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STUDY ON 650MHz 5-CELL PROTOTYPE CAVITIES AT IHEP*

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Abstract

CEPC Pre CDR pointed that the 650 MHz 5-cell SRF cavity could be a candidate for the main ring of the single-ring pretzel scheme at the Higgs energy in 2015. Then EM design of 5-cell cavities were published later. So, the study on the fabrication of a 5-cell prototype cavity with waveguide HOM couplers were carried on at IHEP. In the paper, we will mainly report the mechanical design and fabrication progress of the 5-cell prototype. Besides, fabrication of a bare 2-cell prototype cavity was also carried on according to the further study after Pre-CDR. Challenges and possible solutions for the prototypes development will also be discussed.

INTRODUCTION

After the discovery of Higgs boson in 2012, a Circular Electron Positron Collider (CEPC) was proposed. In 2015, the CEPC Preliminary Conceptual Design Report was published and pointed that the 650 MHz 5-cell SRF cavity could be a candidate for the main ring of the single-ring pretzel scheme at the Higgs energy. On the other hand, further studies showed that a 650 MHz 2-cell cavity would be a better choice for the double ring or partial double ring with the crab waist scheme at the Higgs, W and Z energy, and 5-cell cavity could be used at the possible higher energy upgrade [1].

The electromagnetic (EM) design of 5-cell and 2-cell cavities were published respectively later [2,3]. So, study on the fabrication of a 5-cell with waveguide (WG) HOM couplers for higher HOM power and a bare 2-cell prototype cavities were carried on at IHEP. In the paper, we will mainly report the mechanical design and fabrication progress of the two prototypes. Challenges and possible solutions for the prototypes development will also be discussed.

STRUCTURE AND CHALLENGE OF 5-CELL CAVITY EM DESIGN

Figure 1 shows the EM design model of 5-cell prototype. As we can see, besides a cylinder input coupler, there are also totally five WG couplers in two beam tubes. EM design shows that it has good RF characteristics for the absorption of high power HOM [2].

However, if we directly transfer the EM model to a real cavity for fabrication, there will be several challenges hard to resolve:

1) Whole cavity very large: the length of each WG is near 1m; and beam tubes are about 0.4m;
2) Great cost for both material and fabrication;
3) Almost hard to finish if consider post-treatments for the cavity by existing facilities, such as ultrasonic cleaning, HRP, BCP, heat treatment.
4) A lot problems in the processes of real fabrication, RF test, and usual travel, assembly and so on.

So, structure modification has to be done from EM model to real cavity which is suitable for real fabrication.

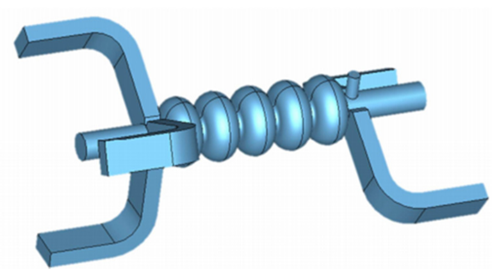

Figure 1: EM design of 5-cell prototype cavity [2].

STRUCTURE MODIFICATION FOR 5-CELL CAVITY PROTOTYPE

According to the challenges discussed above, consideration were made for the modification as following:

1) Post-treatment of cavity: ultrasonic cleaning, HRP, BCP, heat treatment;
2) Cold RF test requirement on the dimension;
3) Cavity performance: Quality factor.

Figure 2 shows the structure after modification. As shown, modification mainly focus on two parts: one is we cut the length of WG; the other is that we add an extension beam tube instead of original beam tube.

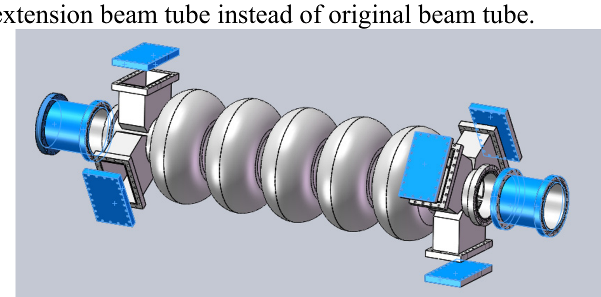

Figure 2: Modified structure for fabrication.

