POST PROCESSING OF SPOKE TYPE SUPERCONDUCTING CAVITIES AT INSTITUTE OF HIGH ENERGY PHYSICS*

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Abstract

After upgrading the post-processing system, several superconducting cavities were RF tested at Institute of High Energy Physics (IHEP) in China recently. The test results of 14 spoke 012 cavities and 6 spoke 021 cavities which used at China ADS injector I and linac all exceeds our design objective. Moreover, a spoke 040, a 650MHz elliptical cavity and a 325MHz HWR cavity are also vertical tested and the test results are all significantly surpass our design value. The post processing of these cavities including Buffered Chemical Polishing (BCP), high temperature heat treatment and High Pressure water Rinsing (HPR) is presented here.

INTRODUCTION

In 2014, IHEP upgraded its superconducting cavity post-processing system to built high quality superconducting cavities for China ADS superconducting proton linac [1, 2]. Two cavity processing bases were built. One is located in Ningxia Orient Superconducting Technology Co., Ltd (OSTEC) where acid license can be got. Buffered chemical polishing, high temperature heat treatment and initial high pressure rinsing are arranged in OSTEC. After that, the cavity is sent back to IHEP to do the final HPR and a 120℃ bake. From the end of 2014, more than twenty cavities are processed by these two processing bases, the processing recipe and RF test results is presented in this paper.

CAVITY PROCESSING

After fabrication, the cavity is sent to OSCTC to do 150 µmBCP etching to remove the contaminated and damaged outmost layer. The BCP facility is located in a two storey house [3]. The acid mixture (Hydrofluoric HF (49%), Nitric (69.5%), and Orthophosphoric (85%)) is prepared downstairs and then be poured into an Acid Supply Tank as shown in Fig. 1. After cooling down to 12 ℃, the acid is pumped into an Acid Tank upstairs which is ~3.5m higher than the Supply Tank. When the cavity is ready, the acid is filled into the cavity downstairs by gravity in one minute. In order to reduce the bubble generated during chemical etching and cooling down the acid temperature, the acid in cavity is circulated in the system driven by a recirculation pump. The acid temperature in the cavity is controlled to be ~15℃ by two water chillers. When a 75 µm etch is performed after about an hour, the waste acid in the cavity is dumped into an Acid Dump Tank. Then Ultra-pure water is filled into the cavity from upstairs by gravity to clean the residual acid on the cavity surface. After about six round of water recirculation, the cavity is removed out of the BCP system to check is there any remained defects and contaminates on the cavity surface. After making sure all the visible defects is removed by the initial etch, the cavity is rotated 180° to perform the other 75 µm chemical etching. An ultrasonic gauge is used to monitor the cavity etching thickness at 16 locations on the outside surface of the cavity. After the same six cycles of water rinsing, the cavity is taken down from the System and sent to perform HPR to remove the residual chemicals on the surface.

Figure 1: Buffered chemical polishing system.

Figure 2 shows the high temperature heat treatment facility. A 750℃ annealing recipe is chosen for bare cavity, warm up 3 hours and heat preserve for 3 hours. This recipe saves time for our program compared to the regular recipe 600℃@10 hours as there are tens of cavities need to be annealed in one year. For cavity with helium vessel, the annealing temperature is set to be 650℃ @ 3 hours

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heat preservation. After that, the cavity is performed 30 μm light BCP etch to remove the residual surface contaminate.

Figure 2: High temperature annealing facility.

Then the cavity is packed at OSTEC and sent to IHEP in Beijing. It is cleaned again by using HPR as contamination maybe happen during transportation. Fig. 3 shows the ultra-pure water system built in 2014. It has a stored water capacity of 3 ton with resistivity 18MΩ · cm.

Figure 3: UPW supply system at IHEP.

High pressure rinsing (HPR) with ultra-pure deionized water is a common way used for the processing of SRF cavity worldwide. It seems be the most effective processing to remove the chemical residuals after BCP and other particles which can cause field emission and can't be processed during RF test. Fig. 4 shows the new HPR system built in 2014, located in a 100 class clean room. The cavity is fixed on a rotatable platform. High pressure water is injected into the cavity by a stainless steel spray bar. Nine sapphire nozzles are mounted at the head of the spray bar to avoid generating stainless steel particles. The spray bar is fixed in the horizontal direction and can be moved in vertical direction and the speed is adjustable. For spoke cavity, the moving speed of the spray bar is chosen to be 30mm/min vertically and the cavity rotating speed is 4RMP. This arrangement of rotation rate and lifting speed can insure the high pressure water cover almost every single spot of the cavity. For each port (2 couple ports and 2 beam tube ports), there are twice rinsing last about 30 minutes. Then the cavity is assembled in a 100 class clean room and vacuum sealed then moved outside the clean room. A 120℃ bake is performed after that as the last step of the post processing.

