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VERTICAL ELECTROPOLISHING OF NIOBIUM NINE-CELL CAVITY WITH A CAVITY FLIPPING SYSTEM FOR UNIFORM REMOVAL

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Abstract

Marui Galvanizing Co., Ltd. has been developing vertical electropolishing (VEP) technology for single and nine-cell niobium superconducting radio frequency cavities using a unique cathode namely Ninja cathode in collaboration with KEK. The VEP process usually results in non-uniform removal with a large asymmetry along the cavity length. In order to suppress the asymmetry in removal, we are making different approaches. Flipping of the cavity during the VEP process is one of the approaches applied so far. A unique VEP setup, which allows the flipping of a multi-cell cavity, has been developed as reported earlier. Here, we report the improvement in the setup with automation for cavity flipping. VEP experiments were conducted with the improved system. VEP parameters were studied and the VEP results including the removal trend are discussed in detail.

INTRODUCTION

Marui Galvanizing Co., Ltd. is working on the development of vertical electropolishing (VEP) technology of niobium superconducting radio frequency (SRF) cavity using Ninja cathode in collaboration with KEK for mass production and cost reduction. In case of 9-cell cavity VEP, there was a big problem that the removal thickness distribution became non-uniform because of bubble accumulation so far. In VEP, because bubbles generated from the cathode rise up and promote polishing during EP, the removal thickness on the upper side is larger than that on the lower side both in-cell and inter-cell, resulting it become asymmetry removal. To solve this problem, we proposed two methods, the separate (dual) flow method and the cavity flipping method [1] [2]. In the separate (dual) flow method, the flow of the EP solution was divided into two, and the bubbles were not diffused into the cavity and drained out of cavity rapidly, so the removal symmetry was successfully improved [1]. The cavity flipping method is a method of compensating for the difference in removal thickness between the upper and lower portions of the cavity during VEP to improve the uniformity of the removal thickness. In this paper, we report the improvement of the equipment of cavity flipping method and the result of VEP experiment.

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CAVITY FLIPPING VEP

Flipping VEP was performed using a dedicated cavity holder [3]. In this holder, the part with the motor and the cathode electrical contact is defined as the top, the state with the top on the upper side is called “Forward position (F)”, and the state with the top on the lower side is called “Reverse position (R)”. The cathode through part of the PVC pod was specially sealed so that the EP solution did not leak when it was reverse position. Cavity flipping was performed using a motor and positioning of the stop was performed using a sensor. This simplifies the flipping operation and improves the position reproducibility. Figure 1 shows a photo and a schematic of the VEP equipment, and Fig. 2 shows a continuous photo of the state of flipping.

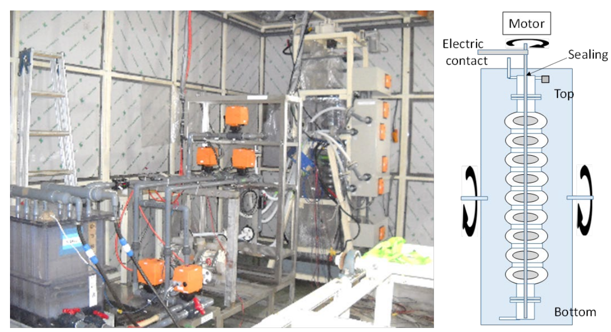

Figure 1: A photo and a schematic of the VEP equipment.

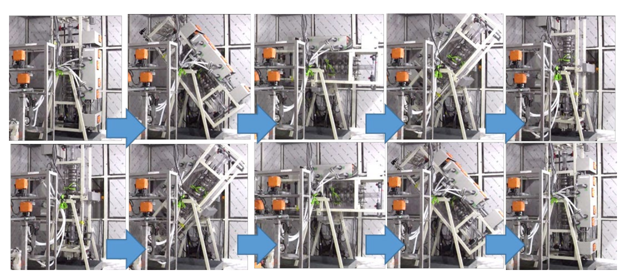

Figure 2: A continuous photo of the state of flipping (Upper: F to R, lower: R to F).