After above two modification, there are also some problems. First is the seal of the WG. Although the cut of WG can make the structure more simple, if a normal stainless steel flanges, a lot of power will be dissipated on it to lower the quality factor of the cavity . Table 1 shows

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the value that RF loss at various stainless steel blank flanges at accelerating gradient of 15MV/m. Comparing with RF loss of about 50W of the cavity in the same situation, they were not be accepted. So, a Nb blank flanges will be used for the structure. Besides, the sealing we will use indium to further reduce the RF loss on the sealing.

Table 1: RF Loss at Various Flanges

Flange	RF loss (W)
1	363
2	362
3	345
4	289
5	293

The second modification are beam tubes. Main consideration is the cold RF test. Since there will be an antenna for each beam tube. If we just cut the length, the antenna will couple too much power outside the cavity. It will bring a big problem for vertical test at 2K. However, if we leave the beam tube as the EM model, the whole cavity will be as long as 2m.The post treatment of the cavity will be a problem. So, after reduce the length of beam tubes, we have to add extensions for them.

Then we suppose that the antenna length is 10mm, two structure choices were considered: one is that the radius of extension is as same as beam tubes. Then Q_e will be 3.3E11 and 2.3E11 when the extension is 400mm. The other is to add a new tube with small diameter of 80mm. If we need same Q_e as first structure, total beam tube need to be 260mm. We think that for the second method, 280mm shrinkage compared with whole length of 2000mm will not help. Besides, the steps from the addition of small diameter extension the may bring a multipacting. So, at last we choose the first method.

In a conclusion, due to the modification of original model, we have to prepare for following parts as accessories of the cavity:

1) Two extensions for each beam tubes;
2) Five Nb blank flanges for each WG ports;
3) Indium sealing.

MECHANICAL CACULATION

The thickness of the prototype cavity we chose is 4mm according to former experience of ADS cavity. However, the mechanical simulations were also done for check the cavity strength by a commercial program of ANSYS Workbench [4].

Table 2: Properties of Nb at Room Temperature Used in Simulation [5, 6]

Material	Density [kg/m^3]	Modulus [kg/m^3]	Poisson's ratio	Yield [MPa]
Nb	8570	105	0.38	38

Since the yield strength of the materials of Nb at room temperature less than that at low temperature, if the design is safe at room temperature, it can also meet the requirement at low temperature. Thus our simulation is mainly carried out at room temperature. The properties of the material are shown as in table 2 [5, 6].

In the fabrication, assembly and other processes, the cavity is usually moved by holding the two beam tubes if there is no special requirements for those operations. Thus the analysis was carried out to verify the safety of this supporting method. The stress distribution is shown as Figure 3. As we can see, the stress is mainly on the beam tube. The maximum v. M. stress is about 7.9MPa. It is much lower than the yield strength 38MPa, which respects that the supporting method will meet the safety requirement.

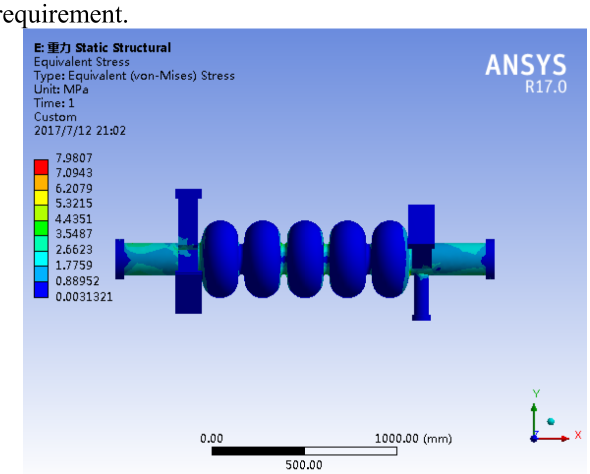

Figure 3: v. M. Stress distribution under self-gravity.

Figure 4 shows a v. M. stress distribution in a situation that the inside of the cavity is vacuum while outside is atmosphere, which is a necessary work for leaking check. As we can see, most v. M. stress are under 20MPa which means safety. Only the maximum v. M. stress is about 41MPa, which is 3MPa higher than the yield strength of 38MPa. However, we found the location of the maxium stress is at a connection corner, where the high stress usually will be higher than real value due to bad meshes. Besides, we found that at similar corner of other ends of WG, there is no similar high stress. So we think the maximum stress should be an artificial result. We don't need pay much attention to it.

