ISBN: 978-3-95450-184-7 doi:10.18429/JACoW-IPAC2018-THPAL029

COMPARISON OF HORIZONTAL AND VERTICAL ELECTROPOLISHING METHODS USING NIOBIUM SINGLE-CELL COUPON CAVITY

V. Chouhan†, Y. Ida, K. Nii, T. Yamaguchi, Marui Galvanizing Co., Ltd, 672-8022 Himeji, Japan
H. Hayano, S. Kato, H. Monjushiro, T. Saeki, M. Sawabe, KEK, 305-0801 Tsukuba, Japan

Abstract

Horizontal electropolishing (HEP) is an established technique for surface treatment of niobium accelerating cavities. Vertical electropolishing (VEP), in which the cavity is electropolished in the vertical posture, is in R&D phase for parameter optimization. We performed HEP and VEP of a niobium single-cell coupon cavity to compare the effect of both the methods on surface state and removal at different positions of the cavity. HEP was performed at STF, KEK with the standard EP parameters. VEP was performed at Marui Galvanizing Company with a cathode called "Ninja cathode" that can be rotated during the VEP process. The optimized cathode design and VEP parameters resulted in symmetric removal as obtained with the HEP technique and yielded a smooth inner surface of the entire cavity.

INTRODUCTION

Electropolishing (EP) method is generally used for the final surface treatment of niobium superconducting RF cavities. EP yields smooth, bright and clean surface of the cavity. Horizontal EP (HEP), in which a cavity is set in horizontal posture, is currently used for the surface treatment of niobium cavities at industrial level. Vertical EP (VEP) process, which is performed in vertical posture with a cost effective setup compared to HEP, is still in R&D phase. We are making our efforts to optimize VEP conditions to obtain similar surface state as from HEP [1-3]. In this paper, we report a comparison of niobium surfaces and removal trend of cavity after being processed with the HEP and VEP methods.

EXPERIMENTS

A 1.3 GHz Nb single-cell coupon cavity was processed with HEP and VEP methods. The coupon cavity contains totally six coupons located at the beam pipes, irises and equator [1]. Viewports were also prepared at the iris and equator positions to observe the bubble behavior inside the cavity during an EP process. The study of coupon currents during EP tests allows one to do in-situ study and decide EP conditions for a long time EP [1-3].

HEP was performed with the standard EP parameters used at surface test facility (STF) at KEK. HEP setup is shown in Fig. 1. The standard cathode for HEP is an Al pipe set at the cavity axis. The cathode was partially covered with insulator near the iris and beam pipe positions. The Al cathode pipe has a hole aligned with equator position to fill the acid into the cavity. An acid quantity in the cavity is maintained to be 60% of the cavity volume. The cavity during HEP was rotated at 1 rpm and cooled with spot air coolers. The coupon currents and cavity temperature were recorded with a data logger fixed on the cavity. An acid was circulated in the cavity at a flow rate of ~5 L/min. After the voltage was turned off the cavity was rotated at 3 rpm and acid was circulated in the cavity for 15 min. The cavity was rinsed with pure water in the vertical posture.

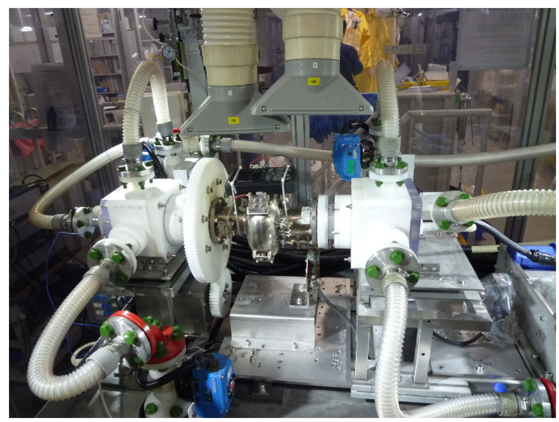

Figure 1: Single-cell coupon cavity on the HEP bed at KEK and a data logger attached to the cavity.

