DEVELOPMENT OF NEW TYPE "NINJA" CATHODE FOR Nb 9-CELL CAVITY AND EXPERIMENT OF VERTICAL ELECTRO-POLISHING

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Abstract

Marui Galvanizing Co., Ltd. has been improving Vertical Electro-Polishing (VEP) technologies and facilities for Nb 9-cell superconducting accelerator cavities for International Linear Collider (ILC) in collaboration with KEK. This time, we developed new type Ninja cathode in order to improve VEP uniformity of Nb 9-cell cavity inner surface based on the results of 1-cell cavity VEP experiments. In this article, we will report construction of new type "Ninja" cathode for a Nb 9-cell cavity and the experiment of VEP using this.

INTRODUCTION

Marui Galvanizing Co., Ltd. has been improving Vertical Electro-Polishing (VEP) technologies and facilities for Nb SRF cavities in collaboration with KEK. So far, we developed our original cathode "i-cathode Ninja" (Ninja), low cost and high durability VEP facilities made by PVC and performed VEP experiments for parameter optimization [1] - [6].

Regarding 9-cell cavity VEP, we had a problem that the cavity surface temperature during VEP became over 30 degrees C (it is said that the optimized temperature for Nb electro-polishing (EP) is around 20 – 25 °C). To solve this problem, we developed an EP solution cooling system and a cavity water cooling system and added them to our VEP facility. Then the cavity surface temperature during VEP was able to be kept around 20 – 25 °C successfully [6]. The polished surface looked like improved, however the removal thickness distribution was not improved.

This time, in order to improve removal thickness distribution and polished surface state, we developed new type Ninja cathode and performed a VEP experiment using this Ninja and a 9-cell coupon cavity.

IMPROVEMENT OF NINJA CATHODE

To improve uniformity of cavity removal thickness distribution and polished surface state, Ninja cathode was improved in several points. First, wings were made with insulating material and the Ninja cathode was covered with mesh sheet to prevent babble diffusion. Second, cathode surface area inside the mesh sheets was enhanced to perform good, uniform EP of whole cavity inner surface. And additional point, the wing number per cell was decreased from 4 to 3 for the purpose of easy fabrication and use in VEP.

Regarding first and second points, we performed 1-cell cavity VEP experiments using the same concept Ninja cathode. Then good, uniform inner surface state and uniform removal thickness distribution were achieved [7]. This time, preparing the same concept Ninja cathode for a 9-cell cavity, we performed a VEP experiment. Figure 1 shows the schematic view of Ninja cathode.

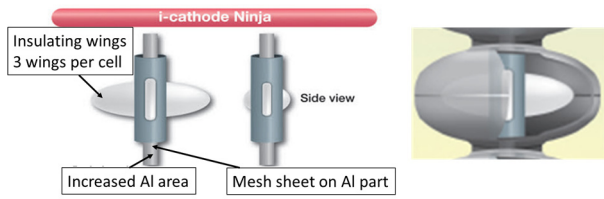

Figure 1: Schematic view of Ninja cathode.

9-CELL COUPON CAVITY

In order to optimize VEP parameters, a 9-cell coupon cavity was fabricated newly [8]. In this cavity, Nb coupons are set on equator positions of 1st, 5th and 9th cell. View ports with Nb coupon are set near iris of 1st, 5th and 9th cell. Figure 2 shows the photo of a 9-cell coupon cavity. These Nb coupons are separated electrically from cavity, so EP current can be measured for individual coupon. And after VEP, coupons can be removed for surface analysis.

Figure 2: Photos of a 9-cell coupon cavity (upper), coupon holders and view ports near iris (lower left), a coupon holder near equator (lower right).

VEP EXPERIMENT

We performed a VEP experiment using new type Ninja cathode and a 9-cell coupon cavity. Table 1 shows the conditions of this VEP experiment. This condition follows the best condition of 1-cell cavity VEP. And Figure 3 shows the VEP setup of this experiment. Top PVC part was put into negative pressure for bubble removal.

