thickness by deep drawing and electron-beam welding. The top/bottom covers were fabricated from niobium sheets of 3 mm thickness by deep drawing. The beam pipes, coupler pipes and process ports pipes were fabricated form niobium rods by machining.

Before welding, all parts were degreased by ultrasonic water rinsing, and a layer of 10 µm was removed at 15-20℃. All parts were drying in class 100 clean room after light BCP, as shown in figure 5. Particularly critical are the four electron- beam welds between inner conductor, outer conductor and top/bottom covers, which are made from the outside, and a reliable method for obtaining a smooth weld seam at the inner cavity surface was required. We assembled the three parts and measure the Eigen frequency of HWR010 before final welding, as shown in figure 6. We cut the inner conductor and outer conductor to final length after frequency measurement. The fabricated HWR010 are shown in figure 7.

Figure 5: Parts of HWR010 in Class 100 clean room.

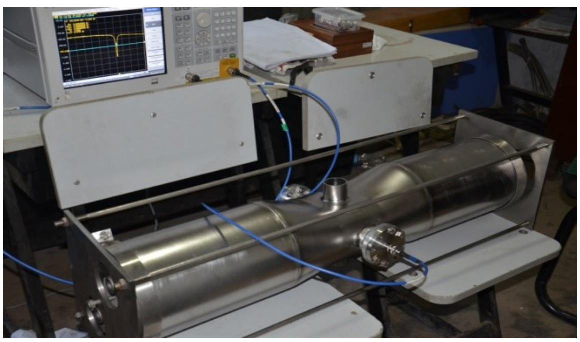

Figure 6: Eigen frequency measurement before final welding.

Figure 7: The fabricated HWR010.

## VERTICAL TEST

A layer of 100-200 µm is typically removed in several steps from the inner cavity surface to obtain good RF performance in the superconducting state. The standard method applied for niobium cavities is buffered chemical polish (BCP). The Preparation process includes:

- Ultrasonic water rinsing.
- Heavy BCP etch of approximately 150 microns.
- 600 ℃ 10 hours or 850 ℃ hours 3 Hours High temperature vacuum baking to remove hydrogen.
- Light BCP etch 25µm.
- High pressure rinse, seal in class 100 clean room.
- 48 hours 120 ℃ baking.
- Vertical test.

Four HWR010s have been vertical tested. All the HWR010s vertical test results better than the RF design values, as shown in figure 8.

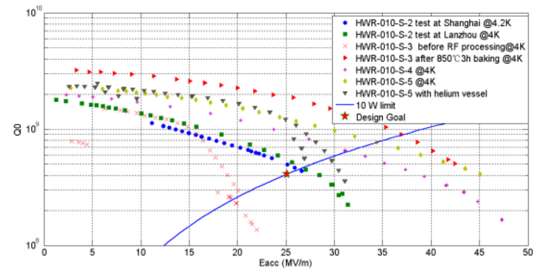


Figure 8: Vertical test results of HWR010.

## CONCLUSION

The HWR010s has finished the vertical testing and the Q0 is 4E8 at Epeak = 45 MeV/m, and one of the HWR010s has been vertical tested with helium vessel. The slow tuner and high power coupler for this HWR have been developed and tested. We expect to horizontal test a HWR010 by the end of this year.

## ACKNOWLEDGMENT

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## REFERENCES


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