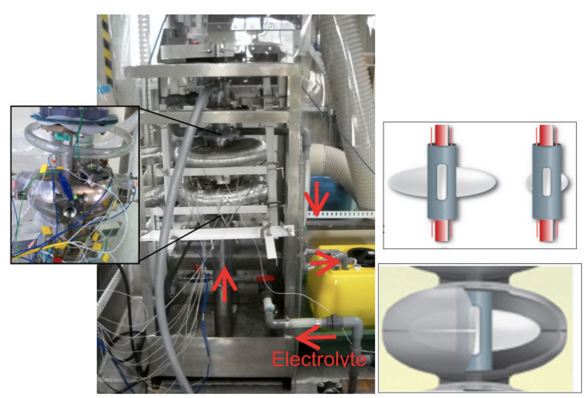

Figure 2: Single-cell coupon cavity at VEP stand (left) and Ninja cathode (right) used for VEP. Red color in the Ninja schematic is showing Al cathode.

A VEP experiment was performed using a rotating Ninja cathode (v5) at 20 rpm. The cathode was designed with four insulating blades and was covered with a meshed housing to guide bubbles along the cathode [2]. The cathode surface area was enhanced with additional four Al rods to reduce cathode screening due to gas bubbles. A VEP setup and a schematic of the cathode are shown in Fig. 2. The cavity was cooled by spraying water on the

†vchouhan@e-marui.jp

Content from this work may be used under the terms of the CC BY 3.0 licence (© 2018). Any distribution of this work must maintain attribution to the author(s), title of the work, publisher, and DOI.

ISBN: 978-3-95450-184-7 doi:10.18429/JACoW-IPAC2018-THPAL029

exterior cavity surface and the acid was cooled in the acid reservoir. Similar to HEP, the acid flow rate was ~5 L/min and acid circulation time after turning off the voltage was ~15 min. The cavity was then rinsed with pure water.

RESULTS AND DISCUSSION

I-V Measurements

I-V data were recorded for the coupons and cavity in both the EP processes. A maximum applied voltage for I-V measurements in HEP and VEP were 30 and 20 V, respectively. The I-V curves are compared in Fig. 3. The cavity current density in HEP was calculated by considering 60% surface area of the cavity. The measured currents for the coupons in HEP were not continuous because the cavity was rotating. The sudden current spikes correspond to the instance when the coupons came in the acid contact. However, the I-V curve trends are apparent. In both the EP processes, EP plateaus in I-V curves for all the coupons and the cavity clearly appeared. In VEP as compared to HEP, the EP plateaus for the iris and equator coupons appeared at a higher voltage. This might be due to strong cathode screening by H_2 gas bubbles. In HEP, bubbles can easily escape from the cavity compared to the VEP. The Ninja cathode rotation, which enhances acid flow rate on the cavity cell surface, also results in the shift of EP plateaus [1-3].

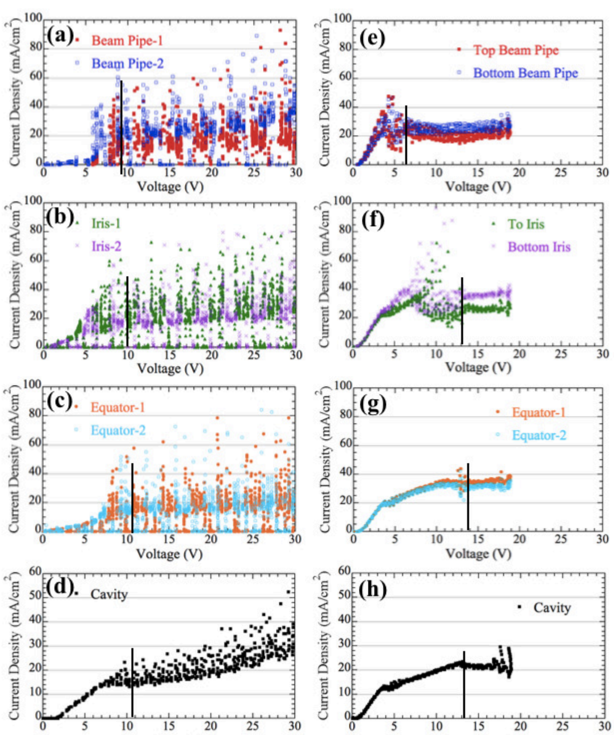

Figure 3: Polarization curves for the coupons and cavity in HEP (a-d) and VEP (e-h). The vertical solid lines indicate starting of EP plateaus.

