HIGH PRESSURE RINSING FOR NIOBIUM SUPERCONDUCTING CAVITY*

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Abstract

Either organic or inorganic residues on the inner surface of the superconducting cavity can cause serious problems during the cavity operation. High pressure rinsing experiments was carried out to check out how a prototype HPR machine removes defects. HPR experiments were performed with a simplified cavity structure, and analyzed as a function of the pressure, the distance from a nozzle, and the sizes of defects on the niobium surface. In this presentation, we will discuss the performance of the prototype HPR machine.

INTRODUCTION

In order to perform surface treatment for low beta cavities in RISP, several typical equipment have been fabricated such as a vacuum furnace for heat treatment [1], a buffered chemical polishing (BCP) tool for chemical treatment [2], and a high pressure rinsing (HPR) machine for cleaning cavities [3]. HPR cleaning has been accepted as very powerful technique for cleaning cavities in many institutes and companies. Harmful defects such as metal residue and other organic/inorganic particles must be removed in order to produce high-performance cavity. These defects can be effectively removed by HPR cleaning. Water-sprays having high pressure of around 100 bar coming out through the small nozzle holes are major factor in order to operate HPR. And this high pressure water-sprays clean the inner surface of the cavity. RISP fabricated a prototype HPR machine and some test results were reported [3]. New HPR machine is under fabricating that has better solid structure and performance for cleaning cavities. Followed by previous tests, we conducted another HPR tests to observe how cleaning proceeds with the treatment numbers and time in the cavity surface. HPR cleaning results were analyzed by taking optical photographs. Thus, some baseline data of HPR with time and the distance between a nozzle and a target will be presented.

EXPERIMENTAL

HPR Equipment Setting

We fabricated a transparent quater-wave cavity (QWR), which is made of plastic, in order to observe how a nozzle moves up and down inside the cavity. This is shown in Fig. 1. By simply looking at the nozzle rod movement through a transparent surface, we confirmed that the nozzle experiences unequal back-force from the target due to the asymmetry of the cavity during the cleaning. In this study, we simulated the real niobium cavity by using an outer conductor made of oxygen free high conductivity copper (OFHC). This is shown in Fig. 3. We attached niobium samples having $10 \times 10\ \mathrm{cm}^2$ to specific places, one side is 30 mm away from the nozzle, the other side is 170 mm from the nozzle. This is shown in (b) of Fig. 1. Twice cleaning passes were carried out for experiments, and each pass took around 5 minutes with the nozzle rod's speed of 20 mm/min. The specifications of a prototype HPR machine are summarized in Table 1. And the pressure of water-spray from the nozzle is listed in Table 2. We measured the pressure of water near an exit from a pump (P@Pump) and near an entrance to the HPR (P@HPR). Therefore, we could assume that the actual pressure exerted on the target was less than the pressure measured near entrance to the HPR (P@HPR). Fig. 2 shows how P@Pump and P@HPR are measured. Deionized water having 18 MΩ was used to operate HPR, and the pressure of the water-spray was 100 bar.

Table 1: Specifications of HPR Machine

Items	Specification	Values	Unit
Dimension	W×L× H	1 × 1 × 3	M
Nozzle	Size, DiameterRRR	0.5	mm
	Number of nozzle	18	EA
Pressure	Water Pressure	< 140	bar

Table 2: Pressure of HPR vs Pump Frequency

Pump Frequency (Hz)	P@Pump (bar)	P@HPR (bar)
30	99	50
35	131	80
40	165	100
45	200	120
48	220	140

HPR Sample Preparation

Series of RRR-grade niobium samples of $10 \times 10\ \mathrm{cm}^2$ that have small holes for fixing themselves to the surface of the outer conductor were prepared for HPR cleaning. The surface of sample was intentionally tainted with a water-soluble painter so that one can observe the cleaning process visually. This water-soluble painter was chosen in a way that one can observe the degree of cleaning gradually with cleaning time [1]. Intentional contamination has two purposes. One is the for creating the worst surface condition on the sample

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surface, and the other is for making it possible to observe the surface visually during the HPR. The surface covered by the painter is shown in 1-(a) and 2-(a) of Fig. 4. Also, top series pictures (notated 1) and bottom series pictures (notated 2) mean samples are 30 mm away from a nozzle and 170 mm away from a nozzle, respectively.