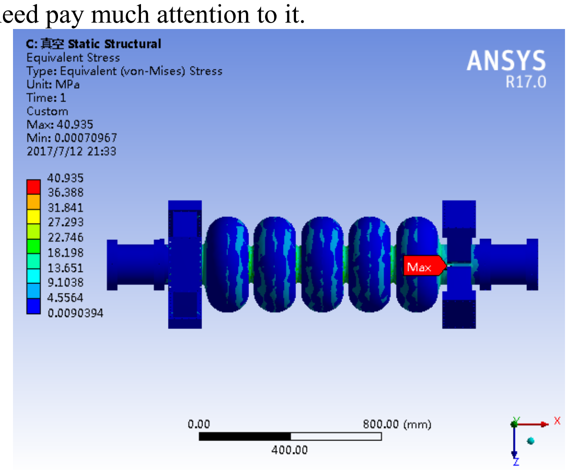

Figure 4: v. M. Stress distribution when inside of the cavity is vacuum.

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EB WELDING

Due to the large aperture of 650MHz cavity, the EB welding machine at IHEP can welds the equation from inside the cavity. So we would like the equator to be welded from both sides of cavity. First welding is from inside the cavity, and then from outside. Our thickness is 4mm. This process of welding can lower the risk from usual welding process, by which the equator will be welded at outside. Besides, the quality of EB welding should also be easy controlled by this way. Figure 5 shows all the fabrication process of 5-cell cavity.

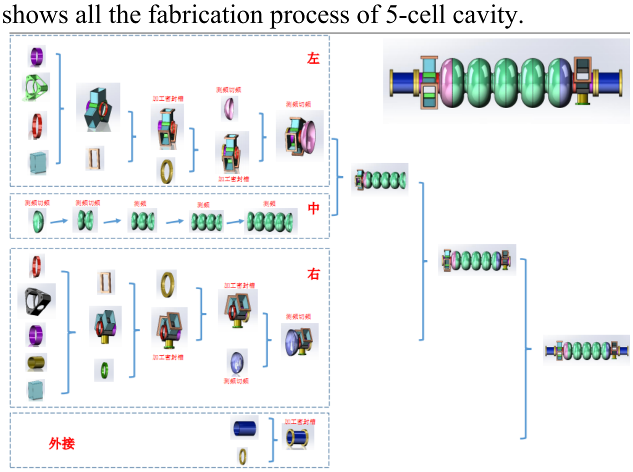

Figure 5: The fabrication process of 5-cell cavity.

650MHz 2-CELL BARE PROTOTYPE CAVITY

Besides 5-cell cavity, a 650MHz 2-cell bare cavity is also under fabrication. Figure 6 shows the 3D models of the 5-cell and 2-cell 650MHz bare prototype cavities. Different from the 5-cell cavity, the HOM coupler of 2-cell cavity is a coaxial coupler due to the small HOM power in new scheme design of CEPC [1]. Details of this HOM coupler please see [7] in this conference. Since the design is a dismountable structure, here we just leave connect ports on the cavity.

At present, both of the two prototype cavities are under fabrication. Now, most machining parts are finished. Next we will begin the EB welding. The whole cavities are planned to finish in the end of this year.

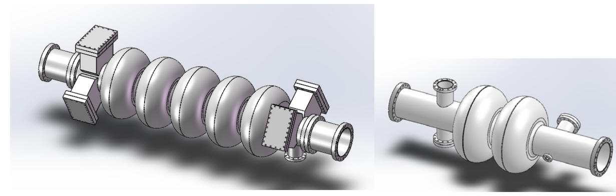

Figure 6: 3D models of the 5-cell and 2-cell 650MHz bare prototype cavities.

SUMMARY

In this paper, we report the progress of studies on 650MHz 5-cell and a 2-cell bare SRF cavities. The structure of 5-cell EM model has be modified to fit the fabrication. Mechanical strength under self-gravity and vacuum are checked by ANSYS Workbench. At present, both of the two cavities are under fabrication. Due to the large aperture of iris, a new EB welding process for equator, that the welding is from outside cavity, will be tried. Both of cavities are planned to finish in the end of this year.

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