HEP and VEP

HEP and VEP were carried out for 2.6 and 2 h, respectively. The applied voltages in HEP and VEP were set to be 29 and 13 V, respectively. The voltage applied in VEP was the minimum voltage required to obtain the EP plateaus in the I-V curves. The voltage was kept low because the chiller capacity was not enough to maintain a low temperature (~15 °C). Cavity current densities, voltages, and cavity temperatures measured at the beam pipe, iris and equator positions are shown in Fig. 4. The cavity temperatures in HEP were oscillating since the cavity was rotating and the spot cooler ducts were fixed. The maximum temperature reached at around 40 °C when the cavity surface was not facing the ducts. In VEP, cooling was almost uniform with the sprayed water on the cavity surface. The cavity temperature was maintained below 16 °C during VEP. The temperature was decided based on our earlier study [3]. During VEP, the current was not oscillating as in HEP. Periodic current oscillations in VEP were found at a voltage of 18 V or higher and were found to be susceptible with the cavity temperature [4].

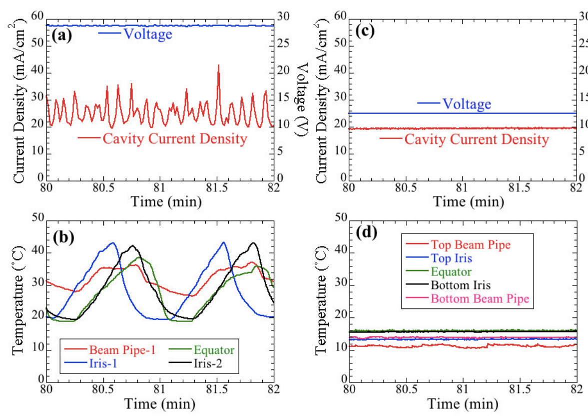

Figure 4: Current, voltage and temperature profiles in HEP (a and b) and in VEP (c and d).

Surface Morphology of Coupons

The coupon surfaces were observed with an optical microscope and surface roughness was measured with a mechanical surface profiler. The coupons used in HEP and VEP were new with typical surface roughness Ra/Rz of 0.6/4.5 µm. The images of the coupons and roughness values after HEP and VEP are shown in Fig. 5 and 6, respectively. In HEP, the equator coupon surface was rougher than the iris and beam pipe coupons. The rougher equator coupon surface might be caused by a higher acid speed on the equator surface as compared to that on the beam pipe and iris. Coupon surfaces after VEP were found to be smoother than that after HEP. The higher temperature in HEP might reduce thickness of the viscous layer to make the surface rougher. Another reason for the rough surface in HEP might be the discontinuation of EP. The EP time for the coupons in one round of the cavity was lasted only for ~36 sec which might have resulted instability in EP. The cavity surface roughness in VEP might be further decreased when VEP is performed at a

Content from this work may be used under the terms of the CC BY 3.0 licence (© 2018). Any distribution of this work must maintain attribution to the author(s), title of the work, publisher, and DOI.

ISBN: 978-3-95450-184-7 doi:10.18429/JACoW-IPAC2018-THPAL029

higher voltage. A lower roughness was observed with another single-cell cavity VEPed at ~18 V [5].

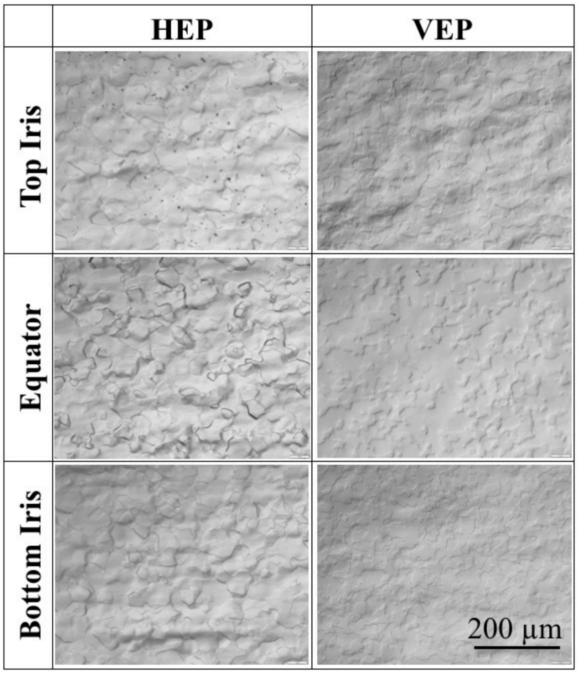

Figure 5: Optical microscope images of iris and equator coupons after HEP and VEP.

