DEVELOPMENT OF FREQUENCY MEASUREMENT SETUP FOR ADS 650 MHz AND 1.3 GHz SUPERCONDUCTING RF CAVITIES AT IHEP

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Abstract

An Accelerator Driven Sub-critical System (ADS) is under development in China. The 650MHz beta=0.82 superconducting RF cavity (SRF) has been chosen as a possible candidate to accelerate the proton bunches in the medium energy section from 360MeV to 1.5GeV [1]. In order to obtain quality management and quality assurance during fabrication, radio frequency measurements on parts and subassemblies of SRF cavities become a proper method [2]. In this paper, study on developing a new frequency measurement setup mainly for half cells and dumb-bells of ADS650MHz cavities at IHEP was reported. A digital pressure sense was assembled in the setup. Together with the simulation on the structural by ANSYS Workbench, a quantitative standard for the frequency measurement was built for the cavity fabrication. Since a 9-cell TESLA-Like cavity is also under study in the meantime, via a slight modification, the setup can be also used for it.

INTRODUCTION

As a high intensity proton accelerator in China, the basic research of Accelerator Driven Sub-critical System (ADS) has been started in 2000 [3]. Recently it was upgraded to be a R&D program proposed by Chinese Academy of Sciences, and started in the first half of 2011. Figure 1 shows the preliminary design of 1.5GeV linac except injector part of the program [4]. As shown, in the program, more than on hundred elliptical superconducting RF (SRF) cavities need to be fabricated. So, the quality control of those SRF cavities in fabrication becomes important.

Figure 1: Scheme for the Accelerator of China ADS 1.5GeV linac [4].

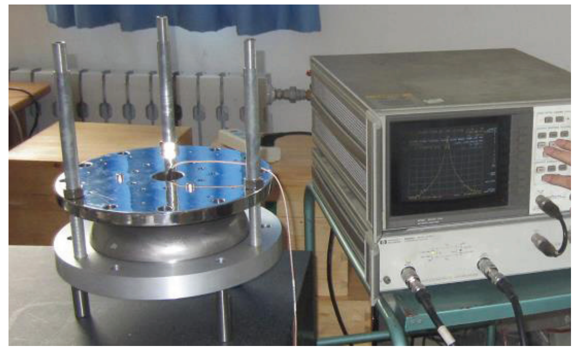

Figure 2: Schematic diagram of the magnetic structure.

To a standard elliptical SRF cavity forming method, usually there are following steps: deep drawing for half-cell cavities, electron beam (EB) welding to form dumbbells, and EP welding to form the whole cavity.

During those process, several factors can impact the final cavity shape, taking for example, shapes after deep draw are sometimes not accurate, there are a deformation during EB welding due to high temperature, and so on. So, the cavity shape needs to deform to a correct shape. One main method to determine correct shape is the frequency measurement [5]. Thus a setup for the RF frequency measurement of those parts or subassemblies is made. Since 1.3GHz SRF cavities are smaller than ADS650MHz SRF cavities, after a litter modification, this setup can be also used for them.

THE SETUP STRUCTURE

Requirements for the Structure

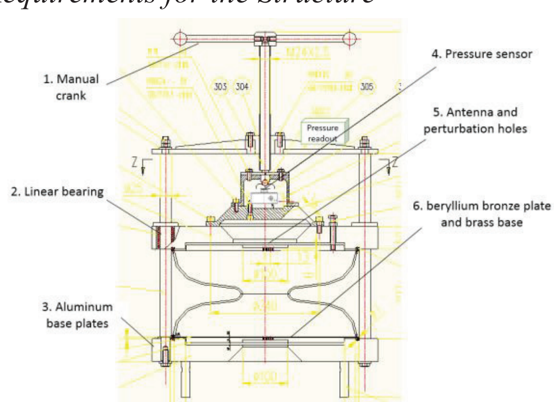

Figure 3: Mechanical design drawing of the setup.

To measure RF frequencies of half-cell or dumbbell cavities, those subassemblies above need to be placed between two contact plates. In the center of each plate,

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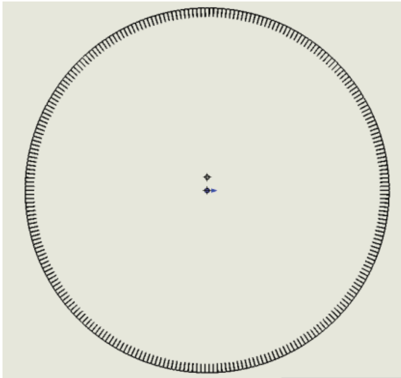

Figure 4: The top view of the beryllium bronze contact plate with about 270 slots in the equator area for sufficient electrical contact.

two antennas will be connected to a Network Analyzer (NWA). Then RF frequency can be measured. In the principle, this process is easy. However, in the experimental process, we find if an accurate or repeatable measured value is expected, the work seem not as easy as talked above. Following some main problems will be discussed that we met in actual experiments as well as its solutions.