VEP EXPERIMENT

Table 1 shows the EP conditions of this flipping VEP. Ninja cathode V6 with metal wings and mesh covers was used for this experiment. EP was performed in the procedure of repeating “3 min forward position EP - EP stop, flipping - 3 min reverse position EP - EP stop, flipping”. The time for stopping and flipping was about 3 minutes. The cavity was cooled with a water shower during VEP.

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Table 1: Conditions of Cavity Flipping VEP

Parameters	Cavity flipping VEP
Voltage	17~18V
Current density	20 – 30 mA/cm^2
Cavity surface temperature	20~25 ºC
Cathode rotation speed	20 rpm (both F and R)
Acid flow rate	~5 L/min
EP process	3min ON (F) – OFF, flipping – 3min ON (R) – OFF, flipping
Target removal thickness	~30um
Cathode	Ninja-v6 (With metallic wings and mesh cover)

The IV curves of the forward position and the reverse position are shown in Fig. 3. In the IV curve of the forward position, the plateau region appears relatively clearly in the region of 8 V or more, but in the reverse position IV curve, although a change in slope is observed, no clear plateau region can be confirmed. The current flow is asymmetrical between the forward position and the reverse position.

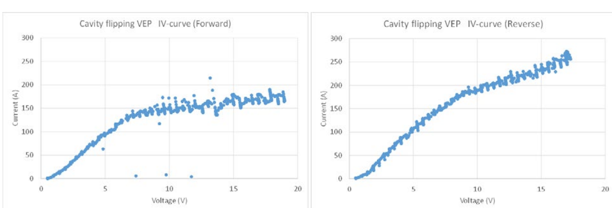

Figure 3: The IV curves of forward position (left) and reverse position (right).

The current, voltage during VEP is shown in Fig. 4, the cavity surface temperature in Fig. 5, the EP solution temperature in Fig. 6, and the EP solution flow rate in Fig. 7.