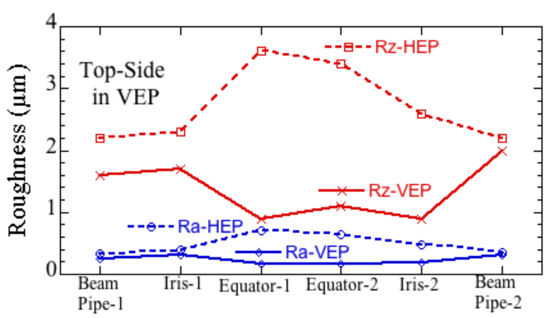

Figure 6: Roughness Ra and Rz of the coupons after HEP and VEP.

Removal Thickness

Average cavity removal thicknesses, which were calculated from the cavity weight loss, in HEP and VEP were 45 and 43 µm, respectively. A removal thickness was also measured locally at different positions of the cavity with an ultrasonic thickness gauge (Fig. 7). The removal in HEP and VEP was symmetric along the cavity length. The symmetric removal in VEP was attributed to the adequate VEP parameters and design of the Ninja cathode which can guide bubbles along the cathode, stop bubbles accumulation on the upper iris of the cavity, and might make uniform viscous layer on the cavity surface at a rotation speed of 20 rpm. Bubble accumulation enhances the EP rate locally at bubble positions as already reported earlier [1]. In this VEP, the bubbles accumulation significantly reduced on the upper iris surface as observed from the cavity viewports.

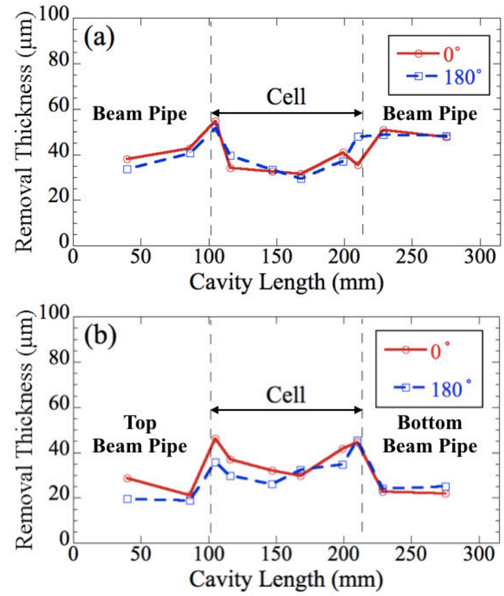

Figure 7: Cavity removal thickness trend along the cavity length in (a) HEP and (b) VEP.

CONCLUSION

The results of HEP and VEP methods applied on the single-cell coupon cavity were compared. The HEP was performed with the standard parameters used at STF, KEK. VEP was performed with our investigated parameters and were not similar to the HEP parameters. The comparison of the surface morphologies of the coupons clearly revealed that the VEP process results in a smooth surface of the entire cavity. The surface was even found smoother than the HEPed surface. The comparison of removal trend along the cavity length was symmetric in both HEP and VEP. The VEP parameters and the designed Ninja successfully resolved the major issues including the rough surface with bubble traces and removal asymmetry.

The optimized parameters were applied on a single-cell cavity which was tested in a vertical cryostat at KEK. Another cavity was VEPed at CEA-Saclay with the Ninja cathode and the similar VEP parameters, and a vertical test was performed. The results are shown in this conference.

We are optimizing VEP parameter for a 9-cell cavity and the recent status is also presented in this conference.

REFERENCES

[1] V. Chouhan *et al.*, Phys. Rev. Accel. Beams 20, 083502 (2017).

[2] V. Chouhan *et al.*, MOPLR037, Proc. LINAC16, Michigan, USA (2016).

[3] V. Chouhan *et al.*, TUPB091, Proc. SRF17, Lanzhou, China (2017).

[4] A. C. Crawford *et al.*, Nucl. Intr. and Meth. A 849, 5 (2017).

[5] K. Nii *et al.*, THPAL032, Proc. IPAC'18, Vancouver, Canada (2018), this conference.

Content from this work may be used under the terms of the CC BY 3.0 licence (© 2018). Any distribution of this work must maintain attribution to the author(s), title of the work, publisher, and DOI.