ISBN: 978-3-95450-194-6 ISSN: 2226-0366 doi:10.18429/JACoW-LINAC2018-TUPO067

STUDY ON NEW REMOVAL THICKNESS DISTRIBUTION IMPROVEMENT METHODS FOR NIOBIUM 9-CELL CAVITY VERTICAL ELECTROPOLISHING WITH NINJA CATHODE

K.Nii#, V.Chouhan, Y.Ida, T.Yamaguchi, Marui Galvanizing Co., Ltd., Himeji, Japan
H.Hayano, S.Kato, H.Monjushiro, T.Saeki, M.Sawabe, KEK, Tsukuba, Japan

Abstract

Marui Galvanizing Co., Ltd. has been developing niobium 9-cell cavity vertical electropolishing (VEP) technologies with Ninja cathode in collaboration with KEK. Conventional 9-cell cavity VEP had a serious problem, which was asymmetry of removal thickness distribution. Usually removal thickness of upper side became larger than lower side in case of both in-cell and inter-cell. So far, as one solution, we proposed “bubble diffusion prevention” method and proved it was effective for uniform removal. This time, as other new solution, we tried “cavity flip upside down” and “Ninja cathode masking” VEP methods. In this article we will report the purpose, intention and VEP experiment result of these methods.

INTRODUCTION

Marui Galvanizing Co., Ltd. is working on the development of vertical electropolishing (VEP) technology of niobium SRF cavity using Ninja cathode in collaboration with KEK for mass production and cost reduction. In the 9-cell cavity VEP, there was a problem that the removal thickness distribution became non-uniform (upper side is larger than lower side) because of bubble accumulation so far. We have done a lot of experiments working on solving this problem. Divide the flow path of the EP liquid into the inside and the outside of the Ninja cathode and optimally control the respective flow velocities and providing the power off time, it was shown that bubbles are prevented from accumulating in the cavity, and the removal thickness distribution is greatly improved to be uniform [1,2].

Furthermore, in order to understand the 9 cell cavity VEP and approach it for improvement, we aimed to solve the problem of non-uniform removal thickness in another way this time. One method is to invert the upper and lower sides of the cavity during VEP to make the removal thickness uniform (Cavity flip upside down VEP), and the other is using masked cathode to control the removal thickness of each part to make it uniform (Cathode masking VEP). We conducted VEP experiments using these methods and a 9 cell coupon cavity. The results such as removal thickness distribution are reported in this article.

#keisuke_nii@e-maui.jp

CAVITY FLIP UPSIDE DOWN VEP

Cavity flip upside down VEP was performed using dedicated cavity holder. In this holder, motor – cathode connection side is defined as top and the state where the top is on the upper side is called the forward position. The cathode penetration part of top PVC piece was specially sealed to prevent EP acid leakage in case of reverse position. The setup and inversion procedure are shown in Figure 1.

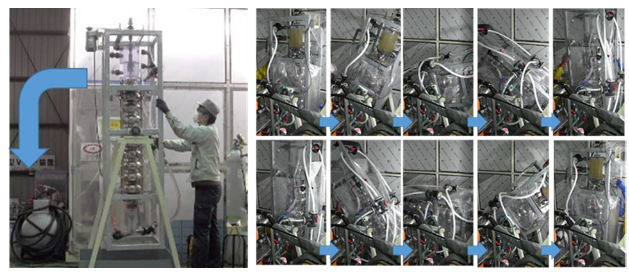

Figure 1: Cavity flip upside down setup and procedure.

Table 1: Conditions of Cavity Flip Upside Down VEP

Parameters	Cavity flip upside down VEP
Voltage	~14V
Current density	20 – 30 mA/cm^2
Cavity surface temperature	20~25 □C
Cathode rotation speed	20 rpm (forward position) 0rpm (reverse position)
Acid flow rate	5~10 L/min
EP time	5min (F-R)+15min (F-R)+20min (F-R)
Average removal thickness	~30um
Cathode	Ninja-v6 (With metallic wings and mesh cover)

Table 1 shows the conditions of cavity flip upside down VEP experiment. For this experiment, a 9cell coupon cavity [3] and Ninja cathode V6 with metal wings and mesh cover were used. The VEP was performed according to the procedure of 5min (forward position) – 5min (reverse position) – 15min (forward position) – 15min (reverse position) – 20min (forward position) – 20min (reverse position). The cathode rotation was carried out in the forward position, however not in reverse position (concerned about EP acid leakage).

ISBN: 978-3-95450-194-6 ISSN: 2226-0366 doi:10.18429/JACoW-LINAC2018-TUPO067

Figure 2 shows the average of coupon current on 5min forward and reverse position VEP and the average of them.