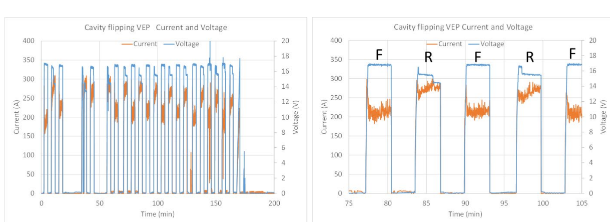

Figure 4: The current, voltage during VEP

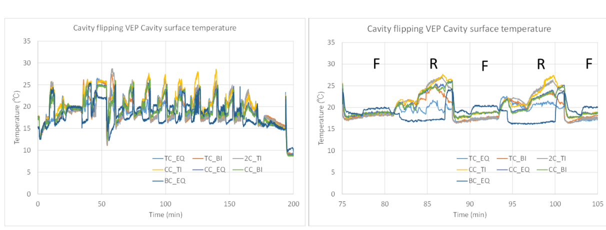

Figure 5: The cavity surface temperature during VEP

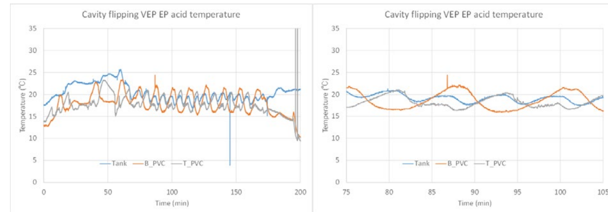

Figure 6: The EP solution temperature during VEP

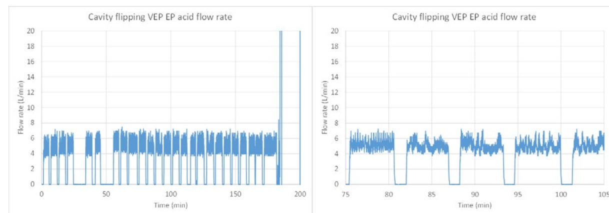

Figure 7: The EP solution flow rate during VEP

The current in VEP differs between the forward position and the reverse position, and the current is larger at the reverse position (Therefore, the voltage is lowered slightly at the reverse position). In addition, the cavity surface temperature is higher at the reverse position. This is the same tendency as the IV curves. Although the cause is not known, it is suspected that a leak current due to the contact of the cathode located on the lower side in the reverse position EP with the cooling water getting wet. This is under investigation. It is also conceivable that there are asymmetric parts in the upper and lower parts of the system and the cathode, which have an influence. The temperature of the EP solution was around 20 ° C., and the flow rate of the EP solution was about 4 - 6 L / min, it was almost on target. The inner surface observation result after flipping VEP is shown in Fig. 8.

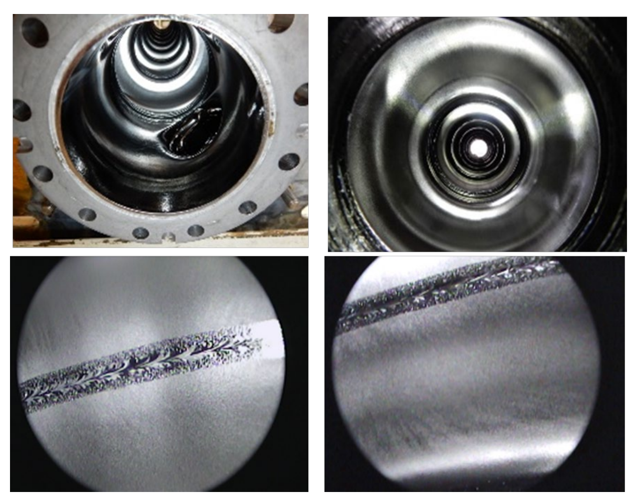

Figure 8: Inner surface observation photos after VEP (upper: with digital camera, lower: with endoscope)

The inner surface after the VEP was glossy, but some bubble traces were also seen. It seems that optimization of conditions and measures against bubbles will be needed in the future. The distribution of removal thickness after VEP is shown in Fig. 9. The upper numbers indicate the average removal thickness in each cell.

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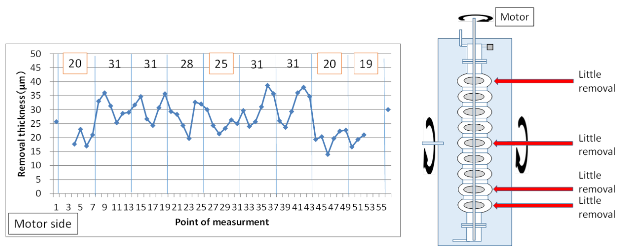

Figure 9: Removal thickness distribution after VEP

Although the distribution is generally good, it can be seen that the removal thickness of the upper and lower and center cells (first, fifth, eighth and ninth cells) are smaller than those of the other cells. Although the cause is not yet known, it is thought that the condition of flipping and the stagnation of bubbles are the candidate. We will improve the system and parameters to improve the distribution of removal thickness between cells in the future.

SUMMARY

In order to improve the non-uniform removal thickness in the upper and lower parts, which is a problem of the 9-cell cavity VEP, we improved the equipment of the cavity flipping VEP and performed VEP and its evaluation. The IV curves showed a plateau region at the forward position, but not clearly seen at the reverse position, there is a difference between the two positions. The current in VEP is also larger at the reverse position, and a difference is seen. After VEP, the inner surface was glossy but some bubble traces were observed. The removal thickness distribution was generally good, but the average removal thickness of the upper, lower and center cells was smaller than other cells. In the future, to improve these, we will perform the improvement of system and cathode symmetry, prevention of bubble retention and electric leakage, optimization of various EP parameters to improve removal thickness distribution and polishing inner surface. And we would like to proceed with the evaluation of cavity acceleration performance.

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