

FABRICATION OF 9 CELL COUPON CAVITY FOR VERTICAL ELECTROPOLISHING TEST

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Abstract

We have been using single cell coupon cavities to establish vertical electropolishing (VEP) process for a couple of years. A series of in-situ measurements of an EP current at an individual coupon in a coupon cavity can help determination of appropriate EP conditions. VEPed coupons which are surface analysed with XPS, SEM and the other tools can also bring lot information and expertise to development of VEP cathode and optimization of VEP conditions. This time we fabricated the world's first 9-cell coupon cavity where 3 sample coupons at the equators and 6 sample coupons at positions close to the irises can be installed. VEP of this coupon cavity with a newly developed Ninja cathode brought useful information for improvement of the VEP facility and optimization of the VEP conditions.

INTRODUCTION

Needless to describe, it is quite obvious that inner surface quality of a SRF cavity fatefully decides the cavity performance. Therefore deep investigation of the hidden inner surface using surface analytical tools is mandatory to develop good cavities or good surface treatment. For this purpose, so called a coupon cavity is a very strong tool. Surface analysis of coupons brings us reduction of research and development cost and time because the surface analysis helps failure cause investigation very well. In case of electropolishing (EP), in-situ measurements of EP current at each coupon can be carried out and help determination of appropriate EP conditions. We fabricated 4 single cell coupon cavities up to now and proved these ideas for different projects [1-5] while one is being used in DESY for centrifugal barrel polishing [6]. In this report, fabrication of the world's first 9-cell coupon cavity for improvement of VEP will be mainly described.

DISMANTLING OF 9-CELL CAVITY

A 9-cell coupon cavity was designed in order that each set of three sample coupons is installed to the 1st, 5th and 9th cell as shown in Fig.1. In a VEP process, these three cells correspond to the top, centre and bottom cells, respectively. For the 9-cell coupon cavity, a vertical tested 1.3 GHz Nb 9-cell SRF cavity was reused. First, the end plates and the magnetic shields were removed with both a turning machine and an electrical discharge machine (EDM) (Fig. 2). Then using the EDM, the cavity was precisely dismantled into five components, that is, a) the 1st cell including the end group with the short beam pipe,

b) the 2nd, 3rd, 4th cells, c) the centre cell, d) the 6th, 7th, 8th cells and e) the 9th cell including the end group with the long beam pipe as shown in Fig.1. The stiffener rings at the cut positions were removed in advance. The dismantlement was needed otherwise it was impossible to make holes for coupons and to weld support legs on the cavity with electron beam welding (EBW).

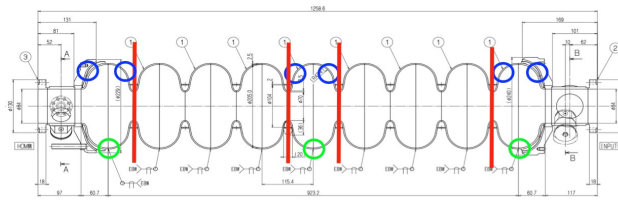


Figure 1: Schematic of the 9-cell coupon cavity. Red lines, blue circles and green circles show the cut positions and the coupon positions at the 1st, 5th and 9th cells, respectively.



Figure 2: Removal of the end plate with an EDM.

SAMPLE COUPON HOLES

For the 9-cell coupon cavity, the same size of coupons that have an analysis diameter of 8 mm and have been being used for 1-cell coupon cavities in KEK for a couple of years was adopted, considering its compatibility.

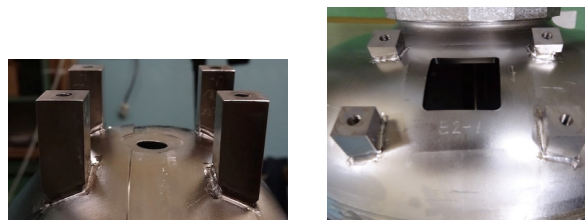


Figure 3: Coupon holes and the support legs for the equator position (left) and the position close to the iris (right).

Totally 9 holes for sample coupons were prepared at three positions of the equators and at the two symmetrical positions close to the irises (Fig.3 and 4). The equator holes to which the coupons with Viton O-rings fit in order to electrically insulate the coupons and to seal EP solution

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have a diameter of 9.2 mm. The iris holes have a square of 24.2 mm since a well-polished transparent PVC plates as view ports are installed with the offset positioned coupons for better observation of the inside of the cavity. To make holes on the 3D curved planes, many jig support tools were additionally fabricated with practical fabrication training using copper cells in advance.

