VERTICAL ELECTROPOLISING STUDIES AT CORNELL WITH KEK AND MARUI

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Abstract

Cornell's SRF group has been developing Vertical Electro-Polishing (VEP) which was applied on 1.3GHz Niobium SRF cavities as the primary surface treatment. The process was done in the vertical direction, the upper and the lower half cell had removal difference. Cavity need to be flipped over during the process to compensate this. Cornell has started collaboration with KEK and Marui Galvanizing Co. Ltd. (Marui) in 2014. The first step of collaboration focused on the demonstration of Marui's original VEP cathode named "i-cathode Ninja®" at Cornell, which was developed to make more uniform VEP removal. The results of VEP using Ninja cathode at Cornell will be presented in this paper.

INTRODUCTION

Cornell's SRF group has developed Vertical Electro-Polishing (VEP) for Superconducting RF niobium cavities [1]. VEP would be much simpler and less expensive compared with the conventional Horizontal EP. Cornell had demonstrated the capability of VEP on the high gradient cavities for ILC (>35MV/m with Q>0.8e10) [2] and High-Q cavities for LCLS-II (Q>2.7e10 at 16MV/m) [3] successfully. The process in vertical direction was affected by gravity, this resulted in the removal difference between upper and lower half cell. In addition, during VEP on multi-cell cavity, the first cell on top of multi-cell cavity had much larger removal than that of the last cell on bottom. To compensate the removal un-uniformity, cavity needed to be flipped over after the half removal of the target removal. Cornell has kept working on to solve this issue. While VEP R&D becomes more popular in many facilities, KEK and Marui also had started VEP R&D collaboration. Marui has focused on VEP application targeted mass-production and has been developing original cathode named "i-cathode Ninja" to improve polishing quality, especially removal uniformity during the process in vertical direction [4]. Marui's challenges agreed with Cornell's requirement on VEP removal R&D. The collaboration between Cornell and KEK-Marui has started in 2014. The first step of this collaboration was the demonstration of Ninja cathode at Cornell.

VEP SYSTEM AT CORNELL

Figure 1 shows Cornell's VEP system with Ninja-cathode installed into 1.3GHz TESLA shape single-cell cavity. The top and bottom EP sleeves were provided from Marui. The acid circulation lines were installed for the process with Ninja cathode. Ninja cathode had a sprocket on the top of cathode rod, and rotated by motor sprocket connected via chain. The negative voltage was applied on cathode through the slide contact. Cornell provided acid tank, I-V source, the cavity outside wall cooling water lines, and all electronics and programs for monitoring the temperatures and for controlling VEP process. The EP electrolyte which was the mixed acid of sulphuric acid and hydrofluoric acid in 9:1 ratio in weight was filled into the cavity by pump through the bottom EP sleeve, overflowed through the top EP sleeve, and back into the acid tank.

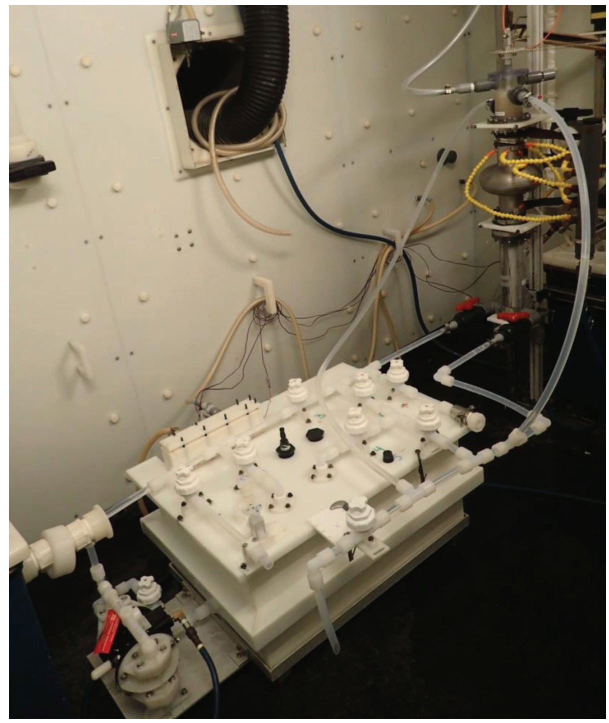

Figure 1: Cornell VEP system with "Ninja" cathode.

Cornell VEP Cathode

Cornell VEP cathode (Fig. 2, top) consists with Aluminium cathode rod and stir tube with puddles (one puddle per cell). The puddles were opened by rotating the stir tube in the electrolyte. The rotation speed was adjustable from 0-1Hz. Teflon mesh lapped around the stir tube (not indicated in figure) prevents the hydrogen bubble produced on cathode surface attacked Nb surface. The mesh guided the bubble to top and out of the electrolyte.