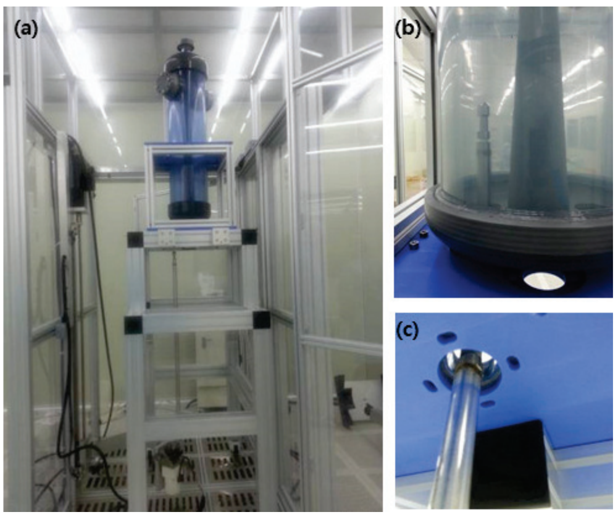

Figure 1: HPR machine setup (a) setup of a transparent QWR in HPR (b) side view of the cavity: close part of the inner surface (left) is 30 mm away from the nozzle distant part of the inner surface (right) is 170 mm away from the nozzle (c) bottom view of the cavity.

RESULTS

The surface of a raw niobium and the surface covered by painter are shown in Fig. 5. Darker color represents the area covered by painter. Optical images of sample surface with HPR treatments are shown in Fig. 4 and Fig. 6. Green arrows and red arrows in Fig. 4 represent not only number of HPR treatments (no pass -> 1 pass -> 2 passes), but also samples of 30 mm away from a nozzle and 170 mm away from a nozzle, respectively. Also, green arrows and red arrows in Fig. 6 represent number of HPR treatments (1pass -> 2 passes) and samples 30 mm away and 170 mm away from a nozzle, respectively. From the optical images, one can observe that the surface area covered by painter decreased with HPR treatments. By comparing 1-(a) and 1-(c) to 2-(a) and 2(c), we observed that the surface of samples 30 mm away from a nozzle showed less covered area with painter than those of 170 mm away from a nozzle. For closer investigation, we obtained approximate the size of painted area and the number of painted particles from Fig. 6. The approximate size of area covered with painter after one pass of HPR were about 20 μm in 30 mm away sample and about 40 μm in 170 mm away sample, respectively. And the number of painted particles of 30 mm away sample was less than that of 170 mm away sample. This cleaning trend was same for samples that experienced another HPR treatment. With two HPR treatments, the approximate size of painted area for both cases was same as less than 10 μm, however, the number of painted particles still less than in 30 mm away sample than 170 mm away sample.

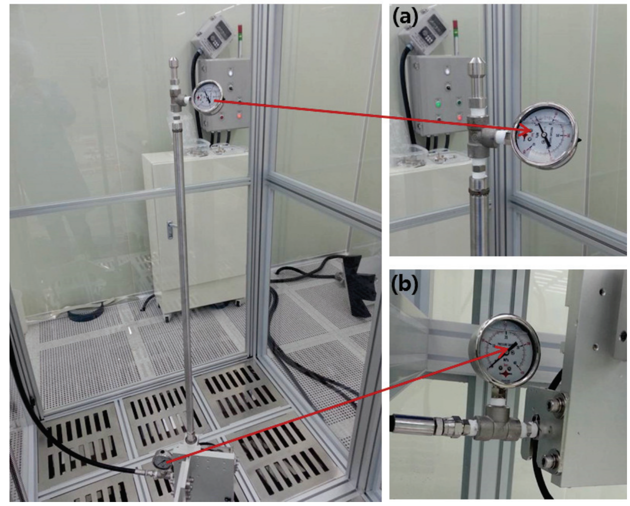

Figure 2: Pressure of water spray in HPR machine. (a) pressure near an entrance to the HPR, P@HPR, (b) pressure near an exit from the pump, P@Pump.

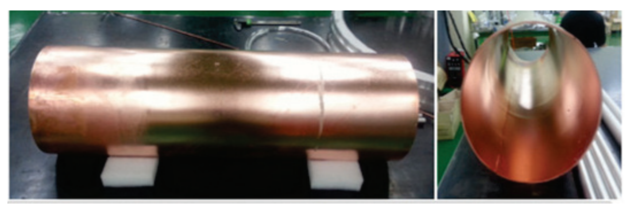

Figure 3: The out conductor made of OFHC for attaching niobium samples, front view (left), side view (right).

