HORIZONTAL HIGH PRESSURE WATER RINSING FOR PERFORMANCE RECOVERY

Y. Morita#, K. Akai, T. Furuya, A. Kabe, S. Mitsunobu, and M. Nishiwaki
Accelerator Laboratory, KEK, Tsukuba, Ibaraki 305-0801, Japan

Abstract

Eight superconducting accelerating cavities were operated for more than ten years at the KEKB machine. Those cavities are also used at SuperKEKB. During the KEKB operation, Q values of some cavities were degraded. Cause of the degradation was contamination by air dusts at a repair of vacuum seals or a gasket replacement of input couplers. So far, those degradations are acceptable for the SuperKEKB operation, however, further degradation will make the operation unstable and, in the worst case, make it impossible. High pressure rinsing (HPR) is an effective method to clean the cavity surface. In order to apply HPR, however, the cavity has to be disassembled from a cryomodule. The disassembly takes time and costs. Furthermore, re-sealed vacuum flanges bring the risk of vacuum leakage again. Therefore we have developed a horizontal HPR. This method applies a high pressure water jet that is inserted horizontally into the cavity in the cryomodule. The wasted water is extracted with an aspirator. This method does not require the disassembly. We applied the horizontal HPR to our degraded cavity. Its RF performance has been successfully recovered.

INTRODUCTION

KEKB superconducting cavities were developed for the KEKB B-factory to accelerate the 1 A electron beam currents. This cavity has a single cell, large beam pipes to heavily damp the higher order modes and an antenna type coaxial input coupler to feed large beam powers. First four cavities were installed and commissioned in 1998. Another four cavities were installed in 2000. Those cavities were operated until the KEKB shutdown in 2010. The maximum accelerated beam current was 1.4 A with the absorbed HOM power of 16 kW. The superconducting cavities will be used for the upgrade machine, SuperKEKB with the designed electron beam current of 2.6 A. The most serious issue of our cavities for application to SuperKEKB is a handling of large HOM powers. This issue will be discussed in this conference [1].

Performance degradation during long term operation in KEKB is another issue. This degradation was mainly due to particle contamination which was caused by an exposure of cavities to the atmosphere at indium joint repair or at exchange of input power couplers [2]. One of the installed cavity modules was opened to the atmosphere three times. The first time was at a vacuum leakage of indium joints in 2001. This cavity was opened to the atmosphere and dismounted from the cryomodule. Then its indium joint was re-sealed. The second time was at the exchange of the coupler gasket in 2004 to increase coupling of the input coupler. Although the indium joints were repaired, this cavity had a vacuum leakage again in 2005. The vacuum leakage was repaired by tightening the volts of the indium joints. Those exposures significantly decreased the Q factor to 1.3×10^8 at the cavity voltage of 2 MV. At the operating voltage for SuperKEKB (1.5 MV), the Q degradation is still acceptable. However, further degradation makes the cavity operation difficult. Performance recovery is desirable.

High pressure water rinsing (HPR) is effective to clean the cavity surface contaminated with particles. It is suitable to apply this method for our performance recovery. On the other hand, HPR application needs to

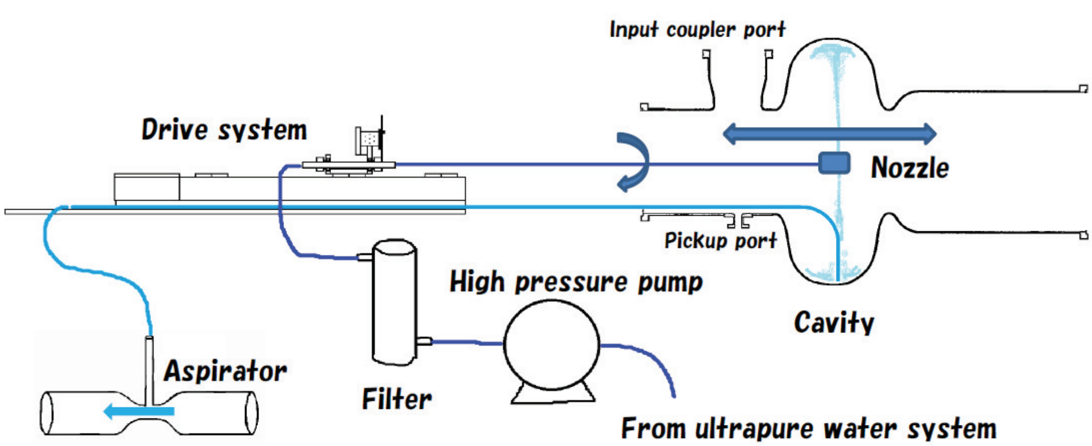

Figure 1: Schematic diagram of horizontal HPR apparatus.

#yoshiyuki.morita@kek.jp

ISBN 978-3-95450-143-4

disassemble the cavity from the cryomodule. If HPR can be applied to the cavity in the cryomodule, we can greatly save time and costs. Furthermore risks of vacuum leakage of the re-sealed metal gaskets or indium seals can be avoided. Therefor we have developed horizontal high pressure rinsing (HHPR) that can be applied to our cavity in the cryomodule.