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Table 1: Conditions of this VEP Experiment

Parameters	Conditions
EP solution (H_2SO_4:HF)	9:1 (Used)
EP solution flow direction	Bottom to top
EP solution flow rate	5-10 l/min
Cathode rotation speed	50 rpm
Cathode	New Ninja
Voltage (target)	Around 13 V
Current density (target)	Around 30 mA/cm^2
Cavity temperature (target)	20 – 25 °C
EP duration	Around 50 min
Cooling method	Cavity water cooling + EP solution cooling
Chiller temperature	Around 15 °C

Figure 3: Photo of the VEP setup of this experiment.

The logged data of current density, voltage, cavity surface temperature during VEP is shown in Figure 4.

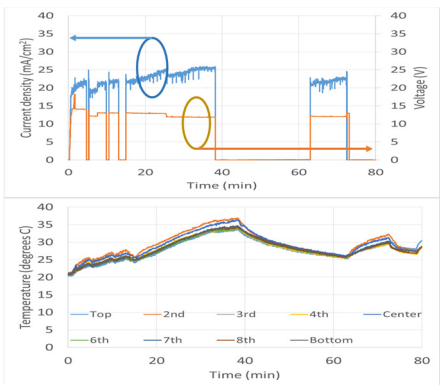

Figure 4: Logged data of current density and voltage (upper), cavity surface temperature of each cell's equator point (lower).

The current density was around 20 – 25 mA/cm^2, this is little less than the target. The voltage was around 12 – 14V, this is near the target. The cavity surface temperature during VEP was 25 – 35 °C, this is higher than the target. This may be due to using only low power chiller in this VEP.

In this experiment, we observed bubbles in the cavity through view ports during VEP. Figure 5 shows the results.

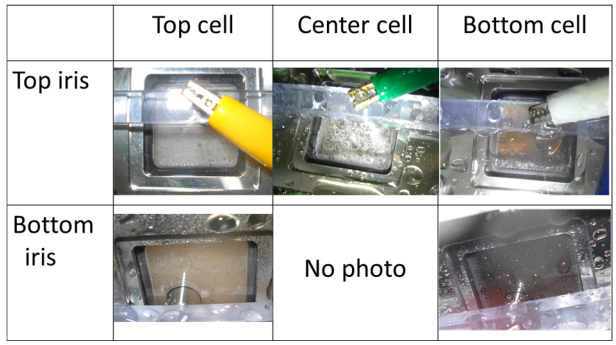

Figure 5: Bubble observation results through the view ports.

A lot of white bubbles were seen in the top cell. Conversely there were few bubbles in the bottom cell. It is thought that bubbles leak out from Al through mesh sheet cracks. Otherwise bubble removal system in the top PVC part didn't work well. We need to revise the states of mesh sheet setting and bubble removal system.

We measured I-V curves of the coupons at the same EP condition (rotation, flow rate etc.). Figure 6 shows the results. The bottom iris curve has polishing region which shows current oscillation around applied EP voltage (12 – 14 V), however the equator curve doesn't have that. This may become the cause of non-uniform polishing.

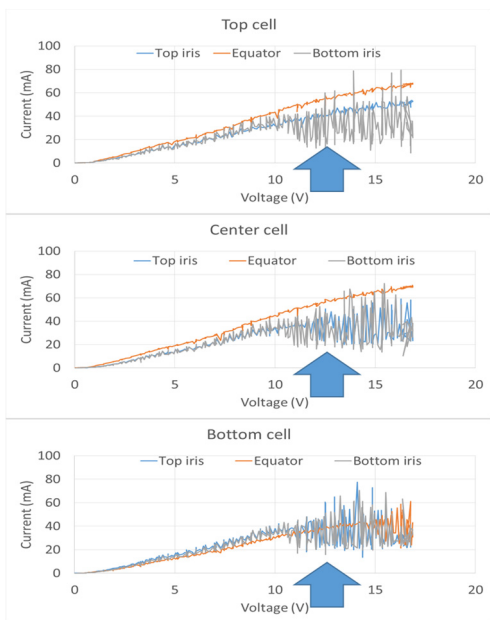

Figure 6: Logged data of coupon I-V curves of the top cell (upper), center cell (middle), bottom cell (lower). Blue arrows show around applied EP voltage.

After this VEP experiment, the coupons were removed, then the surface state and the removal thickness were investigated. Cavity removal thickness was also measured with an ultrasonic thickness gauge. Figure 7 shows

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microscope images and surface roughness Ra values of the coupons. And Figure 8 shows the cavity removal thickness distribution.

