IMPROVEMENT OF TEMPERATURE CONTROL DURING Nb 9-CELL SRF CAVITY VERTICAL ELECTRO-POLISHING (VEP) AND PROGRESS OF VEP QUALITY

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Abstract

Marui Galvanizing Co.,Ltd. has been developing Nb 9-cell SRF cavity vertical electro-polishing (VEP) facility and technique for mass production in collaboration with KEK. Our first 9-cell cavity VEP facility was not enough to control temperature during VEP, so the polishing quality was not so high. In this article, we will report the progress of temperature distribution and polishing quality due to the improvement of temperature control system of electrolyte and cavity during VEP.

INTRODUCTION

International linear collider (ILC) will require around 16000 niobium 9-cell SRF cavities. In order to meet such requirement mass production of cavities with higher efficiency and lower cost is desired. To solve this problem, worldwide development for mass-production is performed. Electropolishing (EP) is considered as a final surface treatment of these cavities to improve the surface quality for their high performance and high mass-productivity, high performance EP method and facility are also required. Marui Galvanizing Co., Ltd. has been developing Nb SRF cavity EP technology in collaboration with KEK based on experience of various materials and shapes parts EP. In this collaboration, we focused on vertical electropolishing (VEP) technique which was considered more suitable to mass-production and have been developing original cathode named “i-cathode Ninja” to improve polishing quality [1], performing VEP parameter investigation and surface analysis after VEP using 1-cell coupon cavity [2-6], preparing VEP facility for ILC 9-cell SRF cavity [7]. In previous work, we prepared 9-cell cavity VEP facility and performed VEP. Though high quality VEP couldn’t be performed because of high cavity temperature (around 50 ^{0}C) during VEP (Usually 20 – 30 ^{0}C is required to perform high quality Nb EP.). To solve this problem, we developed cavity temperature control system during VEP. In this article, we report VEP results using this system.

9-CELL CAVITY VEP WITH HEAT EXCHANGER FOR EP SOLUTION

From the viewpoint of cavity temperature control, babble removal, operation system, following points were improved.

(1) Improvement for cavity temperature control during VEP
  (a) A heat exchanger is injected in EP solution tank and coolant is circulated in it by a chiller.
  (b) Enclosing cavity by acrylic plates and injecting cooler wind into enclosed space (air cooling).
(2) Improvement for bubble removal
  (a) Ninja rotation speed is increased to enhance mixing effect.
  (b) Setting a bubble removal filter.
(3) Improvement for facility usability
  (a) Preparing a control box including all operation controllers.
  (b) Preparing PVC pipes and valves to change flow direction of waste fluid.

Pictures of facility and parts after improvement are shown in Fig. 1.

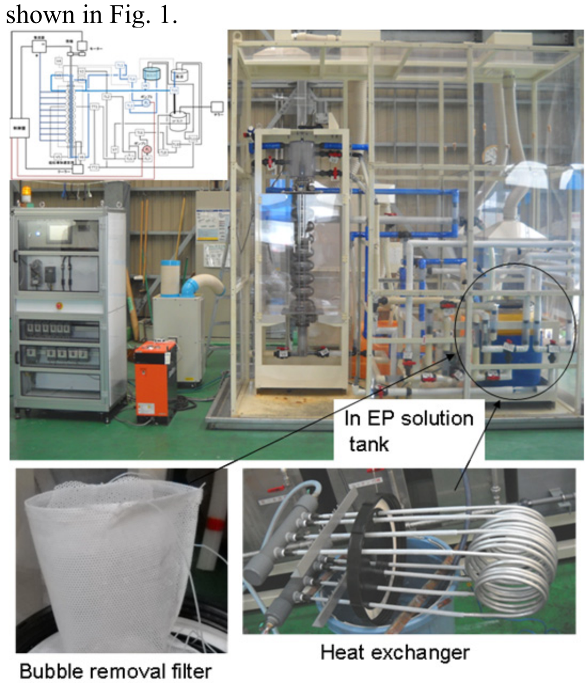

Figure 1: Pictures of facility and parts after improvement.