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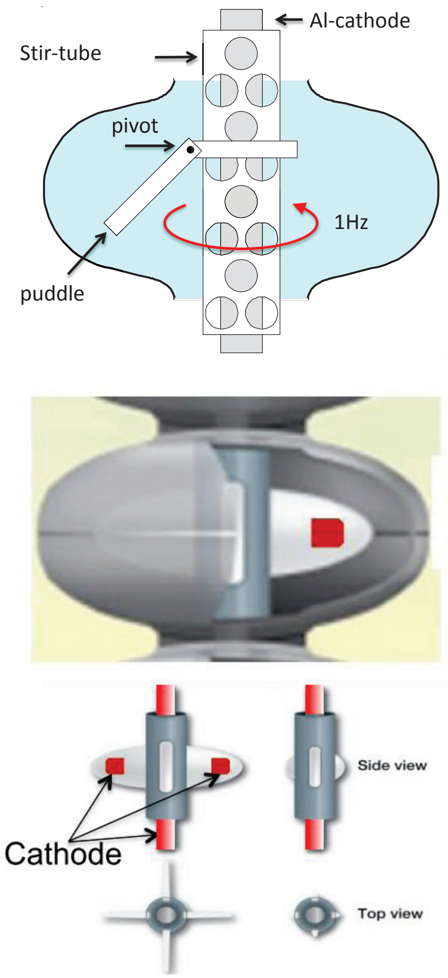


Figure 2: Top: Cornell cathode, Middle: Marui's i-cathode Ninja type-1, Bottom: retractable wings on Ninja cathode type-I.

Marui i-Cathode Ninja

Marui's Ninja cathode consists with aluminium cathode rod, PVC tube, and retractable Teflon wings (four wings per cell). PVC was an acid resistance material, and especially cheap. It would be suitable for the early stage of i-cathode development and the capital cost reduction of VEP. The retractable wings were kept inside PVC tube when the cathode was inserted into the cavity. After cathode installation, the wings were opened. During the disassembly, the wings needed to be closed into the tube before pulling cathode out from the cavity. The wings were designed to have same distance between the cavity cell. Marui has developed several type of Ninja cathode so far. For the first trial of Ninja cathode at Cornell, Marui shipped type-I and type-II Ninja cathode to Cornell. Type-I was designed for having the field uniformly from iris to equator by putting an Al coupon on top of each wing (Fig. 2). Type-II had no Al coupon on wings, but had more cathode surface inside the tube. Type-II was also designed to protect Nb surface from Hydrogen bubble by covering the opening between wings and tube with Teflon mesh.

VEP EXPERIMENTS

Ninja Cathode VEP at Cornell

Cornell had performed two VEP using Ninja cathode of type-I and type-II on TESLA shape single-cell cavity, named NR1-2. NR1-2 had been processed by VEP using Cornell cathode and tested already. Prior to the Ninja cathode VEP, NR1-2 had mechanical polishing about 30um and Buffered Chemical Polishing (BCP) about 60um to reset RF surface. In addition, furnace degassing (800degC*2hrs) was also applied. New electrolyte were mixed and used for each VEP.

VEP Parameters

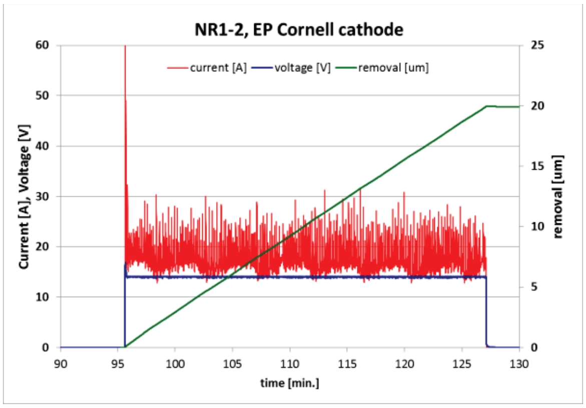
Table 1 shows the parameter summary of Ninja cathode VEP. The parameters for Ninja cathode VEP were chosen based on the parametric studies at Marui, but no optimized was done yet for the usage of Ninja cathode in Cornell's VEP system. The removal monitored during the process was calculated from the current integration, and the actual removal was measured by ultra-sound thickness gauge.

