DUMBBELL FABRICATION AND TUNING OF THE IHEP LARGE GRAIN 9-CELL CAVITY

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Abstract

As the key component of the "IHEP 1.3 GHz SCRF Accelerating Unit and Horizontal Test Stand Project", a low-loss shape bare tube 9-cell cavity using Ningxia large grain niobium is being fabricated at IHEP. This paper presents the fabrication procedure and frequency tuning method of the dumbbells of this cavity. Due to the special properties of the large grain material, several mechanical and RF problems were found and successfully solved. After equator welding, this cavity will be surface treated and tested late this year.

INTRODUCTION

The combination of the low-loss shape and large grain niobium material is expected to be the possible way to achieve higher gradient and lower cost for ILC 9-cell cavities. The cost reduction of the large grain niobium cavities lies in eliminating electro-polishing process, and the newly developed multi-wire slicing technique on large grain niobium ingots at KEK [1].

As the key component of the "IHEP 1.3 GHz SCRF Accelerating Unit and Horizontal Test Stand Project" [2, 3], A low-loss shape bare tube 9-cell cavity using Ningxia large grain niobium is being fabricated at IHEP. A pumping port is added on the beam tube to evacuate the cavity before and during vertical tests. Due to special properties of large grain material, several mechanical and RF problems were found during dumbbell fabrication, EBW and tuning.

IHEP Low Loss Bare Tube Cavity Design Parameters

Active length	1.035 m
Cell to Cell coupling	1.54 %
Geometry factor	285 Ω
R / Q	1189 Ω
E_{peak} / E_{acc}	2.38
B_{peak} / E_{acc}	3.65 mT / (MV / m)

Figure 1: 3D model and design parameters of the IHEP low-loss 9-cell cavity.

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DUMBBELL FABRICATION AND TUNING

Niobium Inspection

Ultrasonic and eddy current scanning were performed on some of the large grain niobium disks provided by OTIC, Ningxia. Some initial results of the ultrasonic scanning seemed to show no apparent defects of the material, while further investigation and improvement of the inspection methods are needed. The measured RRR value of the large grain niobium is 430.

Half Cell Fabrication and Reshaping

Several problems were found during the fabrication of half cells from large grain material. Earrings and steps were found in the equator area. Large cracks and unsmoothness were found between adjacent grains in the iris area. Iris wall thickness was not uniform after trimming (Fig. 2). The largest iris wall thickness difference of a half cell is nearly 1 mm. The spring back after deep drawing of the half cell was large according to 3D measurement (Fig. 2) and the equator became oval due to internal stress.

These problems were due to the different mechanical properties of the large grains with different crystal orientation. The steps and unsmooth area are supposed to be eliminated by CBP (centrifugal barrel polishing) on the 9-cell cavity. For the oval shape, we adjusted the roundness of the half cells by reshaping the equator with a special fixture. The final roundness was less than 0.2 mm.

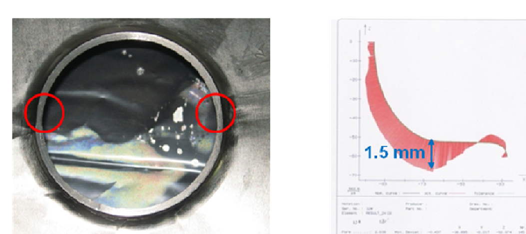

Figure 2: Iris wall thinning and shape spring back.

The designed length of the middle half cell is 57.69 mm. We add 0.2 mm EBW shrinkage allowance on both equator and iris side and another 1 mm allowance on the equator for frequency and length tuning. The theoretical length and frequency is 59.09 mm and 1277.3 MHz. Due to trimming jig mounting error and spring back, the finished length and frequency had a relatively big scattering (Fig. 3).

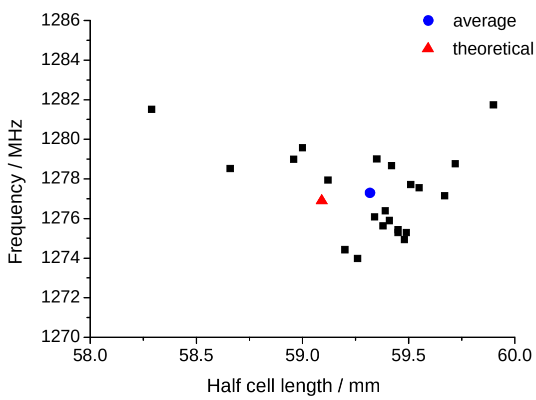

Figure 3: Frequency and length data of 20 half cells.