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ISBN 978-3-95450-178-6

Table 1: Conditions of this VEP Experiment

Parameters	Conditions
EP solution(H_2SO_4:HF)	9:1 (Flesh)
EP solution flow direction	Bottom to top
EP solution flow rate	5-10 l/min
Cathode rotation speed	50 rpm
Cathode	Ninja with Al wings
Voltage	7-9 V
Current density	～30 mA/cm^2
EP time	2 hours
Chiller temperature	5 ^{0}C

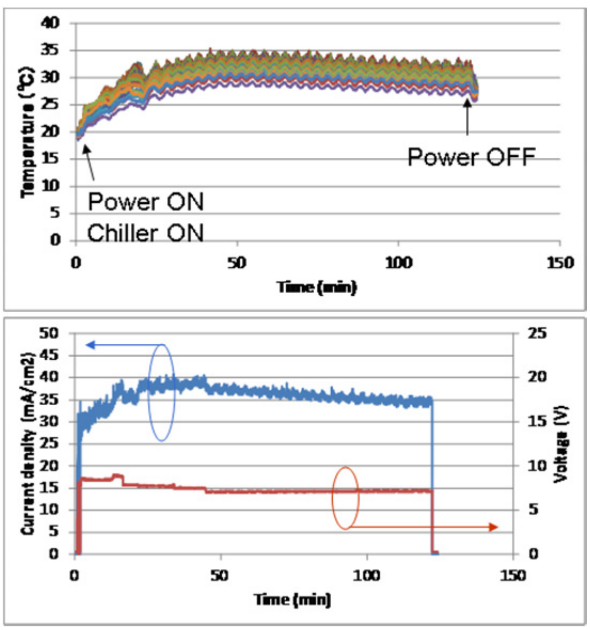

Figure 2: Logged data during VEP, (Upper) cavity temperature, (Lower) current density and voltage.

Using this system, 9-cell cavity VEP experiment was performed. The 9-cell cavity used in this experiment was the same as previous experiment. VEP conditions are shown in Table 1. Logged data of cavity temperature (25 points measurement) and voltage, current density during VEP are shown in Fig. 2. Overall cavity temperature during VEP was around 30 – 35 ^{0}C. This is little higher than 30 ^{0}C (target), however lower than 40 – 50 ^{0}C (previous VEP). This means that temperature is some improved compared with previous VEP. Current density was near the target, and voltage was reduced during VEP not to increase the temperature.

Figure 3 shows inner surface before and after VEP observed with a digital camera (1st cell) and an endoscope (5th cell). As a result of this VEP the surface status was improved. From eyesight, the brightness also was improved. However endoscope inspection result shows that rough surface is not resolved perfectly.

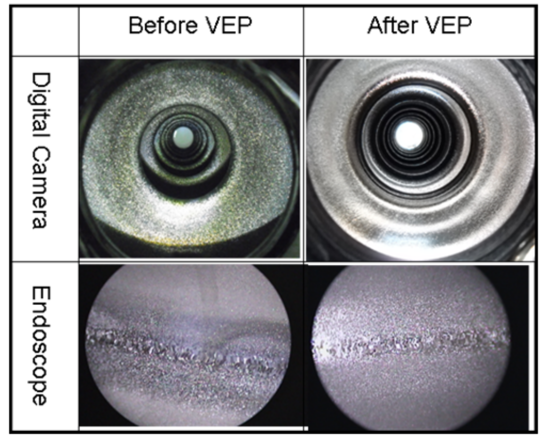

Figure 3: Images of inner surface observed with a digital camera and an endoscope.

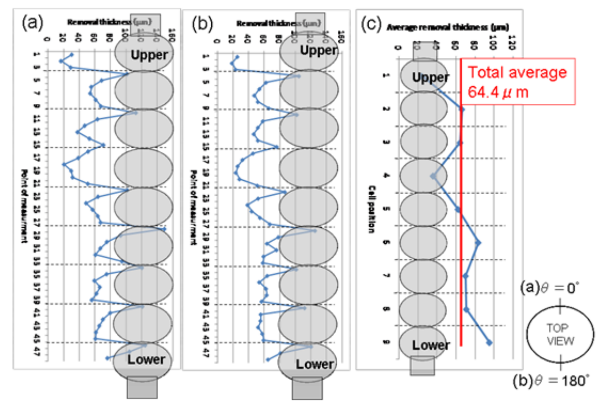

Figure 4: (a) Removal thickness of each part (θ=0) (b) Removal thickness of each part (θ=180) (c) Average removal thickness of each cell.

Figure 4 shows the results of removal thickness. Removal thickness of upper iris is 2 – 3 times larger than that of other parts. And then, overall, the removal thickness of lower cell tends to be larger than upper cell.

VEP WITH CAVITY WATER COOLING SYSTEM AND HEAT EXCHANGER

To keep cavity temperature during VEP under 30 ^{0}C, cavity water cooling system was added. Figure 5 shows pictures and schematic view of this system. Water which is cooled by another heat exchanger and chiller is showered to cavity directly using circulation pump and hoses with some holes. These hoses are set around 1st cell equator and between 4th cell and 5th cell. To check the ability of this cooling system, we circulated hot water (50 ^{0}C) in the cavity and measured the temperature of hot water and cavity surface. Figure 6 shows the results.