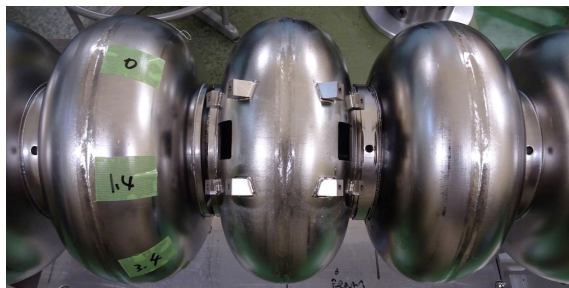


Figure 4: 2 square holes for both view ports and coupons and the 8 support legs at the positions close to irises of the center cell can be seen.

SUPPORT LEGS OF ADAPTER PLATES

To fix the coupons to the cavity totally 36 legs, which support 9 adapter plates for the 9 coupons and are made of pure titanium, were EBWed as shown in Fig. 3, 4 and 6. Similarly to the coupon holes, many jig support tools had to be specially fabricated in order to perform precise welding of the support legs on the 3D curved planes of the cavity. After the welding, the legs were cut to a necessary length with the EDM to fit the adapter plates and the coupons, keeping all the 4 cut planes are in the same plane that should be also parallel to the cavity surface.

RE-EBW OF 9-CELL COUPON CAVITY

Before rewelding 5 components into one, a leak test was performed every time after completion of each component with pressurized water by nitrogen gas of an absolute pressure of 0.2MPa for 15 min. Then the five components were precisely re-EBWed step by step into a 9-cell coupon cavity after buffer chemical polishing (BCP). The 4 stiffener rings were also re-EBWed at the cut positions. Finally straightening of the cavity was carried out as shown in Fig. 5.

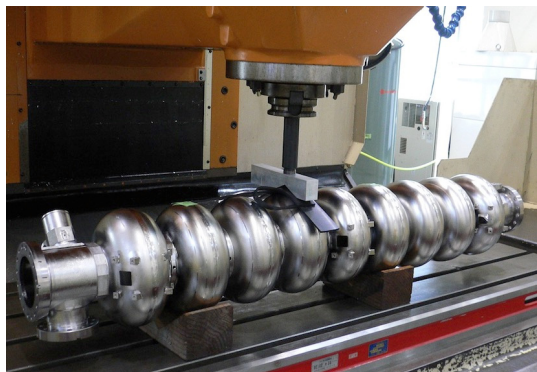


Figure 5: Straightening process after EBW of five components into one.

ASSEMBLING OF COUPON CAVITY

Fig. 6 shows sample coupons and its adapter plates and/or view ports which were installed to the coupon cavity with some additional PVC-made fixing parts. Every coupon was pressed against the cavity hole with only one set screw in order to avoid unequal pressing force that may cause leakage of EP solution. One more Viton O-ring was set between the PVC part and the cavity outer surface at each coupon for safety against leakage of EP solution. After the assembling, the whole coupon cavity was leak-tested with pressurized water by nitrogen gas of an absolute pressure of 0.2MPa for 30 min.

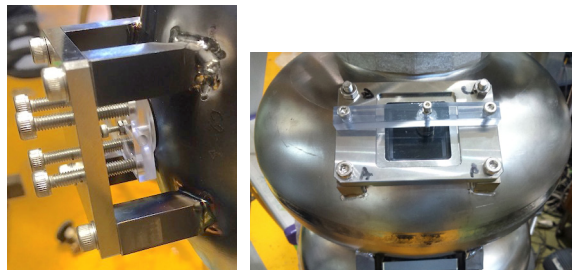


Figure 6: An installed coupon at the equator position (left) and an installed coupon and a view port at the position close to the iris (right).

1ST VEP OF 9-CELL COUPON CAVITY

As shown in Fig. 7, the 1st VEP of the completed 9-cell coupon cavity was carried out with an improved Ninja cathode [7]. While the detail is described elsewhere [8], the coupons after the 1st VEP revealed that more improvements of the VEP facility were required. Briefly after the VEP, the surface quality deteriorated as shown in Fig. 8 and too much H₂ gas bubbles were found at the top