The first problem we met is the contact between the subassemblies and the tow contact plates. At beginning, we just using a 3cm aluminum plots as conduction plate as shown in Fig. 2. In the most time, it seems work fine.

However, for a few of subassemblies, it is hard to find the frequency peaks in NWA, and only after increasing the pressure, we could get it. We think it should be from the deformations from the correct shapes, which impact flatness of edges and the matching between edges and the aluminum plate. Thus, when more force was added, we can see the frequency peak. So, good contact condition between subassemblies and setup is the first requirement.

Another requirement is to ensure the right cavity shape of measurement. It not only means that the shape of cavity is correct, but also the conduction plates need to have a flat surface. In order to resolve the problem referred above, a thin beryllium bronze of 0.5mm is used as the conduction plate. So, in the process of measurement, it may be deformed especially at high pressure. The last one is that we would like to know the pressure or keep pressure the same in each measurement. It will be useful to ensure that there is a comparability for frequencies measured in each time.

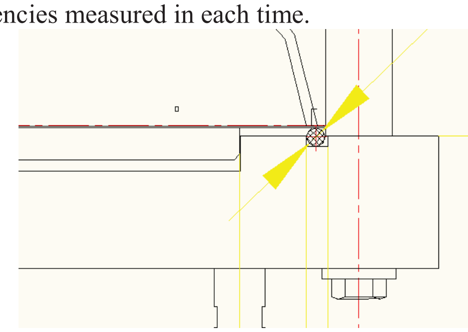

Figure 5: The detailed view for the contact parts.

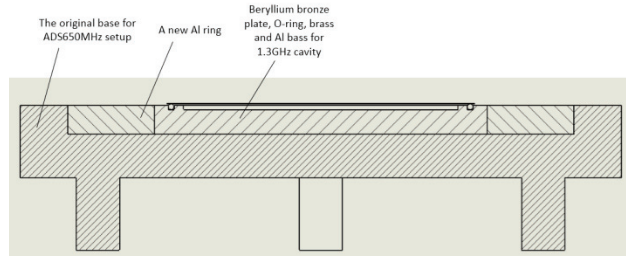

Figure 6: Schematic of the setup modification for 1.3GHz cavities.

Design

According to the requirement discussed above, the design was carried out by the program AutoCAD and SolidWorks. Figure 3 is a conceptual design drawing. It consists of support frame, beryllium bronze plates, pressure sensor, and other RF components.

The frame mainly including following components: two aluminum (Al) base plates, a manual crank part, and four vertical bars. The upper Al base plate can move in the upper-lower direction through the operation of manual crank. The other parts of the frame are fixed. There are four linear bearing in the upper aluminum plate. Besides the help for the moving, it also can ensure parallelism of the two Al plates, the accuracy of which is 0.02mm. It is also helpful for the good contact between the setup and subassemblies of cavities.

Another component to resolve the contact problem discussed as the first requirement is a thin beryllium bronze plate with more than two hundreds of slots on the edge. Figure 4 is the drawing of this part. Beryllium bronze has both good elasticity and electrical conductivity. However, subassembly after process such as deep drawing or EB welding, the edge of the subassembly may be not in a plane. So, slots are opened at the edge.

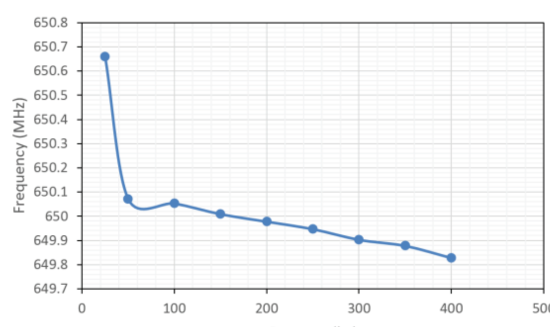

Figure 7: Relationship between pressure and frequency.