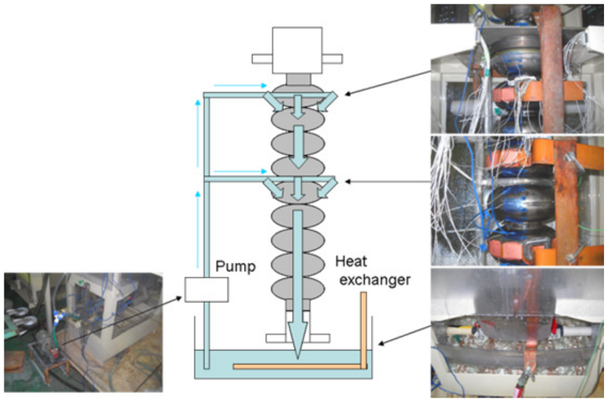

Figure 5: Pictures and schematic view of cavity water cooling system.

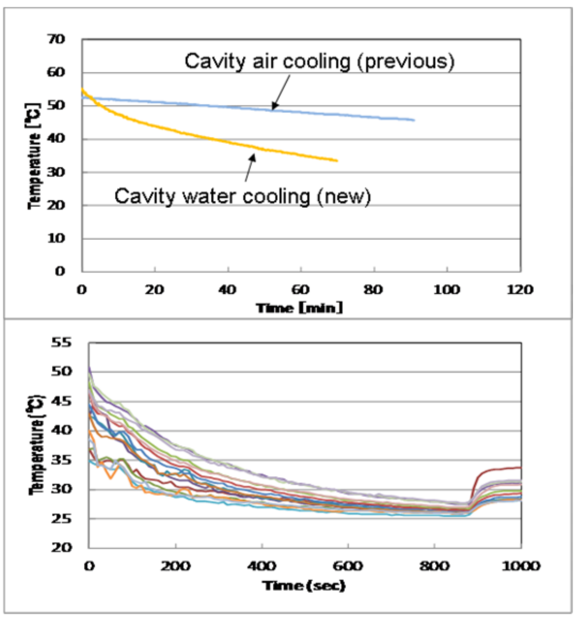

Figure 6: Results of hot water circulation test, (Upper) hot water temperature in cavity with air cooling and water cooling, (Lower) cavity surface temperature (15 points) during water cooling.

Flow rate of cooling water was selected around 8 L/min because it was minimum amount to wet all cavity surfaces. From upper graph of Fig. 6, it is confirmed that water cooling is superior to air cooling for cavity cooling. And from lower graph of Fig. 6, it is also confirmed that the cavity temperature is degraded satisfactorily.

Adding this water cooling system, we performed 9-cell cavity VEP experiment. The 9-cell cavity used in this experiment was the same as last VEP experiment. Conditions of this VEP experiment are shown in Table 2. Logged data of cavity temperature (25 points measurement) and voltage, current density during VEP are shown in Fig. 7.

Table 2: 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	Ninja with Al wings
Voltage	11 V
Current density	～30 mA/cm^2
EP time	2 hours
Chiller temperature	5 ^{0}C
Cooling water flow rate	8 l/min

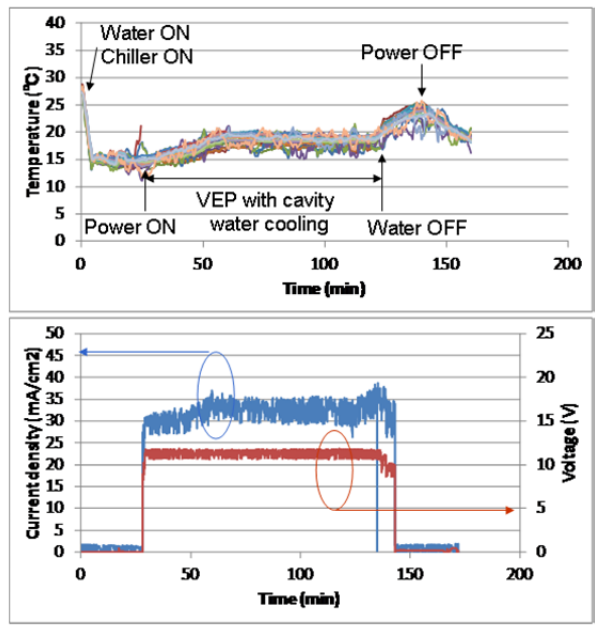

Figure 7: Logged data during VEP, (Upper) cavity temperature, (Lower) current density and voltage.

