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1.3 GHz NB SINGLE-CELL CAVITY VERTICAL ELECTROPOLISHING WITH NINJA CATHODE AND RESULTS OF VERTICAL TEST

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Abstract

Marui Galvanizing Co., Ltd. has been developing Nb cavity vertical electropolishing (VEP) technologies in collaboration with KEK. Until now, we reported that inner surface state and removal thickness distribution were improved in VEP with Ninja cathode and a coupon cavity. This time, a 1.3GHz Nb single-cell cavity VEP with Ninja cathode was performed in Marui and vertical test was performed at KEK. The inner surface state and removal thickness distribution were satisfactory. And as a result of the vertical test, an accelerating gradient of 32MV/m (Q_0=8.0E9) was achieved.

INTRODUCTION

Marui Galvanizing Co., Ltd. (Marui) has been developing Nb accelerating cavity vertical electropolishing (VEP) technologies in collaboration with KEK for low cost cavity production. We developed and improved a VEP facility and a unique structure cathode namely "i-cathode Ninja" (Ninja cathode). Using these facility, cathode and single cell coupon cavity which has Nb coupons for surface and removal thickness distribution analysis, a series of VEP experiments were performed for cathode and parameter optimization. Then we have reported that polished surface and removal thickness distribution after VEP with Ninja cathode are improved compared with horizontal electropolishing (HEP) and VEP without Ninja cathode[1]-[4]. Also single cell cavity VEP experiments with Ninja cathode have performed in collaboration with Cornell University and CEA Saclay [5]-[8]. In order to apply these cavity VEP technologies to accelerator cavity production such as international linear collider (ILC) construction, we need to evaluate an accelerating gradient value after VEP with our facility and Ninja cathode. In this article, we report that an accelerating gradient of 1.3GHz single cell Nb cavity which is VEP'ed with Marui's facility and Ninja cathode is measured and evaluated at KEK.

NINJA CATHODE AND VEP SETUP

In this experiment, KEK's 1.3GHz Nb single cell cavity (TB1-TSB02) was VEPed with Marui's Ninja cathode and VEP setup. For this VEP, a Ninja cathode with insulator wings and enhanced cathode area (Ninja-3) was used. This cathode is confirmed that polished surface and removal thickness distribution after VEP are satisfactory [3]. Figure 1 shows schematics of Ninja cathode.

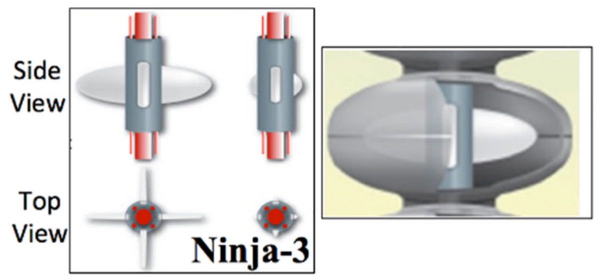

Figure 1: Schematics of Ninja cathode (with insulating wings and enhanced cathode area).

The cavity process was VEP1 (target removal 50 um) – High pressure rinse (HPR), baking and Vertical test 1(VT1) – inner surface inspection and removal thickness measurement – annealing – VEP2 (target removal 10um) – HPR, baking and VT2. HPR, annealing, VT were performed at KEK. VEP was performed in Marui using an automatic valve control system which was developed by Marui, WING and Higashinihon Kidenkaihatsu (Iwate collaboration) [9]. Figure 2 shows the 1.3GHz single cell cavity and the VEP setup of this experiment. During VEP, water spray was used for cavity cooling.

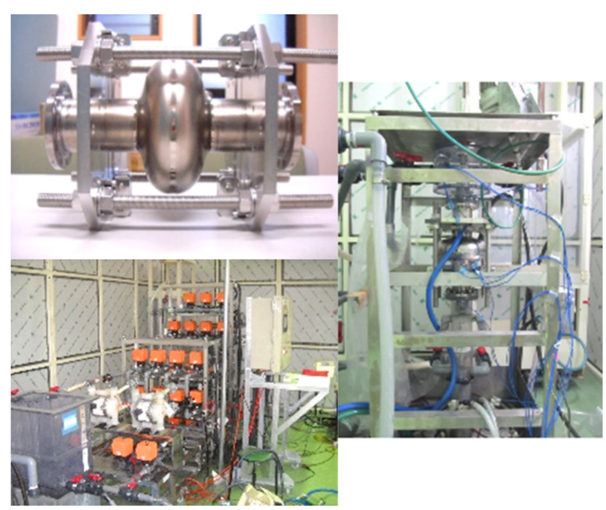

Figure 2: Photos of the VEP setup and the single-cell cavity (Upper left: single-cell cavity, Lower left: automatic valve control system, Right: VEP setup).