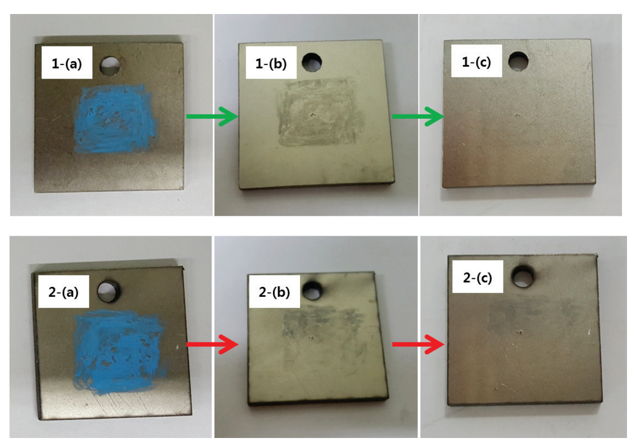

Figure 4: Pictures of niobium samples. For all cases, green arrows and red arrows represent closed samples to nozzle (30 mm) and distant samples from nozzle (170 mm), respectively. For upper 1-series pictures, (a) no HPR pass, (b) 1 HPR pass, (c) 2 HPR passes, For lower 2-series pictures, (a) no HPR pass, (b) 1 HPR pass, (c) 2 HPR passes.

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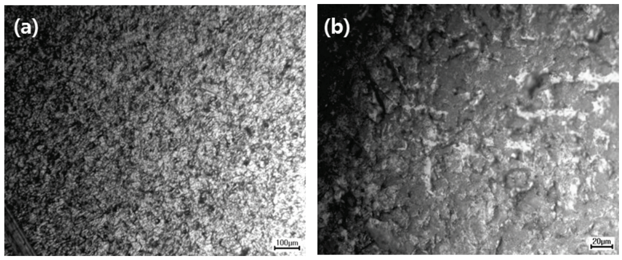

Figure 5: Optical images of niobium sample. (a) the surface of no-painted niobium sample (X100), (b) the surface of fully-painted niobium sample (X500).

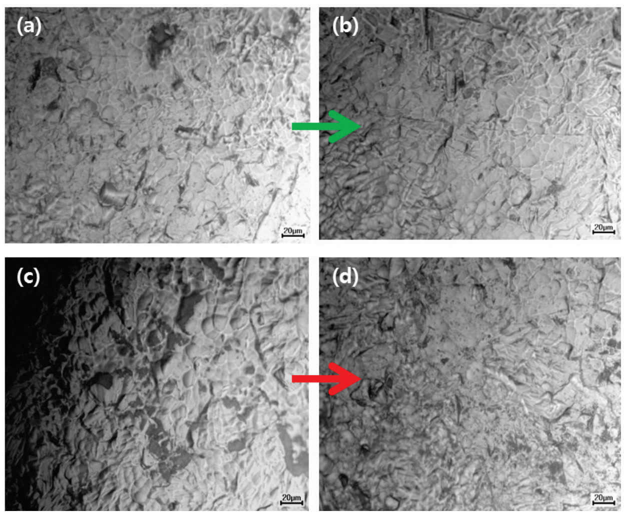

Figure 6: Optical images of niobium sample. All pictures were taken with X500 resolution, and the scale bar at the right bottom is 20 μm . Green arrows and red arrows represent closed samples to nozzle (30 mm) and distant samples from nozzle (170 mm), respectively. (a) and (c) is surface of sample after one HPR pass, (b) and (d) is surface of sample after 2 HPR passes.

DISCUSSION

We observed that the HPR cleaning performance was better in the samples close to the nozzle than those distant from the nozzle. This can be explained that the effective pressure exerted on the sample's surface decreased as the distance between the nozzle and the target increased. Also, we found the HPR performance improved with the number of HPR treatments, and this can be explained that the area contacted with water spray increased as HPR treatments increased. One interesting observation is that the approximate size of painted area for both cases was same as less than 10 μm, even though the number of painted particles are different. Thus, it is considered that micro particles should be carefully cleaned in real cavity treatment. Surface treatment by using ultrasonic cleaning is widely used in fabricating cavity. It is very important to find and apply optimal frequency during ultrasonic cleaning because the size of removed particle is strongly dependent on the operation frequency. A pre-treatment through an ultrasonic treatment with the optimal frequency could perform more effectively for removing particles together with HPR cleaning.

SUMMARY

We have performed HPR tests with intentionally painted niobium samples having different distance from the nozzle. We confirmed that HPR performance improved as the effective water pressure and the time increased. Also, we confirmed that cleaning small size particles should be carefully carried out for obtaining good surface for preparing cavities.

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