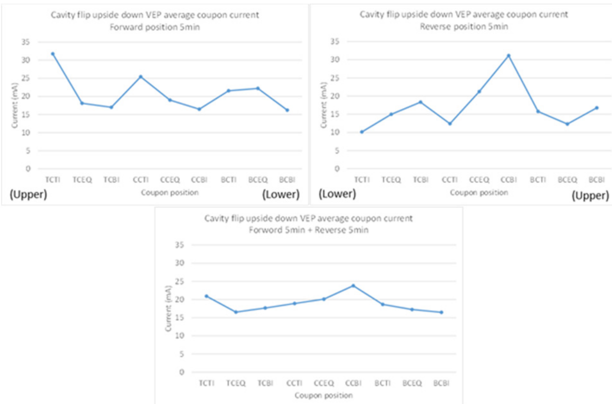

Figure 2: Average of each coupon current, (upper left) 5min forward position VEP, (upper right) 5min reverse position VEP, (lower) the average of them.

It is shown that the upper coupon current is larger than lower one in both forward position and reverse position. This is the same tendency of usual VEP. And taking average of them, coupon current became uniform as a whole. From this it can be seen that the coupon current is made uniform by the effect of cavity flip upside down.

Figure 3 shows the logged data and total average of coupon current during this VEP. Even through all, it is said that the coupon current is averaged and uniform.

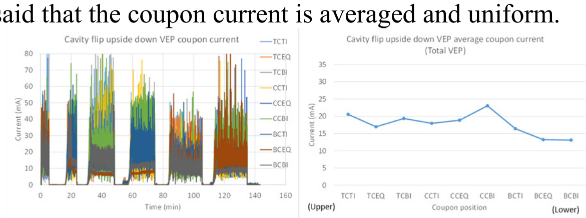

Figure 3: (Left) the logged data of each coupon current, (Right) average of coupon current of total VEP.

Figure 4 shows the removal thickness distribution measurement result after this VEP. The result is compared with that of usual VEP. This measurement was performed using ultrasonic thickness gauge.

On usual VEP, the difference of Max-Min is around 3 times, on the other hand, on flip upside down VEP, that is around within 2 times, it is greatly improved.

Figure 5 shows the coupon surface status and surface roughness.

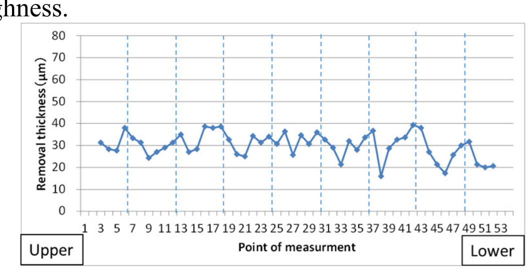

Figure 4: Removal thickness distribution result with cavity flip upside down.

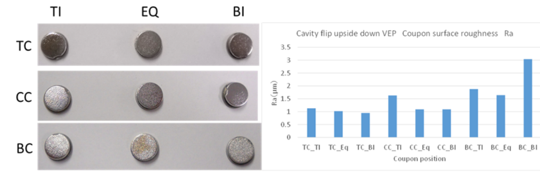

Figure 5: Status and roughness of each coupon after VEP.

The top cell, center cell coupon surface were shiny and low surface roughness, however bottom cell coupon had slightly rough surface. Although the detailed cause is unknown, it is thought that asymmetry of setup is main cause (no rotation in reverse position, different top and bottom PVC piece shape etc.). From now on, we will improve the cathode penetration part seals so that the cathode can be rotated even in the reverse position, adjust the sizes of the top and bottom PVC pieces, and aim for further improvement in removal thickness distribution and polished surface.

CATHODE MASKING VEP

VEP experiments were performed using masked Ninja cathodes with the aim of improving removal thickness uniformity by cathode masking. In order to confirm the effect of cathode masking in the niobium 9-cell cavity VEP, this time we compared the difference between lower 4 cells with no masking and the top 5 cells with masking. Figure 6 shows a schematic view of cathode masking state and Table 2 shows conditions of cathode masking VEP. For this experiment, 9cell coupon cavity and Ninja cathode V6 with metal wings and mesh cover were used.

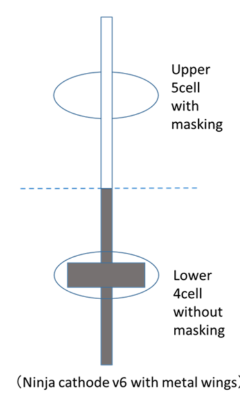

Figure 6: Schematic view of cathode masking state.

Table 2: Conditions of Cathode Masking VEP

Parameters	Cathode masking VEP
Voltage	~15V
Current density	10 – 15 mA/cm^2
Cavity surface temperature	20~25 □C
Cathode rotation speed	20 rpm
Acid flow rate	5~10 L/min
EP time	~60min
Average removal thickness	~20um
Cathode	Ninja-v6 (With metallic wings and mesh cover)

ISBN: 978-3-95450-194-6 ISSN: 2226-0366 doi:10.18429/JACoW-LINAC2018-TUP0067

Figure 7 shows IV curves of each coupon and Figure 8 shows logged data of coupon current during VEP. In the top cell and the center cell with masking, the current was suppressed compared to the bottom cell without masking, but it did not become completely 0 and it was somewhat flowed.