In this paper we present details of HHPR, establishment of this method by using a prototype cavity and performance recovery of our degraded cavity by HHPR.

HORIZONTAL HPR

Figure 1 shows a schematic diagram of HHPR system. An ultra-pure water system provides ultra-pure water (18.2 MΩ) through a 0.2 µm filter. A high pressure reciprocating plunger pump pressurizes ultra-pure water to 7 MPa. The pressurized water was led through a filter (0.5 µm) to a nozzle which has six holes with a diameter of 0.56 mm. The nozzle is made of stainless steel which was hardened by martensitic transformation and supported horizontally by a stainless steel pipe. A driver system, which consists of sliders and pulse motors, horizontally inserts the nozzle into a cavity and moves the nozzle along the cavity axis while rotating it 60 degrees. Wasted water was extracted through a stainless pipe by an aspirator pump.

APPLICATION TO PROTOTYPE CAVITY

The HHPR was first applied to our prototype cavity in a clean room (class 100) [3]. The cavity was rinsed all the inner surface including beam pipes and coupler ports. The cavity was evacuated with remaining water in the cavity cell. After the evacuation the cavity was cooled down without any baking. The accelerating field reached 10 MV/m without field emission and no performance degradation was observed.

The HHPR was then applied to our prototype cavity in a clean booth to simulate HHPR application to our cavity in the cryomodule. Before this application, the prototype cavity was electro-polished 15 µm to reset the effect of previous HHPR tests, baked at 120 °C and cold tested (Fig. 2). The prototype cavity was high pressure rinsed in the cell and iris area only. The total rinsing time was 10 minutes. After HHPR, the prototype cavity was evacuated with a scroll type pump with remaining water in the cavity cell. Then the cavity was evacuated to 10^{-4} Pa with a turbo-molecular pump. Finally it was evacuated to 10^{-6} Pa with an ion-pump. The cavity was cold tested without any baking. After several processing, the accelerating field of this cavity gradually increased to 8 MV/m. Then the field suddenly degraded to 6 MV/m with strong field emission as shown in Fig. 2. We tried RF processing several times, however performance never recovered.

The cavity surface was inspected by a telescope after warm-up. No significant surface damage was found. Strong field emission suggested particle contamination in the cavity, so that we applied HHPR to the prototype cavity once again. This time wider SBP iris area including coupler port was rinsed. The cavity was cold tested again without baking. The RF performance was recovered as shown in the same figure. The accelerating fields reached 12 MV/m which corresponds to the cavity voltage of 3 MV. No field emission was observed. It was found that 1) the cavity once baked after the electro-polishing needed no further baking after HPR, and 2) cell and iris regions were sufficient for HPR to stop field emission. Those results showed applicability of HHPR to our cavity module. HHPR conditions are summarized in Table 1.

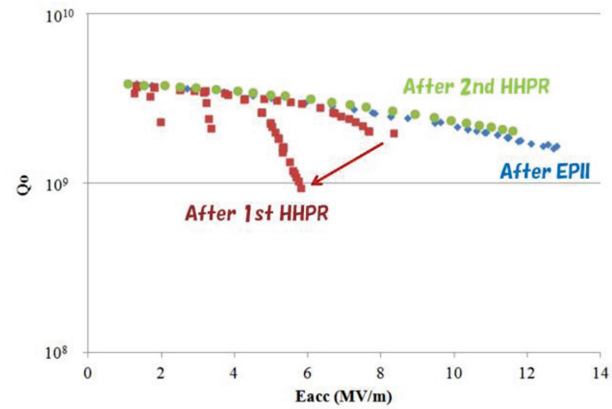

Figure 2: Q-Eacc curves of the prototype cavity after 1st and 2nd HHPR.

Table 1: HHPR Parameters

Water pressure	7 MPa
Nozzle	Martensitic stainless steel 6 holes (ϕ0.54 mm in dia.)
Driving speed	1 mm/sec.
Rotation speed	6°/sec.
Rinsing time	15 min.

APPLICATION TO SPARE CAVITY MODULE

Following the performance recovery of the prototype cavity, we applied HHPR to our degraded cavity module. This cavity leaked at indium sealed joint of the beam pipe during cool-down. The cavity was disassembled and leaked joint was repaired by tightening volts of the indium sealed flange. After the repair, this cavity was high power tested at the test stand. The Q factors significantly degraded with strong field emission above 1 MV. The cavity must be contaminated with particles at the exposure of the cavity to the atmosphere. After RF processing, its Q factor increased slightly to 8×10^8 at 1.3 MV.

In order to apply HHPR to this cavity module, the cavity was moved from the test stand to the assembly area. The inner conductor of the input power coupler and beam pipes with HOM dampers were dismounted in a clean booth. The HHPR drive system was set at the small beam

ISBN 978-3-95450-143-4

pipe side. The stainless steel nozzle and the stainless steel pipe for aspirator were inserted horizontally into the cavity (Fig. 3). The rinsing conditions were the same as the last HHPR for the prototype cavity (Table 1).