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VEP EXPERIMENT AND VERTICAL TEST RESULT

Table 1 shows parameters of VEP1 and VEP2. These are optimized parameters for VEP experiments with Ninja cathode so far. The annealing condition was 750°C, 3hours and the baking condition was 120°C, 48hours.

Table 1: Parameters of VEP1 and VEP2

Parameters	VEP 1	VEP 2
EP acid	H_2SO_4(98%):HF(55%)=9:1	
Voltage	~16 V	~17 V
Current density	20 – 30 mA/cm^2	20 – 30 mA/cm^2
Cavity surface temperature	~20 °C	~20 °C
Cathode rotation speed	20 rpm	20 rpm
Acid flow rate	~5 L/min	~5 L/min
EP time	~180 min	~50 min
Average removal thickness	~36 um	~10 um

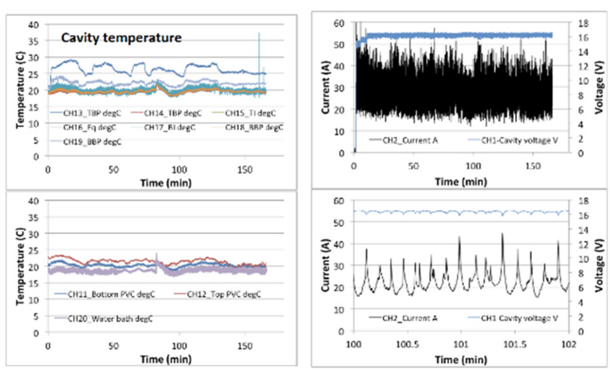

Figure 3: Logged data of voltage, current, temperature during VEP1 (Upper left: cavity surface temperature, Lower left: EP acid temperature, Right: Voltage and current).

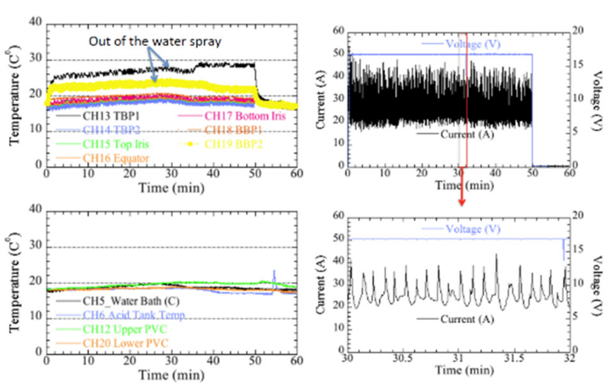

Figure 4: Logged data of voltage, current, temperature during VEP2 (Upper left: cavity surface temperature, Lower left: EP acid temperature, Right: Voltage and current).

Figure 3 and 4 show the logged data of cavity surface temperature, EP acid temperature, voltage and current during VEP1 and VEP2.

The EP current of VEP1 and VEP2 was around 20 – 30 A (equivalent to current density 20 – 30 mA/cm^2), this is almost the same as conventional VEP with Ninja cathode. And current oscillation can be seen in both VEP. The cavity surface temperature during VEP1 and VEP2 was kept around 20°C and the distribution was satisfactory in effect of water spray cooling. It is shown that both VEP were performed with optimum current and temperature condition for Nb EP.

Figure 5 shows the result of removal thickness distribution measurement after VEP1. Removal thickness distribution was calculated from Nb thickness measured with an ultrasonic thickness gauge before and after VEP1.

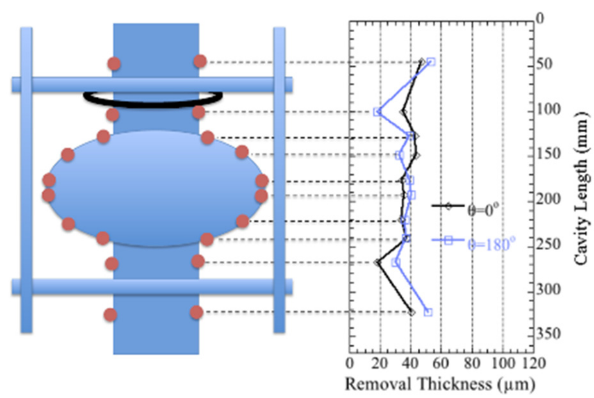

Figure 5: Removal thickness distribution after VEP1.

Except the beam pipe section, removal thickness distribution of the angle of 0 degree and 180 degrees were almost uniform. These are generally aimed and satisfactory results. After VEP2 the measurement was not performed because of low removal thickness.

Figure 6 shows the result of cavity inner surface inspection with a digital camera and a Kyoto camera.