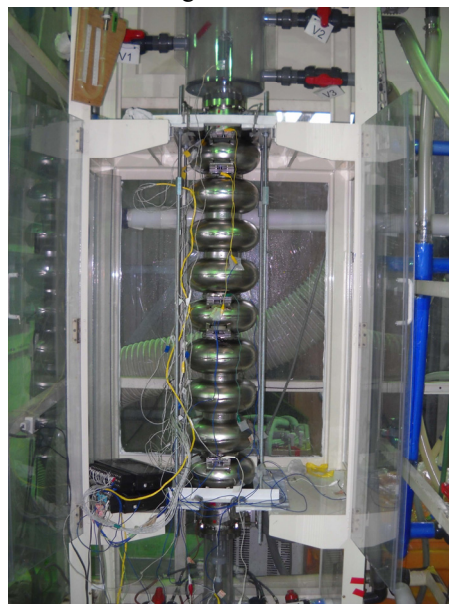


Figure 7: The 1st VEP of the coupon cavity. Many current probe wires to the coupons and thermocouples can be seen around the cavity. Since the cavity rotation is not necessary in the VEP, this kind of measurements are easy.

cell in Fig. 9. Surface analyses of the coupons with XPS and SEM/EDX are scheduled.

While it turned out that the first VEP was not success-

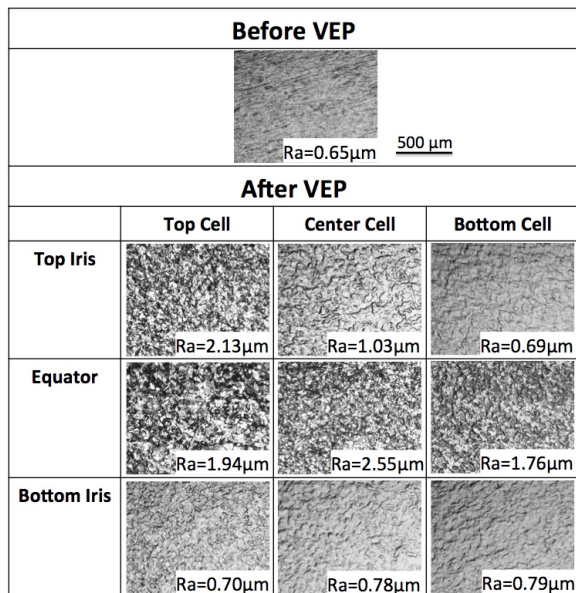


Figure 8: Optical microscope images and average surface roughnesses, Ra of a coupon before the VEP and all the coupons after it. The scale for the all is the same.

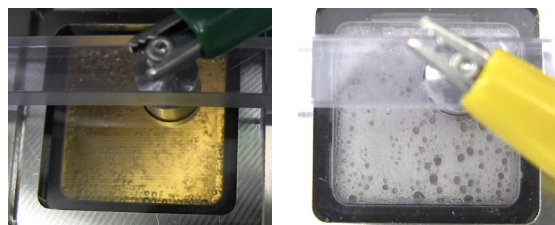


Figure 9: Inside of the center cell (left) and inside of the top cell (right) through the view ports. Even EP solution is invisible at the top due to too much H₂ bubbles.

fully finished, a lot of new findings were obtained. From measured polarization curves at the coupons, optical microscope observation, measured surface roughness of the coupons and visual observation of the cavity inside through the view ports, it was found that insufficient chiller capacity for both EP solution and external water cooling of the coupon cavity caused high temperature of the cavity up to 35 °C and subsequent intentional reduction of the EP voltage which was far from the adequate voltage for a polishing region, namely, an EP plateau. A large quantity of H₂ bubbles might

have also required a higher EP voltage against screening effect to EP voltage due to H₂ bubbles [9, 3 and 4]. Consequently the surface roughening of the cavity inner surface was mainly attributed to too low EP voltage with which only etching of the Nb surface occurred. Concerning the roughening of the top irises was additionally enhanced by strong attack of a significant quantity of H₂ bubbles there.

CONCLUSION

The world's first 9-cell Nb coupon cavity was fabricated as reuse of a 1.3GHz 9-cell Nb SRF cavity with 3 sample coupons at the equator positions and 6 coupons at the positions close to the irises of the 1st, 5th and 9th cells. The 1st VEP of the coupon cavity has brought useful information about the individual polarization curve, the microscopic morphology, the surface roughness at the different positions of the cavity to improve the VEP conditions and VEP facilities. The 9-cell coupon cavity was confirmed to be a powerful tool for investigation of surface quality of a 9-cell SRF cavity.

A coupon cavity can be used not only for VEP but also for HEP and CBP. It also has a potential of applications to nitrogen doping and CVD/ALD processes for SRF cavity manufacturing where good quality control of cavity inner surface is required. It can always contribute to save time and budget in those research and development.

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