Figure 4: High pressure rinsing facility at IHEP.

CAVITY TEST RESULTS

Up to now, the above post processing procedure has been applied to at least 16 spoke 012 cavities, 10 spoke 021 cavities, one spoke 040 cavity, one 650MHz elliptical cavity and one 325MHz HWR cavity. All the cavities show good performance that significantly surpasses our designed objective. For spoke 012 cavity, the designed target is $Q_0 = 5 \times 10^8 @E_{peak} = 31.5MV/m$ ($B_{peak} = 43.5mT$). But most of the cavities reached 90mT B_{peak} and cavity #16 reached 111mT, as shown in Fig. 5. Likewise the B_{peak} of five spoke 021 cavities surpasses 100mT, #6 reaches 118mT.

A spoke 040 cavity was also RF tested at 4.2K, the gradient reaches 11.5MV/m corresponding to $B_{peak} = 94.3mT$ ($E_{peak} = 41.4MV/m$), and Q_0 reaches 2.04×10^9, which exceeds the design value $E_{acc} = 7MV/m$ @ $Q_0 = 1 \times 10^9$. Besides that a 650 MHz elliptical cavity (beta=0.82) is tested at January 2015. It reaches gradient 9MV/m and $Q_0 = 5 \times 10^8$ under 4.2K, exceeds the task target $8\mathrm{MV/m}, Q_0 = 3 \times 10^8$. This cavity was RF tested again under 3.3K and reaches $11.8\mathrm{MV/m}, Q_0 = 1 \times 10^9$ over the design value under 2K ($8\mathrm{MV/m}, Q_0 = 3 \times 10^9$). Soon, a 325MHz HWR cavity is RF tested under 4.2K. The gradient reaches $15.9\ \mathrm{MV/m}$ with $Q_0 = 4.3 \times 10^8$, corresponding to $E_{peak} = 66.2\ \mathrm{MV/m}$ and $B_{peak} = 77.6\ \mathrm{mT}$.

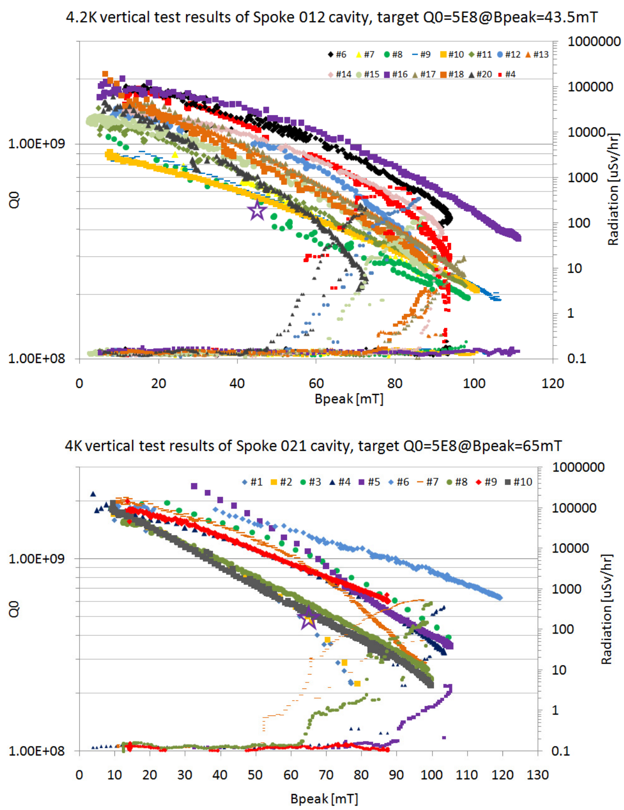

Figure 5: vertical RF test results of spoke 012 and 021 cavities.

CONCLUSION

IHEP has developed two post processing bases. The key facilities such as buffered chemical polishing, high pressure rinsing, high temperature heat treatment facility and bake system has been built. All 14 spoke 012 cavities and 6 spoke 021 cavities for the ADS 10MeV proton injector and the main linac, and a spoke 040 cavity, a HWR cavity and a 650MHz ellipsoidal cavity have been processed by this new built post processing system, and the performance of all the cavities exceeds the design value significantly.

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