SURFACE PROCESSING FACILITIES FOR SPOKE CAVITIES AT IHEP *

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Abstract

The China ADS injector I program is building a CW 10MeV superconducting proton linac at IHEP. To develop the superconducting spoke cavities incorporated in this linac, a set of new surface processing facilities were built and successfully used to treat the Spoke012 prototype cavities. In this paper, we present the design, fabrication and operation of these facilities, including BCP, HPR and UPW, etc.

INTRODUCTION

IHEP is engaging in the development of spoke cavities for China ADS superconducting proton linac [1]. Spoke cavity is a TEM-class and generally superconducting resonator. Its geometry is quite different from an elliptical cavity, and therefore needs special surface processing facilities.

In Daxing district of Beijing, about 40 km far from IHEP campus and where the acid licence could be got, a new surface processing base for development of spoke cavities has been constructed, equipped with the BCP, HPR, UPW and Ultrasonic facilities.

BCP FACILITY

Buffered Chemical Processing (BCP) is one of the traditional chemical milling (etching) methods to remove the damaged and contaminated outmost layer of a superconducting cavity. It was chosen at IHEP for spoke cavities processing because of its feasibility, in addition to its widely understood process techniques and low cost [2].

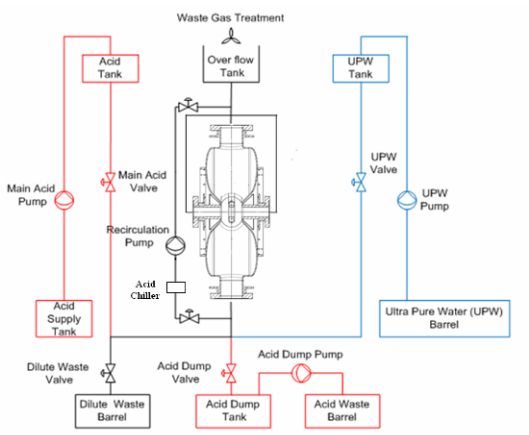

Figure 1: Scheme of BCP.

Figure 1 is the scheme of BCP at IHEP. A mix of three acids: Hydrofluoric HF (49%), Nitric (69.5%), and Orthophosphoric (85%) was prepared and cooled down to 10 °C in the Acid Supply Tank, and then pumped to the Acid Tank which is on the upper platform with the height of 4.5m. When the cavity is sealed and ready for etching, the acid from the Acid Tank will fill up the interior of the cavity by gravity in less than 1 minute, and then the acid recirculation starts, driven by the Recirculation Pump. After the etching is completed, the acid is dumped from the cavity into Acid Dump Tank, and the cavity is immediately filled with ultra-pure water from the UPW Tank. For better rinsing, the water is also circulated by the Recirculation Pump. After about 5 minutes of circulation, the water is dumped and new UPW is filled in the cavity and circulated. In order to reach pH of about 4 as regulations mandate, 4~6 rinsing cycles are usually needed.

There are two water chillers with total capacity of 5 kW in this facility. One is used to cool the stored acid in the Acid Supply Tank and the other for the circulated acid. The heat exchange capacity of the later chiller is about 1kW and may keep the circulated acid below 15°C if needed.

The flow of the circulated acid is monitored by a GF meter. And, in order to adjust the flow, one special valve is used to adjust the pressure of the Recirculation Pump.

The facility is semi-automated and kept in a closed room with the size of 6m (length)*4m (width)*5m (height), shown in Fig. 2.

Figure 2: BCP Facility at Daxing base of IHEP.

During BCP of the spoke cavity, the cavity is oriented with the power coupler port and the vacuum port along the vertical axis and the beam ports along the horizontal axis. The interior cavity is filled up with acid through the bottom port. After shutting off the source of the acid, the Recirculation Pump draws acid from the top port and beam port through 3 soft thin pipes of ϕ20 and sends it back to the bottom port through a hard thick pipe of ϕ40,

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shown in Fig. 3.

During bulk BCP, in order to obtain a symmetric etching and keep the niobium content in the acid below 10g/l, the cavity is etched twice, and between the two etching sessions, the cavity is flipped top to bottom. The reduction in wall thickness is monitored at 16 locations using an ultrasonic thickness gauge.

Figure 3 : Pipes connection of spoke cavity.

UPW SUPPLY SYSTEM AND ULTRA-SONIC BATH

Ultra-pure water (UPW) is widely used for the surface processing of superconducting cavities. A commercial UPW supply system is equipped for the processing of spoke cavities, shown in Fig. 4. Table 1 indicates its main parameters.

Figure 4 : UPW supply system at Daxing base.

Table 1: Main Parameters of UPW Supply System

Resistivity	18MΩ-cm
Stored water capacity	3 Ton
Outlet water pressure	0.4MPa
Outlet water flow	15~20L/h

In preparation for the BCP, the cavity is usually immersed in a bath of UPW with a degreasing agent and ultrasonically cleaned. So, a large ultrasonic bath is also equipped at Daxing base of IHEP, shown in Fig. 5.

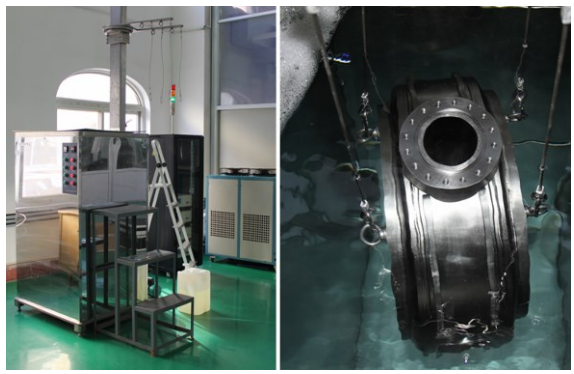

Figure 5 : Ultrasonic bath and Spoke012 cavity in it.

