VERTICAL ELECTRO-POLISHING OF NB NINE-CELL CAVITY USING CATHODE WITH VARIABLE-GEOMETRY WINGS

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Abstract

Marui Galvanizing Co. Ltd. has been studying on Vertical Electro-Polishing (VEP) of Nb nine-cell superconducting accelerator cavity for the mass-production and cost-reduction of Electro-Polishing (EP) process in collaboration with KEK. And we invented our original cathode named "i-cathode Ninja"® which has four Al wing-shape parts per one cell for nine-cell cavity VEP. We thought that these parts can realize uniform distributions of both electric current and EP solution flow at inner surface of cavity. In this article, we will report the first fabrication of VEP facility for nine-cell cavity and VEP results using this cathode.

INTRODUCTION

Electro-polishing (EP) is the most effective method to realize high acceleration gradient of Superconducting Radio-Frequency (SRF) cavity. So far, horizontal electro-polishing (HEP) have been adopted mainly for cavity EP [1-2]. In addition to this, vertical electro-polishing (VEP) is studied actively [3-4]. Marui Galvanizing Co. Ltd., decided to focus on the VEP because of the benefit for mass production (for example space-saving, no cavity rotation). For VEP, we invented our original cathode with variable-geometry wings named "i-cathode Ninja"® [5]. Using this cathode, we have studied single-cell cavity and coupon cavity VEP in collaboration with KEK [5-7]. However, 9-cell cavity is required for linier accelerator production (for example international linier collider (ILC)). Therefore we started to study 9-cell cavity VEP. To realize high performance VEP, more sensitive control of temperature and bubbles are required. In addition, larger and safer facility also is needed. In this article, we report the first fabrication of 9-cell cavity VEP facilities and the results of 1st 9-cell cavity VEP using "i-cathode Ninja"®.

I-CATHODE "NINJA" ®

The schematic view of the "i-cathode Ninja"® which we invented is shown in Fig.1.

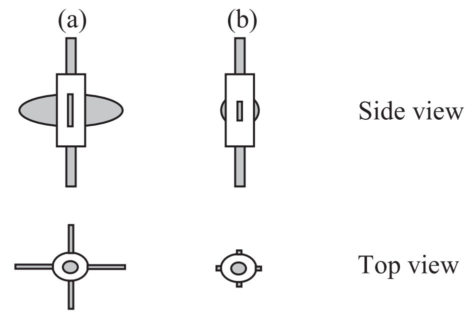

Figure 1: Schematic view of "i-cathode Ninja"®. (a) unfolded status. (b) retracted/folded status.

The most important feature is that it has four wing-like shaped aluminum parts at the center of all cavity cells. Compared with rod type cathode,

(1) The wings work as a baffle plate in the cell of cavity for the flow of electrolyte, and the uniform distribution of electrolyte can be achieved.
(2) The wings make the distance between the cathode and the equator shorter in the cell and realize the uniform distance distribution between cathode and anode.

There are two benefits to use "i-cathode Ninja"®. Then this cathode has a retractable structure of flexible wings and can be folded and unfolded by simple action.

9-CELL VEP FACILITY

Fig.2 shows the pictures of 9-cell cavity VEP facility. And Fig.3 shows the schematic view of 9-cell cavity VEP facility.

Figure 2: (Left) Picture of 9-cell cavity VEP facility. (Right) Picture of 9-cell cavity.

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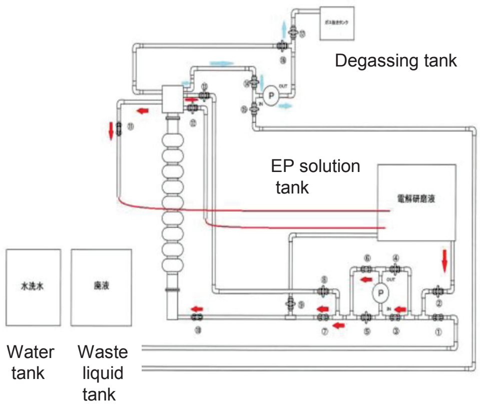

Figure 3: Schematic view of 9-cell cavity VEP facility.