Cavity temperature was kept under 30 ^{0}C successfully (basically the temperature was kept around 20 ^{0}C in most of EP duration). And it was confirmed that EP solution temperature was also kept around 20 – 25 ^{0}C. To check the effect of water cooling, we stopped cooling water around 120 min and confirmed the tendency of temperature. Then the temperature was increased from 20 ^{0}C to 25 ^{0}C. This shows that water cooling is effective to keep the temperature around 20 ^{0}C. The current density was around 30 – 35 mA/cm^2 and it was near the target. This time we didn't need to reduce voltage during VEP with cavity water cooling because we were able to keep the temperature around the target. So it can be said that we can apply higher and fixed voltage for 9-cell VEP now.

Figure 8 shows inner surface before and after VEP. As a result of this VEP, the status of inner surface didn't change largely (Brightness was almost the same).

ISBN 978-3-95450-178-6

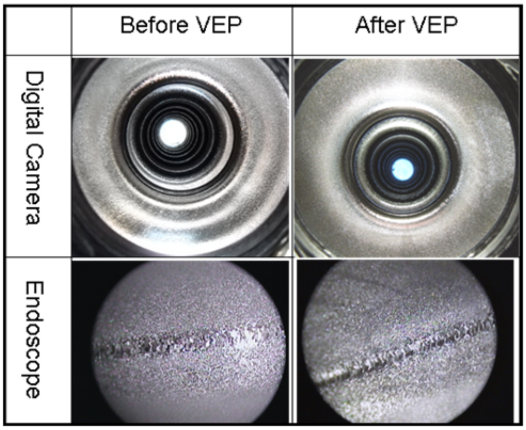

Figure 8: Images of inner surface observed with a digital camera and an endoscope.

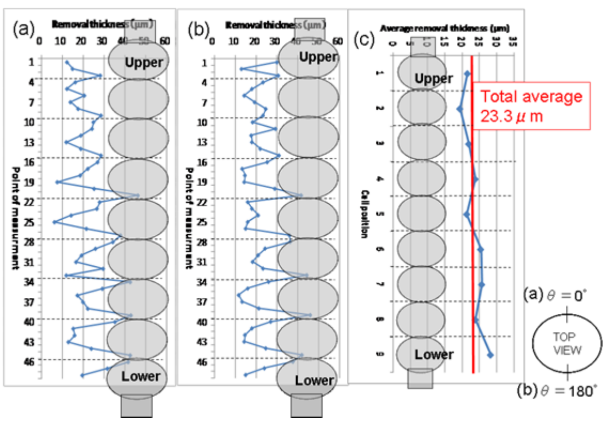

Figure 9: (a) Removal thickness of each part (θ=0) (b) Removal thickness of each part (θ=180) (c) Average removal thickness of each cell.

Figure 9 shows the results of removal thickness. Removal thickness of equator was small, and that of iris was large (2 – 3 times). And then, overall, the removal thickness of lower cell tends to be larger than upper cell. This is similar tendency as last VEP. We think the cause of this non-homogeneity is bubbles from Al wings [5-6]. Bubbles from Al wings seem to attack iris part and enhance removal thickness. To solve this problem, we have been considering wing modification. Using wings like when used in 1-cell coupon cavity experiment [5-6], it is thought that removal thickness non-homogeneity seems to be improved.

FUTURE WORK

After this, we will improve the Ninja cathode to achieve more flat and uniform surface status after 9-cell cavity VEP like 1-cell coupon cavity VEP experiment [5-6]. And we will construct a 9-cell coupon cavity which has several Nb coupons for surface analysis. Then we will perform further VEP experiment, parameter investigation and surface analysis. After improving these matters, using new 9-cell cavity, we will perform vertical test to confirm accelerating gradient after our VEP.

SUMMARY

We constructed temperature control system for 9-cell cavity VEP. First, we added a heat exchanger to cool EP solution and performed VEP. As a result, cavity surface temperature during VEP became around 30 – 35 ^{0}C. This is improved from previous VEP, however not reach our target (under 30 ^{0}C). The inner surface after VEP was improved and became brighter. The removal thickness of upper iris was 2 -2.5 times larger than other part, this is not improved from previous VEP. To achieve further improvement, we added a cavity water cooling system and performed VEP. Then, cavity temperature during VEP was kept under 30 ^{0}C successfully. The inner surface and removal thickness distribution were similar as last VEP. After this, for further improvement, we will perform Ninja cathode improvement, VEP using this, and vertical test to confirm accelerating gradient after our VEP.

ACKNOWLEDGEMENTS

The author would like to thank Mr. Mitoya, Mr. Akabori (Higashi-Nihon Kidenkaihatsu Co., Ltd., Morioka Japan) and Mr. Takahashi, Mr. Anetai (WING Co., Ltd., Kitakami Japan) for the help of cavity water cooling system construction.

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