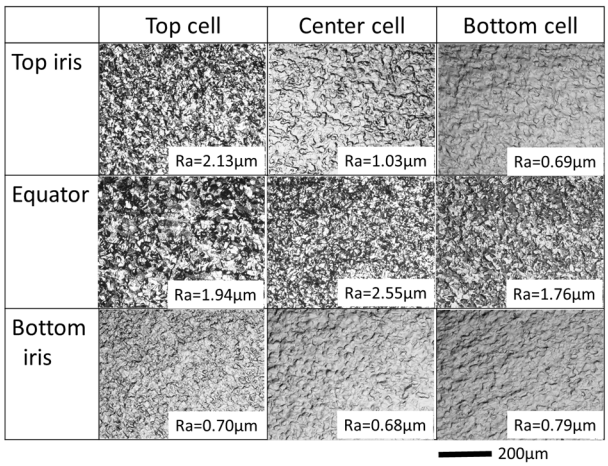

Figure 7: Microscope images and surface roughness Ra values of the coupons after VEP.

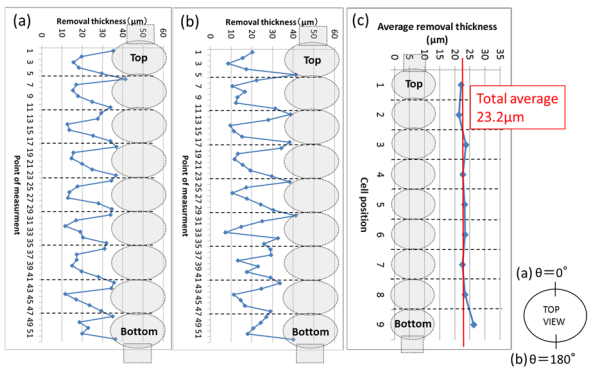

Figure 8: (a) Removal thickness of each part (θ=0) (b) Removal thickness of each part (θ=180) (c) Average removal thickness of each cell.

The coupon surface roughness Ra values of equator part were 3 – 4 times larger than those of bottom iris part. This corresponds the I-V curve result (The rough surface coupon doesn't have a polishing region in the IV curve, in contrast the smooth surface coupon have a polishing region). The removal thickness of near iris part was 2 – 3 times larger than that of near equator part from cavity measurement. From coupon removal thickness measurement (weight loss), similar tendency was obtained.

DISCUSSION

Good surface and uniform removal was not obtain with the VEP as performed only once. However, we obtain a lot of information to improve VEP conditions and our VEP facility. The main points may be,

(1) High cavity temperature during VEP due to insufficient chiller power
(2) Not enough voltage for a polishing region
(3) Bubble diffusion in the cavity
Screening of the cathode surface due bubbles

As countermeasures of these problems, we think,

(1) Use higher power chiller
(2) Application of higher voltage
(3) Revise mesh sheet setting on Ninja cathode
Evacuation or pumping of bubbles

The VEP facility needs to be more improved. After revising these points, we will try 9-cell cavity VEP again and optimize VEP condition.

SUMMARY

We developed new type Ninja cathode for 9-cell cavity VEP to achieve uniform removal thickness distribution and polished surface. A VEP experiment was performed using this cathode and a 9-cell coupon cavity according to the 1-cell VEP best condition. Current density, voltage, cavity surface temperature during VEP were 20 – 25 mA/cm2, 12 – 14V, 25 – 35 °C respectively. The temperature was higher than the best condition. From view port observation, there were a lot of bubbles in the top cell, more than the bottom cell. The coupon IV curves show the difference between equator part and iris part. The IV curves of equator part didn't show a polishing region at this voltage. After VEP, the coupon surface roughness Ra of equator part was 3 – 4 times larger than other parts. The cavity removal thickness of near iris part was 2 – 3 times larger than near equator part. It is said that polishing uniformity was not improved enough because several conditions were not optimized yet.

After this, we need to consider temperature reduction, applying polishing region voltage, bubble diffusion prevention. After revising these points, we will try 9-cell cavity VEP again and optimize VEP condition. And after confirming best condition, vertical test of 9-cell cavity after our VEP will be performed.

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