This facility has an EP solution tank, a rinse water tank, a waste water tank, and an exhaust gas tank. EP, water washing, water wasting can be done by valves and hoses operation. And local exhaust ventilation is prepared and HF gas and H_2 gas don't accumulate in this facility. The outlet of EP solution from the 9-cell cavity (upper part) is absorbed by pomp and become negative pressure. The material of pipe, valve is mainly PVC to reduce production costs. This facility has a motor and an inverter at the top of cavity to rotate cathode.

1ST 9-CELL CAVITY VEP

Using this facility and "i-cathode Ninja"®, we performed 9-cell cavity VEP for the first time. Table 1 shows the VEP conditions. The procedure of VEP experiment is as follows, (1) pure water circulation for rinse and leak test of system, (2) start logging and cathode rotation, (3) EP solution circulation 10 min, (4) power supply turn ON, (5) after fixed time, power supply turn OFF, (6) EP solution circulation 30 min and remove EP solution, (7) rinsing by pure water flow, (8) rinsing by pure water circulation. To investigate temperature distribution of cavity and optimize cooling system, the cavity wasn't cooled in this experiment. Fig.4 shows the bubbles during VEP.

Table 1: Conditions of this VEP experiment

Items	Conditions
Electrolyte composition	H_2SO_4(98%):HF(55%) =9:1(V/V)(Flesh)
Electrolyte flow direction	Bottom to top
Electrolyte flow rate	10 L/min
Cathode rotation speed	1 rpm
Voltage	7-9 V
Target current density	Around 30 mA/cm^2
EP time	90 min

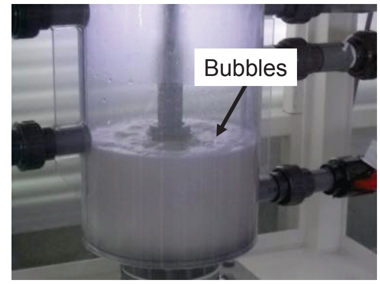

Figure 4: Picture of bubbles at upper side during VEP.

Fig.5 shows the logged data of temperature, current density, voltage during VEP. The temperature was measured at three points, upper iris, equator, lower iris (1st and 9th cell, measured equator and 1 point iris) per 1 cell (total 25 points).

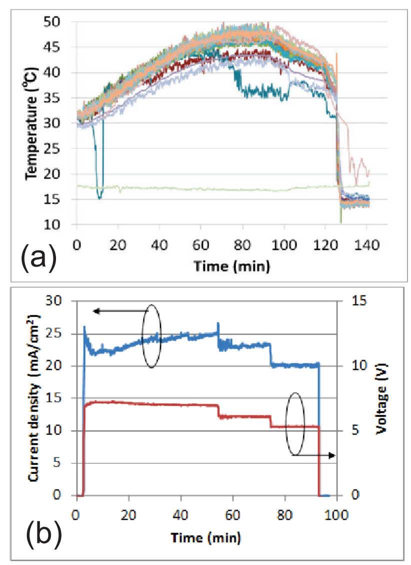

Figure 5: (a) Logged data of temperature of cavity during VEP. The detail of measurement position is omitted in this graph. (b) Logged data of current density and voltage during VEP.

Because of increasing temperature, the voltage was decreased during VEP. The cavity temperature is 40-50°C. This is too high for Nb cavity VEP. Fig.6 shows the distribution of temperature after 60 min VEP .

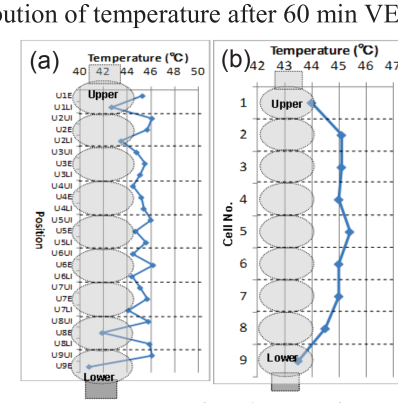

Figure 6: (a) Temperature of each part after 60 min VEP. (b) Temperature of the average of each cell after 60 min VEP.