Dumbbell EBW

We chose two half cells with similar iris diameter to form a dumbbell. Inside and outside EBW were performed on the iris. EBW of the irises did not meet big problems in spite of the large iris wall thickness differences. The iris welding underbeads are very smooth. The shrinkage of the dumbbell length after iris two sides EBW and stiffening ring EBW is about 2 mm.

Figure 4: Fixtures for the iris inner EBW and stiffening ring mounting.

Half Cell & Dumbbell Frequency Measurement

Half cell frequency measurement will give information about the accuracy of the half cells contour by the average value of the frequencies and the reproducibility of shaping the half cells by the spread of frequencies. After EBW of the dumbbells (iris and stiffening ring welding) the resonant frequency is measured. The evaluation of this measurement will determine the amount of trimming at the equator to achieve simultaneously the correct length and the correct frequency of the 9-cell cavity. It also serves as a measure of contour change and reproducibility of iris and stiffening ring welding [4].

We made a fixture to measure the frequencies of the half cells and dumbbells. The contact surface between the old fixture and the equator (or iris) surface was a 3 mm thick niobium plate. The Q values of the half cells and dumbbells were below 1000, and the frequency was not stable. Since the plain and hard contact of the old fixture required much more press and good equator surface flatness, we made a thinner plate with radial slots and elastic washers underneath for good RF contact. With the new fixture and about 10 kg press, the Q values of the half cells and dumbbells are above 5000, and the frequency is stable at kHz.

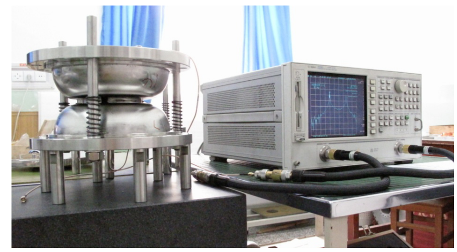

Figure 5: Frequency measurement fixture of half cells and dumbbells.

Dumbbell Reshaping and Tuning

With a special jig, we reshaped the dumbbells to the target length and adjusted the parallelism to be less than 0.2 mm. The reshaping target length was the sum of the two half cells length before welding minus iris EBW shrinkage. With the perturbation method [5], we measured six frequencies to calculate the individual frequency of the half cells of a dumbbell. The perturbation amount was about 50 kHz.

Then, according to the DESY cavity tuning method [6] and the estimated 9-cell cavity frequency and length evolution (Fig. 6), we calculated the trimming length and pre-tuning length for each half cell of the dumbbell (Table 1). The tuning target frequency of the dumbbell π mode is 1298.277 MHz, and the target length is 57.96 mm.

Table 1: Tuning Data of Dumbbells After Reshaping

Dumbbell Number	Half cell frequency / MHz	Trimming length / mm	Pretuning length / mm
#07/14	1298.721 1298.072	0.45 0.88	0.29 0.41
#12/13	1297.776 1297.111	0.82 0.76	0.33 0.20
#08/09	1301.701 1298.928	0.64 0.61	0.87 0.41
#24/48	1296.012 1296.750	0.90 0.79	0.09 0.16
#30/50	1297.830 1297.320	0.82 0.81	0.34 0.25
#23/52	1295.048 1296.734	1.04 0.86	0.01 0.19
#51/53	1294.822 1297.667	1.12 0.67	0.02 0.24