EP Current Profiles

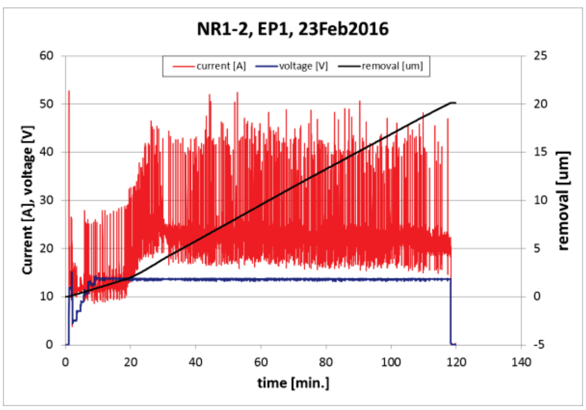
Figure 3 shows time vs. EP currents profile for each cathode. The average current depends on the temperature. Ninja cathode had higher temperature set point than Cornell cathode, so average current was higher than Cornell. Ninja cathode has a larger current oscillation than Cor-

Table1: VEP Parameters

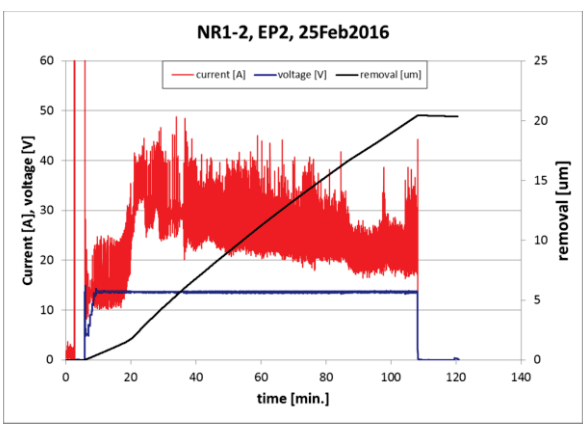
		Cornell cathode	Ninja type-I	Ninja type-II
Voltage [volt]		14	14	14
Current [amps]		~17	~22	~29
Temp. (cavity outside) [degC]		17~18	20~25	20~25
Acid circulation [L/min.]		None	5	5
Agitation speed [Hz]		0~1	0.8	0.8
Puddle type /cell		1Teflon puddle	4 Teflon wings w/ Al	4 Teflon wings
Teflon cathode bag		Yes	None	Yes
Removal [um] (preliminary)	Target	20	20	20
	Top half cell	24	36	29
	Bottom half cell	14	20	18



EP current profile, Cornell cathode



EP current profile, Ninja cathode type-1



EP current profile, Ninja cathode type-2

Figure 3: EP current profiles for Cornell cathode and Ninja cathode Type-I, and -II.

nell. Acid circulation and wings of Ninja cathode could make more effective agitation and might results in the larger current oscillations.

EP Removal

Cavities had no flipped over during VEP to confirm the removal uniformity between top and bottom half cell. Target removal was set to 20um, but actual removal measurements showed top half had larger removal than bottom half cell. This was the first trial and no optimization was done for the process. Further parametric study on Ninja cathode to make more uniform removal in Carnell VEP system is necessary.

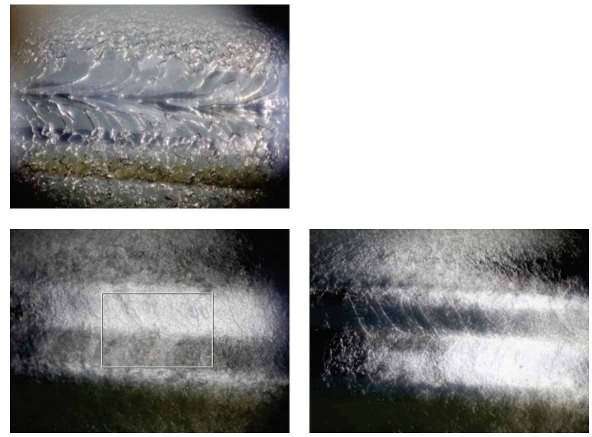


Figure 4: Optical inspection images; Cornell cathode (top), Ninja cathode type-I (bottom left), Ninja cathode type-II (bottom right).

Optical Inspection

Optical inspection was done after each VEP process on NR1-2. Figure 4 shows the images of equator welding seam on inner RF surface. No defect or No specific features were found on surface after the processes. Ninja cathode VEP had no negative impact on surface features.

SUMMARY

Marui's original VEP cathode "Ninja" was installed into Cornell's VEP system and demonstrated with single cell cavity successfully. Parameter optimization for using Ninja cathode with Cornell system was not yet done, so removal uniformity was not optimized yet. Further parametric study on Ninja cathode could improve the removal uniformity. Optical inspection after Ninja cathode VEP showed no defect or no new features. RF test on NR1-2 is planned to see the cavity performance and evaluate Ninja cathode VEP. For the future collaboration, 9-cell VEP with Ninja cathode at Cornell was under discussion.

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