The temperature of 1st and 9th cell was relatively lower than other cell. This seems to be due to no electrode tool at 1st and 9th cell. There is no clear tendency at other part. Next VEP, we will cool around the cavity using air-spot-cooler uniformly. Fig.6 shows the removal thickness of each part and average of each cell. It was measured by ultrasonic thickness gauge (GE sensing & inspection technology, CL-5). To determine the removal thickness, we measured the thickness three times per one point and took the average before and after VEP.

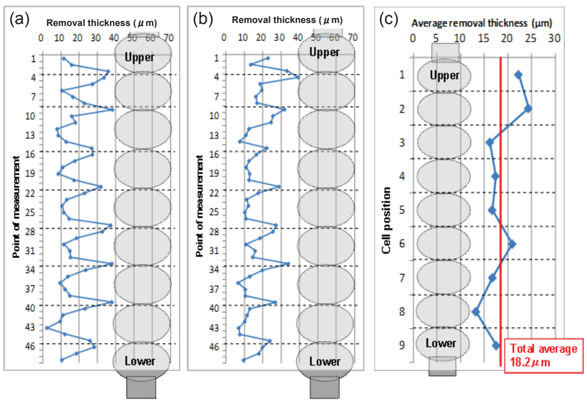

Figure 7: (a) Removal thickness of each part (one side along vertical direction). (b) Removal thickness of each part (180° opposite side of (a) along vertical direction). (c) Average removal thickness of each cell.

As shown in Fig.7, the removal thickness of iris part is 2–4 times larger than that of equator part at all cell. The average removal thickness of all measurement points is 18.2 um. Fig.8 shows the inner surface before and after VEP observed with a digital camera. Fig.9 shows the inner surface of 5th cell after VEP observed with an endoscope.

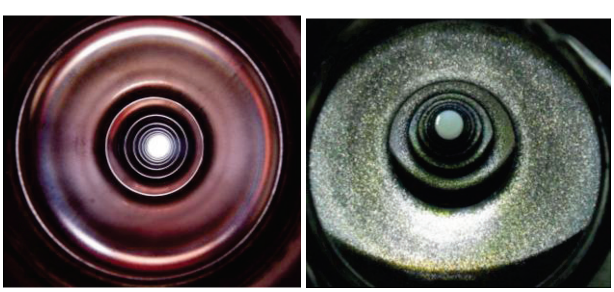

Figure 8: Images of inner surface observed with a digital camera. (Left) before VEP. (Right) after VEP.

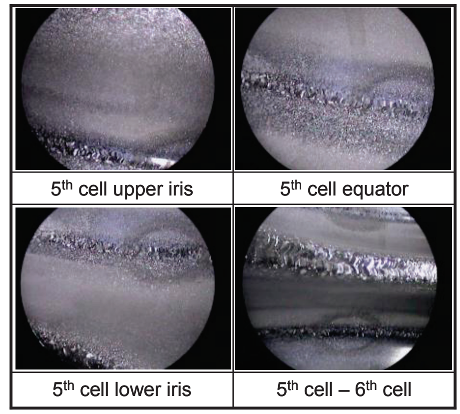

Figure 9: Images of inner surface of 5th cavity after VEP observed with an endoscope.

After VEP, relatively rough inner surface and crystal grain like pattern were observed, especially inter-cell part and equator part. All 9 cells had similar inner surface. This seems to be due to the high temperature during VEP (around 50°C). For next experiment, we will prepare the cavity cooling system using spot-cooler to cool around cavity uniformly. And furthermore, we will optimize the VEP parameter to improve surface roughness and removal thickness distribution.

SUMMARY

We fabricated 9-cell cavity VEP facility and performed 9-cell cavity VEP using "i-cathode Ninja"® for the first time. Temperature during VEP was around 50°C because of no cooling. The removal thickness of iris part is 2–4 times larger than that of equator part at all cell. And after VEP, relatively rough inner surface and crystal grain like pattern were observed at all cells. After this, we will upgrade the facility (mainly addition of new cavity cooling system) and perform 9-cell cavity VEP experiment for parameter optimization to improve inner surface roughness and removal thickness distribution.

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