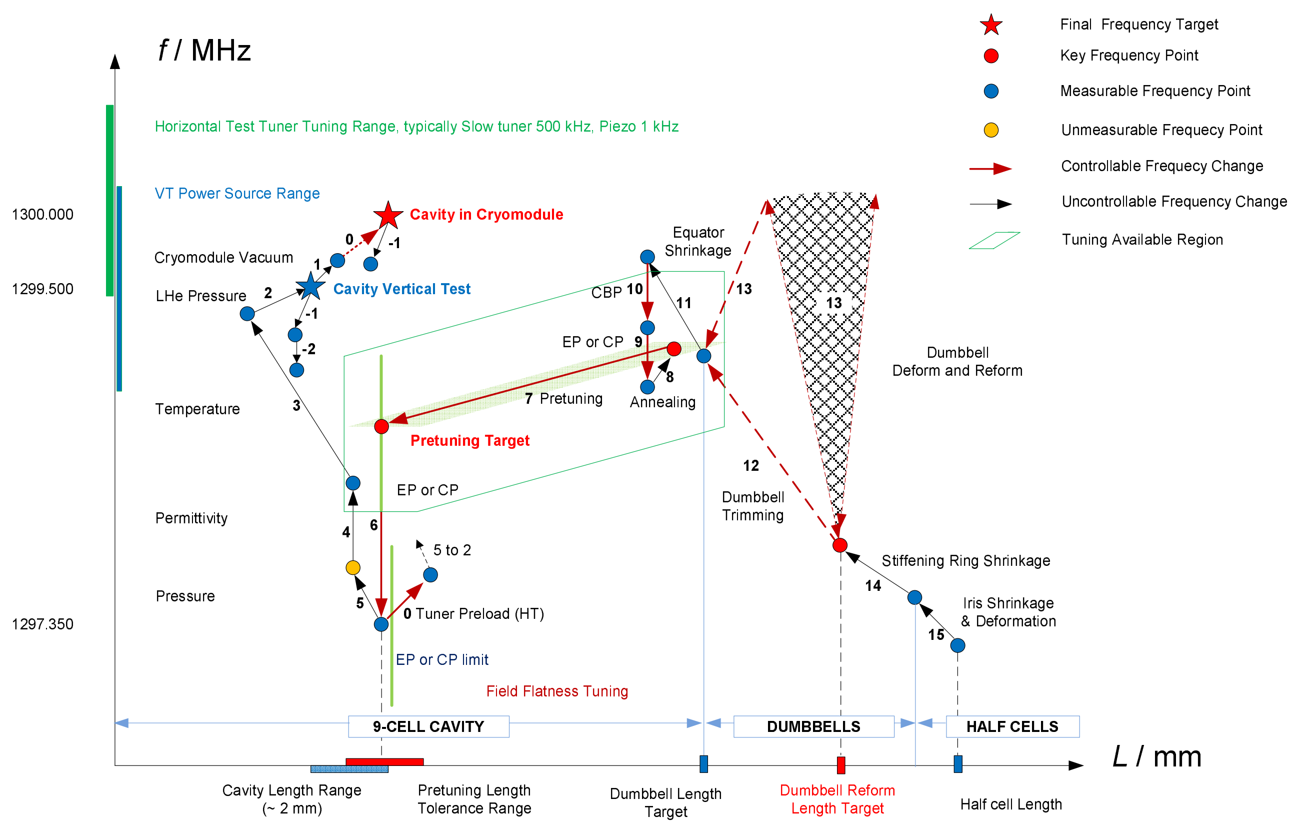

Figure 6: 9-cell cavity frequency and length evolution.

A few half cells had a negative trimming length due to big length or frequency deviation from the theoretical value. Due to the relatively large scattering of the half cell equator diameter, length and frequency, we will make dumbbell matching for equator EBW according to both the equator diameter and the tuning requirement.

SUMMARY

Several problems have been solved during the fabrication, EBW and tuning of 13 dumbbells for the IHEP large grain low-loss shape 9-cell cavity. The whole cavity will be welded and treated in late 2009, and tested in KEK next spring.

Large grain niobium cavity fabrication has many special issues. Dimension and frequency control related to material mechanical properties is important and needs more investigation.

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REFERENCES

[1] K. Saito, "Multi-wire Slicing of Large Grain Ingot Material", THOAAU05, these proceedings.

[2] J. Gao, Y.L. Chi, J.Y. Zhai et al, "ILC 1.3 GHz Superconducting RF Technology Development Program at IHEP", PAC09, Vancouver, Canada, 2009.

[3] J. Gao, Y.L. Chi, J.Y. Zhai et al, "IHEP 1.3 GHz SCRF Technology R&D Progress", TUPPO002, these proceedings.

[4] D. Proch, "DESY Specification of Welded 1.3 GHz Superconducting Resonators for TTF/VUV-FEL", MHF-SL, 09-2005.

[5] A. Sun, L.P. Zhang, Y.Z. Tang, Y.M. Li, Y.S. Cho, "A method to measure the frequencies of individual half cells in a dumbbell cavity", Review of Scientific Instruments, 79, 104701, 2008.

[6] G. Kreps, D. Proch, J. Sekutowicz, "Half-cell and dumbbell frequency testing for the correction of the TESLA cavity length", 9th workshop on RF superconductivity, New Mexico, U.S.A, 1999.