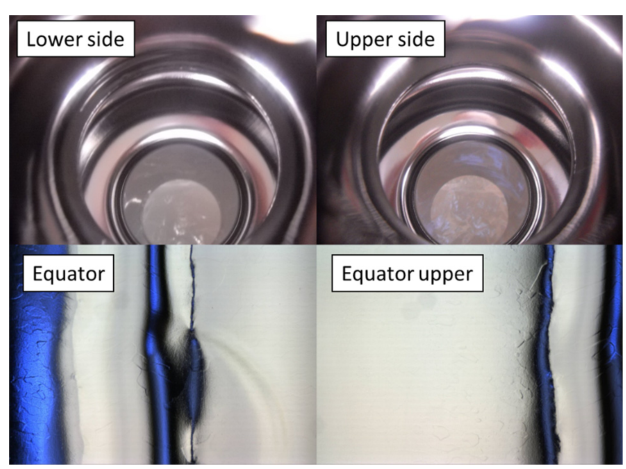

Figure 6: Surface inspection results after VEP1 (Upper: digital camera photos, Lower: Kyoto camera photos).

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From digital camera inspection, very shiny inner surface was inspected after VEP1 in both upper and lower side. And from Kyoto camera inspection very smooth surface was inspected around equator area also. It can be said that good condition EP process is performed.

After VEP process in Marui, a vertical test was performed at KEK. The vertical test after VEP1 was not completed because of power failure, after VEP2 was completed successfully. Figure 7 shows the result of vertical test at 2K after VEP2 and Figure 8 shows the accelerating gradient comparison with VEP and HEP.

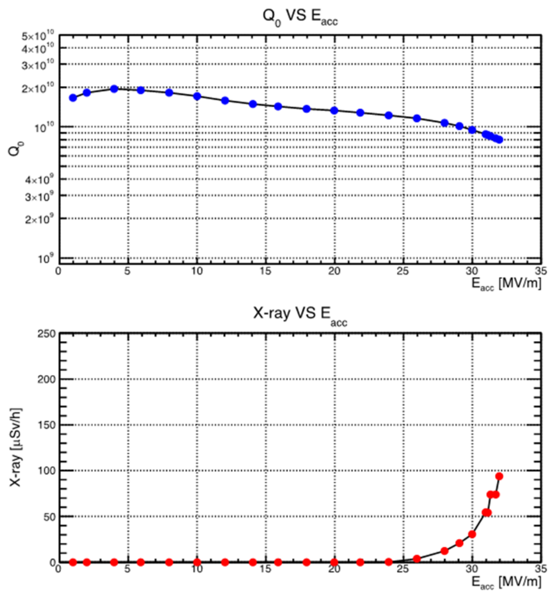

Figure 7: Vertical test result at 2K after VEP2 (Upper: Q_0 vs E_{acc}, Lower: X-ray vs E_{acc}).

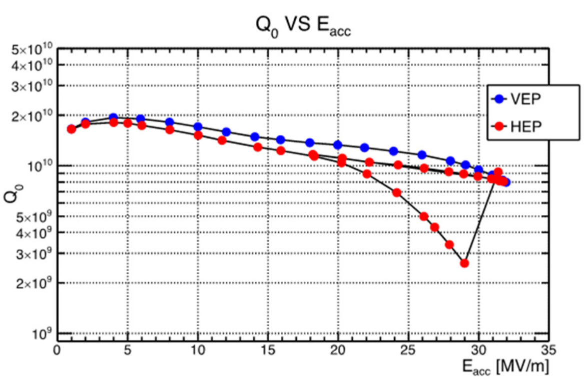

Figure 8: Accelerating gradient comparison of VEP and HEP.

Accelerating gradient of 32MV/m and Q_0 value of 8.0E9 were achieved and finally quench happened. This value is almost the same as that after HEP in KEK using the same cavity. This result suggests that VEP with Marui's Ninja cathode and setup is applicable for production of Nb cavity as with HEP.

Now in case of 9-cell cavity VEP, development of VEP parameters and removal thickness distribution using a coupon cavity, evaluation of accelerating gradient after VEP using a 1.3GHz cavity are under performing [10][11].

SUMMARY

In order to evaluate an accelerating gradient of Nb cavity after VEP with Marui's Ninja cathode and VEP setup, Marui and KEK performed VEP and VT for a 1.3GHz single sell cavity. Optimized parameters for VEP experiments with Ninja cathode were used.

Current density during VEP was almost the same as conventional VEP with Ninja cathode and current oscillation can be seen. The cavity surface temperature during VEP was kept around 20 degC and the distribution was satisfactory. The removal thickness was uniform in VEP1. The polished surface was shiny and this indicates that good condition EP process is performed. From vertical test at KEK, accelerating gradient of 32MV/m and Q_0 value of 8.0E9 were achieved and finally quench happened. This value is almost the same as that after HEP using the same cavity. This result suggests that VEP with Marui's Ninja cathode and setup is applicable for production of Nb cavity as with HEP.

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