ISBN 978-3-95450-122-9

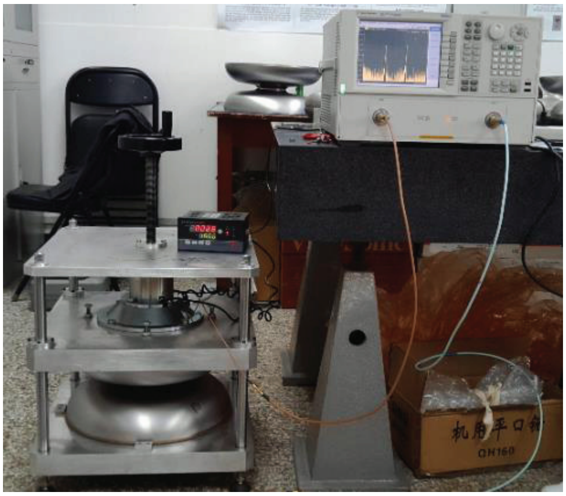

Figure 8: The photo of frequency measurement setup.

Besides, there is also an O-ring under the beryllium bronze to makes a gap between the beryllium bronze and Al base plate as shown in Fig. 5. So, it can resolve those poor contacts due to bad planeness of subassemblies.

As to resolve the problem that the thin contact plate maybe deforms under the pressure which will cause an error for frequency measurement, a bass thick plate of about 4.5mm is fixed on the beryllium bronze by adhesive. So the press on the edges cannot destroy the flatness of thin contact plate.

At last, to well know the accurate pressure we added to the cavity subassemblies, a pressure sensor was added to ensure the measurement consistency for each time.

Modification for 1.3GHz SRF Cavities

The setup is originally made for ADS650MHz cavities. Since the equator diameter of 650MHz cavity is about 2 times larger than that of 1.3GHz cavities, after a little modification, this setup can also be used for 1.3GHz cavities.

Since 1.3GHz SRF cavity is smaller, the beryllium bronze plate and the O-ring need to be fabricated. Then, as shown in Fig. 6, we only add a new Al ring on the original setup to make the size of the support suitable for the 1.3GHz cavity.

QUALITY CONTROL FOR THE MEASUREMENT

Pressure Limitation

Since if large pressure is used in the measurement, subassemblies will be deformed by the setup or even destroyed. So, simulations were done by the program ANSYS Workbench to give the limitations. And the simulation results shows that the pressure used in the experiment should be smaller than 340kg. This result is according to the niobium yield strength of conservative engineering note values 38MPa at 295K [6]. Actually, in the laboratory experiment, the yield strength at 295K is 70.26MPa [6].It means that the maximum pressure can be as high as more than 600kg.

Preliminary Results of the Frequency Sensitivity on Pressure and System Error

Figure 7 shows the preliminary results of the frequency sensitivity on pressure. We can see that when the pressure smaller than 50kg, the frequency changed quickly at the rate of 12 kHz/kg. When pressure is larger than 50kg, the sensitivity is only 0.7 kHz/kg.

Since the accuracy of pressure sensor we used is from 0.6 to 2kg, the system error from will be 7.4 to 24 kHz and 0.4 to1.4 kHz for the pressure smaller and larger than 50kg respectively.

EXPERIENCE OF THE SETUP

The frequencies of subassemblies of ADS650MHz are measured with this setup. The typical QL was above 6000.

By using the data from this setup, the half-cell frequencies of dumbbell from two different calculation methods, the difference is very small.

Figure 8 is the photo taking when the dumbbells are measured.

SUMMERY

This paper reports the study on developing a frequency measurement setup mainly for half cells and dumb-bells of ADS650MHz cavities at IHEP. A digital pressure sensor is used in the setup for the accurate quality control. Together with the simulation on the structural by ANSYS Workbench, some quantitative standards for the frequency measurement were built for the cavity fabrication. After a little modification, this setup can also be used for 1.3GHz cavities.

REFERENCES

[1] LIU Zhen-Chao, et. al., The ADS 650MHz medium beta cavity study and design, accepted and to be published on the journal Chinese Physics C.

[2] J. Iversen, et.al., Development and Design of a Rf-Measurement Machine For The European XFEL Cavity Fabrication, Proceedings of SRF2009, Berlin, Germany, THPPO071.

[3] Shinian Fu, et. al. Proton linac for ADS Application in China, LINAC'10, Tsukuba, Sept. 2010, TUP019, (2010).

[4] Shinian Fu, et.al., Chinese Plans for ADS and CSNS, Proceedings of SRF2011, Chicago, IL USA, FRIOB03, (2011).

[5] J. Iversen, et.al., Development and Design of a RF-Measurement Machine for the European XFEL Cavity Fabricatin, Proceedings of SRF2009, Berlin , Germany, THPPO071,(2009).

[6] M. Merio, Material Properties for Engineering Analyses of SRF Cavities, Fermilab Specification: 5500.000-ES-371110.