The cavity was evacuated with a scroll type pump to remove remaining water in the cavity for more than one day. Then the cavity was purged with pure nitrogen to the atmospheric pressure for re-assembly of the inner conductor and beam pipes. The cavity was evacuated once again with a turbo-molecular pump, and then evacuated with ion pumps attached to the beam pipes.

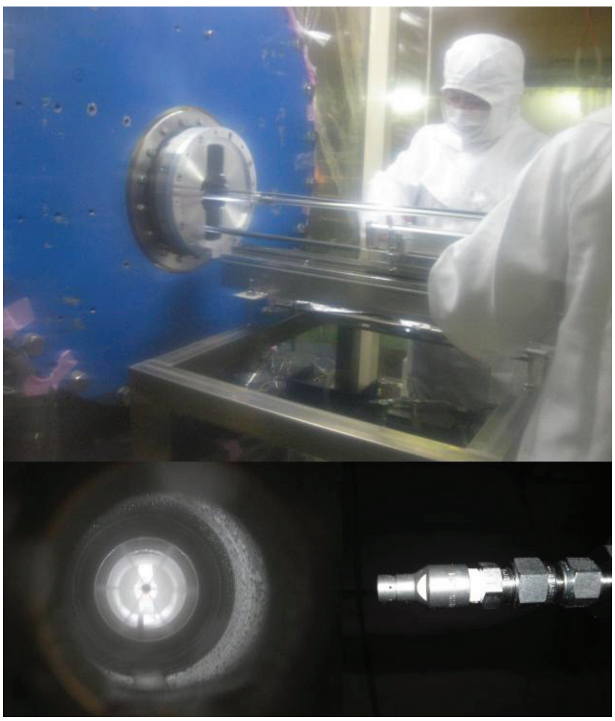

Figure 3: HHPR application to cavity module (top), and stainless steel nozzle and its water jets (bottom).

HIGH POWER CONDITIONING

Conditioning at Room Temperature

Before cool-down, the input power coupler was conditioned with high RF power with perfect reflection up to 300 kW. Main purpose of this conditioning is to process the electron multipacting discharge away on the coupler surface. DC bias voltage up to ±2 kV was applied to the inner conductor. It took more than eight hours to reach 300 kW than usual. The most conditioning time took at the minus bias voltage that enhances the multipacting discharge on the outer conductor surface. This fact indicated that water molecule still condensed on the outer conductor surface.

Conditioning at Low Temperature

The cavity module then cooled down to 4.4 K by a Helium refrigerator with cooling speed of 3 K/h. After the low level RF tuning including tuner adjustment, high power conditioning began. After several RF trips including high voltage discharge in the cavity, the cavity voltage reached 1.5 MV without field emission. The field emission was significantly improved. Above 1.5 MV, field emission began. The cavity voltage finally reached to 2 MV. The field limitation was not by the cavity performance but by the radiation safety limit in the test stand. The Q factors at several cavity voltages were measured by the evaporation speed of liquid helium in the cryomodule. Those values are shown in Figure 4. The Q factors before HHPR and before the vacuum leakage are plotted in the same figure for comparison. The Q factor at 1.5 MV was successfully recovered to 1.6×10^9 that was sufficient recovery for SuperKEKB operation.

Although the performance recovery is sufficient for the SuperKEKB operation, the Q factors did not recover to the values before the leakage. This may come from re-contamination at insertion of the inner conductor of the input coupler or re-assembly of the beam pipes.

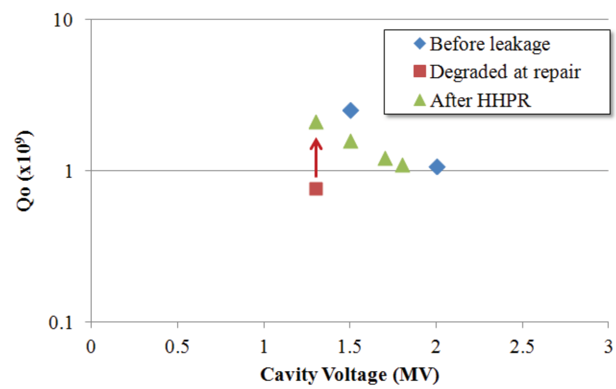

Figure 4: Recovery of Q factors after HHPR.

CONCLUTION

We have developed horizontal high pressure rinsing. This method makes it possible to rinse the cavity without disassembling the cavity module. It can also save time and costs. Furthermore, it can avoid risk of leakage at the re-sealed metal gasket or indium sealing. We applied HHPR to our spare cavity module. The Q values were successfully recovered. We will apply HHPR to another degraded cavity module.

REFERENCES

[1] M. Nishiwaki et al., "Development of HOM dampers for SuperKEKB Superconducting cavity," TUP051, these proceedings.
[2] S. Mitsunobu et al., "Status of KEKB Superconducting Cavities," Proceedings of SRF2007, Peking Univ., Beijing, China.
[3] S. Takano et al., "Horizontal High Pressure Water Rinsing for KEKB Superconducting Cavities," Proceedings of SRF2009, Berlin, Germany.

ISBN 978-3-95450-143-4