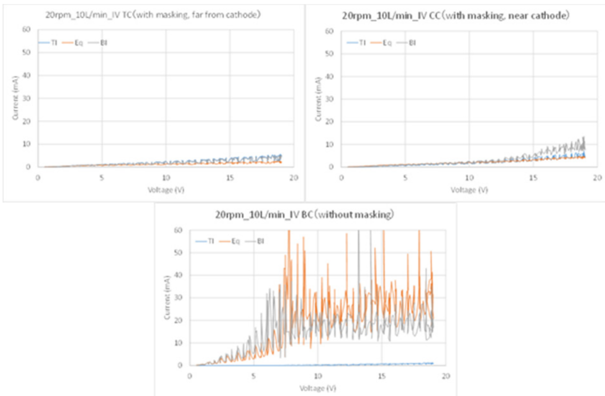

Figure 7: Coupon IV curves of top cell (upper left), center cell (upper right), bottom cell (lower).

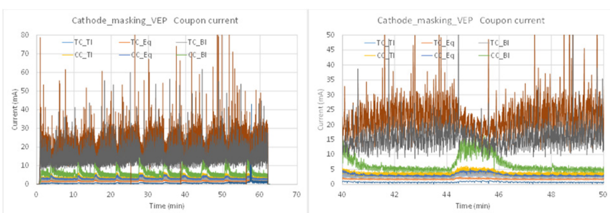

Figure 8: Logged data of coupon current during VEP.

Figure 9 shows the removal thickness distribution measurement result. About no cathode masking part, the distribution tendency was the same as usual VEP, on the other hand cathode masking part, removal thickness became very small, however it was not completely 0 and 5 -10 um removed.

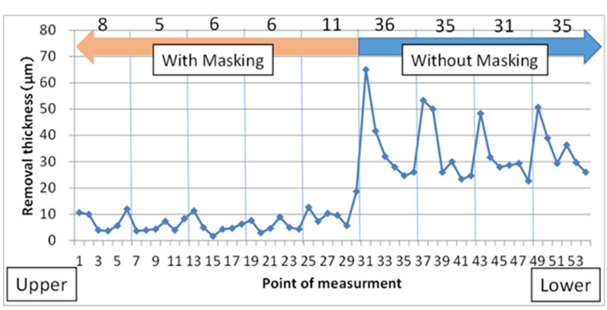

Figure 9: Removal thickness distribution results.

Figure 10 shows the coupon surface status and surface roughness. The top and center cell coupon surface became rough. This seems to be due to the progress of etching under improper conditions in the cathode masking part. Although the effect of masking is seen, it turned out that it is necessary to design the masking shape in consideration of these points in order to realize VEP with uniform removal thickness and shiny surface. We are currently devising a masking shape.

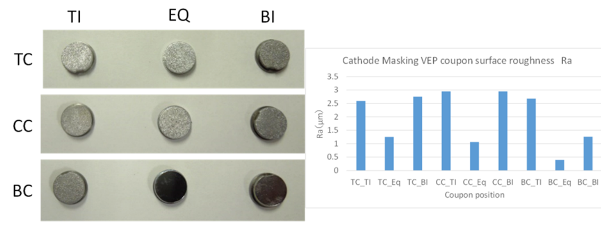

Figure 10: Status and roughness of each coupon after VEP.

SUMMARY

Up to now we have developed EP acid flow separation method to improve the distribution of polishing amount of niobium 9 cell cavity VEP, in addition we have done cavity flip upside down VEP and cathode masking VEP as other methods. On the cavity flip upside down VEP, it was found that the current of each coupon was averaged and the removal thickness distribution greatly improved. The polished surface was almost shiny, but some rough portions were also seen. It seems to be due to the fact that the cathode was not rotated at the time of reverse position and the size of the top and bottom PVC pieces were different. We are making these improvements at the moment and we plan to further advance the VEP experiment. On the cathode masking VEP, although the effect of reducing the polishing amount by masking was observed, there was a problem that the surface was roughened. We plan to proceed with the design and verification experiment of cathode masking VEP considering these in the future.

REFERENCES

[1] V.Chouhan *et al.*, in *Proc. 17th Int. Conf. RF Superconductivity (SRF'15)*, Whistler, Canada, Sep. 2015, paper THPAL030.

[2] V.Chouhan *et al.*, presented at the 29th Linear Accelerator Conf. (LINAC'18), Beijing, China, Sep. 2018, paper TUPO068, this conference.

[3] S.Kato *et al.*, in *Proc. 28th Linear Accelerator Conf. (LINAC'16)*, East Lansing, MI, USA, Sep. 2016, pp. 220--222, doi:10.18429/JACoW-LINAC16- MOPLR038