Table 2: Main Parameters of the Ultrasonic Bath

Bath size	0.65m*0.65m*1.45m(Height)
Ultra-sonic frequency	40kHz
Ultra-sonic power	8kW
Heat Power	8kW
Temperature	Room temp. to 60 °C

HPR FACILITY

Since rinsing with high-pressure ultrapure water (HPR) is the most effective tool to remove micro-particles and therefore reduces field emission and HPR is also effective in reducing field emission which cannot be processed during an RF test, a HPR system is equipped at Daxing base of IHEP [3].

Figure 6 shows the HPR in a class 100 clean room. The cavity is fixed on a rotating platform, and the rotate speed is adjustable. The head with 6 nozzles is welded with a cane and fixed at a vertically moving linear bearing whose speed is also adjustable.

The head is made of stainless steel, and the diameter of the nozzle is about 0.5mm. Angle with 6

The pressure of the pump may be adjusted from 0 to 12MPa, and the flow is about 15L/min at 10MPa which is chosen for the rinsing of the Spoke012 cavity.

There are 4 ports in the spoke cavity, and each port will be rinsed for 30 minutes.

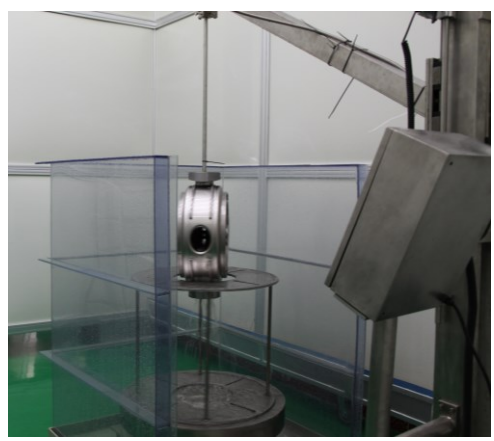

Figure 6 : HPR facility at Daxing base of IHEP.

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SURFACE PROCESSING OF SPOKE012

Spoke012 is the first spoke cavity developed at IHEP. Its Beta is 0.12 and frequency is 325MHz. The out size of the cavity is about ϕ480mm*240mm. The inner volume of the cavity 27L and the surface is 0.72m^2. The first two Spoke012 prototype cavities were fabricated in November of 2012, and then the surface processing of the two cavities was completed at the end of 2012.

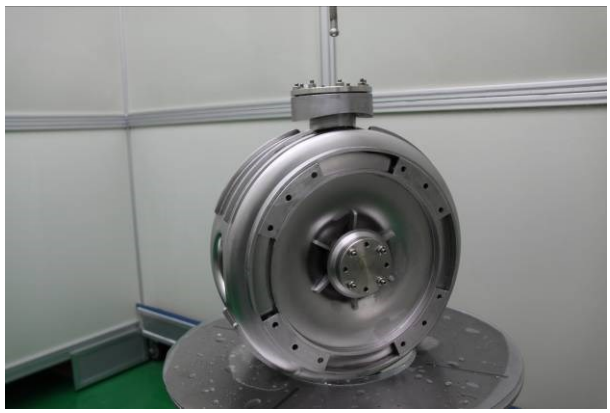

Figure 7 : Spoke012-2# cavity after HPR.

After post processing, the Spoke012 prototype cavities were vertical-tested at the Superconducting RF Lab of IHEP.

The vertical test system consists of 325MHz signal generator,1kW solid state amplifier, LLRF control system and DAQ system, and classical vertical test method was used [4].

In one of the tests, Spoke012-02# reached Eacc=8MV/m at 4.2K, the residual surface resistance (Rs) is 50 nΩ.Here, Eacc is defined as the total accelerating voltage divided by β λ(110mm) [5].

Several different surface processing recipes have been tried with the two prototype cavities and 3 vertical tests completed. From the test results, it is concluded that the recipe shown in Table 3 should be the best and will be adopted as a baseline recipe for next cavities.

Table 3: Spoke012 Cavity Processing Recipe

1. Inspection – RF & Optical
2. Ultrasonic cleaning, 60minutes at 50 °C
3. Bulk BCP, 15~18 °C, flip at 60um
4. Ultrasonic cleaning, 30 minutes at 50 °C
5. HPR, 30minutes
6. Annealing, 3 hours at 750 °C, < 5 °C /min ramp rate, Vacuum <5.0E-4Pa
7. Ultrasonic cleaning, 60minutes at 50 °C
8. Light BCP, 15~18 °C, 30um
9. Ultrasonic cleaning, 30 minutes at 50 °C
10. HPR, 120minutes
11. Drying in class 10 clean room, 12 hours
12. Assemble in class 10 clean room
13. Evacuate + 100 °C Bake 48 hrs
14. Vertical test

CONCLUSION

To develop the superconducting spoke cavities for China ADS linac, IHEP has constructed a set of new surface processing facilities such as BCP, HPR and UPW at Daxing base, and used them to treat the Spoke012 prototype cavities. Several processing recipes were investigated and one preliminary recipe was fixed. Next, according to the experience got in these two years, the HPR facility will be improved and the processing recipe investigated further.

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